PUCRS

ESCOLA DE HUMANIDADES
PROGRAMA DE PÓS-GRADUAÇÃO EM LETRAS – LINGUÍSTICA
DOUTORADO EM LETRAS

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SYNTACTIC PROCESSING OF PREDICATE ARGUMENT STRUCTURE IN BRAZILIAN PORTUGUESE: A BEHAVIORAL AND NEUROIMAGING STUDY WITH HEALTHY INDIVIDUALS

Porto Alegre – RS
2019

PÓS-GRADUAÇÃO - *STRICTO SENSU*

Pontifícia Universidade Católica
do Rio Grande do Sul

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Tese de Doutorado apresentada ao Programa de Pós-Graduação em Letras/Linguística, da Pontifícia Universidade Católica do Rio Grande do Sul, como parte dos requisitos necessários à obtenção do título de Doutora em Letras.

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Porto Alegre – RS

2019

Ficha Catalográfica

R696s Rodrigues, Lisandra Rutkoski

Syntactic processing of predicate argument structure in Brazilian Portuguese : a behavioral and neuroimaging study with healthy individuals / Lisandra Rutkoski Rodrigues . – 2019.
134 f.
Tese (Doutorado) – Programa de Pós-Graduação em Letras, PUCRS.

Orientadora: Profa. Dra. Lilian Cristine Hübner.
Co-orientadora: Profa. Dra. Fernanda Soares Loureiro.

1. Predicate Argument Structure. 2. Verb Type. 3. Syntactic Processing. 4. Functional Magnetic Resonance Imaging (fMRI). I. Hübner, Lilian Cristine. II. Loureiro, Fernanda Soares. III. Título.

Elaborada pelo Sistema de Geração Automática de Ficha Catalográfica da PUCRS
com os dados fornecidos pelo(a) autor(a).
Bibliotecária responsável: Salete Maria Sartori CRB-10/1363

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Tese apresentada como requisito para a obtenção do grau de Doutora pelo programa de Pós-Graduação em Letras da Escola de Humanidades da Pontifícia Universidade Católica do Rio Grande do Sul, na área de concentração de Linguística.

Aprovada em: ____ de __________ de 2019.

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Porto Alegre – RS

2019

To my family,

whose unconditional love and incentive

have made me the person I am.

ACKNOWLEDGMENTS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001. Subsequently, it was financed by CNPq (Conselho Nacional de Desenvolvimento e Pesquisa).

Thanks to Fulbright, for the amazing opportunity to do part of my research in the USA, and to be able to meet the most incredible people from all over the world.

To the IIE (Institute of International Education), in the person of Jessica Rosen, for all the bureaucratic support during my stay in the USA.

To Dr. Swathi Kiran, my adviser at Boston University, for welcoming me at the Aphasia Research Lab, and for allowing me to learn from her and her amazing team.

To Dr. Erin Meier, Natalie Gilmore, Dr. Jeffrey Johnson, Yue Pan, and Maria Dekhtyar, my lab mates at the Aphasia Research Lab, who were always there to help me with anything I needed.

To Dr. Cynthia K. Thompson, Dr. Jennifer E. Mack, and Dr. Elena Barbieri, from Northwestern University, who so kindly agreed to share their task with us, and helped us all along the way.

To Kevin Guerrero and Martina Liviero, my roommates in Boston, and my friend Nikos Fourligas, for all the affection devoted to me while I was so far from home.

To all the participants of my study, for their full cooperation with my research.

To professors Filipe Zabala and Sérgio Kato (PUCRS), for the assistance with statistics.

To Dr. Luiz Carlos Marrone and Dr. Ricardo Soder, for their contribution to the study.

To InsCer (Instituto do Cérebro - PUCRS), including the technicians, nurses, Ms. Denise Marcarini, and Gustavo Cardoso Soares.

To Dr. Alexandre Franco, for his collaboration with the implementation of the neuroimaging study, and for his assistance throughout the process. Also to Ricardo Trentin for the assistance with the fMRI.

To Nathália Bianchini, for her enthusiasm to share her knowledge of neuroimaging.

To Dr. Lucelene Lopes, for her contribution to the construction of the corpus.

To my classmates and dearest friends, Dr. Sabrine Amaral Martins, and Dr. Fernanda Schneider, for the indescribable friendship that we have built. That will last a lifetime!

To GENP (Grupo de Pesquisa em Neurolinguística e Psicolinguística), for the hard group work, the academic enthusiasm, and the million hours of shared laughter.

To my classmates and professors from PUCRS.

To Rodrigo Rutkoski Rodrigues, my brother, and Mariana Ramos, my sister-in-law, for the permanent technical support. You are awesome!

To Anderson Smidarle, my colleague, my ‘right arm’, sometimes ‘my arms and legs’, for all the cooperation during the data collection process. I would not have made it without you!

My warmest thanks to Fernanda Soares Loureiro, my coadviser, for believing in me and embarking on this journey.

Finally, my warmest thanks to Dr. Lilian Cristine Hübner, my adviser, for all we shared along this long journey, and for being such a humane person.

It ought to be generally known that the source of our pleasure, merriment, laughter, and amusement, as of our grief, pain, anxiety, and tears, is none other than the brain. It is specially the organ which enables us to think, see and hear, and to distinguish the ugly and the beautiful, the bad and the good, pleasant and unpleasant... It is the brain too which is the seat of madness and delirium, of the fears and frights which assail us, often by night, but sometimes even by day; it is there where lies the cause of insomnia and sleep walking, of thoughts that will not come, forgotten duties, and eccentricities (Hippocrates).

ABSTRACT

Background Verbs have a crucial role in sentence production and connected speech. They carry both syntactic and semantic information. Different verb types show varying degrees of complexity, which have to do with their predicate argument structure (PAS). Several neuroimaging and behavioral studies have investigated the neural correlates of PAS in populations of individuals with aphasia and healthy subjects, both at single word and at sentence levels, with inconclusive results. *Aims* The present study aimed at investigating the neural correlates of PAS in Brazilian Portuguese (BP) (Study 1), as well as PAS production and comprehension at sentence level (Study 2). The underlying purpose was to understand the neurobiology of syntactic processing and lexical access in a sample of healthy highly-educated adult native speakers of BP, and possibly contribute to language assessment and rehabilitation of Brazilian clinical populations with atypical language, such as people with dementia types such as Alzheimer’s Disease and Primary Progressive Aphasia, and language impairment following a stroke. *Method* This dissertation was organized into two separate studies. The participants were 16 (Study 1) and 21 (Study 2) healthy individuals, mean age 62.06 years (Study 1) and 60.95 years (Study 2), with high educational levels. Study 1 collected functional neuroimaging data (fMRI) during a computerized lexical decision task including four verb types (nonalternating unaccusatives, transitives, alternating unaccusatives, unergatives), and pseudoverbs. Three effects were calculated: effect of number of thematic roles, of number of thematic options, and of unaccusativity. Study 2 included a computerized sentence comprehension task, and an oral sentence production task, both motivated by pictures and the same four verb types as in the lexical decision task of Study 1. *Results* The results of Study 1 revealed clusters of activation in the left fusiform gyrus, left paracentral lobule, left supplementary motor area, and left superior temporal pole for the effect of number of thematic roles. There was activation in the left lingual gyrus for the effect of number of thematic options. Finally, for the effect of unaccusativity, there were clusters of activation in the left cuneus, left supplementary motor area, left precentral gyrus, and in the right middle frontal gyrus, right superior frontal gyrus, and right medial frontal gyrus. Regarding the speed of lexical access, no differences were found among verb types, only between verbs and pseudoverbs, and both number of letters and of syllables impacted the overall reaction times (RTs). The results of Study 2 showed no significant differences among verb types in RTs for sentence comprehension, and no impact from either number of letters or of syllables on overall RTs. The production task, on the other hand, showed that healthy individuals with high educational levels also have difficulties following the instructions to a task, retrieving words, and may present a variety of nontarget responses that would be typical of populations with brain lesions. *Conclusion* This dissertation promoted a reflection on specific features of PAS that may characterize PAS processing and lexical access in BP, both behaviorally and from a neurolinguistic perspective. Our data also contributed in the sense of highlighting the dynamic nature of language, indicating that a plurality of responses should be expected from healthy samples of populations, even in groups with high educational levels. Such findings might guide clinicians to better assess lexical access, sentence comprehension and production in clinical groups, including brain-lesioned individuals.

Keywords: Predicate Argument Structure. Verb Type. Syntactic Processing. Functional Magnetic Resonance Imaging (fMRI).

RESUMO

Contexto Verbos desempenham um papel crucial na produção de sentenças e na fala encadeada. Eles carregam tanto informação sintática quanto semântica. Tipos diferentes de verbos apresentam diversos graus de complexidade, os quais têm a ver com sua estrutura de argumentos (EAs). Vários estudos de neuroimagem e comportamentais investigaram os correlatos neurais da EAs com populações de indivíduos com afasia e de indivíduos saudáveis, tanto no nível da palavra isolada quanto no de sentenças, com resultados inconclusivos. *Objetivos* O presente estudo teve por objetivo investigar os correlatos neurais da EAs no português brasileiro (PB) (Estudo 1), bem como a produção e a compreensão da EAs no nível de sentenças (Estudo 2). O objetivo subjacente foi compreender a neurobiologia do processamento sintático e do acesso lexical em uma amostra de adultos falantes nativos do PB, saudáveis e com alta escolaridade, e possivelmente contribuir com a avaliação e a reabilitação de populações clínicas com linguagem atípica, tais como pessoas com tipos de demência como a doença de Alzheimer e Afasia Primária Progressiva, e comprometimentos linguísticos decorrentes de acidente vascular cerebral. *Método* Esta tese foi organizada em dois estudos separados. Os participantes foram 16 (Estudo 1) e 21 (Estudo 2) indivíduos saudáveis, com médias de idade de 62,06 anos (Estudo 1) e 60,95 anos (Estudo 2), de alta escolaridade. O Estudo 1 coletou dados de neuroimagem funcional (RMf) durante uma tarefa de decisão lexical computadorizada, incluindo quatro tipos de verbos (inacusativos não alternantes, transitivos, inacusativos alternantes, inergativos) e pseudoverbos. Três efeitos foram calculados: efeito do número de papéis temáticos, efeito do número de opções temáticas, e efeito de inacusatividade. O Estudo 2 incluiu uma tarefa de compreensão de sentenças computadorizada e uma tarefa de produção oral de sentenças, ambas motivadas por figuras e os mesmos quatro tipos de verbos da tarefa de decisão lexical do Estudo 1. *Resultados* Os resultados do Estudo 1 revelaram *clusters* de ativação no giro fusiforme esquerdo, no lóbulo paracentral esquerdo, na área motora suplementar esquerda, e no polo temporal superior esquerdo para o efeito de número de papéis temáticos. Houve ativação no giro lingual esquerdo para o efeito de número de opções temáticas. Finalmente, para o efeito de inacusatividade, houve *clusters* de ativação no cúneo esquerdo, na área motora suplementar esquerda, no giro pré-central esquerdo, e no giro frontal médio direito, giro frontal superior direito, e giro frontal medial direito. Quanto à velocidade do acesso lexical, não foram encontradas diferenças entre os tipos de verbos, apenas entre verbos e pseudoverbos, e tanto o número de letras quanto o de sílabas impactaram os tempos de resposta totais (TRs). Os resultados do Estudo 2 não mostraram diferenças significativas entre os tipos de verbos quanto aos TRs na compreensão de sentenças, e nenhum impacto advindo do número de letras ou de sílabas nos TRs gerais. A tarefa de produção, por outro lado, mostrou que indivíduos saudáveis com alta escolaridade também têm dificuldades para seguir as instruções de uma tarefa, recuperar palavras, e podem apresentar uma variedade de respostas não-alvo, o que seria típico de populações com lesões cerebrais. *Conclusão* Esta tese promoveu uma reflexão sobre os traços específicos da EAs que podem caracterizar o processamento dessa e o acesso lexical no PB, tanto comportamentalmente quanto de uma perspectiva neurolinguística. Nossos dados também contribuíram no sentido de enfatizar a natureza dinâmica da linguagem, indicando que uma pluralidade de respostas deve ser esperada de amostras advindas de populações saudáveis, mesmo em grupos com alta escolaridade. Esses achados podem orientar os profissionais a avaliarem melhor o acesso lexical, a compreensão e a produção de sentenças de grupos clínicos, incluindo indivíduos com lesão cerebral.

Palavras-Chave: Estrutura de Argumentos. Tipologia Verbal. Processamento Sintático. Ressonância Magnética Funcional (RMf).

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LIST OF ABBREVIATIONS AND ACRONYMS

ABEP – Associação Brasileira de Empresas e Pesquisa
ACC – Accuracy
AD – Alzheimer's Disease
A-movement – Argument Movement
ASCH – Argument Structure Complexity Hypothesis
BA – Brodmann Area
BP – Brazilian Portuguese
CMLD – Cross-Modal Lexical Decision
CP – Complementizer Phrase
DOP-H – Derived Order Problem Hypothesis
D-structure – Deep Structure
fMRI – functional Magnetic Resonance Imaging
GDS – Geriatric Depression Scale
LH – Left Hemisphere
LHBD – Left-Hemisphere-Brain-Damaged
MMSE – Mini-Mental State Exam
MNI – Montreal Neurological Institute
NP – Noun Phrase
PAS – Predicate Argument Structure
PPA – Primary Progressive Aphasia
PP – Prepositional Phrase
RH – Right Hemisphere
ROI – Region of Interest
RT – Reaction Time
S-structure – Surface Structure
VNeST – Verb Network Strengthening Treatment
VP – Verbal Phrase
WEAVER – Word Encoding by Activation and Verification

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1 INTRODUCTION

1.1 The present study

In the framework of language acquisition theories, there have been several attempts to explain how native speakers of a language are able to tell the difference between what is and what is not part of their grammar. Examples of different approaches that have tried to answer questions such as this one are the idea of *tabula rasa*[1] of behaviorism, the concept of *universal grammar*[2] of nativism, and the *computational models*[3] of connectionism.

Regarding specifically the acquisition of verbs, theorists have been trying to answer questions such as: how children end up learning the argument-taking properties of verbs[4]; what mechanisms they use to learn new verbs; how such verbs are represented in the grammar; and how they are accessed during language comprehension and production (Arunachalam, 2015). However, Shetreet (2014, p. 169) claims that,

> despite the extensive description of verbs within the linguistic literature, many questions have been left unanswered: the types of information that are actually represented within the lexical entry of a verb, the form of representation of this information, and even whether or not any information is stored at all.

Although there is still no consensus regarding the answers to the questions above, theorists can agree on some important facts: that all languages have verbs; that sentences are built around verbs, and therefore verbs have a crucial role in sentence production and connected speech; and that such grammatical category offers smaller or bigger challenges to the learner, depending on language typology.

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1 The assumption that a child is born without any previous knowledge and can only learn a language if someone teaches her (Finger, 2008a).

2 The assumption that a child is born with an innate mechanism that is in charge of language acquisition (Quadros, 2008).

3 Connectionists accept the postulation of an innate brain structure (in charge of restricting language acquisition), but they question whether it is made up of specialized modules according to the type of input to be processed, or whether they include any specific prior knowledge of grammatical structures (Finger, 2008b).

4 "The argument structure of a verb forms the interface between the conceptual/semantic properties of the event denoted by the verb (e.g., how many participants the event includes) and its syntactic properties (e.g., how many noun phrases accompany the verb in a sentence)" (Meltzer-Asscher et al., 2013, p. 1155).

The literature on verbs traditionally contrasts them to nouns. Verbs are more complex than nouns, as Almeida and Manouilidou (2015, p. 3) point out:

> Every linguist assumes that verbs–more than any other grammatical category–carry core semantic properties of the events and states that sentences describe, and also license a myriad of information about the nature of the syntactic arguments that are constitutive of grammatical sentences.

According to Conroy, Sage, and Ralph (2006), there are a number of intrinsic factors that make verbs more susceptible to impairments among clinical populations, as it is the case of people who suffer brain lesions and have *aphasia*[5] as a sequela. The cognitive demands imposed by verb processing and production might be critical for such patients, so there is a need for minimizing the recruitment of executive control in therapies. Verbs also present lower imageability, due to the fact that they describe actions, events, states, or changes of state, rather than concrete objects.

One more reason for such complexity lies on the fact that verbs carry both syntactic information–regarding argument structure and subcategorization frames (e.g., noun phrase (NP), prepositional phrase (PP), complementizer phrase (CP))[6]– and semantic information–regarding the attribution of thematic roles (i.e., agent, theme, goal, recipient, beneficiary, etc.) (Carnie, 2013). In addition to that, working with predicate argument structure (PAS)[7] presupposes two stages of syntactic processing.

Friederici (2002, 2006, 2011) explains that *syntax-first models* work on the basis that syntax is processed autonomously prior to semantic information. The assumption is that the important syntactic processes, relevant for the assignment of the grammatical structure of a sentence, occur only a couple of hundred milliseconds later than the initial *syntactic parsing* (i.e., the process of sorting out the grammatical parts, as well as the way they relate to each other). The parser starts by constructing the simplest syntactic structure based on word-category information, regardless of lexical-semantic information. The latter information is processed in a second stage, in charge of thematic-role assignment. Such models predict that syntactic and semantic processes are supported by different components in the language comprehension

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[5] "An acquired communication disorder caused by brain damage, characterized by an impairment of language modalities: speaking, listening, reading, and writing" (Hallowell & Chapey, 2001, p. 3).

[6] *The boy gave a gift* (NP) *to his sister* (PP). *He said that it was her birthday* (CP).

[7] Term coined by Webster, Franklin, and Howard (2007).

system, and may be implemented at the neuronal level by distinct brain regions. These models receive some support from neurocognitive models of language comprehension, which take into consideration event-related brain potentials (ERPs) to provide crucial information about the temporal structure of language processing (e.g., Friederici, 2002). Syntax-first models contrast with interactive models, for which the parser uses multiple sources of information, including semantic and world knowledge at the same time. Models of processing will be further discussed in section 2.2.

Thompson and Meltzer-Asscher (2014) claim that the relevance of understanding the processing of PAS lies on the fact that PAS is an inherent part of every instance of sentence production and comprehension. For that reason, it is also crucial to distinguish the neural correlates of this type of processing from other types of sentential processing, such as phrase structure building, or semantic integration. The authors advocate for more investigations including both healthy and clinical populations, in order to identify what brain regions are involved in the production and comprehension of PAS, as well as in the detection of PAS violations.

For that matter, a lot has been discussed regarding Broca's Area–the left inferior frontal gyrus. Friederici (2006, 2011) claims that the data about the specificity of Broca's Area, assumedly responsible for syntactic processing, are still inconclusive (for a review, see Rogalsky & Hickok, 2011). Only 50-60% of the patients who have a lesion in Broca's Area present *Broca's aphasia*[8], and about 15% of the patients who present chronic Broca's aphasia do not have lesions in Broca's Area (Dronkers, 2000).

Studies on the neural correlates of PAS including aphasic patients versus healthy individuals have been developed in the last twenty years or so. More recently, investigations have drawn their attention to two specific aspects: 1) number of thematic roles or subcategorization options; and 2) *unaccusative* verbs (intransitive verbs whose syntactic argument is not a semantic *agent*, but a *theme*) versus *unergative* verbs (intransitive verbs which have an agent argument). A third way to assess syntactic processing and its neural correlates is via experiments involving syntactic violations of PAS (i.e., incorrect number of arguments or incorrect

[8] Broca's aphasia is characterized by awkward articulation, restricted vocabulary, agrammatism, and relatively intact auditory and reading comprehension (Goodglass, Kaplan, & Baressi, 2001).

subcategorization options) in contrast to sentences with no syntactic violations (for a review, see Thompson & Meltzer-Asscher, 2014).

Several neuroimaging and electrophysiological studies have investigated the neural correlates of PAS in populations of healthy individuals and of aphasic subjects, both at single word and at sentence levels. They have explored different numbers of thematic roles and of arguments (e.g., Malyutina & den Ouden, 2017; Shetreet, Palti, Friedmann, & Hadar, 2007), processing of verbs with multiple thematic options (i.e., *alternating transitivity verbs*[9]) (e.g., Meltzer-Asscher, Mack, Barbieri, & Thompson, 2015; Meltzer-Asscher, Schuchard, den Ouden, & Thompson, 2013), and processing of unaccusativity (e.g., Shetreet, Friedmann, & Hadar, 2010).

Specifically at single word level, there have been studies (e.g., Meltzer-Asscher et al., 2015; Meltzer-Asscher et al., 2013; Thompson, Bonakdarpour, & Fix, 2009; Thompson et al., 2007) trying to answer whether PAS information is processed even when verbs are encountered in isolation, rather than in a sentence, and whether PAS information is encoded in lexical representations at all. Such questions give rise to controversies between the neurosciences and theoretical linguistics, what will be tackled in section 2.1. The findings of the studies at single word level, as well as at sentence level, will be reviewed in sections 2.3 and 2.4.

1.2 Significance of the present study

Investigations such as the ones described above have a considerable impact on language rehabilitation. Understanding how language works in the brain is vital for the development of instruments for assessment and treatment of the linguistic impairments caused by cerebrovascular diseases, such as *stroke*[10]. That is especially relevant for both lower-middle-income and upper-middle-income countries all over the world, where stroke is among the top ten causes of death.

According to the World Health Organization (2018), stroke was the second leading cause of death in Brazil in 2012, by killing 123.1 thousand people. Patients

[9] Alternating transitivity verbs correspond to two different verbal alternates: transitive and intransitive (Levin, 1993).

[10] A cerebral vascular disease resultant from a blockage, malformation, or hemorrhage which prevents the brain cells from getting enough oxygen. Strokes can be ischemic (when a blood vessel that supplies blood to the brain is blocked by a blood clot or plaque), or hemorrhagic (when a blood vessel in part of the brain becomes weak and bursts open, causing blood to leak into the brain) (Kraft, 2017).

who survive a stroke usually end up with motor, functional, and/or linguistic deficits, which compromise people’s professional, social, and family life, for stroke is one of the most incapacitating acquired neurological conditions.

Despite the high incidence of stroke among Brazilian people, studies on the linguistic impairments due to brain lesions are relatively recent and scarce in Brazil, especially from a neuropsycholinguistic perspective. However, with the rapid advances in the neurosciences, there is a strong need for collaboration among the various scientific areas that deal with language. Investigations developed in the interface between speech therapy, cognitive psychology, neurology, and linguistics can help elucidate the different neurological processes that result in linguistic impairments. Actually, the direct participation of linguists in such an interface can contribute substantially to the understanding of the linguistic deficits in different languages, providing support for language assessment and rehabilitation.

Considering the aforementioned, this dissertation was motivated by a desire to contribute to this field of investigation by exploring PAS processing in a population of healthy monolingual Brazilian Portuguese (BP) speakers. The intent was to study, through functional neuroimaging and behavioral data, the neural correlates of PAS in BP, and to explore both PAS production and comprehension in BP. The idea was to contribute to language assessment and rehabilitation of Brazilian clinical populations with atypical language, such as aphasic subjects, left-hemisphere-brain-damaged (LHBD) individuals and patients with some kind of dementia, as in Alzheimer’s disease (AD), or Primary Progressive Aphasia (PPA).

1.3 How this dissertation is organized, aims and hypotheses

This dissertation is organized into two separate studies. Study 1 presents the neuroimaging data collected with functional magnetic resonance imaging (fMRI) in an event-related design while participants performed a computerized lexical decision task including four verb types with different degrees of PAS complexity: nonalternating unaccusatives, transitives, alternating unaccusatives, and unergatives, along with pseudoverbs. The aim was to establish the neural correlates of PAS in BP through the calculation of three different effects: effect of number of thematic roles, effect of number of thematic options, and effect of unaccusativity. Finally, to analyze the behavioral results (accuracy (ACC), and reaction times (RTs)) regarding verb types, looking for an impact of the lexical variables *number of letters* and *number of syllables*, as well as *verb type*, on the speed of lexical access.

Study 2 presents the results of two behavioral tasks with the same four verb types included in Study 1: a computerized sentence comprehension task (Task 1), and an oral sentence production task (Task 2). In Task 1, participants were presented with pictures followed by sentences on a computer screen and had to respond whether the sentences described the action depicted in each picture or not (responses measured by ACC scores and RTs), while in Task 2, participants were requested to produce a sentence orally to describe the action in each picture. The aim was to investigate participants' performance in both PAS comprehension and production of sentences in BP.

Regarding the hypotheses for Study 1, greater activation is expected in areas in charge of supporting access to stored PAS representations (left posterior perisylvian regions), and in charge of noncanonical argument mapping (the left inferior frontal gyrus). Lower ACC scores and longer RTs are expected for verbs with more complex PAS (alternating and nonalternating unaccusatives) in comparison to activation for the processing of unergatives and transitives.

For Study 2, regarding the behavioral data collected during the comprehension task, lower ACC scores and longer RTs are expected for verbs with more complex PAS (alternating and nonalternating unaccusatives) in relation to unergatives and transitives. Lexical variables such as higher *number of letters* and higher *number of syllables* are expected to impact the general RTs. In the production task, the omission of the external argument (i.e., the subject) is expected, as well as the omission of the internal argument (i.e., the object) of transitive verbs when complements are optional.

This dissertation is organized into six chapters. Chapter 1 is the Introduction. Chapter 2 presents the Theoretical Background by introducing the concepts regarding PAS in 2.1: number of arguments, thematic roles, subcategorization options, unaccusativity versus unergativity, alternating transitivity, as well as their neuropsycholinguistic implications. Next, in 2.2, cognitive models of lexical retrieval are presented, followed by neurocognitive models of syntactic processing. After that, two reviews of studies are presented: one tapping on behavioral studies on PAS production and comprehension (2.3), and another focusing on neuroimaging studies on PAS processing, and the neural correlates of syntax (2.4). Chapter 3 presents the experimental study, and is divided as: Aims, Hypotheses, and Method. Chapter 4 introduces the Results, and 5, the Discussion. Finally, chapter 6 is for the Final Considerations, including main findings, limitations, and suggestions for future research.

Before moving on to the theoretical background of this dissertation, it is important to highlight the context in which this research was carried out. The initial idea for the neuroimaging study (Study 1) was born out of the collaboration previously established between professor Lilian Cristine Hübner, my adviser at PUCRS, and Swathi Kiran, my coadviser at the Aphasia Research Lab at Boston University (BU), USA. The lexical decision task was translated and adapted from English to BP due to an agreement established with the authors of the task–Cynthia Thompson, Jennifer Mack, and Elena Barbieri–all from Northwestern University, USA. They gave us formal consent and kept in touch with us during the whole process, from the translation and adaptation of the stimuli, through the data collection and preprocessing stages.

Last, but not least, it is imperative to mention that it was Fulbright that funded my time in the USA, where I was able to spend nine months at College of Health and Rehabilitation Sciences - Sargent College (BU). That was where I was trained and learned how to analyze neuroimaging data with professor Kiran and her team of the Aphasia Research Lab, which is a reference for neuroimaging studies with aphasic patients. There, I also had the opportunity to meet and learn from several excellent researchers in the field of speech pathology, linguistics, neuropsychology, and neurosciences, who visit the Aphasia Research Lab on a regular basis.

2 THEORETICAL BACKGROUND

This section presents and discusses the theoretical framework for this study, which is divided as follows: 2.1 Predicate argument structure; 2.2 Models of lexical retrieval, and neurocognitive models of syntactic processing; 2.3 Behavioral studies on PAS production and comprehension; and 2.4 Neural correlates of syntax: neuroimaging studies on PAS processing in healthy individuals and aphasic subjects.

2.1 Predicate argument structure

The main topic of investigation in this dissertation is syntactic processing of PAS. According to Mateu (2014, p. 24),

> argument structure can be defined from semantic or syntactic perspectives; [*sic*] it has two faces. As a semantic notion, argument structure is a representation of the central participants in the eventuality (event or state) expressed by the predicate. As a syntactic notion, argument structure is a hierarchical representation of the arguments required by the predicate determining how they are expressed in the syntax.

In order to better understand such concepts, one has to take into consideration all the following aspects, which make up for the complex nature of verbs and their PAS: the number of arguments a verb encodes (one, two, or three arguments), and whether those are internal or external[11] to the verbal phrase (VP), as well as their structural position in the sentence (subject or object); the verb's subcategorization requirements (i.e., whether the arguments belong to one or other syntactic category: i.e., NP, CP, PP); the arguments' thematic roles[12] (e.g., agent, experiencer, theme, etc.); the fact that intransitive verbs can be either unaccusative or unergative, with the possibility of argument movement (A-movement) (to be further explained); and the fact that verbs may have alternating transitivity.

