ESCOLA DE HUMANIDADES
PROGRAMA DE PÓS-GRADUAÇÃO EM LETRAS
MESTRADO EM LINGUÍSTICA

ANDERSON DICK SMIDARLE

THE EFFECTS OF EDUCATION AND READING AND WRITING HABITS ON AUTOMATIC ASSESSMENT OF NARRATIVE RECALL IN TYPICAL AGING AND IN ALZHEIMER'S DISEASE

Porto Alegre - RS
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Master's thesis presented to the School of Humanities' Graduate Program in Letras at the Pontifical Catholic University of Rio Grande do Sul as a requirement for the title of Master in Linguistics.

Advisor: Prof. Dr. Lilian Cristine Hübner
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2020

To the participants of this study,
for their esteemed contribution to science.

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“The limits of my language mean the limits of my world.”

Ludwig Wittgenstein

ABSTRACT

We analyzed oral discourse production to identify the characteristics of language performance in healthy and pathological aging. Most studies have focused on performance in tasks eliciting discourse production through visual stimuli or interviews. Very little is known about the impact of aging-related factors on narrative recall, a complex task that requires comprehension of a narrative to reproduce it. In the present thesis, we address these issues in two studies. In the first study – *Automatic Assessment of Syntactic, Lexical and Semantic Aspects of Narrative Recall in Alzheimer's Disease* –, we compared a group of participants diagnosed with Alzheimer's Disease (AD) with that of a healthy elderly control group in syntactic, lexical and semantic aspects in a narrative recall task. To obtain the scores for the features related to these three aspects, we used a software that automatically analyzes linguistic features from discourse samples. Results indicate that features from all three aspects distinguish elderly adults diagnosed with AD from elderly adults with unimpaired cognition. The second study – *Education and Reading and Writing Habits as Predictors of Narrative Recall Performance in Healthy Aging: a Study with Automatic Assessment* – aimed at investigating the impact of education and reading and writing habits on recalls produced by healthy elderly adults. We adopted the same automatic analysis of Study 1. Results show that education influences performance on syntactic, lexical and semantic aspects of narrative recall. This stresses the importance of education as a source of cognitive reserve for linguistic performance in the elderly. Reading and writing habits did not influence performance in any of the features analyzed. Both studies suggest that the analysis of discourse production can be useful for the detection of changes in linguistic processing. The results from these two studies also indicate that task typology and group characteristics (such as the presence of cognitive impairment or low educational level) must be taken into consideration when investigating specific features of oral discourse production.

Keywords: Oral Discourse Production; Aging; Alzheimer's Disease; Automatic Language Assessment; Education; Reading and Writing Habits; Narrative Recall.

RESUMO

Nós analisamos a produção de discurso oral a fim de identificar características de desempenho linguístico no envelhecimento sadio e patológico. Muitos estudos têm focado no desempenho em tarefas que evocam produção discursiva através de estímulos visuais ou entrevistas. Pouco se sabe sobre o impacto de fatores relacionados ao envelhecimento no reconto de narrativa, uma tarefa complexa que demanda compreensão de uma narrativa para posterior reprodução. Na presente dissertação, nós avaliamos essas questões em dois estudos. No primeiro estudo – *Avaliação Automática de Aspectos Sintáticos, Lexicais e Semânticos do Reconto de Narrativa na Doença de Alzheimer* –, nós comparamos o desempenho de um grupo de participantes diagnosticados com Doença de Alzheimer (DA) com o de um grupo de idosos saudáveis em aspectos sintáticos, lexicais e semânticos de uma tarefa de reconto de narrativa. Para obter os valores das métricas associadas a esses três aspectos, nós utilizamos um software que analisa automaticamente métricas de amostras de discursos. Os resultados indicam que métricas relacionadas aos três aspectos linguísticos distinguem idosos diagnosticados com DA de idosos saudáveis. O segundo estudo – *Escolaridade e Hábitos de Leitura e Escrita como Preditores de Desempenho em Reconto de Narrativa no Envelhecimento Sadio: um Estudo com Análise Automática* –, teve por objetivo investigar o impacto da educação e dos hábitos de leitura e escrita nos recontos produzidos por idosos saudáveis. Nós adotamos a mesma análise automática do Estudo 1. Os resultados indicam que a escolaridade influenciou o desempenho nos aspectos sintático, lexical e semântico do reconto de narrativa. Isso salienta a importância da escolaridade como fonte de reserva cognitiva para o desempenho linguístico de idosos. Os hábitos de leitura e escrita não influenciaram o desempenho em nenhuma das métricas analisadas. Ambos os estudos sugerem que a análise da produção de discurso pode ser útil para a detecção de mudanças no processamento linguístico durante o envelhecimento. Os resultados desses dois estudos indicam também que a tipologia da tarefa e as características do grupo (como a presença de declínio cognitivo ou baixo nível de escolaridade) devem ser consideradas na investigação de métricas específicas de produção de discurso oral.

Keywords: Produção de Discurso Oral; Envelhecimento; Doença de Alzheimer; Análise Automática de Linguagem; Escolaridade; Hábitos de Leitura e Escrita, Reconto de Narrativa.

LIST OF TABLES AND FIGURES

LIST OF ABBREVIATIONS

AD – Alzheimer's Disease

BALE – Bateria de Avaliação da Linguagem no Envelhecimento

BM – Brain Maintenance

BMC – Brain Reserve Capacity

BR – Brain Reserve

CR – Cognitive Reserve

GDS – Geriatric Depression Scale

HHE – Healthy Adults with High Education

HLE – Healthy Adults with Low Education

MMSE – Mini-Mental State Examination

PPA – Primary Progressive Aphasia

TTR – Type-Token Ration

TABLE OF CONTENTS

INTRODUCTION

In the past 30 years, there has been a significant increase in life expectancy in Brazil, with citizens currently living an average of 76 years (IBGE, 2018). With the increase of life expectancy rates, researchers are turning their attention to issues related to aging, especially to the impact of aging on cognitive processing. As we age, we experience a continuous decline in some areas in cognitive functioning. There is a debate on when such a decline begins. Some studies indicate that it begins in early adulthood, supported by evidence of changes in brain volume (ALLEN *et al.*, 2005; KRUGGEL, 2006). Other studies, however, present neuropsychological evidence that cognitive aging is only triggered later in life, at around 60 years or later (AARTSEN *et al.*, 2002; SCHAIE, 1989). There is also a third approach to age-related cognitive decline defending that some cognitive abilities suffer a decline, while others improve until early old age (SALTHOUSE, 2009). Despite the argument on when cognitive decline is triggered, there seems to be a consensus that, from around 60 years of age, individuals start experiencing a continuous and more prominent decline in cognitive processing (AARTSEN *et al.*, 2002; SALTHOUSE, 2009; SCHAIE, 1989).

One of the most explored aspects on studies on aging is the influence of lifestyle factors such as education and reading and writing habits on overall cognitive processing. As the elderly present different rates of cognitive decline even in healthy aging, it is argued that such factors assist in the development of a cognitive reserve that increases the brain's resilience to atrophy (STERN, 2002; STERN *et al.*, 2018).

Although a certain degree of cognitive decline is expected with aging, the individual's functionality should remain unaffected. A decline in functionality may be an indicator of dementia, such as Alzheimer's Disease (AD). AD is characterized by a progressive decline in memory (mainly, in general) and other cognitive functions – including language –, as well as a decline in functionality (AZEVEDO *et al.*, 2010). It is estimated that there are around 1,2 million cases of AD in Brazil, with most cases still undiagnosed (ABRAZ, 2019). As a result, additional methods of cognitive impairment assessment must be developed to facilitate an early diagnosis of dementia, thus allowing a fast intervention to increase or at least maintain the patient's quality of life.