Furthermore, it is important to bear in mind the fact that languages of contrasting typologies pose distinct levels of complexity as well. They may mark their major arguments in three possible ways: by word order, by *case inflections* on

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[11] An internal argument is assigned by the verb (i.e., object), while an external argument is not part of the meaning of the main verb (subject), and therefore, is generated outside the VP (Carnie, 2013).

[12] Thematic relations are "particular semantic terms that are used to describe the role that the argument plays with respect to the predicate" (Carnie, 2013, p. 229).

nouns[13], and/or by agreement markers on the main verb. Languages may use exclusively one or more than one of such mechanisms to mark their arguments, leading to different levels of opacity/transparency of PAS across languages (Lieven, 2014). In addition to that, Iggesen (2005) points out that languages that lack morphological case (e.g., Vietnamese) may also express grammatical relations by using morphologically and prosodically independent function words, such as prepositions and postpositions.

Languages that are morphologically richer than others–such as Greek and German–are inflectional, and therefore, do not need to have a fixed word order. Contrastively, BP combines word order (i.e., subject-verb-object (SVO)) with agreement markers on the main verb, as exemplified in [1]:

[1] *Pedro descascou uma laranja*.
Pedro peeled an orange.

A canonical affirmative sentence in BP starts with a subject (*Pedro* – a proper noun), followed by a verb (*descascar*) conjugated according to tense (*descascou* has the suffix -*ou*, marking the third person singular past tense), and an object (*uma laranja*). A sentence like [1] could also have a personal pronoun as a subject, as in [2], or a null subject, as in [3]:

[2] *Ele descascou uma laranja*.
He peeled an orange.

[3] *Ø Descascou uma laranja*.
*Ø Peeled an orange[14].

Being a *pro-drop* language (Chomsky, 1981) (i.e., one that allows for the omission of constituents–either pronouns or nouns), BP can have declarative sentences in which there is the ellipsis of the subject (i.e., the external argument), as long as it is clear who is responsible for the action or state. However, differently from

[13] "Morphological case on nominals is a common device to express the syntactic and semantic relationships between clausal constituents" (Iggesen, 2005, p. 202).
[14] The asterisk is used throughout this study to signal agrammatical or incorrect sentences.

Italian[15], whose inflectional paradigm is regular, BP has a rather unusual one[16], as Bavin (2009, p. 265) points out:

> In Italian, each person/number has a distinct morpheme associated with it, and no single morpheme refers to more than one person/number. This is a regular, unmarked agreement system. Compare this to the BP system, which is significantly different. Notice that the only morpheme in BP that uniquely corresponds to a single person/number the way all six do in Italian is first person singular. The remaining morphemes are either conflations of multiple person/number references, or are complicated in some other way. The morpheme *-e* is used with second person singular, third person singular and first person plural subjects. So *-e* seems to occur in all three persons, and in both the singular and plural. Furthermore, *-em* occurs when the subject is either second or third person, plural. And finally, there are two (seemingly non-distinct) forms for first person plural: *-e* and *–emos*. Thus the BP agreement system is significantly less regular and predictable than that of Italian[17].

BP also allows for the omission of the direct object (internal argument) whenever it can be apprehended through the textual or situational context, as in [4]:

[4] A- *Você viu quem passou por aí?* (Castilho, 2016, p. 267)
Did you see who came by?
B- *Ø Vi Ø.*
*Ø Saw Ø.

Another key concept to the present study is *transitivity*. Carnie (2013, p. 58, emphasis in original) explains that:

> the property of transitivity refers to how many arguments follow the verb. In predicates with a valency of 1, no arguments follow the verb (the single argument *precedes* the verb), so these predicates are said to be ***intransitive***. Predicates that take two obligatory arguments

[15] Both Italian and BP are Romance languages and, as such, have a lot in common.

[16] Italian:

1st sg	(Io)	corr – o
2nd sg	(Tu)	corr – i
3rd sg	(Lui/Lei)	corr – e
1st pl	(Noi)	corr – iamo
2nd pl	(Voi)	corr – ete
3rd pl	(Loro)	corr – ono

BP:

1st sg	Eu	corr – o
2nd sg	Você	corr – e
3rd sg	Ele	corr – e
1st pl	A gente	corr – e
1st pl	Nós	corr – emos
2nd pl	Vocês	corr – em
3rd pl	Eles	corr – em

[17] Bavin (2009) left out '*tu*', which is the official second person singular in the inflectional paradigm of BP, and whose morpheme is *-es*.

> have a valency of 2; some examples are *hit*, *love*, *see*, *kiss*, *admire*, etc. These predicates are said to be ***transitive***, because they have a single argument after the verb (the other argument precedes the verb). Finally predicates that take three arguments have a valency of 3. *Put* and *give* are the best examples of this class. These predicates have two arguments after the verb so are said to be ***ditransitive****.*

Castilho (2016) claims that grammatical transitivity is a property of the sentence, rather than of the verb, for there are no verbs that are exclusively transitive or intransitive–it all depends on the speaker's intention while building a sentence. Cançado, Amaral, and Meirelles (2017) systematize these various possibilities by classifying verbs according to the classes and subclasses they belong in, along with their syntactic-semantic properties (see Table 1).

Table 1: Classes, Subclasses, and Syntactic-Semantic Properties of '*Cantar*' (To Sing)

VERBO: Cantar **EXEMPLO**: O tenor cantava muito.
Classe: Verbos de atividade (inergativos) **Propriedades da Classe**:
Conteúdo semântico recorrente na classe: fazer/dar/produzir um evento Estrutura da forma sintática básica: [SN V] (verbo intransitivo) Estrutura dos papéis temáticos: {Agente} Estrutura dos predicados primitivos: [X DO <EVENT>] Estrutura temporal (aspecto lexical básico): atividade Licencia a inserção de SN cognato eventivo: O tenor cantou um canto comovente. Licencia a inserção de um adjunto equivalente ao objeto cognato: O tenor cantou comoventemente.
Subclasse: Verbos de expressão (modo de fala) **Propriedades da Subclasse**:
Denota a realização de um evento de fala Licencia um objeto direto denotando conteúdo de expressão: O tenor cantava as mais belas músicas. Licencia um objeto direto denotando conteúdo de expressão acrescido de SP Alvo: O tenor cantava as mais belas músicas para sua amada. Licencia um objeto indireto alvo do conteúdo de expressão: O tenor cantava para sua amada. Licencia um objeto sentencial: O tenor cantava que seu amor pela donzela era infinito.

Retrieved from http://www.letras.ufmg.br/verboweb[18].

18 Translation: Verb: To sing Example: The tenor has sung a lot.
Class: Activity verbs (unergative)
Class Properties: Recurring semantic content in the class: make / give / produce an event
Structure of the basic syntactic form: [NP V] (intransitive verb)

We can see, from the example above, that a verb such as '*cantar*' (to sing), is classified primarily as intransitive (i.e., a 1-argument verb), but it also accepts a direct object, behaving transitively (as a 2-argument verb). That will be better explained in the subsequent paragraphs, along with the concept of alternating transitivity.

Haegeman (1994, p. 44) points out that "the argument structure of the verb predicts the number of constituents needed but not necessarily their type". Verbs not only differ on how many arguments they take, but also on what kind of subcategorization options[19] they take, i.e., the syntactic types of phrases they can have as complements, as illustrated in Table 2.

Table 2: Subcategorization Options of English Verbs and BP Verbs

SUBCATEGORY	ENGLISH	BP
Intransitive: NP + V	**Tom** left. NP	***Tom*** *partiu.* NP
Transitive (type 1): NP + V + NP	**He** ate **the apple**. NP NP	***Ele*** *comeu* ***a maçã***. NP NP
Transitive (type 2): NP + V + {NP/CP}	**The boy** asked **the time**. NP NP **He** asked **if I had the time**. NP CP	***O menino*** *perguntou* ***as horas***. NP NP ***Ele*** *perguntou* ***se eu tinha horas***. NP CP
Ditransitive (type 1): NP + V + NP + NP	**They** consider **him** **a pop star**. NP NP NP	**Eles** **o** consideram **um astro do pop**. NP NP NP
Ditransitive (type 2): NP + V + NP + PP	**The kid** put **the book** **in the box**. NP NP PP	***A criança*** *colocou* ***o livro*** ***na caixa***. NP NP PP

Structure of the thematic roles: {Agent}
Structure of the primitive predicates: [X DO <EVENT>]
Temporal structure (basic lexical aspect): activity
It licenses the insertion of an eventive cognate NP: The tenor sang a moving song.
It licenses the insertion of an adjunct equivalent to the cognate object: The tenor sang movingly.
Subclass: Expression verbs (speech mode)
Subclass Properties:
It denotes the holding of a speech event
It licenses a direct object denoting expression content: The tenor sang the most beautiful songs.
It licenses a direct object denoting expression content plus a target PP: The tenor sang the most beautiful songs for his beloved one.
It licenses an indirect object that is target of the content of expression: The tenor sang to his beloved one.
It licenses a sentential object: The tenor sang that his love for the maiden was infinite.

[19] It is important to highlight that *complements* are selected by the verb and, therefore, are arguments. *Adjuncts*, on the other hand, are not arguments–they are not selected by the verb, cannot be replaced by a pronoun, and can be omitted (Castilho, 2016).

Table 2 (continued)

SUBCATEGORY	ENGLISH	BP
Ditransitive (type 3): NP + V + NP + {NP/PP}	**She** gave **John** **a gift**. NP NP NP **She** gave **a gift** **to John**. NP NP PP	- ***Ela*** *deu* ***um presente*** ***pro João***. NP NP PP
Ditransitive (type 4): NP + V + NP + {NP/PP/CP}	**She** told **me** **a story**. NP NP NP **She** told **a story** **to me**. NP NP PP **She** told **me** **that the class was over**. NP NP CP -	***Ela*** ***me*** *contou* ***uma história***. NP NP NP ***Ela*** *contou* ***uma história*** ***pra mim***. NP NP PP ***Ela*** ***me*** *disse* ***que a aula acabou***. NP NP CP ***Eu*** *disse* ***a ele*** ***que a aula acabou***. NP PP CP

Source: the author (2019). *Note*. CP = complementizer phrase; NP = noun phrase; PP + prepositional phrase. The curly brackets and a slash {__/__} = "a choice of __ or __".

For intransitive verbs, there is only one argument, which is usually an NP. However, subcategorization options may vary across languages in what regards transitive and ditransitive verbs. As highlighted in Table 2, there are some differences between English and BP verbs. For instance, in BP, a sentence such as '*Ela deu John um presente*' (She gave John a gift) would be agrammatical. The only possibility of conveying the same meaning would be to add a PP after the verb, such as in '*Ela deu pro John um presente*'. Also, in BP, we can say '*Eu disse a ele que a aula acabou*', where there is a PP after the verb. The same sentence, translated into English, would be 'I told (to) him that the class was over', where the insertion of the PP would make the sentence agrammatical. A lot more differences could be pointed out between the two languages, but that would exceed the aims of this dissertation.

Going further into PAS complexity, intransitive verbs can be divided into unergatives and unaccusatives (Perlmutter, 1978). Although they are both intransitive, these types of verbs differ semantically, because the only one argument of unergative verbs is an *agent* (i.e., a (volitional) causer of the action), while the only one argument of unaccusative verbs is a *theme* (i.e., an entity that undergoes actions or is moved, experienced, or perceived) (Carnie, 2013). Syntactically, unaccusative verbs are more complex than unergative verbs, because a theme argument is supposed to fill in the canonical position of a direct object. However, there is movement of the theme-object to subject position, as exemplified in [5] with '*cair*' (to fall), contrasting with '*correr*' (to run) in [6]:

[5]	*O homem*	<u>*caiu*</u>	*(O homem)*.
	The man	<u>fell</u>	(The man).
		V	NP (theme)

[6]	*O menino*	*correu*.
	The boy	ran.
	NP (agent)	V

In [5], the NP '*o homem*' (the man) is base-generated in object position in *D-structure*[20], but involves movement of the NP from object to subject position, and the unaccusative verb '*cair*' (to fall) is an *achievement, i.e., a*n instantaneous event that results in a change of state (Smith, 1991). Contrastively, in [6], the NP '*o menino*' (the boy) is base-generated in subject position, and the unergative verb '*correr*' (to run) is an *activity*, i.e., a process that involves physical or mental activity, and consists entirely in the process (Smith, 1991).

In order to better differentiate unaccusative from unergative verbs, Table 3 presents their subcategories, which can be applied to verbs in any language. However, it is important to consider each verb when making cross-linguistic comparisons, since a verb in one language might not be exactly equivalent to an apparent synonym in another language (Perlmutter, 1978). For that matter, Rosen (1984) highlights the fact that verbs with similar meanings may have a different classification in, and across languages.

[20] The deep structure (D-structure) encodes the predicate argument relations and the thematic properties of the sentence, while the surface structure (S-structure) representation accounts for the surface ordering of the constituents. The S-structure is the output of the transformations suffered by the D-structure, reflecting the more superficial properties of the sentence (Carnie, 2013; Haegeman, 1994).

Table 3: Subcategories of Unaccusative and Unergative Verbs in English

	UNACCUSATIVE VERBS	
1	**Predicates expressed by adjectives in English**	Verbs describing sizes, shapes, weights, colors, smells, states of mind, etc.
2	**Predicates whose initial nuclear term is semantically a patient**	Burn, fall, drop, sink, float, slide, slip, glide, soar, flow, ooze, seep, trickle, drip, gush, hang, dangle, sway, wave, tremble, shake, languish, flourish, thrive, drown, stumble, trip, roll, succumb, dry, blow away, boil, seethe, lie (involuntary), sit (involuntary), bend (involuntary), etc. Inchoatives[21]: melt, freeze, evaporate, vaporize, solidify, crystallize, dim, brighten, redden, darken, yellow, rot, decompose, germinate, sprout, bud, wilt, wither, increase, decrease, reduce, grow, collapse, dissolve, disintegrate, die, perish, choke, suffocate, blush, open, close, break, shatter, crumble, crack, split, burst, explode, burn up, burn down, dry up, dry out, scatter, disperse, fill, vanish, disappear, etc.
3	**Existing and happening**	Exist, happen, transpire, occur, take place. Various inchoatives: arise, ensue, result, show up, end up, turn up, pop up, vanish, disappear, etc.
4	**Non-voluntary emission of stimuli that impinge on the senses (light, noise, smell, etc.)**	Shine, sparkle, glitter, glisten, glow, jingle, clink, clang, snap (involuntary), crackle, pop, smell, stink, etc.
5	**Aspectual predicates**	Begin, start, stop, cease, continue, end, etc.
6	**Duratives**	Last, remain, stay, survive, etc.
	UNERGATIVE VERBS	
1	**Willed or volitional acts**	Work, play, speak, talk, smile, grin, frown, grimace, think, meditate, cogitate, daydream, skate, ski, swim, hunt, bicycle, walk, skip (voluntary), jog, quarrel, fight, wrestle, box, agree, disagree, knock, bang, hammer, pray, weep, cry, kneel, bow, curtsey, genuflect, cheat, lie (tell a falsehood), study, whistle (voluntary), laugh, dance, crawl, walk, etc. Manner-of-speaking verbs: whisper, shout, mumble, grumble, growl, bellow, blurt out, etc. Sounds made by animals: bark, neigh, whinny, quack, roar (voluntary), chirp, oink, meow, etc.
2	**Involuntary bodily processes**	Cough, sneeze, hiccough, belch, burp, vomit, defecate, urinate, sleep, cry, weep, etc.

Source: Adapted from Perlmutter (1978).

In a study with BP verbs, Ciríaco and Cançado (2004) list all the properties that characterize unergative and unaccusative verbs. Prototypically unergative verbs: have one initiator in their *thematic grid*[22]; are activities, and so accept the durative phrase *for X min*; do not accept the postposition of the subject; accept the

[21] Verbs showing a process of beginning or becoming.

[22] Or theta grid: “the schematic representation of the argument structure of a predicate, where the theta roles are listed” (Carnie, 2013, p. 240).

indetermination of the subject; and do not accept the absolute participle[23]. Verbs such as '*caminhar'* (to walk)*, 'cantar'* (to sing)*, 'correr'* (to run)*, 'dançar'* (to dance)*, 'falar'* (to speak)*, 'nadar'* (to swim)*, 'pular'* (to jump)*, 'respirar'* (to breathe)*, 'voar'* (to fly)*, 'flutuar'* (to float), and *'andar'* (to walk) are examples of that category. Prototypically unaccusative verbs, on the other hand: do not accept an initiator in their thematic grid; are achievements, and so do not accept the phrase *for X min*; freely accept the postposition of the subject; do not accept the indetermination of the subject–do not have a subject in D-structure, but an object; and accept the absolute participle, which only occurs with objects. Examples of such verbs are: '*adormecer'* (to fall asleep)*, 'amanhecer'* (to dawn)*, 'morrer'* (to die)*, 'acontecer'* (to happen)*, 'desabrochar'* (to bloom)*, 'chegar'* (to arrive)*, 'florescer'* (to bloom)*, 'nascer'* (to be born)*, 'aparecer'* (to appear)*, 'sumir'* (to vanish)*, 'desaparecer'* (to disappear), and *'desmaiar'* (to faint)*.*

The authors also point out the fact that some verbs do not fall in any one of those categories, for they present properties of both. Therefore, they should be considered less prototypically unaccusative (e.g., '*adoecer'* (to get sick)*, 'cair'* (to fall)*, 'decair'* (to decay)*, 'desfalecer'* (to faint)*, 'despertar'* (to wake up)*, 'fracassar'* (to fail)*, 'amadurecer'* (to mature), and *'sair'* (to leave)), or less prototypically unergative (e.g., '*sentar'* (to sit)*, 'dormir'* (to sleep), '*repousar'(*to rest)*, 'suar'* (to sweat), and '*transpirar'* (to perspire)).

One more aspect of PAS complexity to be discussed is *alternating transitivity*, i.e., the fact that some verbs have two argument realization options. As such, they are labeled *alternating unaccusatives*, because they are either 2-argument verbs (transitives) or 1-argument verbs (intransitives – unaccusative). That is the case of verbs such as '*quebrar*' (to break) and '*queimar*' (to burn), as in [7] and [8] in contrast to [9] and [10]:

[7]	<u>*Os meninos*</u>	*quebraram*	<u>*a vidraça*</u>.
	<u>The boys</u>	broke	<u>the window glass</u>.
	NP (agent)	V	NP (theme)

23 **Corridos os atletas, a prova acabou*. (*Ran the athletes, the race was over).

[8]	*O homem*	*queimou*	*a casa*.
	The man	burned	the house.
	NP (agent)	V	NP (theme)

[9]	*A vidraça*	*(se) quebrou*.	(*A vidraça*)
	The window glass	broke.	(The window glass)
		V	NP (theme)

[10]	*A casa*	*queimou*.	(*A casa*)
	The house	burned down.	(The house)
		V	NP (theme)

In both [7] and [8], '*os meninos*' (the boys) and '*o homem*' (the man) function as the agents or initiators of the actions, while '*a vidraça*' (the window glass) and '*a casa*' (the house) function as themes. However, in [9] and [10], both '*a vidraça*' (the window glass) and '*a casa*' (the house) appear in subject position (S-structure), as a result of A-movement, but they were generated in object position (D-Structure).

Having covered the formal aspects related to PAS, I now explore it from a neuropsycholinguistic perspective. I start by conceptualizing *lexicon*: a dictionary-like cognitive information structure containing a person's vocabulary, with the morphology, PAS, thematic role, and meaning of a vocabulary item (Shelley-Tremblay, 2011). It is comparable to a store of lexical representations with both semantic and syntactic information (Longworth & Marslen-Wilson, 2011).

As stated in the Introduction, theorists have been trying to understand how PAS is represented in the brain. One of their questions is whether alternating unaccusatives have only one or two lexical entries in our mental dictionary. If the answer is two separate lexical entries, we could assume greater activation in middle-superior frontal regions for alternating than for nonalternating verbs, since these regions are associated with ambiguity[24] resolution (Meltzer-Asscher et al., 2013; Shetreet et al., 2007). If the answer is one, i.e., an alternating unaccusative verb has a single lexical entry with a single thematic grid (either transitive or intransitive), then we can assume that the other use of the verb is derived online via a lexical or

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[24] Ambiguity in this case refers to the fact that alternating unaccusative verbs have two possible interpretations: an intransitive and a transitive one.

grammatical operation. However, that is still an open question (Meltzer-Asscher et al., 2015).

Regarding neural correlates of unaccusativity, Thompson and Meltzer-Asscher (2014, p. 154) claim that:

> unaccusativity exemplifies a different dimension of argument structure complexity, related not to the number of thematic roles, but to their mapping into syntactic positions. Given their syntactic complexity, it is not surprising that the region most consistently implicated in the processing of unaccusative verbs and sentences is the left inferior frontal gyrus, which is independently assumed to be involved in complex syntactic processing.

According to Shetreet et al. (2010), several developmental (e.g., Costa & Friedmann, 2009; Friedmann, 2007; Lorusso, Caprin, & Guasti, 2005) and online processing studies (Friedmann, Taranto, Shapiro, & Swinney, 2008) have shown differences between unergative and unaccusative verbs. The same is true for aphasic individuals in a series of studies. Although comprehension of both unaccusative and unergative verbs seems to be spared in *agrammatic* individuals[25] (Lee & Thompson, 2004; Thompson, 2003), production appears to be impaired (for further details, see sections 2.3 and 2.4).

The evidence described above finds support in the *Derived Order Problem Hypothesis* (DOP-H) (Bastiaanse & van Zonneveld, 2005), and in the *Argument Structure Complexity Hypothesis* (ASCH) (Thompson, 2003). According to the DOP-H, any order that differs from the basic one is derived and, therefore, difficult to produce and comprehend. That explains why agrammatic speakers find it more difficult to deal with unaccusative verbs. The ASCH, on the other hand, predicts that the more complex PAS is, the more difficult it is for an agrammatic speaker to retrieve the verb, as is the case of 3-argument verbs, or verbs with alternating transitivity. As Thompson (2003, p. 151) points out, "when verbs become more complex in terms of the number of associated arguments or when the argument structure entry of the verb does not directly map to its S-structure representation, production difficulty increases".

Another question still to be answered regards whether lexical representations of verbs carry any thematic information. That is a controversial issue between

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[25] Agrammatic speech is one that lacks function words or morphemes, as well as syntactic structures (Fromkin, Rodman, & Hyams, 2003).

neurosciences and theoretical linguistics. The two diverging approaches to that are called the *Lexical-Thematic* approach, and the *Generative-Constructivist* approach, respectively. The *Lexical-Thematic* approach (e.g., Horvath & Siloni, 2011; Meltzer-Asscher, 2011; Reinhart, 2002) claims that the lexicon includes, for each verb, a thematic grid–or different possible thematic grids–and such information is projected from the lexicon during the construction of a sentence, determining the number of NPs to go with that sentence.

Contrastively, linguists such as Chomsky (1986, 1995) and Pesetsky (1982) defend the idea that the representation of complementation options could be reduced to the representation of thematic roles. The *Generative-Constructivist* approach (e.g., Borer, 2005) claims that the lexicon does not carry any grammatically relevant information–i.e., it does not specify thematic grids. This approach views syntactic building as free, and restricted only by word knowledge. Therefore, it would not predict differential brain activations in response to any PAS contrast (e.g., transitive vs. intransitive) when verbs are presented in isolation (Meltzer-Asscher et al., 2013).

According to Shetreet (2014), theoretical linguistics usually offers competing theories to the same questions asked by neurosciences. The author suggests that, if the contrast between what is predicted by linguistic theories can be translated into a contrast between their predictions regarding brain activation, neuroimaging can prove useful to help decide between such theories. Apparently, the debate between such different scientific areas is a productive one, and deserves proper attention.

The next section will focus on cognitive models of lexical retrieval, as well as neurocognitive models of syntactic processing regarding their relation to PAS comprehension and production.

2.2 Models of lexical retrieval, and neurocognitive models of syntactic processing

Lexical access refers to the act of retrieving the words or labels stored with their corresponding meanings in our long-term lexical memory (i.e., our mental lexicon) (Taft, 2013). Laine and Martin (2006, p. 1) point out that:

> Occasional word-finding difficulties are common to us all. Gropings for words and the accompanying frustration give us a glimpse of the

> more severe and more persistent *anomic*[26] experience, word retrieval deficits caused by brain damage. They also show that word retrieval, like any cognitive skill, is by its nature not error free but sensitive to various perturbations. Given the size of our mental lexicons and the speed with which we retrieve words, it is actually surprising that we do not err more often.

The literature on language disorders presents a number of cognitive models of word retrieval processes. Some recent ones are divided into three different types: functional, localist connectionist (also known as interactive activation models), and distributed connectionist. Shelley-Tremblay (2011, p. 211) claims that “local models are defined as ones in which each ‘concept’ in semantic memory[27] has a unique location, or ‘node’ in memory, while distributed systems posit that the same representational structures subserve multiple ‘concepts’”.

Among functional models, there are: Fromkin's (1971), Garrett's (1975), and Levelt, Roelofs, and Meyer's (1999). Both Fromkin’s and Garrett’s influenced American studies on word retrieval impairment in aphasia in the 1970s and early 1980s. They share the assumption that semantic and phonological representations of a word are retrieved independently of each other, and that word retrieval implicates three different stages: retrieval of a word’s meaning, retrieval of a corresponding word form, and assembly of the phonemes that constitute that word (Laine & Martin, 2006).

Garrett’s model (1975), specifically, is divided into five stages: 1) inferential (message-level); 2) logical and syntactic (functional level); 3) syntactic and phonological (positional level); 4) regular phonological (phonetic level); and 5) motor coding (articulatory). The functional level is the one in charge of the development of PAS, of the identification of the words to be retrieved, and of the assignment of the thematic roles derived from the message-level.

The model by Levelt et al. (1999) details links between conceptual representations and *lemmas* (i.e., “an abstract lexical representation of a word that is

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[26] Anomia is a difficulty in word retrieval, which is a sign of aphasia that is usually present in practically all types of both fluent and non-fluent aphasia (Damasio, 1998).

[27] Semantic memory is “a broad domain of cognition composed of knowledge acquired about the world, including facts, concepts, and beliefs. In comparison to episodic or autobiographical memory, it consists of memories that are shared by members of a culture rather than those which are unique to an individual and are tied to a specific time and place. For example, whereas remembering what you had for breakfast yesterday is dependent on episodic memory, knowing the meaning of the word “breakfast” is dependent on semantic memory. Thus one component of semantic memory is the information stored in our brains about the meanings of objects and words” (Martin, 2006, p. 153).

linked to the concept denoted by the word, and also to its phonological form (the lexeme)") (Laine & Martin, 2006, p. 19), and the phonological encoding operations on the lexeme. It was computationally[28] instantiated in a model called WEAVER (Word Encoding by Activation and Verification).

Regarding localist connectionist models, Dell's (1986) and Rapp and Goldrick's (2000) agree with the functional models about the stages of word retrieval. However, many of the localist connectionist models believe there is interaction among some, or even among all, the stages of word retrieval, an idea that is not shared with functional models such as Butterworth's (1981) and Levelt's (1983) (Laine & Martin, 2006). Dell proposes a two-step model, which shows two retrieval stages that are not independent, but rather interactive, contrasting with Levelt et al.'s (1999) model. Such an interaction is due to two distinct mechanisms: access to semantic and phonological representations of a word, and the overlap in time of the two separate stages of word retrieval (Laine & Martin, 2006).

The third type of models is the distributed connectionist ones, for which Plaut and Shallice's (1991) is the best known. Just like the localist models, the distributed ones are about the dynamics of word processing. However, they differ in two ways: about the semantic representations of words, and about one's ability to learn words. What is important to say is that distributed connectionist models have been able to successfully demonstrate aspects of processing which are useful for the diagnosis, and also for the treatment, of language disorders such as aphasia and deep dyslexia (Laine & Martin, 2006).

Having described the best known models of lexical retrieval, it is now time to turn to neurocognitive models of syntactic processing, as well as their relation to sentence comprehension and production, and to PAS. One of the first models that attempted to explain speech and language localization in the brain was the Wernicke-Lichtheim Model (Lichtheim, 1885), whose focus was to understand language breakdown in aphasia. Then, there came the Dual Stream model of cortical brain organization, by Hickok and Poeppel (2004, 2007). Their neuropsychological model describes two processing routes, a dorsal one–supposedly supporting speech

[28] "A computational model is a model expressed as a computer program. When a model's diagram is very complex or includes probabilistic notions, a theorist needs an automated way to determine the consequences of damage to components of the model" (Dell & Kittredged, 2011, p. 169).

production–and a ventral one–supporting comprehension–both derived from studies including subjects without brain lesions.