Language evaluation is a widely used tool to investigate cognitive decline in healthy aging and in dementia, as it allows for a non-intrusive assessment that is sensible to changes in cognitive processing. Many studies focus on tasks that measure performance at the word level, since it is a faster way to determine decline. Other linguistic levels, however, are also affected by cognitive changes and must be further investigated to determine the process

behind these effects. Although narrative production and comprehension has been explored in the past decades, narrative recall has still not been explored in depth, despite being an essential resource for human communication and for our interaction with other individuals and the world. Narrative recall is a complex task, as it involves encoding and storage processes for the comprehension stage, and a retrieval process for the production stage (OLIVEIRA *et al.*, 2017).

There are several approaches on how narratives can be explored. It is possible to evaluate their level of complexity and readability, their cohesion and coherence, among other aspects. Also, in recent years, different types of software were developed to assist in narrative analysis. For instance, researchers from São Paulo University (USP) developed *NILC Metrix*[1], a software that analyzes narratives produced by cognitively healthy and impaired individuals to establish a pattern that can assist on the early diagnosis of dementia.

Through this research, we expect to identify linguistic patterns in healthy older adults according to their schooling level and reading and writing habits, and in Alzheimer's Disease. This may lead to a better understanding on how narrative recall is processed cognitively, thus contributing to the literature in the field and to the diagnosis of linguistic changes – normal or impaired - related to aging. We hypothesize that, in the first study, which will compare narrative recall between healthy older adults and AD participants, there will be an impact on narrative recall performance, with AD patients showing worse performance on features assessing syntactic, lexical and semantic aspects of narrative recall. AD patients will produce shorter and less complex narratives at all aspects. For the second study, which compared narrative recall between two healthy adults elderly groups as a function of their educational level, we hypothesize that education and reading and writing habits will have an impact on syntactic, lexical and semantic features of narrative recall. Both variables will be related with more complex, longer and more complex narrative recalls.

To address the impact of AD and cognitive reserve on narrative recall, this thesis will be organized in four chapters. The first chapter provides an overview on how narratives are structured and produced, and how age, cognitive reserve factors and AD affect general cognitive processing, emphasizing language aspects. The second chapter consists of the first study that composes this thesis. In this study – *Automatic Assessment of Syntactic, Lexical and Semantic Aspects of Narrative Recall in Alzheimer's Disease* –, we are going to investigate the impact of AD on syntactic, lexical and semantic aspects of narrative recall.

[1] Access in: https://simpligo.sidle.al/

The recalls are going to be analyzed via software of automatic language assessment, to address its applicability in cognitive studies. The third chapter consists of the second study that composes this thesis. In this study – *Education and Reading and Writing Habits as Predictors of Narrative Recall Performance in Healthy Aging: a Study with Automatic Assessment* –, we are going to adopt the same procedure from the first study in order to investigate whether the same linguistic features adopted to distinguish healthy elderly adults from elderly adults diagnosed with AD are able to distinguish elderly individuals according to their level of education and reading and writing habits. To conclude this thesis, in the fourth chapter we present a brief discussion on the similarities and differences observed between the two studies, in the light of the literature on previous studies. We also offer some suggestions for future studies to address other variables that may influence narrative recall performance.

1 THEORETICAL BACKGROUND

In this chapter, we are going to present a brief overview on theories addressing narrative structure and production (section 1.1). Then, we are going to discuss age-related changes on language production and the impact of education and reading and writing habits on the preservation of language abilities (section 1.2). The discussion on age-related changes in language processing will be followed by an overview on the impact of Alzheimer's Disease on language production (section 1.3). Finally, a discussion on tools for automatic assessment of language samples will be conducted (section 1.4). This chapter is going to provide a general overview on the topics addressed in this thesis, contributing to the discussion of our findings.