The dorsal pathway, in blue (see Figure 1), is strongly left dominant. It involves structures in the posterior frontal lobe and the posterior dorsal-most aspect of the temporal lobe and parietal operculum. It is in charge of mapping sensory/phonological representations onto articulatory motor representations. The ventral pathway, in pink, contrastively, is bilaterally organized with a weak left-hemisphere bias. It includes structures in the superior and middle portions of the temporal lobe, mapping sensory/phonological representations onto lexical conceptual representations. The green areas on the dorsal surface of the superior temporal gyrus are proposed to deal with spectrotemporal analysis, while the ones in orange, in the posterior half of the superior temporal sulcus, are implicated in phonological-level processes (Hickok & Poeppel, 2007).

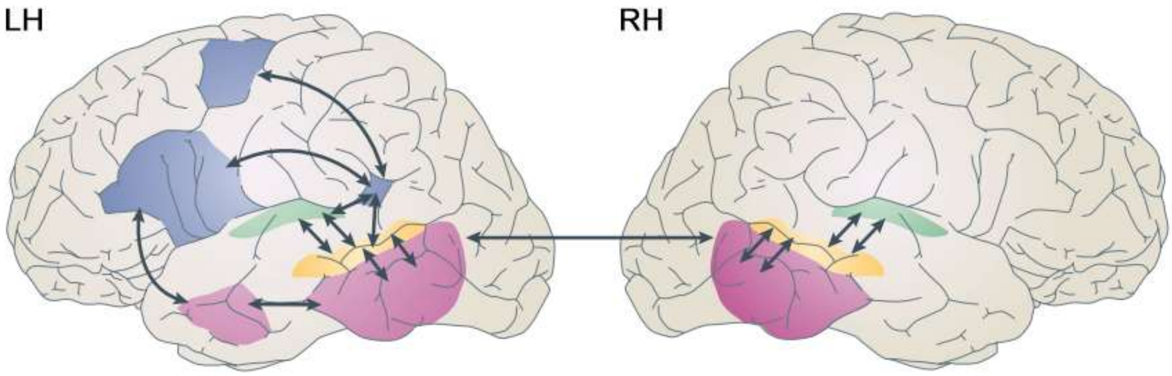

Figure 1. The Dual Stream Model.
Adapted from "The cortical organization of speech processing," by G. Hickok and D. Poeppel, 2007, Nature Reviews. Neuroscience, 8(5), p. 395. Note. LH = left hemisphere; RH = right hemisphere.

The Dual Stream model has been recently applied to lesion data (Fridriksson et al., 2018) in order to: investigate the anatomical boundaries of the dorsal and ventral streams supporting speech and language processing, and to investigate the effect of cortical damage and disconnection involving both streams on aphasic impairment. The findings indicated that impaired grammatical processing of sentences was more related to damage to the ventral stream–and not to the dorsal stream–as previous studies (e.g., Bornkessel-Schlesewsky & Schlesewsky, 2013; Friederici, 2009; Mesulam, Thompson, Weintraub, & Rogalski, 2015; Wilson et al., 2011) had suggested. In the case of patients with frontal damage and their difficulty to process grammatically complex sentences, the results confirmed that impairment seems likely to be related to the disconnection of frontal lobe regions from temporal lobe structures, reinforcing den Ouden et al.'s (2012) claim that the ventral and dorsal streams both contribute to grammatical processing (in healthy speakers) in an interactive manner.

Another model to be highlighted is the neurocognitive model of PAS processing, proposed by Thompson and Meltzer-Asscher (2014). It involves both word and sentence levels, and includes three functions: access to stored lexical information (i.e., retrieval of PAS information from the mental lexicon), structure building and manipulation, and syntactic–semantic integration of the verb and its arguments (Meltzer-Asscher et al., 2015). According to Thompson and Meltzer-Asscher (2014, p. 155-156),

> verb argument structure processing is subserved by a language network involving both anterior and posterior perisylvian regions in the left hemisphere, as well as some focal regions in the right hemisphere. Specifically, this network involves regions in the inferior parietal lobule bilaterally, in the left posterior temporal gyrus, and in the left inferior and middle frontal gyri.

Regarding sentence production, the model predicts that speakers first gain access to the verb lemmas with all their grammatically relevant semantic properties, and also PAS information. That happens with the help of inferior parietal regions bilaterally, which also support other aspects of lexical semantic complexity. Then, after the lemma and its PAS information are accessed, that information triggers initial phrase structure building operations in the inferior frontal gyrus. In turn, left posterior regions (i.e., specifically the superior temporal gyrus and middle temporal gyrus) are required for sentence production, for they support integration of the verb with its arguments (Thompson & Meltzer-Asscher, 2014) (see Figure 2-A).

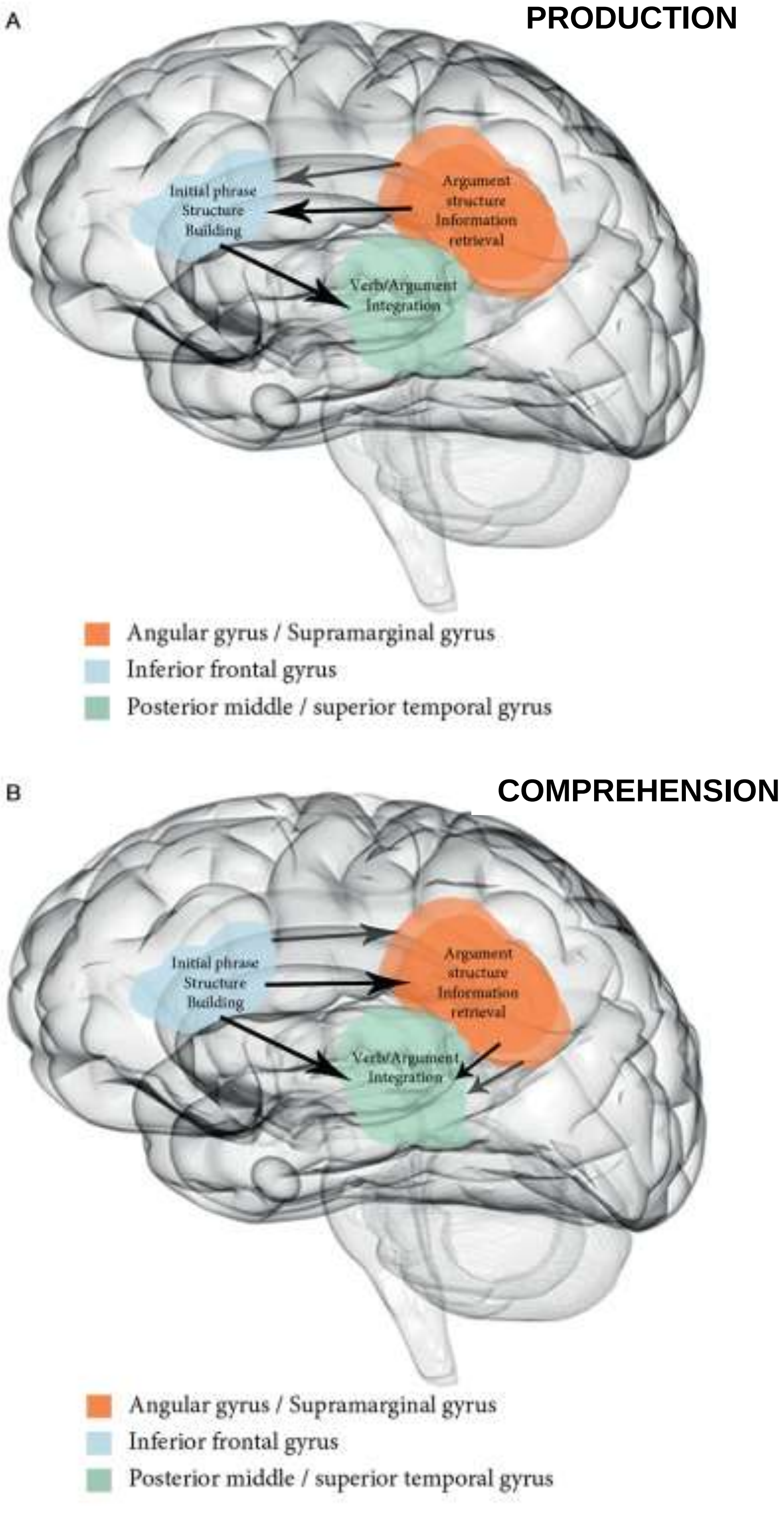

Figure 2. The Neurocognitive Model of PAS Processing.
Adapted from “Neurocognitive mechanisms of verb argument structure processing,” by C. K. Thompson and A. Meltzer-Asscher, 2014, p. 159-160. In A. Bachrach, I. Roy, and I. Stockall (Eds.), Structuring the Argument: Multidisciplinary research on verb argument structure. Philadelphia: John Benjamins Publishing Company.

Sentence comprehension processing, on the other hand, starts with initial syntactic parsing and phrase structure building in the inferior frontal gyrus. PAS information associated with the verbs in the sentence is then retrieved, supported by the angular and supramarginal gyri. The basic phrase structure is then fed, along with PAS information, to posterior temporal regions, for integration. In the case of incompatibility between a syntactic structure and a verb's PAS requirements, repair processes take place (Thompson & Meltzer-Asscher, 2014) (see Figure 2-B).

Finally, I present Friederici's (2016) Neuroanatomical Pathway Model of Language, which is divided into four language-related pathways. The model includes two ventral and two dorsal streams regarding their possible relevance for semantic and syntactic processing during language comprehension. Functionally, three of the four pathways (i.e., two ventral and one dorsal) are involved in sentence comprehension. The other dorsal pathway connects the temporal cortex to the premotor cortex, and is in charge of connecting the brain regions involved in the repetition of speech (see Figure 3).

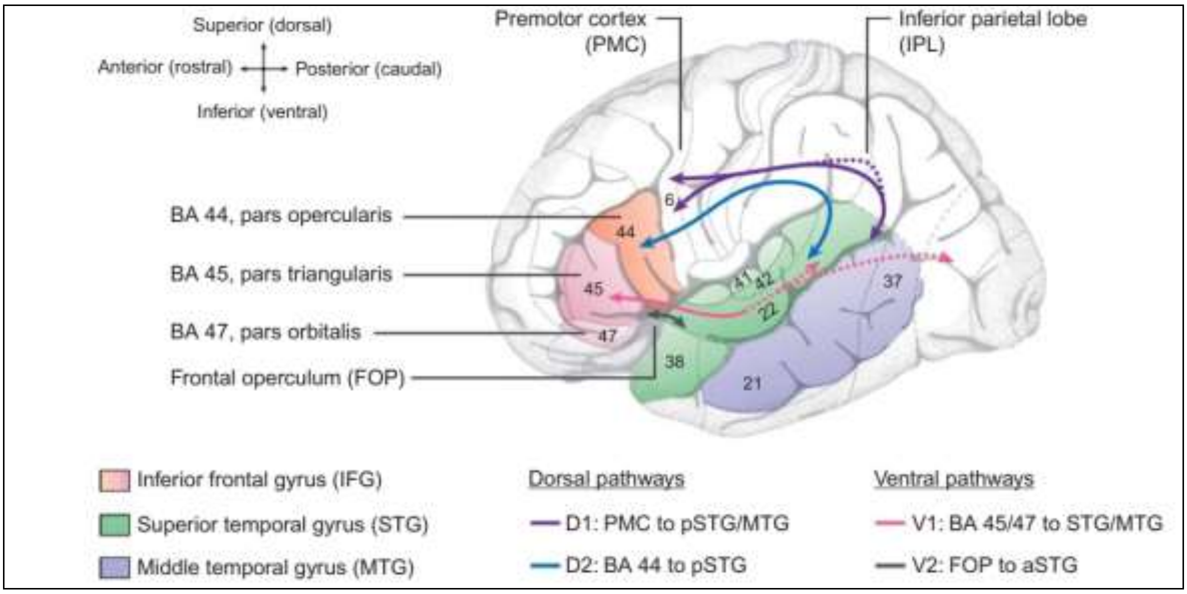

Figure 3. The Neuroanatomical Pathway Model of Language.
Adapted from "The neuroanatomical pathway model of language: syntactic and semantic networks," by A. D. Friederici, 2016, p. 351. In G. Hickok and S. L. Small (Eds.), Neurobiology of language. Academic Press.

Neuroanatomically, one dorsal pathway connects the temporal cortex to the premotor cortex via the inferior parietal cortex and parts of the superior longitudinal fasciculus. The other one connects the temporal cortex to Brodmann Area (BA) 44, as part of Broca’s area, via the arcuate fasciculus. The ventral pathway consists of two fiber tracts that run closely together–the uncinate fasciculus–connecting the anterior ventral inferior frontal cortex to the temporal pole–and the extreme capsule fiber system–mediating the inferior fronto-occipital fasciculus, and connecting the inferior frontal cortex along the temporal cortex to the occipital cortex (Friederici, 2012, 2016).

As explained in the Introduction, syntax-first models assume that syntax is processed autonomously prior to semantic information. The Neuroanatomical Pathway Model of Language is a weak syntax-first model. The model assumes that the processing system starts by building up a local phrase structure on the basis of the available word category information. Semantic and higher-order syntactic relations are processed only after that (unless the context is syntactically and semantically highly predictive). These two different stages of syntactic processing are taken to be represented in two different syntactic networks (Friederici, 2016).

Still according to this model, there are two syntactic networks, a dorsal and a ventral one. The ventral one involves the frontal operculum and the anterior superior temporal gyrus, plus BA 44, and is responsible for the most basic syntactic processes–local syntactic computations (e.g., determiner or PP). The dorsal one deals with more global computations, such as the hierarchical dependencies, as in syntactically complex sentences, such as the ones with noncanonical word order or with varying degrees of embedding. This latter syntactic network involves the posterior superior temporal gyrus and superior temporal sulcus. These areas are in charge of syntactic complexity and of verb-argument resolution, and they also activate whenever the semantic relation between a verb and its argument cannot be resolved. According to Grodzinsky and Friederici (2006), these areas integrate syntactic information and semantic verb-argument information. BA 44 is also a component of this syntactic network, supporting the build-up of hierarchical structures of nonadjacent elements (Friederici, 2016).

Complementarily, there are also two semantic networks, with both a dorsal and a ventral pathways. Only one of such networks, involving the anterior temporal lobe, the inferior frontal cortex, and the posterior temporo-parietal region, is, along with the two syntactic networks, involved in sentence processing. Table 4 summarizes the main features of each of the neurocognitive models.

Table 4: Neurocognitive Models of Syntactic Processing (Language Production and Comprehension)

Dual Stream Model (Hickok & Poeppel, 2004)	**Neurocognitive Model of PAS Processing (Thompson & Meltzer-Asscher, 2014)**	**Neuroanatomical Pathway Model of Language (Friederici, 2016)**
Dorsal Stream: Speech Production	Sentence production	Four pathways one dorsal + one ventral: Syntactic Processing Networks
Structures in posterior frontal lobe and posterior dorsal-most aspect of temporal lobe and parietal operculum. Maps sensory/phonological representations onto articulatory motor representations.	Angular and supramarginal gyri bilaterally involved in lemma access and retrieval of PAS information. Initial phrase structure building processes generated in left IFG. Sentence level syntactic and semantic integration engage left posterior MTG/STG.	Posterior superior temporal gyrus and superior temporal sulcus – in charge of syntactic complexity and of verb-argument resolution. Frontal operculum, anterior superior temporal gyrus, and BA 44 – in charge of local syntactic computations.
Ventral Stream: Comprehension	Sentence comprehension	one dorsal + one ventral: Semantic Processing Network
Structures in the superior and middle portions of the temporal lobe. Maps sensory/phonological representations onto lexical conceptual representations.	Initial syntactic parsing and structure building – left IFG. Bilateral angular/supramarginal gyri engaged to support retrieval of associated PAS information – transmitted to left temporal regions for sentence-level semantic and syntactic integration.	Anterior temporal lobe, inferior frontal cortex, and posterior temporo-parietal region involved in sentence-level semantic processes.

Source: The author (2019). *Note:* MTG/STG: middle temporal gyrus/superior temporal gyrus; IFG: inferior frontal gyrus.

In the next section, 2.3, a review of cross-sectional behavioral studies on PAS production and comprehension will be presented. Most of the studies selected for the review deal with syntactic impairments observed mainly in aphasic populations, in comparison to healthy controls. Then, section 2.4 presents a review of neuroimaging studies on PAS processing in healthy individuals and aphasic subjects.

2.3 Behavioral studies on PAS production and comprehension

The literature on PAS investigating stroke patients and healthy controls offers a wide range of cross-sectional behavioral studies on both production and comprehension. The findings indicate more serious impairments in production, rather than in comprehension tasks.

I start this section by presenting the studies on PAS production, including the ones with picture naming tasks with both verbs and nouns, followed by the ones with sentence elicitation tasks, and also a sentence production priming paradigm. Then, I move on to the studies on comprehension, including the ones with grammaticality judgement. The studies on comprehension will be presented according to the following criteria: studies exploring verbs versus nouns; studies exploring the number of arguments, number of subcategorization options, and of thematic options; and studies contrasting unaccusative to unergative verbs, and the concept of A-movement. Because a lot of the studies in this review have investigated both production and comprehension, they were all organized in Table 5, which presents the participants, the languages investigated, the aims, and the main results of each one.

Table 5: Cross-Sectional Behavioral Studies on PAS Production and Comprehension

STUDIES	N	LANG.	AIMS	RESULTS
Bastiaanse and van Zonneveld (2005)	8 (Broca) 5 (anomic) 3 (Wernicke) (ANI) 6 (HI) (ANI)	Dutch	To test the hypothesis that individuals with Broca's aphasia have problems with sentences in which the verb and its arguments are not in their base position.	Broca patients: significantly better in producing the transitive sentences than the unaccusative ones. No difference for the patients with anomic/Wernicke's aphasia.
Collina, Marangolo, and Tabossi (2001)	3 (PWA) 49 years old 40 years old 54 years old	Italian	The role of PAS complexity in the production of nouns and verbs in Italian agrammatic patients.	Fewer errors in the production of non-argumental nouns than in the production of verbs. Fewer errors with 1- than with 2-argument verbs, and with non-argumental than with argumental nouns.
De Bleser and Kauschke (2003)	11 (PWA) 48-72* 35 (HI) 22.5**	German	To elicit data on noun and verb processing in language production from German aphasic adults.	A clearcut noun advantage and a tendency to prefer intransitive verbs.
Dragoy and Bastiaanse (2010)	16 (agrammatic) 44** 16 (HI) (ANI)	Russian	To explore verb production in agrammatic aphasia in Russian, a structurally different language with rich morphology and relatively free word order.	Agrammatic speech difficulties are related to the number of arguments explicitly mentioned in a sentence, to the number of operations applied to the syntactic structure of a produced sentence, and to changing the base-generated position of a constituent.
Friedmann et al. (2008)	120 (HI) (ANI)	English	To compare sentences with unergative verbs to sentences with alternating and nonalternating unaccusative verbs using a Cross Modal Lexical Priming technique.	Subjects of unaccusatives reactivate after the verb, while subjects of unergatives do not. Alternating unaccusatives showed a mixed pattern of reactivation.

Table 5 (continued)

STUDIES	N	LANG.	AIMS	RESULTS
Kim and Thompson (2000)	7 (agrammatic) 57,7**	English	To examine the relationship between verb retrieval and PAS properties.	The results suggest that no necessary relationship exists between production difficulties and comprehension of nouns/verbs in agrammatism.
Kim and Thompson (2004)	14 (Prob. AD) 77** 9 (agrammatic) 55.7** two groups of 10 (HI) 69.7** 55.1**	English	To test the hypothesis that AD patients' verb deficit involves the semantic aspect of the verb's representation while agrammatic aphasic patients' verb deficit is influenced by PAS.	While both PrAD and agrammatic subjects showed impaired verb naming, PAS influenced agrammatic, but not AD patients' verb production ability.
Kiss (2000)	2 (Broca) 55 years old 37 years old	Hungarian	To investigate the influence of the "representational complexity" of verbs on the sentence production of two agrammatic Broca's aphasics.	PAS and thematic information are partly accessible from the lexical entry of the verb. However, patients failed to construct full syntactic representations of simple sentences because of a syntactic 'mapping deficit'.
Lee and Thompson (2004)	8 (agrammatic) 58.8** 15 (HI) 19.7**	English	To examine the ASCH by investigating agrammatic aphasic comprehension and elicited production of unergative and unaccusative verbs in sentence contexts.	Agrammatic aphasic subjects had production difficulty with unaccusative verb sentences, as compared to unergatives, in the face of near-normal comprehension of both sentence types.
Luzzatti et al. (2002)	58 (PWA) (ANI) 45 (HI) (ANI)	Italian	To estimate the rate of dissociated impairments for nouns and verbs on a large sample of mild to moderate PWA and to investigate the mechanisms underlying such phenomena.	Selective impairment of verbs more frequent than that of nouns. In many cases, the dissociated pattern of naming impairment disappeared when the effects of word frequency and imageability were removed, but in approximately one-fifth of the cases the noun or verb superiority was preserved.
McAllister, Bachrach, Waters, Michaud, and Caplan (2009)	9 (PWA) 37-93* 12 (HI) 52-82*	English	To test the hypothesis that PWA would be affected by features of unaccusatives in comprehension, and would show similar deficits in sentences with unaccusatives and passive sentences.	PWA performed less well than the controls, and there were effects of the presence of movement in both groups and an interaction between group and sentence type in the sentence production task.
Shapiro and Levine (1990)	7 (agrammatic) 54-69* 6 (fluent) 51-65* 10 (HI) (ANI)	English	To examine whether agrammatic patients are normally sensitive to a verb's PAS and its thematic roles, and whether the mental device that activates the verb and its PAS operates in a normally fast-acting and automatic fashion during sentence comprehension.	RTs showed that normal controls and agrammatic Broca's aphasic subjects activate multiple PAS possibilities for a verb in the vicinity of the verb, yet at a point downstream from the verb such effects disappear.

Table 5 (continued)

STUDIES	N	LANG.	AIMS	RESULTS
Shapiro, Gordon, Hack, and Killackey (1993)	6 (Broca) 65-79* 4 (Wernicke) 56-72* 10 (HI) 62-75*	English	To explore the real time access of PAS: thematic representations of verbs in active, passive, cleft-subject, and cleft-object sentences.	Healthy controls and Broca's aphasic subjects show sensitivity to the thematic properties of all verb types, while Wernicke's aphasic subjects do not.
Stavrakaki, Alexiadou, Kambanaros, Bostantjopoulou, and Katsarou (2011)	5 (nonfluent) 49.6** 15 (HI) 49.26**	Greek	To investigate whether the deficits that the aphasic participants showed mainly in the production of unaccusative verbs were extended to comprehension.	PWA performed better on the production and comprehension of transitives than of unaccusatives, showed significantly lower performance on the comprehension of unaccusatives with active morphology, and produced transitive (S)VO structures instead of the unaccusative ones.
Thompson (2003)	8 (agrammatic) 50.7** 7 (HI) 56.9**	English	To examine patterns of verb production in narrative samples and verb comprehension of unaccusative and unergative verbs in agrammatic individuals.	PWA showed a preference for production of verbs with fewer arguments. Both groups showed fewer productions of unaccusative verbs in their narrative samples as compared to other verb types.
Thompson and Lee (2009)	8 (PWA) 58.8** 5 (HI) 19.7**	English	To test aphasic's comprehension and production of active and passive sentences using two types of English psych verbs (with an Experiencer-marked subject, and with an Experiencer-marked object).	ObjExp verbs were more impaired than SubjExp verbs. The opposite pattern was noted for passive sentence production. All participants had difficulty producing passives of both types, but better performance on ObjExp verbs. PWA showed a preference for producing actives for SubjExp verbs and passives for ObjExp verbs.
Thompson, Lukic, King, Mesulam, and Weintraub (2012)	52 (StrAph) 57.21** 28 (PPA) 63.75** 28 (HI) 63.25**	English	To examine noun and verb comprehension in individuals with StrAph and PPA.	StrAg and PPA-G groups showed no comprehension impairment for nouns and verbs. Three PPA-S participants showed poorer noun compared to verb comprehension. StrAn and the PPA-L participants showed no significant differences between nouns and verbs in comprehension.

Source: The author (2019). *Note:* *Age range. **Mean age. Prob. AD = probable Alzheimer's Disease; StrAph = Stroke-induced aphasic; StrAn = anomic; PPA = Primary Progressive Aphasia; ASCH = Argument Structure Complexity Hypothesis; ANI = age not informed; PWA = persons with aphasia; LANG = language; PPA-G = agrammatic; PPA-S = semantic; PPA-L = logopenic; HI = healthy individuals.

I start presenting the studies on production with Kim and Thompson's (2000, 2004), who conducted picture naming tasks with nouns and verbs (obligatory 1-, 2-, and 3-argument verbs[29], and optional 2- and 3-argument verbs). Noun naming was better than verb naming in both studies for all participants (i.e., agrammatic, patients with probable AD, and healthy individuals). Regarding verbs, results showed that it is more difficult for agrammatic aphasic patients to produce verbs as the number of thematic roles increases. The same pattern has been noted in studies with populations of aphasic patients who speak languages other than English, such as Hungarian (Kiss, 2000), Italian (Luzzatti et al., 2002), German (De Bleser & Kauschke, 2003), and Russian (Dragoy & Bastiaanse, 2010). In Luzzatti et al. (2002), both aphasic and healthy individuals performed significantly better at naming nouns than verbs in Italian.

Collina et al. (2001) also conducted a picture naming task. Their results showed that three agrammatic subjects, native speakers of Italian, performed better with 1- than with 2-argument verbs, and with non-argumental than with argumental nouns[30]. The results of such studies corroborate the assumption that PAS complexity may affect the ability of aphasic subjects to produce words. However, Collina et al. (2001) claim that, since PAS complexity is necessarily associated with verbs and only rarely with nouns, caution is recommended in order to avoid confoundings between PAS complexity effects and grammatical class effects, which could lead to erroneous interpretations of patients' performance.

Regarding the production of unaccusative verbs, Thompson (2003) had agrammatic and healthy controls produce unaccusative and unergative verbs in response to pictures. Participants were instructed to name the action depicted by each picture. Results showed that naming of unaccusative verbs was poorer than naming of unergatives, with a statistically significant difference in production of the two verb types for both agrammatic and healthy controls. Following Thompson's (2003) methodology, McAllister et al. (2009) tested people with aphasia and healthy controls. Similar to Thompson's (2003) results, unergative verbs were named with significantly higher ACC scores than unaccusative verbs. However, there was a

[29] In both Kim and Thompson (2000, 2004), the authors use the term 'place' to mention the number of object arguments a verb takes. In order to keep it easier for the reader, I decided to rename 0-, 1-, and 2-place verbs as 1-, 2- and 3-argument verbs.

[30] According to Collina et al. (2001, p. 1131), "most argumental nouns are morphologically derived from verbs, and there is a systematic relation between the number of arguments they take and their derivational complexity such that two place argument nouns are usually more complex and longer than one place argument nouns (e.g., distruzione-destruction from distruggere-to destroy vs. sosta-halt from sostare-to halt)".

significant main effect of group, with controls responding with greater ACC scores than the aphasic group.

Moving on to the studies that used sentence elicitation tasks, Bastiaanse and van Zonneveld (2005) investigated the production of sentences with verbs of alternating transitivity in Dutch. Participants included people with different types of aphasia (i.e., Broca's, *anomic*[31], and *Wernicke's*[32]) and healthy controls. Participants were presented with pictures, which had the infinitive form of the verb printed underneath, and were supposed to produce a sentence with either the transitive or the unaccusative form of each verb. For Broca's patients, it was significantly more difficult to produce unaccusative verbs. However, for the anomic and Wernicke's patients, the unaccusatives were slightly easier. Bastiaanse and van Zonneveld emphasize that their results for Broca's patients are in line with the DOP-H, and also corroborate the ASCH (Thompson, 2003), both explained in section 2.1. The authors also draw attention to the fact that, although unaccusatives have only one argument and the transitives have two, unaccusatives are more difficult to produce.

The studies by Lee and Thompson (2004), McAllister et al. (2009), and Stavrakaki et al. (2011) used very similar sentence production tasks including picture stimuli. Participants were instructed to use the verb provided acoustically and/or in written form (above or below the pictures) to produce a complete sentence to describe the action depicted in the pictures as accurately as possible. Lee and Thompson (2004) identified a deficit in the production of unaccusative, in comparison to unergative verbs, in a group of agrammatic aphasics in comparison to unimpaired production by healthy controls. Similar results were obtained for both the aphasic group and the healthy controls in McAllister et al.'s (2009) study.

Stavrakaki et al. (2011) used both transitive and intransitive verbs in Greek. Differently from Lee and Thompson's (2004) and McAllister et al.'s (2009), Stavrakaki et al.'s participants were presented with a verb in the first person singular form of the past tense, and had to produce the third person singular form of the same verb in order to describe the action in the picture. In all three studies, correct responses were

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[31] Anomic aphasia is characterized by intact repetition and fluent speech, but serious difficulty finding the right words to convey an idea.

[32] According to Damasio (1998, p. 34), "Wernicke's aphasia is perhaps the least controversial of the aphasia types. Speech is fluent and well articulated, with frequent paraphasias (both verbal and literal). Syntactic structure appears less disturbed than in Broca's aphasia, but it is reasonable to say that both Wernicke's and Broca's aphasics exhibit some form of agrammatism. Aural comprehension is defective. Repetition of words and sentences is also defective. In general, both reading and writing are disturbed".

the ones with the required thematic structure of the verb, produced in the correct order. Because Greek is a null subject language, subject omission was accepted. Object omission in transitive structures, on the other hand, was not accepted because that did not appropriately describe the picture. The same was true for voice errors, given the fact that, in Greek, morphological voice is a significant feature of PAS.

In Thompson and Lee (2009), active and passive sentences were elicited using picture stimuli and psych verbs (e.g., those with an Experiencer-marked subject (e.g., *fear, admire*) and those with an Experiencer-marked object (e.g., *frighten, amuse*)). Participants were instructed to describe each picture by using the given verb in a single complete sentence, without any instructions whether to produce an active or a passive sentence. After the production of a sentence, the examiner pointed to the desired sentential subject and asked participants to produce a sentence beginning with that item. If they had produced an active sentence first, they were supposed to produce a passive sentence regarding the same picture next. Healthy participants had little difficulty producing either sentence type with both types of verbs. In contrast, for aphasic subjects, there was a significant effect of sentence voice. They produced Subject-Experiencer verbs significantly more successfully than Object-Experiencer verbs, but production of passives was impaired for both verb types.

The last behavioral study on PAS production to be reviewed is Dragoy and Bastiaanse's (2010), who used a sentence production priming paradigm in Russian, a language which has rich morphology and relatively free word order. In this study, there were six conditions: sentences with one or two arguments, direct or indirect thematic role mapping, and basic or scrambled word order. Participants were presented with a pair of pictures. First the experimenter named the objects, people, and animals in the picture, in order to ensure proper recognition. Then, participants were instructed to listen while the experimenter read the sentence describing the first picture in the pair (i.e., prime sentence), and then they were supposed to describe the second one in a similar way (i.e., target sentence). The action presented in each pair of pictures was the same, but the entities were always different. Healthy participants performed significantly better on the test, compared to agrammatic ones. When agrammatic participants produced ungrammatical responses, they consisted of verb omission or wrong lexical or grammatical form choice. They also produced grammatical sentences that were different from the target ones, especially by changing the word order.

Moving on to PAS comprehension, it is important to highlight that, in general, most of the research on PAS comprehension shows practically intact comprehension, even in impaired populations who present difficulties in PAS production. However, there are some subtle differences in results among studies due to tasks, samples, and populations of impaired patients variables.

While contrasting the comprehension of nouns to that of verbs, Kim and Thompson (2000, 2004) applied a spoken word-to-picture matching task and a written word-to-picture matching task, respectively. Both tasks had a verb version and a noun version. In all cases, participants were instructed to point either to the picture (Kim & Thompson, 2000) or to the word (Kim & Thompson, 2004) that corresponded to the word/picture indicated by the examiner. Pictures/words had to be chosen between two (semantic, phonogical and/or unrelated) distracters. Although in both studies agrammatic participants had a good comprehension of both word classes, in Kim and Thompson (2004) they were significantly better at comprehending nouns than verbs[33], while in Kim & Thompson (2000) their performance was intact for both word classes. The agrammatic and anomic aphasic participants of Thompson et al. (2012) also performed equally well in both word classes, in a very similar comprehension task.

Concerning number of arguments, subcategorization and thematic options, Shapiro and Levine (1990) tested both Broca's aphasic and *fluent*[34] aphasic, and healthy individuals in two different comprehension tasks. The authors used a Cross-Modal Lexical Decision (CMLD) task, in which the visual probes were presented right after the verb in one set of sentences, and four syllables past the verb, very close to the preposition in the PP, in a separate set of sentences. The idea was to explore whether the cost associated with activating all of a verb's PAS possibilities right after the verb would dissipate as the sentence unfolded over time. Four categories of verbs were included in the experiments: pure transitives[35], obligatory 3-argument

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[33] The data regarding the probable AD patients of Kim and Thompson (2004) and the PPA aphasic participants of Thompson et al. (2012) will not be discussed here because they are types of dementia, and not stroke-induced neurological conditions.

[34] According to Hallowell and Chapey (2008), the three basic types of fluent aphasia are: conduction, Wernicke's, and transcortical sensory aphasia.

[35] Verbs that allow only one argument structure (Canseco-Gonzalez, Shapiro, Zurif, & Baker, 1990).

verbs, nonalternating datives, and alternating datives[36]. The results showed that Broca's aphasic individuals, just like healthy controls, had longer RTs for verbs with multiple subcategorization options than for verbs with only one subcategorization option. Fluent aphasic individuals, on the other hand, did not show any sensitivity to PAS, what suggests that their sentence processing deficit may have a semantic, and not a syntactic, explanation.

In order to confirm Shapiro and Levine's (1990) results, Shapiro et al. (1993) decided to conduct similar experiments with the CMLD task, including Broca's and Wernicke's aphasic, and also healthy individuals. The idea was to raise the level of complexity of the sentences, since the agrammatic participants of the 1990 study had had no difficulties interpreting the sentences. In the new study, passive and cleft-object sentences[37] were included, in contrast to active and cleft-subject sentences. The results again were very similar to Shapiro and Levine's (1990). Broca's aphasic subjects showed normal PAS effects as before, even in complex sentences that they usually do not comprehend, such as passive and cleft-object sentences. Finally, Wernicke's patients again did not show sensitivity to PAS effects, although this time they were a more homogenous group of fluent aphasics. Therefore, the results reinforced the assumption that Wernicke's aphasia implies a semantic deficit, and that during online sentence comprehension they are not provided with the set of lexical-conceptual features that a verb has.

The following studies investigated both unaccusative and unergative verbs. Thompson (2003) conducted a spoken word-to-picture matching task. Similar to Kim and Thompson's (2000, 2004) studies, participants were instructed to avoid the distracters and point to the picture that corresponded to the target verb presented auditorily by the examiner. The aphasic individuals showed no difficulty in comprehending either type of verb, indicating that their access to the lexicon of verbs is relatively intact. The same is true for Lee and Thompson (2004), who conducted a truth-value judgment task. Participants were supposed to respond 'yes' or 'no',

[36] "Nonalternating datives allow two possible strict subcategorizations, an NP and an NP PP, as well as accommodating two possible argument structure arrangements of the forms (x,y) and (x,y,z). Alternating datives allow three possible strict subcategorizations, an NP, an NP PP, and an NP NP. But like nonalternating datives, alternating verbs allow two possible argument structures of the forms (x,y) and (x,y,z)" (Shapiro & Levine, 1990, p. 30).

[37] A cleft sentence is one "in which focus is given to either the subject or object using a beginning 'It...' (e.g., *It was my brother who lent me the money*) or 'What...' (e.g., *What you need is a Holiday*)" (Hewings, 2013, p. 206).

whether the pictures they saw, one at a time, corresponded to a spoken test sentence. Again, no significant differences were found between unaccusative and unergative verbs, neither between the performance of aphasic and healthy individuals.

The study by Friedmann et al. (2008) was meant to test whether sentences with unaccusative verbs result from the A-movement of the object to subject position. The assumption would be that, if unaccusative subjects undergo such movement, there would be reactivation of the subject in the trace position after an unaccusative verb, but not after an unergative verb. The study also aimed at comparing both alternating and nonalternating unaccusatives in relation to their reactivation after the verb. The authors conducted a Cross-Modal Lexical Priming task, in which only healthy participants were placed in a small sound-proof testing booth in front of a computer screen, with headphones and a button box. Then, they heard sentences presented aurally at a normal speaking rate, and at some point during each sentence, a letter sequence (a word or a nonword) was visually displayed on the screen. Participants were instructed to make a lexical decision as quickly and accurately as possible, by pressing a button, whenever a letter string appeared on the screen. The two response keys were labeled ‘word’ and ‘nonword’[38]. The results showed that subjects of unaccusative verbs reactivated after the verb, while subjects of unergatives did not. Alternating unaccusatives, on the other hand, showed a mixed pattern of reactivation, since some of them had the same pattern as the non-alternating, while others had the same pattern as the unergative verbs. The authors believe that could have been due to the fact that the alternating unaccusatives are formally identical to transitive verbs and the parser is not able to tell, at an early point, which of the possibilities corresponds to the processed sentence.

Thompson and Lee (2009) decided to test the assumption that Object-Experiencer psychological verbs (e.g., *frighten, amuse*) are more complex than Subject-Experiencer psychological verbs (e.g., *fear, admire*). Object-Experiencer verbs lack an external argument and, therefore, license movement of the Theme-marked argument to the subject position. According to syntactic accounts of unaccusatives, A-movement is obligatory, since all NPs must be assigned Case. This extra NP movement is what makes Object-Experiencer psychological verbs more

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[38] “The nonword probes conformed to English orthographic and phonological rules and appeared with the filler sentences” (Friedmann et al., 2008, p. 361).

complex. Therefore, the authors conducted a sentence-verification task, in which the same pictures were used to test both active and passive forms of the target verbs. The aphasic and healthy participants were instructed to respond ‘yes’ or ‘no’, whether the sentence they heard corresponded to each picture they saw. The results showed relatively intact lexical representation for the agrammatic participants, except in passive constructions with Subject-Experiencer psychological verbs, due to the difficulty to deal with passive in relation to active constructions.

The study by Stavrakaki et al. (2011), with Greek speakers, also included passive and active voice. What is interesting about Greek is that it is a language with a relatively free word order, and there is no A-movement. Besides, different Greek unaccusative verbs appear with different voice morphologies (i.e., active, non-active, or both). The task presented participants with three pictures. They were supposed to point to the one that corresponded to the transitive/intransitive (unaccusative) form of the verb they heard. There was a semantic distracter as well. Among the unaccusative verbs, there were some that only appeared in active voice, some that only appeared in non-active voice, and some that appeared in both active and non-active voice. The results indicated a significantly better performance of healthy controls in comparison to the aphasic group in both transitive and unaccusative verbs. However, it was significantly more difficult for the aphasic group to deal with unaccusatives. Regarding morphology, the aphasic participants had a significantly better performance with unaccusatives with non-active morphology than with active morphology.

McAllister et al. (2009) used a computerized sentence-picture matching task including transitive/intransitive (unaccusative) and active/passive pairs. The idea was again that non-canonical word order, as in the case of unaccusative verbs and passive constructions, would cause difficulty to aphasic individuals. In the picture pairs with unaccusative stimuli, one picture represented the subject NP as the theme of the verb, being the intended target in the intransitive ([+ movement]) condition. The other picture depicted the subject NP as the agent of the verb, being the target in the transitive condition. Results regarding sentences without A-movement, in comparison to movement constructions, showed an effect of group in RTs, pointing to the importance of a common mechanism in determining comprehension of these two sentence types. Because such an effect was found in both healthy and aphasic participants, the authors believe that it reflects the processing demands of the sentences, instead of an aphasia-specific deficit in processing certain structures. They also claim that, because their aphasic participants have mild, fluent aphasia, rather than agrammatic or Broca's, that could account for the disturbances affecting comprehension of the sentences in their study.

This section closes with the studies that used grammaticality judgment tasks. Both Kim and Thompson's (2000, 2004) studies were meant to test if the subjects could detect grammatical violations involving verb argument structure requirements. They both used simple, canonical sentences, in which the only grammatical violation was that of subcategorization. Sentences contained verbs with different numbers of obligatory arguments: obligatory 1-, 2-, and 3-argument verbs. Half of the sentences were grammatical and half were ungrammatical. Participants were supposed to point to a different card if the sentences, presented auditorily, were either 'good' or 'bad'. In both studies, the aphasic participants had very high ACC scores, regardless of sentence type, indicating a well-preserved ability to detect syntactic errors associated with PAS.

Now, I present a review of neuroimaging studies on PAS processing, and then close with a study on PAS production using fMRI.

2.4 Neural correlates of syntax: neuroimaging studies on PAS processing in healthy individuals and aphasic subjects

Several studies have investigated PAS processing, both neuroanatomically and functionally, by using different neuroimaging techniques and methods of analysis, and looking into populations of both healthy and aphasic individuals, as well as different age groups. Such studies were not only motivated by a need to understand lexical representations in the brain, but also to find answers that might be applicable while treating clinical populations.

According to Malyutina and den Ouden (2017), verb-based treatments for both sentence production and comprehension in agrammatic aphasia might benefit from an understanding of PAS neuroanatomical and functional features in several ways: knowing which PAS characteristics affect processing complexity will help approaches that sequence treated stimuli in the order of increasing or decreasing complexity; knowing PAS effects under various processing conditions can inform the choice of most efficient tasks to tap into PAS retrieval, by suggesting whether tasks need to be focused on syntactic structure, on verb semantics, or even whether retrieval of isolated verbs may provide sufficient exposure to PAS; also, knowing the neural bases of PAS processing may suggest targets for brain stimulation treatments of verb and/or sentence processing in aphasia, and inform pre-surgical language mapping.

One such verb-based treatment in aphasia is Verb Network Strengthening Treatment (VNeST) (Edmonds, Nadeau, & Kiran, 2009). VNeST promotes the generation of both agent and patient arguments following exposition to verbs, without explicit training of those verbs. The treatment was designed to promote generalization to the lexical retrieval of untrained concepts in the production of sentences and in untrained discourse contexts. It is based on the assumption that the verb is the nucleus of the sentence, and that there is overlapping among the nouns that can fill the thematic roles with different verbs. It involves three subprocesses: semantic activation, generation of PAS, and the assignment of thematic roles (Edmonds, Obermeyer, & Kernan, 2014). In VNeST, syntax and semantics are seen as indissociable, collaborating to the improvement of both sentence production, and the reinforcement of the semantic network. The development and efficacy of treatments such as VNeST demonstrate the relevance of investigations focusing on PAS with healthy and clinical populations.

However, for the purposes of this dissertation, only cross-sectional, rather than longitudinal, studies on PAS processing using fMRI with comprehension tasks have been chosen for this review (see Table 6 for a summary of the studies to be further detailed), and will be presented according to the following criteria: studies looking into the neural differences between nouns and verbs; studies investigating number of arguments, number of subcategorization options, and number of thematic options; and studies focusing on alternating transitivity and unaccusativity. To close this section, a recent study investigating the neural correlates of PAS production will also be presented.

Table 6: Cross-Sectional Studies on PAS Processing with fMRI

STUDIES	N	LANG.	AIMS	RESULTS
Garbin, Collina, and Tabossi (2012)	12 (HI) 21-29*	Italian	To investigate the grammatical categories of object noun, event noun, and verb, to assess the cortical regions of activation supporting their processing.	Noun versus verb: differences in regions of activation in the left inferior frontal cortex and in the extent of the same areas.
Hernández, Fairhall, Lenci, Baroni, and Caramazza (2014)	14 (HI) 18-38*	Italian	To test whether the intrinsic 'predication-building' function of verbs is what drives the verb–noun distinction in the brain.	Neural activity in the left posterior middle temporal and inferior frontal gyri correlates with transitivity, indicating sensitivity to predication.
Malyutina and den Ouden (2017)	17 (HI) (Exp. 1) 20-29* 21 (HI) (Exp. 2) 19-30*	English	To investigate neural effects of three PAS structure features (number of arguments, of subcategorization options, and of thematic options) in lexical decision and sentence well-formedness judgment.	Increased PAS complexity in terms of subcategorization and thematic options had a detrimental effect on sentence processing, but facilitated lexical access to single words.
Meltzer-Asscher et al. (2013)	14 (HI) 19-29*	English	To compare brain activation in response to alternating transitivity verbs, with two different verbal alternates–one transitive and one intransitive–and simple verbs, with only one, intransitive, thematic grid.	Greater activation in the angular and supramarginal gyri extending to the posterior superior and middle temporal gyri bilaterally, for alternating compared to simple verbs. Additional activation was detected in bilateral middle and superior frontal gyri.
Meltzer-Asscher et al. (2015)	16 (HI) 19-38* 13 (HI) 54-70*	English	To examine three aspects of PAS complexity: number of thematic roles, of thematic options, and mapping (non)canonicity (unaccusative vs. unergative, and transitive verbs).	Increased number of thematic roles elicited greater activation in the left posterior perisylvian regions. Unaccusative verbs elicited longer response times and increased activation in the left IFG.
Shetreet et al. (2007)	12 (HI) (Exp. 1) 14 (HI) (Exp. 2) 23-33*	Hebrew	Exp. 1 - To identify brain regions sensitive to the number of arguments by comparing 1-, 2-, or 3-argument verbs[39], presented in sentential context. Exp. 2 – To compare sentences with 1-, 2-, and 3-subcategorization and thematic frames options verbs where nonfinite clauses stood as a different semantic and syntactic category than finite clauses.	Graded activations in the left superior temporal gyrus and the left IFG in correlation with the number of options. The areas that correlated with the number of complements (the right precuneus and the right cingulate) not conventionally linguistic.

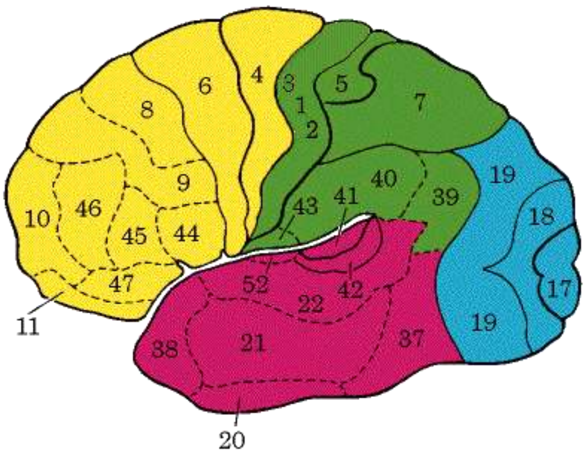
[39] In Shetreet et al. (2007), the authors use the term 'complement' to mention the number of object arguments a verb takes. In order to keep it easier for the reader, I decided to rename 0-, 1-, and 2-complement verbs as 1-, 2- or 3-argument verbs. The same was done regarding Malyutina and den Ouden (2017), in substitution for the term 'valency frames'.

Table 6 (continued)

STUDIES	N	LANG.	AIMS	RESULTS
Shetreet et al. (2010)	18 (HI) 22-44*	Hebrew	To examine whether the cortical representation of unaccusative verbs differs from that of unergative and transitive verbs.	The IFG may be involved with the execution of the syntactic operation, whereas the MTG may be responsible for the lexical operation that derives unaccusative verbs.
Takashima, Meyer, Hagoort, and Weber (2018)	30 (HI) (ANI)	Dutch	To test whether brain activation patterns differed during the production of sentences with different numbers of verb arguments.	Retrieval of more complex lexical-syntactic patterns for sentences with more verb arguments lead to increased activation in the posterior language network related to the lexical-syntactic information stored in the mental lexicon.
Thompson et al. (2009)	14 (HI) 45-68* 5 (PWA) 36-65*	English	To examine the neural mechanisms of verb processing in older normal volunteers and patients with stroke-induced agrammatic aphasia.	Three- and 1-argument verbs comparisons showed activation of the angular gyrus in both hemispheres and this same heteromodal region was activated in the LH in the (2- + 3-) - 1-argument verbs contrast. For aphasics, activation was unilateral (in the RH for three participants).
Thompson et al. (2007)	14 (HI) 18-27*	English	To examine the activation patterns derived for verbs with different PAS.	Activation of the supramarginal and angular gyri, limited to the LH when 2-obligatory-argument verbs were compared to 1-argument verbs. Bilateral activation for 2- and 3-argument compared to 1-argument verbs.

Source: The author (2019). *Note*. *Age range. ANI = age not informed; PWA = persons with aphasia; LANG = language; IFG = inferior frontal gyrus; MTG = middle temporal gyrus; HI = healthy individuals.

This review starts with two studies that investigated whether nouns and verbs are processed differently in the brain. In Garbin et al. (2012), participants were instructed to press a button if the word they saw on the screen was an Italian word. Words were divided into object nouns, event nouns, verbs, and pseudowords. Object nouns, in comparison to verbs, presented activation involving the inferior frontal gyrus, the left insula, and the left inferior parietal lobe. There were similarities in the pattern of activation for event nouns and verbs. Compared to verbs, event nouns presented activation in BAs 44 and 46 (see Figure 4), and in the insula bilaterally, also in right BA 45, in the superior temporal gyrus bilaterally (more extensively in the right hemisphere (RH)), and in the left parahippocampal gyrus. The opposite comparison showed activation of the left inferior frontal gyrus, toward the anterior cingulate gyrus, and of the middle and superior temporal gyrus bilaterally. According to the authors, event nouns, and the verbs from which they derive, share semantic and argument structure properties, what might explain the similarity in activation between these two word classes.



9 –	Dorsolateral prefrontal cortex
10 –	Anterior prefrontal cortex (most rostral part of superior and middle frontal gyri)
20 –	Inferior temporal gyrus
21 –	Middle temporal gyrus
22 –	Superior temporal gyrus (the caudal part is usually considered to contain the Wernicke's area)
37 –	Fusiform gyrus
38 –	Temporopolar area (most rostral part of the superior and middle temporal gyri)
39 –	Angular gyrus (considered by some to be part of Wernicke's area)
40 –	Supramarginal gyrus (considered by some to be part of Wernicke's area)
44 –	Pars opercularis (part of the IFG and of Broca's area)
45 –	Pars triangularis (part of the IFG and of Broca's area)
46 –	Dorsolateral prefrontal cortex
47 –	Pars orbitalis (part of the IFG)
52 –	Parainsular area (at the junction of the temporal lobe and the insula)

Figure 4. Brodmann Areas.
Retrieved and adapted from http://umich.edu/~cogneuro/jpg/Brodmann.html. Note. IFG = inferior frontal gyrus.

Hernández et al. (2014) conducted an experiment in order to identify cortical regions that are more sensitive to verb relative to noun processing. The stimuli were Italian verbs (both action verbs and event verbs) and nouns presented as single words or short phrases. Participants were instructed to indicate whether a memory probe was identical to one of the three stimuli previously presented. The authors came up with the following verb-preferring regions of interest (ROIs): the posterior middle temporal gyrus and the mid-middle temporal gyrus in lateral temporal cortex, and the middle frontal gyrus, the inf-inferior frontal gyrus, and the sup-inferior frontal gyrus in frontal regions. Then, the authors examined whether those ROIs were sensitive to the property of predication and found a positive correlation with transitivity in the posterior middle temporal gyrus and the inf-inferior frontal gyrus. No other semantic–syntactic property of verbs independently modulated activity in any of the ROIs. The authors concluded that, at least in the posterior lateral temporal cortex and the inferior frontal cortex, the distinctions in activation reflect the representation of grammatical (verbs vs. nouns), and not semantic, properties associated with action concepts (e.g., telicity[40], dynamicity[41], and subject agentivity[42]).

The studies by Thompson et al. (2007) and Thompson et al. (2009) used the same lexical decision task with the same set of stimuli to investigate PAS in healthy and aphasic individuals, respectively. Both groups were of monolingual English speakers who were instructed to press a button for words and another for pseudowords. The stimuli included verbs (1-argument, 2-argument and 3-argument verbs), nouns, and pseudowords. Thompson et al. (2007) found largely overlapping activation maps for both word classes, but no significant activation in the comparison of either verbs to nouns, or nouns to verbs. However, the healthy controls of Thompson et al. (2009) showed significant activation for verbs in the left superior temporal gyrus and middle temporal gyrus.

Regarding number of arguments, both studies found quite similar results, despite the difference in age between the groups (see Table 6), and the inclusion of the aphasic patients. The main finding concerns the fact that the more complex argument structure, the many more demands of posterior brain regions, such as the angular gyrus. Thompson et al. (2007) found activation of the supramarginal and angular gyri in the left hemisphere (LH) in the comparison between 2-obligatory-argument and 1-argument verbs. Moreover, there was bilateral activation between 2- and 3-argument verbs in comparison to 1-argument verbs. Thompson et al.'s (2009) results were slightly different for the healthy controls. The angular gyrus was activated bilaterally in the comparison between 3- and 1-argument verbs, but only in the LH in the 2- and 3-argument verbs in comparison to 1-argument verbs. For three agrammatic aphasic patients, however, activation was only in the RH, probably because their lesions extended to the left temporoparietal region.

As Thompson et al. (2009) point out, although other studies' results (e.g., Bornkessel, Zysset, Friederici, Von Cramon, & Schlesewsky, 2005; Shetreet et al., 2007) might vary regarding the exact posterior regions activated during processing of PAS, they usually point to the inferior parietal, posterior middle, and posterior superior temporal gyri complex, for both younger and older individuals. Shetreet et al.

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[40] "Telicity refers to the extent to which an action entails a natural endpoint" (Hernández et al., 2014, p. 1832).

[41] "Dynamicity refers to the expression of change or process" (Hernández et al., 2014, p. 1832).

[42] "Agentivity refers to an action intentionally performed by the subject" (Hernández et al., 2014, p. 1832).

(2007), in experiment 1, for instance, applied a semantic decision task with sentences presented via MRI compatible headphones. Monolingual Hebrew speakers were supposed to press a ‘yes’ or a ‘no’ button with their left hand fingers after each sentence, whether it described an event more likely to happen at home or not. Contrary to expectations, no canonical language areas were activated (i.e., Broca’s and Wernicke’s areas). There was activation only in the right anterior cingulate (BA 32) and in the right precuneus (BA 7)–not conventionally linguistic areas–for the contrast between 2-argument and 1-argument verbs. The authors attribute the activation pattern in the right precuneus to the high incidence of imageable entities in the sentences, which, during processing, could have been held in imagistic form, and have required graded imagistic resources.

Malyutina and den Ouden (2017) conducted two separate experiments, one with a sentence-level task, and the other with a single-word-level task. In both tasks, the following three PAS structure characteristics were assessed: number of arguments, of subcategorization options, and of thematic options. In both experiments, the same four categories of verbs were used: *complete-verbs* (one argument and one subcategorization option, used with NPs); *demand-verbs* (one argument but multiple subcategorization options, either an NP or at least one other subcategorization option, such as an infinitive and/or a dependent clause); *sing-verbs* (two arguments, used both intransitively and transitively, but only one frame for thematic role assignment (i.e., the subject NP has the thematic role of agent)); and *break-verbs* (two arguments, used both intransitively and transitively, but two thematic-role options (i.e., the role of the subject differs between the transitive and the intransitive uses)).

Regarding number of arguments in the sentence-level task, there was increased activation between *sing-verbs* and *complete-verbs* only associated to a lower number of arguments, with a cluster of increased activation in the left superior frontal gyrus, and supplementary motor area. In the single-word-level task, there was increased activation associated with a greater number of arguments in the left mid-anterior middle temporal gyrus, while with a lower number of arguments the activation was in white matter underlying the right middle temporal gyrus, and in the RH caudate nucleus and cerebellum.

Concerning a greater number of subcategorization options in the sentence-level task, the contrast between *complete-verbs* and *demand-verbs* revealed activation in the left angular and supramarginal gyri, the left posterior middle temporal gyrus, the frontal superior, and the superior medial gyri, the left precuneus, and the posterior cingulate gyrus, several subcortical structures including the left and the right thalamus, and the right cerebellum. With a lower number of subcategorization options in the single-word-level task, there was activation in the bilateral frontal and occipital lobes, and in the left parietal lobe.

Finally, regarding a greater number of thematic options in the sentence-level task, *break-verbs* and *sing-verbs* revealed activation in white matter underlying the left inferior frontal gyrus, in the left caudate nucleus, and left middle cingulum. The opposite contrast revealed activation at the junction of the right angular, the superior temporal and the middle temporal gyri. In the single-word-level task, there was activation only associated with a lower number of thematic options, found in the left posterior, and the mid-anterior middle temporal gyrus, and the insula.

Shetreet et al. (2007), in experiment 2, also looked at subcategorization and thematic options. The stimuli consisted of verbs with one (obligatory transitives), two, and three options, of both subcategorization and thematic frames, plus a category of special transitives that had two subcategorization options, but only one thematic option. Like in experiment 1 of the same study, monolingual Hebrew speakers were instructed to press a ‘yes’ or a ‘no’ button with their left hand fingers after hearing each sentence, whether it described an event more likely to happen at home or not. In experiment 2, there were significant activations in language areas, differently from experiment 1 regarding the number of arguments. Activations were in the left superior temporal gyrus and in two clusters in the left inferior frontal gyrus–in BA 9 and in BA 47. The authors suggest that processing the number of options is more specifically linguistic than processing the number of arguments, also indicating that subcategorization might be indispensable in verb processing. Such statement goes against the claims made by linguists such as Chomsky (1986, 1995) and Pesetsky (1982), for whom representation of complementation options could be reduced to the representation of thematic roles, as previously explained in section 2.1.

The last studies to be reviewed in this section are the ones investigating alternating transitivity and unaccusativity. Shetreet et al. (2010) conducted a comprehension task similar to the one in Shetreet et al. (2007). Again, monolingual Hebrew speakers were instructed to press a ‘yes’ or a ‘no’ button with their left hand fingers after hearing each sentence, whether it described an event more likely to happen at home or not. The difference in the new study resided in the type of verbs, divided into unaccusative[43], unergative, and transitive. All sentences included a subject (*theme* for unaccusatives and *agent* for unergatives and transitives), plus the verb, and two other constituents: for unaccusative and unergative verbs, there was a PP adjunct and modifier, or an additional adjunct, and for transitive verbs, a PP complement and an adjunct or a modifier. Interestingly, this was the first study, according to the authors' acknowledgement, to investigate the neural bases of processing unaccusative verbs.

Results showed that the brain differentiates between unaccusative and unergative verbs, even when appearing in identical structures (i.e., NP-V[44]). The comparison between unaccusatives and unergatives revealed activations in the left inferior frontal gyrus (BA 45/46/47), the left posterior middle temporal gyrus (BA 21), the left medial superior frontal gyrus, and the right cerebellum. The left inferior frontal gyrus (BA 45/46/47) and the left middle temporal gyrus were also activated in the comparison between unaccusatives and transitives, besides activations in the left inferior parietal lobule, the left middle frontal gyrus, and the right middle temporal gyrus. According to the authors, these results corroborate the idea of the involvement of the inferior frontal gyrus with the execution of the syntactic operation, and the responsibility of the middle temporal gyrus for the lexical operation that derives unaccusative verbs.

The study by Meltzer-Asscher et al. (2013) was the first explicit investigation on the neural bases of alternating transitivity. English alternating unaccusative verbs were compared to simple intransitive (unergative) verbs and pseudowords, all presented in isolation in their infinitive form (without *to*) during a lexical decision task. Participants were instructed to press a button with their left hand when they saw a pseudoword.

Taking into account Thompson et al. (2007, 2009), Meltzer-Asscher et al. (2013) expected to find activation in the supramarginal or angular gyri bilaterally–given the fact that alternating transitivity verbs have a greater number of thematic roles and thematic grids–as well as activation in mid-superior frontal regions, since such regions are implicated in ambiguity processing. As predicted, for the contrast of

[43] In Shetreet et al. (2010), only nonalternating unaccusatives were used (i.e., always used intransitively).

[44] "In Hebrew and European Portuguese, both V-NP and NP-V are acceptable with unaccusative verbs, but only NP-V with unergative verbs" (Shetreet et al., 2010, p. 2307).

alternating transitivity over simple intransitives, there was bilateral activation in the angular and supramarginal gyri (BAs 39 and 40), extending to the posterior superior and middle temporal gyri, and in the middle and superior frontal gyri (BAs 8 and 9). There was also small activation in the anterior cingulate, but no activation for the opposite contrast. Perhaps, the most interesting about these results is that they seem to corroborate the Lexical-Thematic approach to PAS, for which thematic information is listed in the lexicon, since it is possible to differentiate verbs even in single-word-level tasks, such as this one. Findings like these once more defy the claims by linguists such as Chomsky, who defend the Generative-Constructivist approach by claiming that lexical representations of verbs do not carry any thematic information.

Starting where Meltzer-Asscher et al. (2013) left off, Meltzer-Asscher et al. (2015) decided to add one more aspect to the investigation, by including nonalternating unaccusative verbs as well. A lexical decision task was designed so that younger and older participants would press a button to respond to real verbs, and another button to pseudoverbs. Differently from Meltzer-Asscher et al. (2013), the verbs were all presented in isolation preceded by *to*, in order to avoid confusion with possible homonyms (e.g., *to break* vs. *break*). The stimuli were divided into five categories: unergatives, nonalternating unaccusatives, alternating unaccusatives, transitives, and pseudowords. The authors were seeking for three different effects of PAS complexity: effect of number of thematic roles (transitive > nonalternating unaccusative + unergative); effect of number of thematic options (alternating unaccusative > transitive + nonalternating unaccusative + unergative); and effect of unaccusativity (nonalternating unaccusative > transitive + unergative).

Results revealed a cluster of activation in posterior perisylvian regions (the left posterior middle temporal gyrus and the left middle occipital gyrus) for the effect of number of thematic roles, comparable to the results by Thompson et al. (2007) and Thompson et al. (2009). There was no effect of thematic options, though (differently from Meltzer-Asscher et al., 2013). Finally, for the effect of unaccusativity, activation was found in the left precentral gyrus and pars opercularis of the inferior frontal gyrus. No activation was found in the reverse order for any of the effects, as well as no significant effects of participant age (older versus younger) as a covariate for any of the contrasts.

The fact that there was no activation for the effect of thematic options gave rise to a debate, since the findings did not replicate the activation found in the middle frontal gyrus, as in Meltzer-Asscher et al. (2013). A possible explanation would be that, in the 2015 study, the English verbs and pseudowords were presented with the infinitive *to*, which could have made them look less ambiguous, and so, processed differently.

I end this section by adding one more study that is the only one at present, to my knowledge, to include the neural correlates of production of PAS. Takashima et al. (2018) conducted an experiment using fMRI in which participants were supposed to produce sentences using a Dutch existing verb or pseudoverb of 1-, 2-, or 3-arguments. Three geometric figures (i.e., circle, triangle, square) were used in place of the agent and verb arguments. Participants were instructed to overtly produce a sentence with the same structure as the example they saw on the screen, using the (pseudo)verb and the figures (e.g., "The *triangle* gives the *square* to the *circle*"). The authors were looking for a verb lexicality effect (verb > pseudoverb sentences) and a verb argument effect (ditransitive > intransitive). The former effect was found in the left inferior frontal gyrus and in the left posterior middle temporal gyrus, along with greater activation in a more posterior bilateral middle temporal region extending to the angular gyrus. The latter effect was accompanied by an increase in activation in the left posterior middle temporal gyrus (overlapping substantially with the cluster found for the lexicality contrast), and the bilateral precuneus. Results of this study showed an overlap between the production network and the comprehension network.

So far, I have covered the major concepts regarding syntactic processing of PAS, and reviewed some of the most significant behavioral and neuroimaging studies on PAS production and comprehension. I highlighted the dearth of investigations on a wider range of languages of different typologies, such as Romance languages, including BP. That was the motivation for the present study, which intends to contribute to the understanding of syntactic processing in BP, and to research in language rehabilitation as well.

I now move on to the presentation of the experimental study, divided in Study 1 and Study 2. Study 1 investigated syntactic processing of BP through the use of an event-related fMRI design and a lexical decision task, and Study 2 investigated PAS production and comprehension at sentence level in BP.

3 EXPERIMENTAL STUDY

This chapter, organized in three main sections, describes in detail the present study. Section 3.1 introduces the aims (general and specific), and the hypotheses in 3.2. Section 3.3 describes the method and is subdivided as follows: 3.3.1 describes the ethical procedures; 3.3.2 describes the participants; 3.3.3 presents the instruments for sample selection and characterization according to inclusion and exclusion criteria; 3.3.4 describes the instruments and procedures for cognitive and neuropsychological data collection; and 3.3.5 presents the instruments and procedures for behavioral data collection. Finally, 3.3.6 describes the neuroimaging data acquisition and statistical analysis, and 3.3.7 describes the behavioral data acquisition and statistical analysis.

3.1 Aims

3.1.1 General aim

To explore the neural correlates of PAS in BP through fMRI, and both PAS comprehension and production, by healthy BP speakers.

3.1.2 Specific aims – Study 1

1) to investigate the neural correlates of PAS complexity in BP in an fMRI lexical decision task regarding the following effects: number of thematic roles, number of thematic options, and of unaccusativity;
2) to investigate the behavioral performance (ACC and RTs) of healthy BP speakers regarding verb types, looking for an impact of the lexical variables *number of letters* and *number of syllables*, as well as *verb type*, on the speed of lexical access.

3.1.3 Specific aims – Study 2

1) to analyze the impact of *verb type*, *number of letters*, and *number of syllables* in a sentence comprehension task in BP, as measured by ACC scores and RTs;

2) to analyze the specific features of PAS in BP in a sentence production task, according to verb typologies (nonalternating unaccusative, transitive, alternating unaccusatives, and unergatives).

3.2 Hypotheses

The corresponding hypotheses to the previously mentioned aims are presented below.

3.2.1 Study 1:

1) greater activation is expected in areas in charge of supporting access to stored PAS representations (the left posterior perisylvian regions), and in charge of noncanonical argument mapping (i.e., the left inferior frontal gyrus);
2) in the lexical decision task, lower ACC scores and longer RTs are expected for verbs with more complex PAS (alternating and nonalternating unaccusatives), and pseudoverbs in relation to verbs.

3.2.2 Study 2:

1) in the sentence comprehension task, lower ACC scores and longer RTs are expected for verbs with more complex PAS (alternating and nonalternating unaccusatives);
2) in the sentence production task, participants are expected to produce sentences with the required thematic structure for each verb type, and in the right order, but to omit the external argument (subject), and to omit the optional internal argument (object) of transitive verbs.

3.3 Method

3.3.1 Ethical procedures

This study belongs in the Research Line 'Language Theories and Language Use', and integrates the umbrella research project '*Processamento discursivo, semântico e sintático na afasia: um estudo longitudinal com neuroimagem estrutural* *e funcional*'[45], approved by the Research Ethics Committee of Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS), and registered under number 1.378.955/2015. The project is coordinated by Dr. Lilian Cristine Hübner, who also coordinates the '*Grupo de Estudos em Neurolinguística e Psicolinguística*' (GENP)[46], with the collaboration of the Neurology Department of Hospital São Lucas, and Instituto do Cérebro (InsCer – Brain Institute), both at PUCRS. All participants signed free and informed consent forms (see Appendixes A and B) prior to taking part in the behavioral and neuroimaging data collection.

3.3.2 Participants

3.3.2.1 Study 1:

Sixteen healthy individuals with high educational levels (range 11-26, M = 17 years, SD = 4.29) took part in Study 1. They were all right-handed, monolingual BP speakers, 3 male, age range 51-77 years (M = 62.06, SD = 6.88), with normal or corrected-to-normal vision and hearing, and no reported history of neurological or speech-language disorders, as well as depression or any type of dementia. They were invited to take part in this study via e-mail, WhatsApp or Messenger, from a list of volunteers or the main investigator's personal contacts. No reward was offered in exchange for their participation, apart from a free MRI followed by a medical report.

3.3.2.2 Study 2:

Twenty-one healthy (all the participants of Study 1 plus five more) individuals with high educational levels (range 11-26, M = 17.26 years, SD = 4.13) took part in Study 2. They were all right-handed, monolingual BP speakers, 4 male, age range 49-77 years (M = 60.95 years, SD = 7.12), with normal or corrected-to-normal vision and hearing, and no reported history of neurological or speech-language disorders, as well as depression or any type of dementia. They were contacted via e-mail, WhatsApp or Messenger, from a list of volunteers or the main investigator's personal

[45] Translation: Discursive, semantic, and syntactic processing in aphasia: a longitudinal study with structural and functional neuroimaging.
[46] Translation: Study Group in Neurolinguistics and Psycholinguistics (GENP).

contacts. Table 9, providing participants' sociodemographic, cognitive, and neuropsychological data, will be presented in the Results section.

3.3.3 Instruments for sample selection and characterization according to inclusion and exclusion criteria

Interviews, administered for the sample selection and characterization, and for the neuropsychological and behavioral data collection, took about one hour. They were carried out at InsCer or at building 8 (both at PUCRS), or at participants' homes or work places, making sure they all took place in a very quiet room. The application of the different tests and tasks was randomized and recorded on audio files. The neuroimaging data were collected at InsCer in sessions of 40 minutes, including both functional and structural MRI. About 30 minutes before the neuroimaging data collection, participants were trained in a mock scanner in order to get familiar with the machine and procedures for the test, and were also instructed on how to do the lexical decision task by practicing on a laptop computer with 22 training trials (with different stimuli, but similar to the experimental ones). The entire process, from the recruitment of the participants to all data collection, was carried out by the main investigator (this author, during her doctoral study) and by an assistant researcher of GENP.

3.3.3.1 Questionnaire about health conditions, sociodemographic and sociocultural aspects

The questionnaire about health conditions, sociodemographic, and sociocultural aspects (adapted from Fonseca et al., 2012) was used to exclude participants with history of neurological, psychiatric, and heart diseases, as well as heavy smoking, alcohol, and drug abuse. It was also used to investigate participants' educational levels and their knowledge of language(s) other than BP.

3.3.3.2 Edinburgh Handedness Inventory

The Edinburgh Handedness Inventory (Oldfield, 1971) was used to classify handedness by means of a quantitative scale regarding ten different actions, such as writing, drawing, lighting a match, etc., and how often participants do each of them using the right hand, the left hand, or both. In this study, only participants above 75% right-hand dominance were included.

3.3.3.3 Mini-Mental State Exam (MMSE)

The MMSE (Chaves & Izquierdo, 1992) was used to look for symptoms of dementia. The test contains 11 questions and is applied in five to ten minutes. In section one, participants are supposed to answer verbally to questions covering orientation, memory, and attention. In section two, they are required to name, follow both verbal and written commands, write a spontaneous sentence, and copy a complex geometric shape. The minimum score is 0 and the maximum is 30. Chaves and Izquierdo (1992) suggest a cutoff point of 24. However, they do not take into account educational levels. Brucki, Nitrini, Caramelli, Bertolucci, and Okamoto (2003) suggest a cutoff point of 20 for illiterate people, of 25 for people with 1-4 years of formal education, 26.5 for 5-8 years, 28 for 9-11 years, and 29 for more than 11 years of education. In this study, the cutoff point was 29 due to participants' high levels of education.

3.3.3.4 Brazilian version of the geriatric depression scale (GDS) short form

The GDS (Almeida & Almeida, 1999, adapted from Yesavage et al., 1983) was used to diagnose (non-treated) depression. The version of the test used includes 15 questions to be answered 'yes' or 'no'. Scores to the test are interpreted as follows: from 0 to 4 = absence of depression; from 5 to 7 = mild levels of depression; from 8 to 10 = moderate depression, and from 11 to 15 = severe depression. Participants with a score between 5 and 7, or higher, were not included in this study.

3.3.3.5 Brazilian Economic Classification Criteria

The Brazilian Economic Classification Criteria (ABEP - Associação Brasileira de Empresas de Pesquisa, 2018) was used to classify participants regarding their socioeconomic status. The questionnaire allows for a classification of households regarding the amount of rooms in their house, amount of comfort items they have at home (e.g., cars, motorbikes, computers, dishwashers, etc.), as well as their educational level, and access to public utility services. Social classes are classified according to the following criteria: A (45-100 points); B1 (38-44 points); B2 (29-37 points); C1 (23-28 points); C2 (17-22 points); D (11-16 points); and E (1-10 points).

3.3.3.6 Questionnaire about reading and writing habits

The questionnaire about reading and writing habits (adapted from Pawlowski et al., 2012) contains questions about how often participants read and write different types of texts (daily = 4 points; some days a week = 3 points; once a week = 2 points, hardly ever = 1 point, and never = 0 points), and also the modality of the texts read (digital or printed), and written (digitally or manually). The maximum score for reading/writing is 16 points.

3.3.3.7 Brazilian version of Pfeffer's Functional Activities questionnaire (P-FAQ)

The P-FAQ (Pfeffer, Kurosaki, Harrah, Chance, & Filos, 1982) was used to assess pathological cognitive aging. The questionnaire investigates a possible presence of dementia by asking about participants' performance on every day activities that demand cognitive skills, such as: going shopping, preparing meals, administering their own medication, walking around their neighborhood, managing their own money, etc. The scores go from 0 to 30, and the higher the score obtained, the higher the level of inability of the subjects to perform different tasks (cutoff point: 6 points or higher).

3.3.3.8 Screening questionnaire for neuroimaging

The screening questionnaire for participation in the neuroimaging study (Study 1) was provided by InsCer, and was used to rule out participants with: pacemakers, permanent prosthetics, automatic insulin pumps, piercings, recent tattoos or permanent make-up, recent eye and ear surgeries, and claustrophobia[47].

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[47] Four participants of Study 1 were allowed to enter the fMRI scanner with one or two permanently fixed dental prostheses because that did not seem to cause participants any harm, nor compromise the quality of the images.

3.3.4 Instruments and procedures for behavioral data collection

Three linguistic tasks were used and will be detailed below regarding the construction of the stimuli and administration procedures.

3.3.4.1 Lexical Decision Task

As already mentioned in the Introduction, we had formal consent from Cynthia Thompson, Jennifer Mack, and Elena Barbieri (from Northwestern University, USA) to translate and adapt the lexical decision task (Meltzer-Asscher et al., 2015) from English to BP. In order to do that, we compiled a corpus of written BP. The verb extraction process was performed using ExATO software, a textual extractor capable of identification of grammatical structures in texts written in Portuguese and English, with the support of Dr. Lucelene Lopes, at the Department of Computer Science, at PUCRS (Lopes, Fernandes, & Vieira, 2016). ExATO receives a collection of POS (part-of-speech) annotated texts split in specific domain corpora. Among ExATO features, it is possible to extract noun phrases and verbs, lemmatization and statistical analysis of extracted terms. ExATO also generates terms' hierarchies and the context of extracted terms, i.e., a list of all sentences with a given extracted term. In the context of this work, ExATO was employed to extract verbs, compute their frequencies and list the contexts of each verb. Specifically, ExATO was applied to eight corpora (see Table 7).

Table 7: Description of the Corpus

CORPUS	DESCRIPTION	SOURCE	TEXTS	WORDS
PG_FALE	Thesis and Dissertations of PUCRS FALE department from 2006 to 2015		209	9,175,608
PG_FACIN	Thesis and Dissertations of PUCRS FACIN department from 1996 to 2015	Lopes and Vieira (2015)	370	7,827,098
Lacio_ref	Excerpt of the Lacio Reference Corpora		3,459	4,956,734
Ped	Articles from Brazilian Pediatrics Journal	Lopes (2012)	281	878,522
Geo	Articles from Geology domain	Lopes (2012)	234	2,020,527

Table 9 (continued)

CORPUS	DESCRIPTION	SOURCE	TEXTS	WORDS
DM	Articles from Data Mining domain	Lopes (2012)	53	1,127,816
PP	Articles from Parallel Processing domain	Lopes (2012)	62	1,086,771
SM	Articles from Stochastic Modeling domain	Lopes (2012)	88	173,401
Total			4,756	27,246,477

Source: The author (2019).

From the mentioned corpora, all verb occurrences were extracted and 18 among the most frequent of four verb classes were selected: nonalternating unaccusative, transitive, alternating unaccusative, and unergative. Similar to the original study in English, the 72 BP verbs selected were initially classified into these four different verbal categories. Then, BP intransitive verbs were classified as either unergative or unaccusative based on Mioto, Silva, and Lopes (2013), and Ciríaco and Cançado (2004). Finally, for the selected verbs, ExATO was applied to locate their contexts to illustrate their use in the chosen corpora, so the selected verbs could be extracted within the context of the first one hundred sentences in which each verb appeared[48]. The corpus was also entered in the AntConc software (http://www.laurenceanthony.net/software/antconc/) to be double checked with the help of the concordancer. Sentences were then carefully analyzed, whether verbs were used transitively or intransitively, so that the percentage of intransitive use for each verb could be calculated (nonalternating unaccusatives: 88%; transitives: 10% of intransitive use; alternating unaccusatives: varying between 12%-85% of intransitive use; and unergatives: 83%) (please refer to Appendix C).

The construction of the stimuli list was carried out with the aid of the statistical software SPSS 17.0. In order to check for a normal distribution of the data, tests of normality of Shapiro-Wilk were also used, in order to choose between parametric or nonparametric tests. The frequency values of the 72 verbs were obtained from the psycholinguistic corpus LexPorBR (Léxico do Português Brasileiro)

[48] Not all verbs appeared in a minimum of 100 sentences, but percentages of intransitive use were calculated based on the highest number of occurrences found for each one.

(http://www.lexicodoportugues.com/). Given the difficulty to match the four categories of verbs in number of letters (Z (3,68) = 4.365, p = .225)[49], number of syllables (Z (3,68) = 5.181, p = .159), and frequency, and since the context of use from where the verbs had been extracted was the priority in this study, a significant difference in frequency (Z (3,68) = 10.156, p = .017) could not be avoided. Multiple post hoc tests with Bonferroni correction (p < .008) revealed that there was a highly significant difference (Z (2,69) = -3.132, p = .002) only between transitives (M = 35.42, SD = 27.11) and unergatives (M = 16.78, SD = 25.77)[50].

Twenty extra healthy participants (all with a degree in linguistics) acted as judges and rated the verbs in their infinitive form on a 1-5 scale regarding imageability (please see Appendix C). The four verb types differed significantly in imageability (Z (3,68) = 13.151, p = .004). Multiple post hoc tests with Bonferroni correction (p < .008) revealed that unergative verbs (M = 4.10, SD = 1.12) were significantly more imageable than nonalternating unaccusatives (M = 3.06, SD = .99), transitives (M = 3.10, SD = .95), and alternating unaccusatives (M = 3.04, SD = 1.02). However, just like in Meltzer-Asscher et al. (2015), the selected verbs were not controlled for imageability. In the American study, the lexical variables *frequency*, *number of letters*, and *imageability* were entered in the statistical analysis as predictors that may impact the speed of lexical access and word recognition. For BP, we added one more lexical variable–*number of syllables*– that we assumed could also interact with our overall RTs.

Differently from the original study–in which monosyllabic and bisyllabic verbs were used–only bisyllabic and trisyllabic BP verbs were included, varying between 4-9 letters. Regarding conjugation, only verbs ending in their infinitive forms -AR, -ER, and -IR were used. Verbs ending in -OR were not included. Additionally, a list of 48 pseudoverbs (24 disyllables and 24 trisyllables, with a word-pseudoword ratio of 3:1) was created, following the same criteria used for real verbs, without significant differences between pseudoverbs and verbs regarding number of letters (Z = -.161, p = .872), and number of syllables (Z = -1.046, p = .295).

The stimuli were presented, one by one, on a computer screen using the software E-Prime 2.0, which registered ACC scores and RTs, while participants were

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49 In this dissertation, we are considering statistically significant a p < .05.

50 It was difficult to find a high incidence of unergative verbs such as *latir* (bark), *miar* (meow), etc., given the nature of the majority of texts (academic, scientific, etc.) that make up most of the corpora of written contemporary BP available.

lying inside a GE HDxT 3.0T scanner. All the stimuli were written in font Arial, size 48, in capital letters, bold, forecolor black and backcolor white. Participants were instructed to hold a Cedrus Lumina LS-Pair response box with their left hand and press the right button with their index finger for real verbs, and the left button with their middle finger for pseudoverbs[51]. Differently from the original study, in which stimuli were presented for 1,500 ms (milliseconds), followed by a 500-ms presentation of a dashed line, BP verbs and pseudoverbs were presented for 2,000 ms, without the 500 ms presentation of a dashed line. That was an adaptation discussed with the authors of the original study, considering the fact that BP verbs had more syllables (2-3) than the ones in English (1-2). Everything else was identical to the original study, with jittered null events (65 null trials for Run 1 and 70 for Run 2) ranging from 0 to 20 s interspersed between stimuli. The length and the order of the null events had been optimized with OPTSEQ (http://surfer.nmr.mgh.harvard.edu/optseq/). The experiment was composed of two runs of 10 min each. All the 72 real verbs appeared on both runs, while the 48 pseudoverbs were divided between Run 1 and Run 2 (see Figure 5).

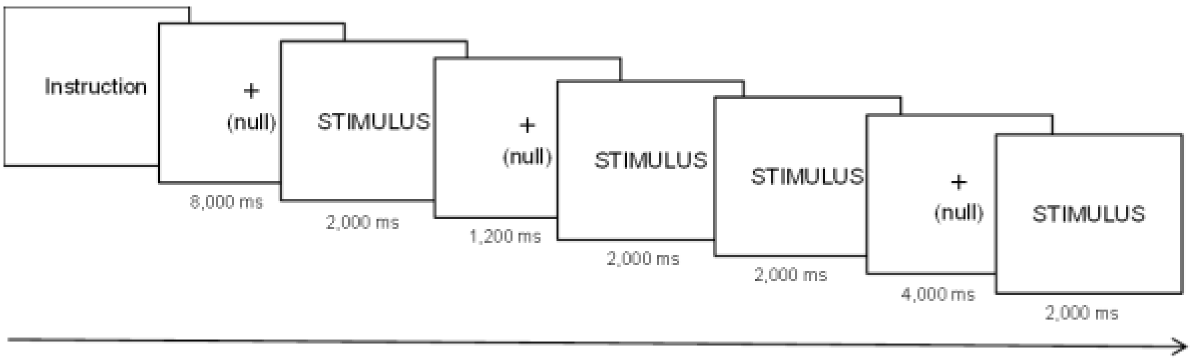

Figure 5. Experimental Design of the Lexical Decision Task.
Source: the author (2019).

3.3.4.2 Sentence Comprehension Task

A sentence comprehension task was designed[52] to test participants' ability to decide whether the sentences they saw on the computer screen corresponded to the

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51 Participants responded with their left hand in order to avoid motor-related activations in the LH, same measure adopted in the original study.

52 It was based on Lee and Thompson (2004) and Thompson and Lee (2009). However, we decided to have it computerized, so we could register both ACC scores and RTs. We also preferred to present the stimuli (sentences) only visually, rather than auditorily.

actions depicted by the pictures which had been presented. The stimuli were a set of 40 pictures, presented one by one, and followed by a sentence each. Pictures were selected from Google Images and only the ones free of copyrights were used. They were all converted to .bmp, and colored ones were changed to black and white with the help of Photoshop before being inserted into the script on E-Prime 2.0. They were all resized to measure approximately 300 pixels vertically and/or horizontally. Sentences were all affirmative, with the gerund form of the verb, containing the structure NP + V + (NP). The NPs were preceded, or not, by a determiner in order for the sentences to be matched in length (i.e., overall number of syllables). They were written in font Arial, size 18, bold, forecolor black and backcolor white.

The 40 pictures and the 40 sentences corresponded to four verbal categories (i.e., nonalternating unaccusative, transitive, alternating unaccusative, and unergative), with 10 verbs for each category. For the alternating unaccusative verbs, in half of the sentences verbs were used transitively and in the other half they were used intransitively. There were equal numbers of predicted 'yes' and 'no' responses for each verbal category. Both arguments (subject and object) always corresponded to the pictures. The only incorrect piece of information was the verb, which did not match half of the pictures (please see Appendix D).

Verbs and nouns were selected based on their frequency of occurrence according to LexPorBR. Sentences were controlled for frequency of verbs ($Z(3,36) = 2.849$, $p = .415$), frequency of nouns ($Z(3,51) = 4.745$, $p = .191$), and number of syllables ($F(3,36) = 2.839$, $p = .052$), according to verb type. Verbs were also controlled for number of syllables ($Z(3,36) = 5.842$, $p = .120$) and number of letters ($Z(3,36) = 3.222$, $p = .359$).

Participants were presented with the following instruction: "*Você verá uma figura e, na tela seguinte, uma frase. Você deverá decidir se a ação descrita na frase corresponde à figura. Se corresponder ao que está na figura, pressione a tecla '1'. Se não corresponder ao que está na figura, pressione a tecla '2'. Responda o mais rápido possível*"[53]. Stimuli were presented as follows: first a picture was on the screen for 5,000 ms, then, the interval stimulus was a fixation cross (+) presented for 1,000 ms, followed by a sentence that was on the screen until participants responded

[53] "You will see a picture and, on the next screen, a sentence. You will have to decide whether the action described by the sentence corresponds to the picture. If it does, press '1', if it does not, press '2'. Respond as quickly as possible".

to it. The total duration of the experiment depended on how fast participants responded to the experimental trials (sentences). ACC scores and RTs were recorded by the software E-Prime 2.0 on a 15” LG laptop computer. Before the experimental trials, participants practiced with a short version of the same task, but with different stimuli from the real experiment, presenting two trials, one correct and one incorrect.

3.3.4.3 Sentence Production Task

A sentence production task was designed[54] to test participants’ ability to produce complete sentences in BP making sure to use the proper argument structure for different verb types. The stimuli were 40 black and white pictures printed on paper, also from Google Images, showing actions that fit the same four verbal categories of the previous tasks: 10 nonalternating unaccusative, 10 transitive, 10 alternating unaccusative, and 10 unergative verbs. Pictures were presented randomly. For transitive verbs, the pictures could elicit the production of both subject and object, while only the subject for intransitive verbs. Each picture had the verb in its infinitive form written in capital letters at the top of the page. The purpose of having the verbs written above the picture was to avoid misunderstandings regarding the actions depicted by the images, since the focus was on the PAS required by each verb according to the categories they belong in (see Appendix E). The stimuli for the four verbal categories were matched in frequency ($Z (3,36) = 3.309$, $p = .346$) according to LexPorBR, in number of letters ($Z (3,36) = 3.573$, $p = .311$), and in number of syllables ($Z (3,36) = 4.558$, $p = .207$).

Participants were instructed to use the verb as they liked in order to produce a complete sentence describing what was happening in the picture as accurately as possible. There was no training because they were all individuals without brain lesions who had high levels of education. The idea was for them to feel comfortable to produce sentences they thought could describe the action depicted by each picture.

All responses provided by participants were recorded and later written down and analyzed on the basis of the following criteria: responses were considered

[54] It was based on the studies by Lee and Thompson (2004), Stavrakaki et al. (2011), and McAllister et al. (2009).

correct if they had the required thematic structure of the verb in transitive or intransitive form. Given the fact that BP is a null subject language, subject omission was not considered a grammatical error. Object omission, on the other hand, could be considered a grammatical error depending on the verb (some transitive verbs allow for the omission of the complement, as explained in section 2.1).

3.3.5 Neuroimaging data acquisition and statistical analysis

The neuroimaging technique used in this study was fMRI. It consists of a noninvasive technique which can measure changes in blood oxygenation, while someone performs an experimental task inside a scanner. It provides maps of how a specific function is represented within the brain, also graphs of the relative timing of activation within a particular brain area, as well as network diagrams showing functional relations among many different brain regions. It also allows for the identification of abnormalities in blood vessels (e.g., stroke), tumors, and several other conditions. Given the fact that blood oxygenation levels change rapidly following the activity of neurons in a brain region, researchers are able to localize brain activity on a second-by-second basis, and within millimeters of its origin with the aid of fMRI. In order to create images, a series of changing magnetic gradients and oscillating electromagnetic fields (known as a pulse sequence), are used by the scanners, which are tuned to the frequency of hydrogen nuclei (Huettel, Song, & McCarthy, 2009).

Next, I present the parameters used for the acquisition and statistical analysis of the fMRI data.

3.3.5.1 Data acquisition and analysis – fMRI

The neuroimaging data collection was done on a GE HDxT 3.0T scanner and with an 8HRBRAIN head coil. T1-weighted anatomical scans were acquired according to the following parameters: TR = 6.272 ms; TE = 2.256 ms; flip angle = 11º; matrix size = 512 X 512; FOV = 512 mm; voxel size = 0.5 X 0.5 X 1; 196 slices. Functional volumes with BOLD contrast were acquired with gradient echo-planar imaging sequences with the following parameters: TR = 2,000 ms; TE = 30 ms; flip angle = 90º; matrix size = 64 X 64; FOV = 64 mm; voxel size = 3.75 X 3.75 X 3.6; 29 slices.

All the preprocessing and the statistical analysis of fMRI data of the first ten participants were carried out during my 9-month program as a doctoral student[55], training at College of Health and Rehabilitation Sciences - Sargent College, at Boston University (BU), USA, under the supervision of professor Swathi Kiran. When I was back to Brazil after my period of doctoral training abroad, we decided to add six more participants, so the new data were preprocessed, analyzed and added to the initial sample for statistical analysis.

The fMRI data were analyzed with software SPM12 (http://www.fil.ion.ucl.ac.uk/spm/software/spm12/) running in a Matlab R2017b environment (The MathWorks, Inc., Natick, MA). The DICOM files generated during the scanning process were converted into NIFTI files with the software dcm2nii (http://people.cas.sc.edu/rorden/mricron/dcm2nii.html). There were 8,903 DICOM files for each run, which were then converted into 307 NIFTI files for each. Then, the first four NIFTI files of each run were manually excluded, since SPM12 does not automatically exclude the initial damaged volumes (i.e., T1-equilibrium effect) generated by a GE scanner, as it does for images generated by a Siemens.

Preprocessing consisted of slice-acquisition timing correction, realignment of the anatomical scans to the mean functional volume, normalization of anatomical and functional scans to the MNI (Montreal Neurological Institute) 152-subject template brain, and smoothing using a 6 mm kernel[56]. In first level analysis, a 128 s high-pass filter was applied. The four *verb type*s and pseudoverbs were modeled as conditions. *Imageability*, *frequency*, *number of letters*, *and number of syllables* were entered as parametric modulators to each verb type[57]. The six movement parameters from realignment were entered as regressors. Just like in Meltzer-Asscher et al. (2015), the following contrasts were used to test for effects of PAS complexity: effect of number of thematic roles: transitive > nonalternating unaccusative + unergative; effect of number of thematic options: alternating unaccusative > transitive + nonalternating unaccusative + unergative; and effect of unaccusativity: nonalternating

55 The period at BU was funded by Fulbright, and lasted from 1st August, 2017, to 31st May, 2018.
56 In the original study, a 9 mm kernel was used. Nowadays, a 6 mm kernel is more appropriate with 3T scanners, though.
57 No frequency or imageability scores for pseudoverbs, though.

unaccusative > transitive + unergative[58]. The Automated Anatomical Labeling atlas (AAL) (Tzourio-Mazoyer et al., 2002) was used to localize significant clusters of activation. In second level analyses, all the effects were tested using one-sample T-Tests. I also ran Multiple Regression analyses including each of the modulators as a covariate. Group analyses were thresholded at $p < .005$, uncorrected, with a cluster extent threshold of $k \geq 200$ voxels. Table 8 summarizes the methodological parameters used in this study and in the American study which based ours.

Table 8: Methodological Differences Between this Study and Meltzer-Asscher et al.'s (2015) Study

	Parameters	**BP**	**Eng**
DATA COLLECTION	Scanner	GE	Siemens
	N	16	28
	Presentation of the stimuli	2000 ms	1500 ms
PREPROCESSING	Smoothing	6 mm	9 mm
STATISTICAL ANALYSIS	p-value	.005	.05
	Threshold	200 voxels	25 voxels
	Correction	Uncorrected	FDR-corrected

Source: The author (2019). *Note:* BP = Brazilian Portuguese; Eng = English; N = amount of participants; ms = milliseconds; FDR = false discovery rate.

3.3.5.2 Data acquisition and analysis – Lexical decision task

The behavioral data of the lexical decision task were recorded by E-Prime 2.0 and the statistical analyses were run in SPSS 17.0. ACC scores and RTs (only the RTs of the correct trials were computed in the analysis) were treated as dependent variables according to *verb type*. The lexical variables *number of letters* and *number of syllables* were also considered as dependent variables according to overall RTs, in order to check if any of them would facilitate lexical access and word recognition. To check for a normal distribution of the data, tests of normality of Shapiro-Wilk were

58 Reverse contrasts were also calculated (i.e., nonalternating unaccusative + unergative > transitive; transitive + nonalternating unaccusative + unergative > alternating unaccusative; and transitive + unergative > nonalternating unaccusative), following the analyses procedures adopted by Meltzer-Asscher et al. (2015). However, we decided to not include them in the dissertation and explore them in subsequent papers.

also run. In the case of normal distribution, T-Tests or One-Way Anovas were used. If not, non-parametric tests of Mann-Whitney or Kruskal-Wallis were run. In the case of significant differences, post hoc tests with Bonferroni correction were used to identify the differences between the groups of verbs.

To calculate mixed-effects models, the software R (http://www.Rproject.org) was used, along with the lme4 package (Bates, Maechler, & Bolker, 2012) to calculate regression. RTs were treated as dependent variables by means of multiple regression, with *item* (i.e., verbs) and *participant* as random factors[59]. *Verb type* was the main variable of interest, with four verbal categories (nonalternating unaccusatives, transitives, alternating unaccusatives, and unergatives). Besides *verb type*, the following lexical variables were entered in the model as predictors to account for factors that might influence speed of lexical access and word recognition: *number of letters*, *number of syllables*, *frequency*, and *imageability*. As mentioned previously, *number of syllables* was added to this study due to its relevance in BP. In order to avoid collinearity, continuous variables were centered on their means before being added to the statistical analysis. The analysis was performed stepwise, with one predictor (fixed effects) at a time. ANOVAs were run to evaluate each predictor's contribution to the model. Regarding significant predictors, random slopes were also added to the analysis, so that their contribution to the model could be evaluated as for fixed effects.

3.3.6 Behavioral data acquisition and statistical analysis

3.3.6.1 Analysis of the Sentence Comprehension Task

The data of the sentence comprehension task were recorded by E-Prime 2.0 and the statistical analyses were run in SPSS 17.0. ACC scores and RTs (only the RTs of the correct trials were computed in the analysis) were treated as dependent variables according to *verb type*. The lexical variables *number of letters* and *number of syllables* were also considered as dependent variables according to overall RTs, in order to check if any of them would facilitate lexical access and word recognition. To

[59] On behavioral data, when using *item* and *participant* as random factors in mixed-effects regression, it allows us to look at the effect of our variable of interest (i.e., *verb type*) regardless of the fact that one item may be particularly difficult, or one participant may have particularly high ACC scores or long RTs.

check for a normal distribution of the data, tests of normality of Shapiro-Wilk were also run. In the case of normal distribution, T-Tests or One-Way Anovas were used. If not, non-parametric tests of Mann-Whitney or Kruskal-Wallis were run.

3.3.6.2 Analysis of the Sentence Production Task

After reviewing the most relevant studies on sentence production in section 2.3, the decision to adopt the taxonomy used by McAllister et al. (2009) as the evaluation criteria for the sentence production task was made. However, given the fact that the present study involves only healthy subjects with high levels of education (rather than stroke patients), and because it has a descriptive (rather than a prescriptive approach), the criteria for scoring were properly adapted to the sample (see the Results chapter for examples of each criterion).

Correct sentences included: 1) a target sentence in which all obligatory arguments were presented in the target order; 2) a target sentence in which participial, gerund, or nominal form of the target verb was used with preserved thematic structure; 3) valency decrease (subject omission): differently from English, BP is a pro-drop language, therefore subject omission was allowed; and 4) valency decrease (omission of optional object without thematic violation). Incorrect sentences included: 1) valency decrease (omission of obligatory object); 2) fragment (not able to stand as a matrix clause): participants were supposed to produce complete sentences; 3) direct object was realized as a PP; 4) the produced sentence was not a description of the picture; and 5) a wrong target verb was used. The last two criteria were added in order to describe the types of recurrent errors performed by our sample.

The other remaining criteria adopted by McAllister et al. (2009) were judged as inadequate to this study, either to the sample, or to the language. For the purposes of this dissertation, the number of occurrences for each criterion was turned into percentages for each verb, as well as for the occurrences of each of the criteria, and will be presented in Table 15, followed by a qualitative analysis in section 4.5.

Having covered all the methodological procedures for the present study, I move on now to the presentation of the Results.

4 RESULTS

The Results chapter starts by providing information on participants' sociodemographic, cognitive, and reading/writing habits data (see Table 9). Then, in each section, the specific aims and hypotheses are restated, followed by the descriptive and statistical analyses for Study 1 and Study 2, respectively.

Table 9: Participants' Sociodemographic, Cognitive, and Reading/Writing Habits Data – Study 2

(N = 21, 17F)	**M**	**SD**
Age	60.95	7.12
Educational Level (in years)	17.26	4.13
Socioeconomic Status	40.05	10.11
Reading Habits	11.24	3.06
Writing Habits	6.9	2.7

Source: the author. *Note*: N = number; F = female; M = means; SD = standard deviation.

Participants showed no signs of untreated depression, dementia, or loss of functionality, as verified by the GDS, MMSE, or P-FAQ Tests, respectively. Concerning their socioeconomic status, they were classified as B1, which corresponds to an average monthly household income estimation of R$10,386.52 (based on PNADC 2017 – Pesquisa Nacional por Amostra de Domicílios Contínua).

4.1 Study 1 – First aim

The first aim of Study 1 was to investigate the neural correlates of PAS complexity in BP in a lexical decision task with an fMRI paradigm regarding the following effects: number of thematic roles, number of thematic options, and of unaccusativity. Greater activation was expected to be found in areas in charge of supporting access to stored PAS representations (i.e., left posterior perisylvian regions), and in charge of noncanonical argument mapping (i.e., the left inferior frontal gyrus). The results of the referred three contrasts are presented in Table 10.

Table 10: Areas of Activation for Contrasts of PAS Complexity

CONTRASTS	REGIONS	K	T	Peak MNI coordinates		
				X	Y	Z
Effect of number of thematic roles						
Transitive (2) > nonalternating unaccusative (1) + unergative (1)	L Fusiform Gyrus	640	4.15	-19	-87	-7
	L Paracentral Lobule	721	5.14	-2	-28	66
	L Supplementary Motor Area	721	5.29	-6	-21	65
	L Superior Temporal Pole	205	3.94	-41	10	-16
Effect of number of thematic options						
Alternating (2) > transitive (1) + nonalternating unaccusative (1) + unergative (1)	L Lingual Gyrus	350	4.21	-17	-91	-8
Effect of unaccusativity						
Nonalternating unaccusative > transitive + unergative	L Cuneus	396	5.43	-4	-80	35
	L Supplementary Motor Area	390	5.50	-12	-9	67
	L Precentral Gyrus	423	3.52	-35	3	44
	R Middle Frontal Gyrus	323	4.81	30	1	59
	R Superior Frontal Gyrus	1716	4.95	14	25	58
	R Medial Frontal Gyrus	1716	4.07	7	32	46

Source: the author (2019). *Note*: L = left; R = right. Peak MNI (Montreal Neurological Institute) coordinates, cluster size (k), maximal t-values, and voxel-level p-values ($p < .005$, uncorrected, $k \geq 200$) are reported.

For the first contrast established, i.e., effect of number of thematic roles (transitive > unaccusative + unergative), there were the following four clusters of activation, all in the LH: in the fusiform gyrus, paracentral lobule, supplementary motor area, and superior temporal pole. Because the paracentral lobule is a more subcortical region, it is not visible in Figure 6.

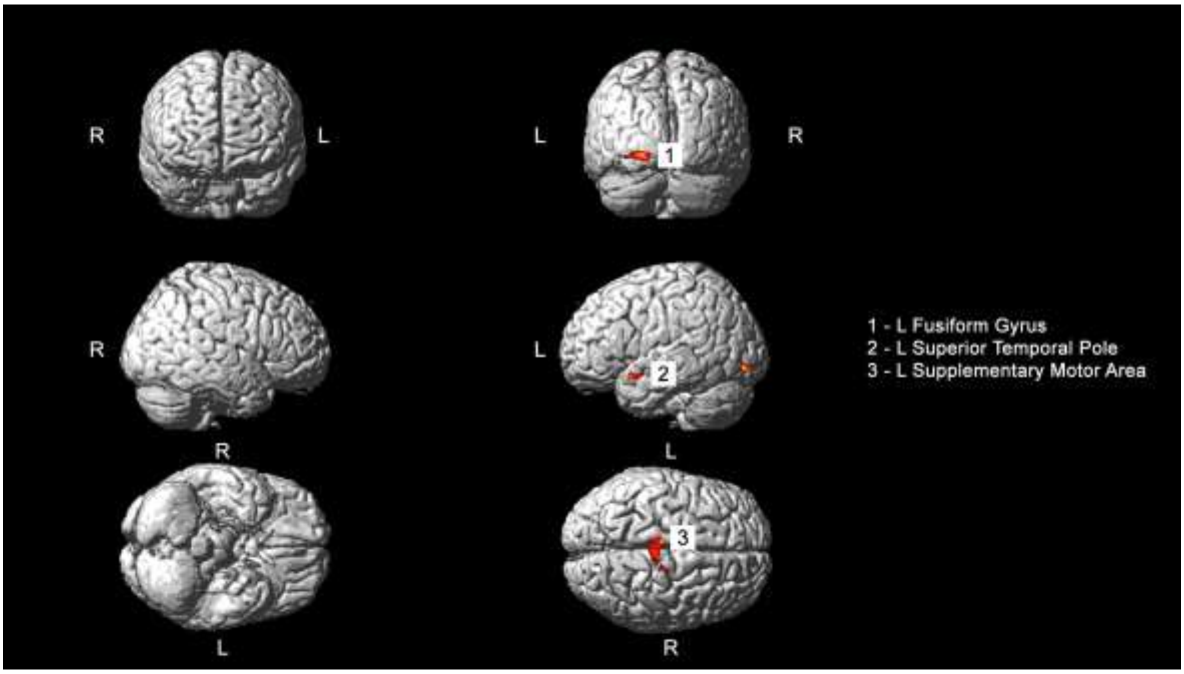

Figure 6. Areas of Differential Activation for the Effect of Number of Thematic Roles.
Source: The author (2019).

The second effect, number of thematic options (alternating unaccusative > transitive + nonalternating unaccusative + unergative), revealed only one cluster of activation, in the left lingual gyrus (see Figure 7).

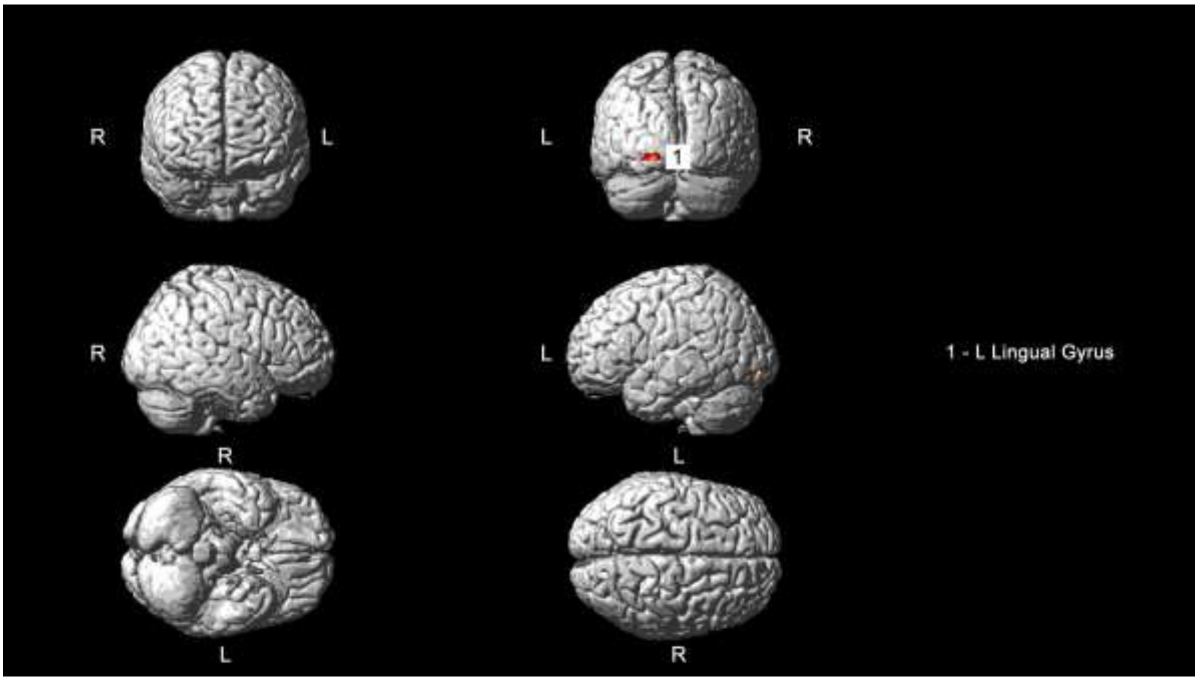

Figure 7. Area of Differential Activation for the Effect of Number of Thematic Options.
Source: The author (2019).

Finally, for the effect of unaccusativity (nonalternating unaccusative > transitive + unergative), there were clusters of activation in the left cuneus, left supplementary motor area, left precentral gyrus, and in the right middle frontal gyrus, right superior frontal gyrus, and right medial frontal gyrus (see Figure 8).

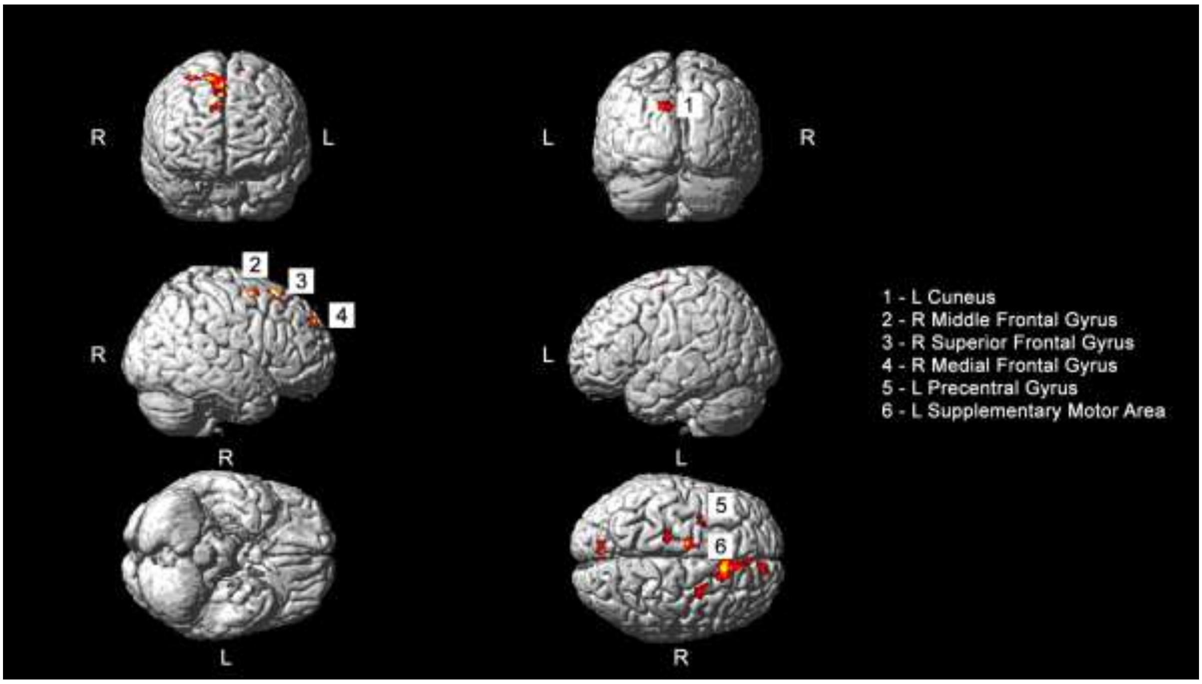

Figure 8. Areas of Differential Activation for the Effect of Unaccusativity.
Source: The author (2019).

For the three effects, none of the predictors (i.e., *imageability*, *frequency*, *number of syllables*, and *number of letters*), which were added as covariates to the statistical analyses, had any impact on the ROIs.

According to the results reported above, hypothesis 1 of Study 1 was partially corroborated. There were activations for the three established contrasts. However, the clusters of activation expected for the left posterior perisylvian regions and for the left inferior frontal gyrus were not found, what will be further discussed in section 5.1.

4.2 Study 1 – Second aim

The second and last aim of Study 1 was to analyze the behavioral data (ACC and RTs) regarding verb types, looking for an impact of the lexical variables *number of letters* and *number of syllables*, as well as *verb type*, on the speed of lexical access. Lower ACC scores and longer RTs were expected for verbs with more complex PAS (alternating and nonalternating unaccusatives), and pseudoverbs in relation to verbs.

The data of Run 2 of one participant were not registered due to a technical failure. Mean ACC was computed for all the 16 participants, who performed well overall on the task (93%). ACC was above 86% for all conditions: nonalternating unaccusative – 97%; transitive – 99%; alternating unaccusative – 98%; unergative – 96%; and pseudoverbs – 86%. A Kruskal-Wallis Test showed a highly significant statistical difference in ACC scores (χ^2 (4) = 41.35, p = .000). Multiple post-hoc tests with Bonferroni correction (p < .005) revealed that the difference was between pseudoverbs and the four verbal categories, but not among them.

Mean RTs were computed only on correct responses. A Kruskal-Wallis Test showed a highly significant difference (χ^2 (4) = 44.55, p = .000). Multiple post-hoc tests with Bonferroni correction (p < .005) revealed that the difference in RTs, just like for the ACC scores, was between pseudoverbs and the four verbal categories (see Table 11 and Figure 9), with no difference among the other four verb types.

Table 11: Medians, Interquartile Range, and Means of RTs by Verb Type in the Lexical Decision Task

Verb Type	**Median**	**Interquartile Range**	**M**	**SD**
Nonalternating unaccusative	865.16	44.78	890.50	88.66
Transitive	905.34	112.76	907.67	83.55
Alternating unaccusative	879.55	83.35	883.50	73.98
Unergative	888.55	107.07	890.27	105.06
Pseudoverb	1082.03	217.58	1064.20	135.66

Source: The author (2019). *Note:* M = means. SD = standard deviation.

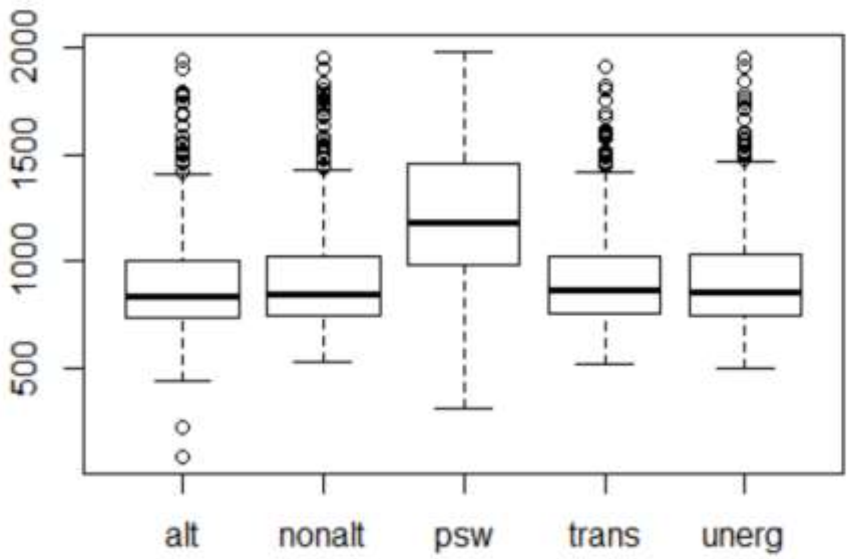

Figure 9. Boxplot of RTs (ms) according to Verb Types.
Source: The author (2019). Note: Alt = alternating unaccusative. Nonalt = nonalternating unaccusative. Psw = pseudoverb. Trans = transitive. Unerg = unergative.

Table 12 provides a list of the verbs used in the lexical decision task. They are presented by verb type, and in ascendant order of RTs, in order to illustrate which verbs, in each verbal category, were accessed faster by the participants.

Table 12: Verbs of the Lexical Decision Task by Verb Type and Ascendant RTs

Nonalternating Unaccusatives		**Transitive**		**Alternating Unaccusative**		**Unergative**	
Verb	**RT (ms)**	**Verb**	**RT (ms)**	**Verb**	**RT (ms)**	**Verb**	**RT (ms)**
crescer	814.03	aceitar	802.94	fechar	743.65	agir	735.58
sumir	821.32	matar	806.39	casar	782.65	correr	769.23
chegar	828.1	marcar	823.06	acabar	784	sorrir	778.42
cair	836.81	chamar	824.58	abrir	843.29	dormir	813.52
partir	851.94	vestir	827.9	mudar	847.45	fumar	826.29
sair	856.23	levar	857.42	seguir	848.23	trabalhar	828.19
entrar	857.1	construir	865.77	parar	859.77	voar	869.94
nascer	860.71	escolher	886.29	apagar	866.77	andar	876.06
viver	862.06	esperar	901.77	terminar	872.94	funcionar	888.32
subir	868.26	adotar	908.9	quebrar	886.16	sentar	888.77

Table 12 (continued)							
Nonalternating Unaccusatives		**Transitive**		**Alternating Unaccusative**		**Unergative**	
Verb	**RT (ms)**	**Verb**	**RT (ms)**	**Verb**	**RT (ms)**	**Verb**	**RT (ms)**
morrer	868.35	gastar	920.52	dobrar	888	mentir	897.9
existir	868.42	enfrentar	923.77	combinar	896.68	miar	899.97
morar	886.29	causar	935.23	melhorar	904.81	latir	902.68
faltar	891.35	cortar	937.39	agravar	914	remar	929.94
surgir	897.68	perceber	947.16	girar	977.06	caminhar	930.87
emergir	931.77	atrair	1017.68	piorar	989.39	repousar	987.39
decair	1053.77	destruir	1068.81	aumentar	995.9	mergulhar	1000
perdurar	1174.81	contratar	1082.48	atrasar	1002.26	trafegar	1201.84

Source: The author (2019). *Note:* RT = reaction time; ms = milliseconds.

Regarding lexical variables, *number of letters* (χ^2 (5) = 7.68, p = .175) did not have an impact on general RTs, as revealed by a Kruskal-Wallis Test. *Number of syllables*, on the other hand, proved highly influential, as shown by a Mann-Whitney Test (Z = -3.25, p = .001). Bisyllabic verbs were accessed faster than trisyllabic verbs (see Table 13).

Table 13: Medians, Interquartile Range, and Means of RTs by Number of Syllables in the Lexical Decision Task

Syllables	**Median**	**Interquartile Range**	**M**	**SD**
Bisyllabic	888.00	175.66	931.97	135.74
Trisyllabic	978.73	190.74	998.76	131.51

Source: The author (2019). *Note:* M = means. SD = standard deviation.

Finally, regarding the calculation of the mixed-effects model, the aim was to evaluate which lexical variables could contribute to the speed of lexical access. The RTs of the four verb types (excluding pseudoverbs) were used, and each predictor was included, one at a time. *Verb type*, which was the main predictor of interest, proved nonsignificant (p = n.s.). Variables such as *frequency*, and *imageability* did not contribute to the model fit either. However, T-Tests showed that both *number of syllables* (t = 6.683, $p < .001$) and *number of letters* (t = 4.186, $p < .001$), individually, were highly significant and improved the model. Both *number of syllables* and *number of letters* refer to the length of a word, so, when put together in the same model, one overcame the other. Even so, either one or the other could be a predictor for the speed in lexical access in BP.

The results reported above partially corroborated hypothesis 2 of Study 1. Pseudoverbs were in fact more difficult that verbs, and showed a significant statistical difference both in ACC scores and RTs. However, there was no significant statistical difference in ACC scores and RTs for verbs with more complex PAS (alternating and nonalternating unaccusatives), what will be discussed in section 5.1. Now I move on to the results of Study 2.

4.3 Study 2 – First aim

The first aim of study 2 was to analyze the impact of *verb type*, *number of letters*, and *number of syllables* in a sentence comprehension task in BP, as measured by ACC scores and RTs. Lower ACC scores and longer RTs were expected for verbs with more complex PAS (alternating and nonalternating unaccusatives).

Mean ACC was computed for the 21 participants, who performed well overall on the task (88%). ACC was above 83% for all verb types (nonalternating unaccusative: 85%; transitive: 83%; alternating unaccusative: 91%; and unergative: 92%). A Kruskal-Wallis Test showed no significant statistical difference in ACC scores among verb types (χ^2 (3) = 6.94, p = .074). Regarding RTs, a One-Way Anova showed no significant differences among verb types either (F (3,36) = 2.13, p = .114) (see Table 14).

Table 14: Means of RTs by Verb Type in the Sentence Comprehension Task

Verb Type	**M**	**SD**
Nonalternating unaccusative	1915.82	241.65
Transitive	1919.55	399.69

Table 14 (continued)

Verb Type	M	SD
Alternating unaccusative	2084.74	362.58
Unergative	1716.74	276.11

Source: The author (2019). *Note:* M = means; SD = standard deviation.

The lexical variables *number of letters* and *number of syllables* were analyzed regarding their impact on overall RTs. There were no significant statistical differences between verbs with fewer or more letters on RTs, as indicated by a Kruskal-Wallis Test (χ^2 (6) = 8.35, p = .213). The same was true for number of syllables, according to a One-Way Anova (F (2) = .49, p = .782).

The results of the sentence comprehension task did not corroborate hypothesis 1 of Study 2 regarding verb types in either ACC scores or RTs, neither regarding the impact of lexical variables in overall RTs.

4.4 Study 2 – Second aim

The second and final aim of Study 2 was to analyze the specific features of PAS in BP in a sentence production task, according to *verb types* (nonalternating unaccusative, transitive, alternating unaccusative, and unergative). Participants were expected to produce sentences with the required thematic structure for each verb type, and in the right order, but to omit the external argument (subject), as well as the optional internal argument (object) of transitive verbs.

Twenty-one individuals were part of Study 2. However, due to a technical failure to record the audio of one participant, only the data of twenty individuals were included in the analysis. I start by presenting the quantitative results with the percentages for each verb according to each of the criteria, as well as the percentage for the occurrences of each of the criteria (see Table 15) (for the translation of the BP verbs into English see Appendix E). Then, I present the qualitative results by providing examples from the resultant corpus. As explained in the Method, I adopted a descriptive, rather than a prescriptive approach. Even so, the first four criteria are signaled as √ (correct), and the remaining five as X (incorrect), for the purposes of the task.

Table 15: Results (%) of the Sentence Production Task for each Verb

VERB TYPE	VERB	√	√	√	√	X	X	X	X	X
		1- Target sentence in target order	2-Target sentence: participial, gerund, or nominal form	3-Valency decrease: subject omission	4-Valency decrease: omission of optional object	5-Valency decrease: obligatory object	6-Fragment: cannot stand as a matrix clause	7-Direct object is realized as PP	8-Not a description	9-Wrong target verb
ALTERNATING UNACCUSATIVE	abrir	80%	0%	5%	0%	0%	5%	0%	10%	0%
	acender	75%	0%	5%	0%	0%	5%	0%	15%	0%
	acordar	75%	0%	5%	0%	0%	0%	0%	20%	0%
	casar	75%	0%	0%	0%	0%	0%	0%	20%	5%
	dobrar	60%	5%	10%	0%	5%	10%	0%	10%	0%
	estragar	60%	25%	0%	0%	0%	0%	0%	15%	0%
	furar	75%	0%	0%	0%	5%	5%	0%	10%	5%
	parar	45%	0%	0%	0%	0%	0%	0%	15%	40%
	quebrar	95%	0%	0%	0%	0%	0%	0%	5%	0%
	seguir	85%	5%	5%	0%	0%	0%	0%	5%	0%
TRANSITIVE	assistir	80%	0%	0%	0%	0%	5%	0%	10%	5%
	carregar	80%	0%	0%	0%	5%	0%	0%	15%	0%
	chutar	70%	0%	5%	0%	5%	0%	0%	15%	5%
	dirigir	60%	0%	0%	15%	0%	0%	0%	25%	0%
	lamber	80%	0%	0%	0%	0%	5%	0%	10%	5%
	morder	85%	0%	0%	0%	5%	5%	0%	5%	0%
	pedir	65%	0%	0%	0%	15%	5%	0%	10%	5%
	pintar	60%	5%	0%	0%	20%	0%	0%	15%	0%
	puxar	80%	0%	5%	0%	0%	5%	0%	5%	5%
	servir	60%	0%	0%	0%	10%	10%	5%	15%	0%
NONALTERNATING UNACCUSATIVE	Cair	90%	0%	0%	0%	0%	0%	0%	10%	0%
	chegar	55%	0%	5%	0%	0%	0%	0%	20%	20%
	descer	75%	0%	0%	0%	0%	5%	0%	20%	0%
	entrar	40%	0%	0%	0%	0%	0%	0%	20%	40%
	fugir	95%	0%	0%	0%	0%	0%	0%	5%	0%
	morrer	80%	10%	0%	0%	0%	0%	0%	10%	0%
	nascer	60%	0%	10%	0%	0%	0%	0%	10%	20%
	partir	85%	0%	0%	0%	0%	0%	0%	5%	10%
	sair	70%	0%	5%	0%	0%	0%	0%	15%	10%
	subir	65%	0%	0%	0%	0%	20%	0%	15%	0%
UNERGATIVE	andar	60%	0%	5%	0%	0%	15%	0%	15%	5%
	caminhar	85%	0%	0%	0%	0%	0%	0%	15%	0%
	cantar	80%	0%	0%	0%	0%	5%	0%	10%	5%
	dançar	65%	0%	0%	0%	0%	5%	0%	30%	0%
	dormir	65%	0%	10%	0%	0%	0%	0%	25%	0%
	falar	45%	0%	15%	0%	0%	5%	0%	30%	5%
	gritar	70%	0%	0%	0%	0%	10%	0%	20%	0%
	nadar	70%	0%	0%	0%	0%	0%	0%	20%	10%
	sentar	10%	60%	0%	0%	0%	10%	0%	15%	5%
	voar	75%	0%	0%	0%	0%	10%	0%	15%	0%
	M	**70%**	**3%**	**2%**	**0%**	**2%**	**4%**	**0%**	**14%**	**5%**

Source: The author (2019). *Note:* √ = correct; X = incorrect; M = means.

Considering the first criterion, target sentence in target order, participants used several different tenses or verb forms to describe the action depicted by the pictures, as can be seen in examples [1] to [4]:

[1] *O homem carrega uma caixa*. (*Presente*)
The man carries a box.

[2] *O entregador está carregando uma caixa*. (*Gerúndio*)
The delivery guy is carrying a box.

[3] *O peão carregou a mudança*. (*Pretérito Perfeito*)
The handyman carried the boxes[60].

[4] *O carregador carregava um pacote pesado*. (*Pretérito Imperfeito*)
The carrier was carrying a heavy parcel.

All the tenses and verb forms above were accepted as possibilities to a description. In the case of the present tense with the gerund form, there were a few occurrences of the construction '*estar a fazer*', which is typical of European Portuguese, as can be seen in [5] and [6] below:

[5] *O casal está a andar na chuva*.
The couple is walking in the rain.

[6] *O cantor está a cantar*.
The singer is singing.

Sentences produced in the future tense were judged as "not target sentence", unless the correspondent pictures showed an action that was about to happen, such as in examples [7] and [8] for '*entrar*' (to go in) and '*partir*' (to leave), respectively:

[60] I could not find a specific word in English for '*mudança*'.

[7] **O homem* <u>*vai entrar*</u> *na porta*.
*The man is going to go in the door.

[8] *O homem está se despedindo e* <u>*vai partir*</u>.
The man is saying goodbye and is going to leave.

For the second criterion (target sentence: participial, gerund, or nominal form), there were only occurrences of participial form in passive voice constructions, as in [9] to [12]:

[9] *A mulher está* <u>*sentada*</u>.
The woman is sitting.

[10] *O carro está* <u>*estragado*</u>.
The car is broken.

[11] *Uma menina* <u>*está sendo seguida*</u> Ø. (*por um homem/rapaz*)
A girl is being followed Ø. (by a man/a guy)

[12] *A parede* <u>*foi pintada*</u> Ø. (*pelo pintor/pelo homem*)
The wall was painted Ø. (by the painter/man)

Regarding subject omission, it was possible to identify the subjects 'I', 'they', and 'he' through the verb forms in [13], [14], and [15], respectively. The presence of the subject would have been redundant:

[13] Ø *Acord*<u>*ei*</u> *tarde*.
I woke up late.

[14] Ø *Est*<u>*ão*</u> *andando na chuva de mãos dadas*.
They are walking in the rain holding hands.

[15] *Para se fazer ouvir*, Ø *est*<u>*á*</u> *falando com um megafone para a multidão*.
To be heard, he is speaking on the megaphone to the crowd.

For the third criterion, there was only one verb for which an optional object was omitted repeatedly, and that was '*dirigir'* (to drive), as in [16], which could only refer to driving a vehicle (e.g., a car, a truck, etc.):

[16] *Ele está dirigindo Ø*.
He is driving Ø.

There were several examples of omission of obligatory object, though. In all the cases, the direct object was relevant and, therefore, should not have been left out, as highlighted in [17] to [24]:

[17] **Um senhor está carregando Ø*. (*uma caixa/pacote*)
*A gentleman is carrying Ø. (a box/a parcel)

[18] **Ele está dobrando Ø*. (*um papel*)
*He is folding Ø. (a sheet of paper)

[19] **Ela está chutando Ø*. (*a bola*)
*She is kicking Ø. (the ball)

[20] **O cachorro mordeu Ø*. (*a perna de alguém*)
*The dog bit Ø. (someone's leg)

[21] **O mendigo está pedindo Ø*. (*esmola*)
*The beggar is asking for Ø. (handouts)

[22] **O mendigo pede Ø pro transeunte*. (*esmola*)
*The beggar asks for Ø to the passerby. (handouts)

[23] **O homem está pintando Ø*. (*a parede*)
*The man is painting Ø. (the wall)

[24] **A menina está servindo Ø à mãe*. (*café*)
*The girl is pouring Ø for her mother. (coffee)

A sentence such as [21] can only be understood if we take into consideration our world knowledge and assume the beggar could only be asking for something such as food or money. Sentence [23] is ambiguous because when a man is painting, that could be either because he is painting a wall, or a house, as a job or a hobby, or he is a painter who paints on canvas, which is a type of art. Those are rather different actions. Such ambiguities could have been avoided by the insertion of the object.

The examples for the sixth criterion (fragment: cannot stand as a matrix clause) were all either because the auxiliary verb was missing, as in [25] to [27], or because the target verb was in its infinitive form, as in [28] to [30]:

[25] *Uma senhora Ø acendendo uma vela*. (*está*)
A lady Ø lighting a candle. (is)

[26] *Um menino Ø puxando um elefante*. (*está*)
A boy Ø pulling an elephant. (is)

[27] *Um pobre Ø pedindo esmola*. (*está*)
A poor man Ø asking for handouts. (is)

[28] *Dobrar uma folha no capricho*.
To fold a sheet of paper carefully.

[29] *Andar na chuva somente de sombrinha e guarda-chuva*.
To walk in the rain only with an umbrella.

[30] **Servir um chá da tarde com a mãe*.
*To pour some afternoon tea with her mother.

Regarding the seventh criterion, there was only one occurrence of a direct object realized as PP. The picture for '*servir'* (to pour) shows the subject (the girl), the direct object (the coffee), and the indirect object (the mother), acting as a ditransitive verb, as in [31] below. However, the participant added a preposition to the direct object:

[31] **A menina está servindo* de café à sua mãe.

*The girl is pouring of tea for her mother.

Before moving on to the last two criteria, it is important to draw attention to the verbal categories per se. Starting with alternating unaccusatives, the picture regarding '*acordar'* (to wake up) showed both a girl waking up and the alarm clock going off. However, in all the sentences, the verb was used intransitively, with the girl displayed as the subject. Sometimes the alarm clock was mentioned, but always placed as an adjunct, as in [32]:

[32] *A moça está acordando pelo barulho do despertador*.

The young lady is waking up by the noise of the alarm clock.

Concerning '*quebrar'* (to break), the picture displayed a broken window and a boy holding a baseball bat. Most of the produced sentences highlighted the boy being responsible for the action, as in [33]. Only in [34] the verb was used intransitively:

[33] *O moleque quebrou o vidro*.

The naughty boy broke the glass.

[34] *O vidro quebrou*.

The glass broke.

Regarding the other two categories of intransitive verbs, it is important to mention the fact that some sentences were produced in which verbs were used transitively, due to the addition of a direct object. Examples of unergative verbs were '*cantar'* (to sing), as in [35] and [36], and '*dormir'* (to sleep), as in [37] and [38]. The same happened to the nonalternating unaccusative verbs '*descer'* (to go down) and '*subir'* (to go up), as in [39] and [40], respectively:

[35] *O senhor está cantando uma música alegre*.

The gentleman is singing a happy song.

[36] *O cantor canta sua música*.
The singer sings his song.

[37] *O homem dorme um sono profundo*.
The man sleeps a deep sleep.

[38] Ø *Dormiu o sono dos justos*.
(He) slept the sleep of the just.

[39] *Ele desceu a escada*.
He went down the stairs.

[40] *A pessoa está subindo os degraus*.
The person is going up the steps.

The eighth criterion was created to cover the sentences that did not match the task because they were functionally not descriptions, but rather, opinions, commands, invitations, offers, or comments, as in [41] to [45], respectively:

[41] *Abrir a porta é necessário*. (opinion)
To open the door is necessary.

[42] *Agora dobre o papel*. (command)
Now fold the sheet of paper.

[43] *Vamos dobrar o papel*? (invitation)
Let's fold the sheet of paper?

[44] Ø *Posso te servir um chá*? (offer)
Can I pour you some tea?

[45] *Elas adoram dançar*. (comment / affirmation)
They love dancing.

The last criterion referred to the use of the wrong target verb, which occurred in three different situations: 1) the target verb (written above each picture) was ignored and completely substituted by another verb because of a misinterpretation of the picture, as in [46]; 2) the target verb was substituted by a verb with the same or similar meaning, as in [47] to [50]; or 3) the target verb was placed somewhere else in the sentence, such as in the syntactic position of adjunct (not part of PAS, i.e., it is not an argument), as in [51] and [52], or of object, as in [53]:

[46] *O cão está mordendo o menino*. (*lamber*)
The dog is biting the boy. (to lick)

[47] *O pedinte solicita auxílio ao homem*. (*pedir*)
The beggar asks the man for help. (to ask for)

[48] *Eles estão caminhando abrigados na chuva*. (*andar*)
They are walking protected in the rain. (to walk)

[49] *Ele está gritando "Fora Temer!"*. (*falar*)
He is yelling "Go away, Temer!". (to speak)

[50] *A senhora está vendo televisão*. (*assistir*)
The lady is seeing television. (to watch)

[51] *Ao nascer, a criança chorou*. (*nascer* - adjunct)
At birth, the child cried. (to be born)

[52] *O casal demonstra felicidade ao casar*. (*casar* - adjunct)
The couple shows happiness while marrying. (to marry)

[53] *O guarda mandou parar o carro*. (*parar* – object)
The police officer told the car to stop. (to stop)

Example [54] is worth mentioning, since the picture showed a young lady kicking a ball, but someone used '*chutar'* (to kick) with a figurative meaning, as in the idiom below:

[54] Ø *Chutou tudo pro ar*.
She gave it all up.

Having provided examples for all the nine criteria, it is also relevant to present one extra set of examples, which highlight the fact that the healthy participants of this study had difficulty retrieving some words. There were several naming errors, as can be seen in examples [55] to [58]:

[55] *O menino quebra o espelho*. (*vidraça*)
The boy breaks the mirror. (window glass)

[56] *O cachorro morde o braço*. (*a perna*)
The dog bites the arm. (the leg)

[57] *Ø Está falando ao microfone*. (*megafone*)
He is speaking on the microphone. (megaphone)

[58] *O boneco fala no saxofone*. (*megafone*)
The puppet is speaking on the saxophone. (megaphone)

Thus, taking into account the results presented above, hypothesis 2 of Study 2 was partially corroborated. Participants produced sentences with the required thematic structure for each verb type, and in the right order, in 70% of the occurrences (according to the first criterion). However, there were few occurrences of omission of the external argument (subject) (2%), and the omission of the optional internal argument (object) happened only with one verb, '*dirigir*' (to drive).

Having finished the presentation of the results for both Study 1 and Study 2, I move on to the Discussion chapter.

5 DISCUSSION

From now on, the Discussion of the results of Study 1 and of Study 2 will be presented, respectively. Then, in Chapter 6, the Final Considerations for this dissertation will be highlighted by including its main findings and limitations, as well as suggestions for future investigations.

5.1 Study 1

Study 1 involved a lexical decision task with four verb types in BP (nonalternating unaccusative, transitive, alternating unaccusative, and unergative) carried out inside an fMRI scanner. The data collection process generated both neuroimaging and behavioral data. The first specific aim was to investigate the neural correlates of PAS complexity in BP, through the analyses of three main contrasts established to investigate different dimensions of complexity: 1) transitive > nonalternating unaccusative + unergative, seeking for an effect of number of thematic roles; 2) alternating unaccusative > transitive + nonalternating unaccusative + unergative, for an effect of number of thematic options; and 3) nonalternating unaccusative > transitive + unergative, for an effect of unaccusativity.

This study was based on Meltzer-Asscher et al. (2015), which was carried out with monolingual English speakers. Considering the first effect (number of thematic roles), the American study had focused on the role of posterior regions in accessing stored PAS representations. The aim was to seek for activations contrasting 2-argument verbs (transitive) to 1-argument verbs (nonalternating unaccusative and unergative). The authors hoped to replicate the findings of previous studies that had associated posterior regions to increased number of thematic roles. They found clusters of activation in the left posterior middle temporal gyrus, and in the left middle occipital gyrus, thus replicating the activations found in studies such as Ben-Shachar et al. (2003) and den Ouden et al. (2009). Thompson et al. (2007, 2009) had also found activation in posterior perisylvian regions related to increased number of thematic roles, although these were found in bilateral perisylvian regions.

In this study, there were four clusters of activation: the left fusiform gyrus (BA 37), the left paracentral lobule, the left supplementary motor area, and the left superior temporal pole. The left fusiform gyrus has been pointed out as linked to different neural pathways related to recognition, especially known for its relations to reading. It corresponds to the location of the visual word form area, in charge of written word recognition (Dehaene & Cohen, 2011). To our knowledge, no studies have associated the left fusiform gyrus to any aspect of PAS yet.

The activation of the supplementary motor area, in combination with the superior frontal gyrus, was associated with a lower number of arguments in Malyutina and den Ouden (2017). Such finding contradicts the ones found in this study, in which the activation of the left supplementary motor area was associated to a greater number of arguments (transitive = 2), instead of a lower one (nonalternating unaccusative and unergative = 1). The left paracentral lobule, which is not a conventionally linguistic area, but related to movement, was also activated.

Finally, the last activation for the effect of number of thematic roles was in the left superior temporal pole. As highlighted in Thompson et al. (2009), superior temporal regions are among the ones usually involved in the processing of PAS. Activations in the superior temporal gyrus are correlated with the complexity of verb-argument integration (Thompson & Meltzer-Asscher, 2014). Furthermore, both the anterior and the posterior superior temporal gyri are cited as part of the two syntactic processing networks described in the Neuroanatomical Pathway Model of Language (Friederici, 2016), in which the author describes a dorsal and a ventral pathways. The dorsal pathway, involving the posterior superior temporal gyrus and superior temporal sulcus, deals with syntactic complexity and verb-argument resolution. These areas are activated whenever the semantic relation between a verb and its argument cannot be resolved. The ventral pathway combines the anterior superior temporal gyrus, along with the frontal operculum[61] and BA 44, in more global computations (syntactically complex sentences). The results for the first effect in BP differ from the ones found in the American study, in which they found activation specifically in the left posterior middle temporal gyrus. However, all differences considered, there was the involvement of the superior temporal pole with the BP sample.

The second effect (number of thematic options) was meant to determine whether alternating unaccusative verbs engage regions of the language network associated with ambiguity resolution, such as middle-superior frontal regions, as

[61] The frontal operculum is sometimes discussed in regard to the role of Broca's area in sentence processing (Friederici, Meyer, & von Cramon, 2000).

indicated by Meltzer-Asscher et al.'s (2013) findings. The authors also found bilateral activation in the angular and supramarginal gyri, extending to the posterior superior and middle temporal gyri, as well as small activation in the anterior cingulate. However, in the 2015 study, they found no activation for such contrast, thus not replicating their own previous results.

When we talk about ambiguity in this context, we refer to the fact that alternating unaccusative verbs have two argument realization options (or two thematic grids)–one transitive and one intransitive. These two options, on some accounts, are associated with two lexical entries, i.e., the thematic role information is part of the verbal entry in the mental lexicon. This approach to explain the nature of the lexicon-syntax interface, called Lexical-Thematic (Horvath & Siloni, 2011; Meltzer-Asscher, 2011; Reinhart, 2002), contrasts with the Generative-Constructivist approach (Borer, 2005), for which the lexicon does not specify thematic grids, and thematic information does not exist outside of a syntactic context. The findings by Meltzer-Asscher et al. (2013) seem to have corroborated the Lexical-Thematic approach, otherwise they would not have found activation in the contrast between alternating unaccusative and simple intransitive verbs presented in isolation. They also indicated that alternating unaccusative verbs require greater processing resources, in comparison to simple intransitives. The fact that Meltzer-Asscher et al. (2015) did not find differential activation for the effect of thematic options contradicts their own previous findings. However, the authors claim they might have avoided grammatical category ambiguity by introducing *to* before the verbs in the 2015 study, and, as a consequence, have managed to decrease the level of ambiguity.

Considering Meltzer-Asscher et al.'s (2013, 2015) results, an effect of thematic options should not be expected in this study, taking into account the fact that verbs in BP carry the suffixes -AR, -ER, and -IR, typical of the infinitive form. As such, they cannot be confused with another word class, as in English. Interestingly, in BP, there was one cluster of activation, in the left lingual gyrus, which is an area known for the identification and recognition of words, analysis of logical conditions, naming of stimuli. It has also been related to visual memory (Bogousslavsky et al., 1987), vivid visual imagery (Belardinelli et al., 2009), and motion imagery (Malouin et al., 2003). Interestingly, a recent study (Zhang et al., 2016) has also indicated that the lingual gyrus is related to inhibitory control[62]. If we consider the fact that alternating unaccusative verbs have two argument realization options, and that they are possibly associated with two lexical entries, we could take it as a possible explanation for the activation of the lingual gyrus. Participants could have tried to inhibit one of the two options while responding to the task. So far, it is only an assumption, and should be pursued in subsequent investigations, though.

The third and last effect (unaccusativity) focused on examining the role of the left inferior frontal gyrus in noncanonical mapping of internal arguments. For that, nonalternating unaccusative verbs, whose only argument is generated in object position and is moved to subject position (i.e., A-movement), were contrasted to transitive and unergative verbs, whose only argument (i.e., subject) is generated in canonical position. Meltzer-Asscher et al. (2015) found a cluster of activation in the left precentral gyrus and pars opercularis of the inferior frontal gyrus. The left precentral gyrus is the site of the primary motor cortex, and its activation was not discussed in the American study. All the focus was on the pars opercularis of the inferior frontal gyrus, which is part of Broca’s area.

The inferior frontal gyrus has been associated to syntactic processing, particularly in the comprehension of complex structures. However, Rogalsky and Hickok (2011) claim that other studies have found a lack of correspondence between sentence processing and activity in Broca’s area, and that the specific role of this area is still an unresolved question. Meltzer-Asscher et al. (2015) defy that by citing previous neuroimaging studies (e.g., Hirotani, Makuuchi, Ruschemeyer, & Friederici, 2011; Kinno, Kawamura, Shioda, & Sakai, 2008; Mack, Meltzer-Asscher, Barbieri, & Thompson, 2013) that have found activations in the inferior frontal gyrus while supporting the processing of passive sentences. Just like unaccusative verbs, passive sentences have a *theme* argument surfacing in subject position. According to Meltzer-Asscher et al. (2015), despite the fact that the lexical decision task was at single word level, participants could have built sentence-level representations encoding the noncanonical mapping of unaccusative structures, thus corroborating the idea that PAS is activated even when verbs are found in isolation. If that is what

[62] “Inhibitory control of attention (interference control at the level of perception) enables us to selectively attend, focusing on what we choose and suppressing attention to other stimuli” (Diamond, 2013, p. 137).

happened, then we could assume that the inferior frontal gyrus indeed supports syntactic movement, or the linearization of arguments within sentences.

The present study found six clusters of activation for the effect of unaccusativity, three in the LH, and three in the RH. The ones in the LH were in the left cuneus, the left precentral gyrus (also found in the American study), and the left supplementary motor area. The cuneus is related to basic visual processing. The precentral gyrus, as previously mentioned, is the site of the primary motor cortex.

The supplementary motor area, traditionally not among the major language areas in the brain (Geschwind, 1970), has been implicated in speech and language processing as well. According to Hertrich, Dietrich, and Ackermann (2016), the anterior part of the supplementary motor area is involved in procedural aspects of cognitive processing, such as attentional switching, ambiguity resolution, context integration, and coordination between procedural and declarative memory structures. It is also involved in the use of inner speech mechanisms during language encoding, lexical disambiguation, syntax and prosody integration, and context-tracking. Something to emphasize is that participants in this and in the American study were instructed to respond with their left hand, so that motor-related activations in the LH could be avoided. Taking that into account, we could assume that the activation of the supplementary motor area in the LH had to do with some aspect of language processing. That should be looked at more thoroughly in subsequent studies.

Finally, the activations in the RH were in the right middle frontal gyrus, the right superior frontal gyrus, and the right medial frontal gyrus. These results did not resemble the activations found in Meltzer-Asscher et al. (2015). Although they were all in the frontal gyrus, they were not in the inferior frontal gyrus, and were not in the LH. The right middle frontal gyrus has been linked to executive functions, such as executive attention (Hesse & Fink, 2014). According to Petrides (2016), damage to both the middle and superior frontal gyri (particularly in the LH) results in severe impairments in aspects of working memory and attentional control, but not in language production or comprehension.

Shetreet et al. (2010) found activation in both the left superior frontal gyrus and the left middle frontal gyrus for monolingual Hebrew speakers. The left superior frontal gyrus was activated in the contrast between unaccusatives and unergatives. The activation in the left middle frontal gyrus was in the contrast between unaccusatives and transitives. In both contrasts, there were unaccusative verbs (whose S-structure ‘subject’ is a theme, resultant from A-movement) in comparison to verbs whose subjects are agents generated in canonical position. These results resemble the ones found in this study for the effect of unaccusativity, but they do not explain why the activations were all in the RH, while Shetreet et al.’s (2010) were all in the LH.

The study by Meltzer-Asscher et al. (2013) also found activations for these frontal regions. They were in bilateral middle and superior frontal gyri (BAs 8 and 9), with smaller clusters in the RH. Meltzer-Asscher et al. (2013) also used a lexical decision task similar to the one used in this study, with English verbs presented in isolation. However, they had predicted midsuperior frontal brain regions to be activated in the contrast between alternating transitive verbs and simple verbs, based on the results of previous studies that had found such activations for the processing of words with multiple meanings (i.e., processing of ambiguous stimuli) (e.g., Chan et al., 2004; Mason & Just, 2007). What needs to be highlighted, though, is that they found such activations regarding alternating transitive verbs, while in BP these same activations (only in the RH, not bilaterally) were found for the effect of unaccusativity.

The activations found in this study seem to be specific of the BP. However, the lexical variables *frequency*, *imageability*, *number of letters*, and *number of syllables* were added to the statistical analysis as covariates, but they did not impact the activations. Such patterns of activation could also be a ‘group effect’, or even not task-related at all.

The second and last aim of Study 1 was to calculate the behavioral results measured by ACC scores and RTs during syntactic processing and lexical access. Lower ACC scores and longer RTs were expected for verbs with more complex PAS (alternating and nonalternating unaccusatives), and pseudoverbs in relation to verbs. The results in BP partially corroborated the hypothesis, since pseudoverbs were in fact more difficult than verbs, and showed a significant statistical difference both in ACC scores and RTs. However, there was no significant difference between verb types, and they were different from Meltzer-Asscher et al.’s (2015) results.

Regarding error rates, both language groups had very high ACC scores, with almost identical results in relation to the four verb types. The American study did not provide their ACC scores for pseudoverbs, though. Both English and BP speakers showed highly significant statistical differences in RTs between pseudoverbs (more difficult) and verbs (less difficult). However, Americans showed a significant difference between verb types, having longer RTs for nonalternating unaccusatives (i.e., verbs with noncanonical mapping of internal argument) in comparison to the other verb types. BP speakers, on the other hand, showed no differences in the speed of lexical access among verb types.

Regarding lexical variables, both *number of syllables* and *number of letters* contributed equally to the best fit model, according to the mixed-effects model. Shorter verbs (bisyllabic) were accessed faster than longer verbs (trisyllabic). In the American study, the variable *number of letters* was considered in the statistical analysis, but it did not contribute to a difference in lexical access. *Number of syllables* was not even considered in their study. However, it makes sense to consider such differences between English and BP, given the fact that the syllabic formation of BP differs considerably from the one in English. Among the monosyllabic and bisyllabic verbs used in Meltzer-Asscher et al. (2015), there were verbs such as 'disappear', with nine letters and only two syllables, and 'shrink', with six letters and only one syllable. In BP, because of different rules of syllabic formation, we find verbs of nine letters, such as '*mergulhar*' (to dive), with three syllables, and verbs of four letters, such as '*cair*' (to fall), with two syllables. BP is a more transparent language than English, whose phoneme-grapheme distance is larger. Thus, future crosslinguistic investigations should consider that and look for an effect of language transparency/opacity as well.

The main variable of interest in this study, which was expected to impact the speed of lexical access, was *verb type*, but it did not prove significant. The present results in the lexical decision task at single word level revealed different neuroimaging and behavioral patterns that seem singular of BP. As mentioned in the Introduction, there is a dearth of investigations in Romance languages on PAS processing. The purpose of this study was to encourage crosslinguistic comparisons in this line of research.

Now I move on to Study 2 to discuss the results in both comprehension and production of PAS at sentence level.

5.2 Study 2

Study 2 included two behavioral tasks in BP involving sentences and pictures: one of comprehension (Task 1), and another of production (Task 2). Task 1 aimed at analyzing the impact of *verb type* (nonalternating unaccusative, transitive, alternating unaccusative, and unergative), and of the lexical variables *number of letters* and *number of syllables*, in a computerized sentence comprehension task in BP, measured by ACC scores and RTs. Despite the fact that the literature on PAS shows practically intact comprehension in both healthy and aphasic individuals, differences in ACC and RT measures were expected for verbs with more complex PAS (alternating and nonalternating unaccusatives). However, the results of Task 1 did not corroborate the hypothesis, either regarding verb types in ACC scores or RTs, or regarding the impact of the lexical variables on overall RTs.

Like in the lexical decision task of Study 1, there was no significant difference between verb types in ACC or RT measures. However, these are tasks of different natures, for they measure different abilities. The lexical decision task was at single word level, was presented to participants while in the fMRI scanner, and had them make decisions while looking at the stimuli (verbs). The comprehension task, on the other hand, was at sentence level, and had participants hold the pictorial information in working memory[63] while making a decision on the veracity of the sentences.

In the sentence comprehension task, there was a more expressive numerical difference in RTs (see Table 14 again) between alternating unaccusative verbs (2084.74 ms), considered more complex, and unergative verbs (1716.74 ms), considered less complex. Even so, such difference was not statistically significant. The evidence that the comprehension of sentences was not affected either by verb type, or by the size of the verbs in BP, may be helpful to future research and has clinical implications for the treatment, for instance, of sentence comprehension in aphasia.

Task 2 of Study 2, on the other hand, was meant to analyze the specific features of PAS in BP in oral sentence production motivated by pictures showing actions, along with the corresponding verb. Again, verbs were of four types: nonalternating unaccusative, transitive, alternating unaccusative, and unergative. Participants were expected to produce sentences with the required thematic structure for each verb type, and in the right order, what they did in 70% of the occurrences (according to the first criterion). They were also expected to omit the external

[63] "A brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning" (Baddeley, 1992, p. 556).

argument (i.e., the subject), as well as the optional internal argument (i.e., the object) of transitive verbs. The results partially corroborated the hypothesis, since there were few occurrences of omission of the external argument (2%), and the omission of the optional internal argument happened with only one transitive verb (0%).

While looking at such results, one has to bear in mind the fact that they were produced by a population of healthy individuals with high educational levels. In other words, we are dealing with what we would call a 'prototypical sample', in the sense that their production is the best to be expected from a group of Brazilian Portuguese native speakers at their age. We are fully aware of the issues in the educational system in Brazil, which means we must always take into account and control participants' socioeconomic status, as well as sociocultural aspects and reading and writing habits, to better assess cognitive and linguistic abilities.

In the task, participants were instructed to produce a sentence with the verb given, as long as it was a complete sentence that described what was going on in the picture, and were not given a model sentence. By not having them train to do the task, they were not offered a strict verbal pattern to follow (e.g., the present tense with the gerund form), and that allowed them to use a variety of verbal tenses or constructions as they liked, as long as they followed the instructions. That means they were free to use both active and passive voice, or compound verbal forms ('*locuções verbais*'[64]), which are very frequently used in BP, as exemplified in [1]-[2]:

[1] *O cachorro deu uma mordida na perna de alguém*. (*morder*)
The dog bit someone's leg.

[2] *José foi caminhar no parque ensolarado*. (*caminhar*)
José went for a walk in the sunny park. (to walk)

Despite participants' overall good performance, there were a lot of occurrences in which they did not fulfill the aims of the task. I emphasize once more that this study had no intention of being prescriptive. All the examples classified as 'correct' or 'incorrect' according to the adopted criteria were meant to describe the production of this group of healthy BP speakers with high educational levels, and not

64 I could not find a proper word for it in English.

to judge them in terms of adequacy to standard grammar. Similar production tasks have been applied to aphasic subjects and healthy controls in other languages (e.g., Lee & Thompson, 2004; McAllister et al., 2009; Stavrakaki et al., 2011). The production by people with aphasia is usually impaired, especially that of verbs and, consequently, of sentences. A lot of times they produce only fragments, instead of complete sentences. They also change the target verb, or have difficulty retrieving words in general. However, a behavior that is attributed to brain lesions could be expected from healthy individuals as well, as observed in this study.

As examples of nontarget production, participants produced a lot of fragments (4%), did not fulfill the task by not producing a description of the pictures (14%). They also used the wrong target verb sometimes (5%), despite having the target verb written on the page above the picture. There were naming problems, meaning that healthy individuals also have trouble retrieving words, or some might even not know a word. Not knowing a word is one more reason to encourage the proper translation and cultural adaptation of a task built originally in another language. Many times, what seems to be an impairment in lexical access is originated by methodological decisions in task construction.

Examples [3] and [4] illustrate a semantic aspect worth mentioning:

[3] *O carro está estragando*. (*estragar*)
The car is breaking down. (to break down)

[4] *A criança está nascendo*. (*nascer*)
The child is being born. (to be born)

The examples above were considered ‘target sentence’ according to the first criterion. However, both verbs, either in BP or in English, carry the property of telicity. *Telic* verbs describe actions which have an endpoint, and the pictures for these verbs were very clear about that. They showed a car that was already broken down, and a child that had already been born. Even so, that did not prevent some participants from using the gerund form to describe these pictures.

Something intriguing refers to one specific participant, who reluctantly did not produce the target sentence for most of the verbs, even after the examiner had repeated the instructions more than once. Sentences [5]-[9] are a few examples of such occurrences:

[5] *Planta murcha é próprio de morrer sem água*. (*morrer*)
Fading flower is characteristic of dying without water. (to die)

[6] *Chegar no final da corrida como vencedor é próprio dos vencedores*. (*chegar*)
To arrive at the end of the race as a winner is characteristic of winners. (to arrive)

[7] *Pedir esmola é próprio de quem está deficiente*. (*pedir*)
To ask for handouts is characteristic of who is in need. (to ask)

[8] *Abrir a porta com fechadura é sinal que estamos entrando em nossa casa*. (*abrir*)
To open the door with a keylock is a sign that we are entering our own house. (to open)

[9] *Puxar um elefante num carrinho, seria bom deixá-lo caminhar*. (*puxar*)
To pull an elephant on a wagon, it would be nice to let it walk. (to pull)

None of the sentences above were descriptions of what was going on in the pictures. Some of them even seem nonsensical, and full of verbosity. Despite that, this participant was not ruled out as an outlier because her results in the neuropsychological tests and in the other two behavioral tasks were impeccable. What seems to be the case is that these results are illustrative, for instance, of the participant's personality traits, including *off-target verbosity*. Such behavior is typical of older adults as inhibition breaks down as age increases (Pushkar et al., 2000).

Concerning the construct of transitivity, we were well aware, during the selection of the verbs and pictures for Task 2, of the fact that the classification of verbs according to verb types (nonalternating unaccusative, transitive, alternating unaccusative, and unergative) would not be as clear-cut in production as in comprehension. First, it is not possible to control what happens to verbs when people use them in actual speech in a not fully controlled task. As mentioned in section 2.1, grammatical transitivity is a property of the sentence, for there are no verbs that are exclusively transitive or intransitive, but dependent on the speaker's intention while building a sentence (Castilho, 2016). That is also constrained by the rules of each individual language, and by the way a language evolves along time. Therefore, sentence production was not assessed strictly by verb type. Instead, a more qualitative analysis was carried out by presenting examples according to their relevance for the characterization of the production.

As presented in section 4.5, there were occurrences of verbs expected to be dealt with intransitively, which were used transitively, even when the picture did not portray a complement, such as in '*Ø Dormiu* <u>*o sono dos justos*</u>.' (He slept <u>the sleep of the just</u>.), or '*O cantor canta* <u>*sua música*</u>.' (The singer sings <u>his song</u>.), both unergative verbs. With the nonalternating unaccusatives '*subir*' (to go up) and '*descer*' (to go down), almost all the produced sentences included '*escada*' (stairs), which were portrayed in the picture because that was the only pictorial resource available to convey the intended meaning of the verbs.

One final example regards unaccusativity. Out of all the sentences built with unaccusative verbs, there was only one occurrence in which there was no A-movement. The NP appeared in its original syntactic position, that of *complement* (direct object), as illustrated in [10]:

[10] *Nasceu um bebê*. (*nascer*)
A baby was born (a baby). (to be born)

As final remarks about Study 2, I would like, first, to point out that, to the best of my knowledge, there are no similar studies (behavioral and neuroimaging) in BP or in any other Romance language, rather than in Italian. As stated in the Introduction, this study was meant to contribute to language assessment and rehabilitation of Brazilian clinical populations with atypical language, by providing evidence of sentence production by a group of healthy adult individuals with the sociodemographic characteristics here selected. Second, taking into account the literature on language rehabilitation in aphasia, verbs have a crucial role in sentence production and connected speech (Conroy et al., 2006). Thus, more investigations should be made around verbs. Through the work with verbs and their PAS, we can access nouns as well. As a third and final remark, I emphasize the fact that language is dynamic, and any native speaker of a language is prone to make mistakes, break rules, ignore instructions, which includes healthy and well-educated individuals such as the participants of this study, let alone subjects with brain lesions.

The next chapter, Final Considerations, will present the main findings of this study, along with its limitations, and end with some suggestions for future investigations.

6 FINAL CONSIDERATIONS

In this dissertation, two separate studies were carried out. Study 1 explored the neural correlates of PAS in BP, through functional neuroimaging and behavioral data. The population investigated was a group of 16 healthy monolingual speakers of BP with high educational levels. Study 2 explored both PAS comprehension and production in BP, with the same participants of Study 1, plus five more added to the sample. The underlying purpose was to understand the neurobiology of BP regarding syntactic processing and lexical access in a sample of healthy highly-educated adults, and possibly contribute to language assessment and rehabilitation of Brazilian clinical populations with atypical language, such as people with types of dementia or following a stroke, as in the case of aphasia.

Study 1 revealed clusters of activation in the left fusiform gyrus, left paracentral lobule, left supplementary motor area, and left superior temporal pole for the effect of number of thematic roles. There was activation in the left lingual gyrus for the effect of thematic options. Finally, for the effect of unaccusativity, there were clusters of activation in the left cuneus, left supplementary motor area, left precentral gyrus, and in the right middle frontal gyrus, right superior frontal gyrus, and right medial frontal gyrus. Hopefully, these results may contribute to the discussion about the neural correlates of syntactic processing of PAS across languages, and especially of BP. Such a discussion is relevant to clinicians investigating language impairments due to brain lesions, as well as to research on the foundations of syntactic processing of PAS and lexical access of verbs.

As a way to contribute to speech pathologists dealing with Brazilian aphasic patients, a list was provided showing the verbs of the lexical decision task organized by verb type and ascendant order of RTs. These data inform clinicians about which verbs, in each verbal category, were accessed faster by the participants in this study. That may be helpful to decide on which verbs to use in language rehabilitation.

In Study 2, sentence comprehension was not affected by verb type (or by the size of the verbs in BP), corroborating previous findings with both healthy participants and aphasic subjects in other languages. In addition to that, Study 2 generated results on the patterns of sentence production as well. The results showed the multiple possibilities of verbal constructions, use of voice, and transitivity. The findings also indicated that even highly-educated healthy individuals may have problems to follow the instructions to a task and to find words, despite not having neurological impairments or major memory deficits. These findings confirm the fact that language is dynamic, and that a plurality of different responses should be expected from populations with both typical and atypical language in a sociolinguistic perspective. The sample is obviously not representative, thus we cannot make generalizations. Even so, it points to how this group of individuals produces in the context of this kind of task.

As for the limitations of Study 1, the main challenge was the high cost of the neuroimaging collection, which prevented us from collecting data with a larger sample. In addition to that, methodological, demographic, and sociocultural differences make it impossible to replicate a neuroimaging study, although we tried to keep as close as possible to the procedures of the American study. That included the construction of the stimuli list, the preprocessing of the images, and the statistical analysis, which were conducted in constant contact with the authors of the original study, from Northwestern University (USA).

Regarding the translation and adaptation of the stimuli of the lexical decision task to BP, the expectation was to control for all the different lexical variables that had been controlled in English. That was another limitation, since we do not have the same linguistic resources for BP as they have in software available with several linguistic metrics. That was also a considerable limitation for Study 2 in both the comprehension and the production tasks. We could not find corpora that could provide us with all the variables needed. For the lexical decision task (Study 1), we had to build our own corpus, from which we could select the verbs in the context of sentences, and measure the percentage of intransitive use. Anyway, controlling for frequency of the verbs and number of letters, and adding number of syllables (only relevant to BP) in the same task proved very difficult, as explained in the Method. Because the priority was the context of use of the verbs, and their percentage of intransitive use in the corpus, we ended up with a significant difference in frequency between transitives and unergatives. Unfortunately, to the present moment, we do not have one single corpus in BP that is big or complete enough to provide us with all the psycholinguistic features we need for such studies, such as scores of frequency, imageability, age of acquisition, frequency of bigrams, etc.

As suggestions for future investigations, I believe the inclusion of a clinical group should be pursued. Another suggestion for future studies is the enlargement of the sample, as well as the inclusion of a group of healthy individuals with low educational levels, in order to explore a possible effect of schooling and reading and writing habits in lexical access, and in sentence comprehension and production of PAS.

Regarding the neuroimaging data collection, I still have the reverse contrasts to explore, as well as Diffusion Tensor Imaging (DTI) data, which were also acquired in the same neuroimaging acquisition section, and could be further correlated to the neuropsychological and linguistic data. The behavioral data collection, on the other hand, also included the production of written narratives, which were left out of this dissertation, but should be explored in subsequent studies.

Summing up, this dissertation was meant to provide with innovative contributions to the research on PAS and to clinical treatment of individuals who have suffered brain lesions due to stroke (especially to the LH) and have ended up with language impairments. Last, but not least, to generate imaging pioneering data on the topic in BP.

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APPENDIX A - FREE AND INFORMED CONSENT FORM (BEHAVIORAL STUDY)

PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO GRANDE DO SUL
PROGRAMA DE PÓS-GRADUAÇÃO EM LETRAS

Termo de Consentimento Livre e Esclarecido
Autorização para participar de um projeto de pesquisa

Título do estudo: “Processamento discursivo, semântico e sintático na afasia: um estudo longitudinal com neuroimagem estrutural e funcional”

Instituição: Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS) – Faculdade de Letras, Programa de Pós-Graduação em Letras
Pesquisadora responsável: Profª Drª Lilian Cristine Hübner
Telefones para contato: (51) 3320-3676 (secretaria PPGL); (51) 3320-3500 (ramal 4606) (gabinete da Profª Drª Lilian Hübner).
Nome do participante: ____

Objetivo e benefícios do estudo: O objetivo da pesquisa é analisar questões relacionadas ao processamento e à recuperação de diferentes níveis linguísticos na afasia, com uma análise complementar de dados de neuroimagem funcional e estrutural. Os resultados fornecerão subsídios para uma melhor compreensão do funcionamento dos aspectos acima mencionados, bem como o suporte teórico para futuras técnicas de terapia e de reabilitação da linguagem em sujeitos com esse tipo de lesão.
Explicação dos procedimentos: O(a) senhor(a) será convidado(a) a responder a perguntas e a realizar tarefas que fazem parte deste estudo. Algumas dessas tarefas serão gravadas. A aplicação será feita em um ou mais encontros, de aproximadamente 50 minutos cada, dependendo da necessidade da pesquisa. Sua participação é voluntária. Só responderá às avaliações se concordar.
Possíveis riscos e desconfortos: O possível desconforto do participante está relacionado ao cansaço ao longo da execução das tarefas.
Direito de desistência: O(a) senhor(a) pode desistir de participar a qualquer momento sem nenhum prejuízo.
Sigilo: Todas as informações obtidas neste estudo poderão ser publicadas com finalidade científica, preservando-se o completo anonimato dos participantes.
Consentimento: Declaro ter lido – ou me foram lidas – as informações acima antes de assinar este formulário. Foi-me dada oportunidade de fazer perguntas, esclarecendo totalmente as minhas dúvidas. Por este documento, tomo parte, voluntariamente, deste estudo.

Porto Alegre, _____ de __________________ de 20___.

____
Assinatura do participante

____
Assinatura do pesquisador responsável

Comitê de Ética em Pesquisa (CEP)
Av. Ipiranga 6690, Prédio 60 – Sala 314
Porto Alegre/RS – Brasil – CEP: 90610-900
Fone/Fax: (51) 3320.3345
Email: cep@pucrs.br
Horário de funcionamento: Segunda a sexta-feira, das 08h às 12h e das 13h30 às 17h.

APPENDIX B - FREE AND INFORMED CONSENT FORM (NEUROIMAGING STUDY)

PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO GRANDE DO SUL
PROGRAMA DE PÓS-GRADUAÇÃO EM LETRAS

Termo de Consentimento Livre e Esclarecido
Autorização para participar de um projeto de pesquisa

Título do estudo: "Processamento discursivo, semântico e sintático na afasia: um estudo longitudinal com neuroimagem estrutural e funcional"

Instituição: Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS) – Faculdade de Letras, Programa de Pós-Graduação em Letras
Pesquisadora responsável: Profª Drª Lilian Cristine Hübner
Telefones para contato: (51) 3320-3676 (secretaria PPGL); (51) 3320-3500 (ramal 4606) (gabinete da Profª Drª Lilian Hübner).
Nome do participante: ____

Você está sendo convidado a participar de uma pesquisa que tem o objetivo de estudar as características do processamento discursivo, semântico e sintático da linguagem na afasia. Caso concorde em participar, você irá realizar algumas tarefas para avaliar seu reconhecimento de palavras/frases; isso será feito durante um exame de ressonância magnética funcional do cérebro, no Instituto do Cérebro – InsCer – da PUCRS.
Procedimentos: Durante o exame, você ficará deitado no equipamento, usando fones de ouvido e visualizando um monitor no qual aparecerão algumas palavras/frases para que você identifique. Você deverá usar uma button-box, que estará na sua mão direita, para identificar as palavras dadas. O único desconforto é um ruído, que é amenizado por fones de ouvido. A ressonância magnética não utiliza radiação, ao contrário do raio-X e da tomografia. Portanto, não existem efeitos prejudiciais conhecidos ao organismo. Contudo, o exame pode gerar alguma angústia ou ansiedade, pois se pede que o participante permaneça o mais imóvel possível dentro da máquina enquanto realiza o exame. Algumas pessoas podem sentir um desconforto por estarem dentro da máquina. O exame pode ser interrompido a qualquer momento.
Benefícios: Não há benefício direto para os indivíduos que participarem deste estudo. No entanto, a sua participação ajudará a entender melhor o funcionamento da linguagem no cérebro humano.
Sigilo e privacidade: As informações produzidas serão mantidas em lugar seguro, codificadas e a identificação só poderá ser realizada pelo pessoal envolvido diretamente com o projeto. Caso o material venha a ser utilizado para publicação científica ou atividades didáticas, não serão utilizados nomes que possam vir a identificá-lo(a).
Despesas e compensações: Acredito ter sido suficientemente esclarecido a respeito das informações que li ou que foram lidas para mim, descrevendo o estudo. Ficaram claros para mim quais são os propósitos do estudo, os procedimentos a serem realizados, seus desconfortos e riscos, as garantias de confidencialidade e de esclarecimentos permanentes. Concordo voluntariamente com a participação e poderei retirar o meu consentimento a qualquer momento, sem penalidades ou prejuízo no meu atendimento neste Serviço.
Se houver perguntas sobre esse estudo, favor entrar em contato com a Profa. Dr. Lilian Cristine Hübner no seguinte endereço: Faculdade de Letras, Av. Ipiranga, 6681, Prédio 8, Sala 427, Porto Alegre/RS. Fone: 3320.3500 (ramal 4606) ou no Comitê de Ética em Pesquisa da PUCRS, Av. Ipiranga, 6690, Prédio 60, Sala 314, Porto Alegre/RS. Fone: 3320-3345 (horário de funcionamento de segunda a sexta-feira, das 08h às 12h e das 13h30 às 17h).
Dou meu consentimento de espontânea vontade e sem reservas para participar deste estudo.

-- Assinatura do paciente/representante legal	-- Profa. Dr. Lilian Cristine Hübner Pesquisadora responsável	Data / /

APPENDIX C - STIMULI, IMAGEABILITY RATINGS AND PERCENTAGE OF INTRANSITIVE USAGE OF VERBS IN THE LEXICAL DECISION TASK

Verb	**Imageability**	**% Intransitive use**	**Verb**	**Imageability**	**% Intransitive use**
Nonalternating unaccusatives			**Transitives**		
morrer	3.8	100%	*vestir*	4.35	5%
subir	4.3	97%	*contratar*	2.6	8%
faltar	1.85	91%	*matar*	4.3	10%
cair	4.65	100%	*destruir*	3.95	6%
sumir	2.58	100%	*cortar*	4.65	3%
emergir	3.35	90%	*enfrentar*	2.55	0%
nascer	4.47	100%	*aceitar*	2	0%
viver	1.8	88%	*esperar*	3.05	3%
sair	3.65	100%	*marcar*	3.2	1%
morar	3	100%	*escolher*	2.8	0%
crescer	3.5	100%	*adotar*	2.35	0%
entrar	3.73	99%	*chamar*	3.85	10%
partir	3.05	100%	*causar*	1.65	0%
surgir	2.6	100%	*perceber*	1.55	0%
perdurar	1.85	100%	*gastar*	3	0%
decair	1.85	100%	*atrair*	2.85	4%
chegar	3.45	100%	*construir*	4.35	0%
existir	1.55	100%	*levar*	2.75	0%
Alternating unaccusatives			**Unergatives**		
atrasar	2.7	28%	*sorrir*	4.95	100%
agravar	1.4	65%	*mentir*	1.65	100%
piorar	1.75	80%	*mergulhar*	4.6	90%
girar	3.85	92%	*repousar*	3.65	100%
apagar	4.2	47%	*sentar*	4.6	100%
dobrar	4	60%	*dormer*	4.8	100%
fechar	4.1	31%	*fumar*	5	89%
quebrar	4.3	39%	*caminhar*	5	100%
parar	3	55%	*andar*	4.75	100%
casar	4.63	43%	*agir*	2.3	100%
combinar	2.15	12%	*latir*	4.64	100%
terminar	2.4	75%	*voar*	4.85	100%
acabar	2	85%	*miar*	4.5	100%
abrir	3.7	13%	*remar*	4.78	83%
aumentar	3.14	58%	*trafegar*	3.28	88%
seguir	3.28	22%	*correr*	4.95	87%
mudar	2.55	68%	*funcionar*	1.85	100%
melhorar	1.65	44%	*trabalhar*	3.6	100%

APPENDIX D – SENTENCE COMPREHENSION TASK

Stimuli:

+

***O moço está cortando grama*.**

(The guy is mowing the lawn.)

+

***A mulher está casando*.**

(The woman is getting married.)

A planta está crescendo.
O carteiro está chegando.
O adolescente está caindo.
O sol está nascendo.
O suspeito está fugindo.
A árvore está morrendo.
As pessoas estão saindo.
O alpinista está descendo.
O esportista está subindo.
Os estudantes estão entrando.
A garota está assistindo TV.
O guri está gastando água.
A mãe está chamando a polícia.
A vó está servindo chá.
O moço está cortando grama.
A menina está matando a flor.
A mulher está sujando a casa.
O rapaz está consertando a mesa.
O cão está mordendo o gato.
O pai está tirando a roupa.
A mãe está dobrando as roupas.
A menina está acordando.
As máquinas estão perfurando o solo.
O bambolê está girando.
O bombeiro está apagando o fogo.
A garota está amassando papel.
A mulher está casando.
A pá está quebrando.
O menino está melhorando.
O homem está fechando a porta.
A menina está rezando.
A moça está correndo.
A mulher está pulando.
O homem está fumando.
O aluno está estudando.
A garota está caminhando.
As crianças estão brincando.
O garoto está nadando.
O menino está mergulhando.
A adolescente está rindo.

APPENDIX E – SENTENCE PRODUCTION TASK

Stimuli:

Cair (to fall)
Chegar (to arrive)
Descer (to go down)
Entrar (to go in)
Fugir (to run away)
Morrer (to die)
Nascer (to be born)
Partir (to leave)
Sair (to go out)
Subir (to go up)
Assistir (to watch)
Carregar (to carry)
Chutar (to kick)
Dirigir (to drive)
Lamber (to lick)
Morder (to bite)
Pedir (to ask for sth.)
Pintar (to paint)
Puxar (to pull)
Servir (to pour)

Abrir (to open)
Acender (to light)
Acordar (to wake up)
Casar (to marry)
Dobrar (to fold)
Estragar (to break down)
Furar (to drill)
Parar (to stop)
Quebrar (to break)
Seguir (to follow)
Andar (to walk)
Caminhar (to walk)
Cantar (to sing)
Dançar (to dance)
Dormir (to sleep)
Falar (to speak)
Gritar (to yell)
Nadar (to swim)
Sentar (to sit down)
Voar (to fly)