1.1 DISCOURSE STRUCTURE AND PRODUCTION

The narrative genre is omnipresent in our lives. Its usage to demonstrate and to interpret our relationship with the people and the world surrounding us can be traced back to the rudimental cave paintings (MUNGIOLI, 2002). The study of narratives can be divided in two moments: in the first moment, narrative studies focused on the interpretation of the narrative, while the second moment was characterized by the systematic study of narrative structure and how its construction and organization influence meaning achievement (MUNGIOLI, 2002).

It is important to have a clear understanding of what exactly a text is. It can be interpreted in several ways. Marcuschi (2014) defines text as a communicative unit whose structure is dependent on the understanding of co-textual and contextual elements. Halliday and Hassan (1976) describe text as having a pragmatic nature. These authors postulate that text is a unit of meaning, not a unit of form. This social interpretation of text, however, may lead to a conflict between the concept of text and the concept of discourse. Although text and discourse share similar notions, some authors postulate there is a difference between these two concepts (FÁVERO; KOCH, 1994), while others tend to take them interchangeably (MARCUSCHI, 2008). According to Fávero and Koch (1994), text corresponds to any manifestation of human textuality. Discourse, on the other hand, refers to the verbal language produced during a social interaction. Under this perspective, text is "a unit of meaning, from a contextual communicative continuum that is characterized by a group of relations responsible for the *weaving* of the text"[2] (FÁVERO; KOCH, 1994, p. 25). Yet as Marcuschi (2008) points

[2] Original text: "...o texto é uma unidade de sentido, de um contínuo comunicativo contextual que se caracteriza por um conjunto de relações responsáveis pela *tessitura* do texto."

out, a strict distinction between text and discourse should not be made, since the current tendency leads to a continuum between the two terms. According to him, the text needs a context, which cannot be rigorously separated from the text, nor from its discursive context. Marcuschi (2008) postulates that discourse is the enunciation, and text is the global configuration that may range from a single utterance to a whole novel, always connected to the context level, similarly to the discourse. In this thesis the terms discourse and text may be taken interchangeably, following the theoretical perspective proposed by Marcuschi (2008). In the following sections of this subchapter, we are going to discuss the components of discourse and how they are processed in the brain.

Several discourse models have been proposed in an attempt to formalize how discourse is processed by individuals. One of the most accepted models is the propositional[3] model developed by Kintsch and van Dijk (1978). The model proposed by Kintsch and van Dijk is a semantic processing model that stipulates three sets of operation: first, there is the *organization* of the text into a coherent concept; then, there is the *condensation* of the meaning of the propositions of the text into its gist; finally, there is the *generation* of a new text based on memory from the information obtained during comprehension. The new text is organized in semantic structures on a series of levels, from micro to macrostructure. This organization, according to Kintsch and van Dijk (1978), happens in cycles, or levels. The first, *surface level*, represents linguistic units such as phonemes, morphemes and word combinations. This level is followed by the *semantic level*, which represents the expressed concepts and the links between them. The third level, *situational level*, represents the relations among the concepts representing the events depicted, followed by the fourth and final level, *structural level*, representing the sequential and temporal organization of the concepts. At this level, the type of discourse is identified (e.g. narrative, argumentative). Microstructures are processed into macrostructures through the application of a set of macrorules, described in Table 1.

[3] Van Dijk (1988, p.31) defines propositions as being the smallest independent meaning constructs of language and thought. According to him, propositions are usually expressed by single sentences or clauses (VAN DIJK, 1988).

Table 1. Set of macrorules proposed by Kintsch and van Dijk (1978)

Macrorule	Explanation	Example
Deletion	It is the most general rule proposed by van Dijk. It deletes from the textbase propositions that are considered irrelevant, that is, propositions that do not denote facts deemed important to the macrostructure. It can also be referred to as *selection*, regarding the emphasis given to its effects of deleting all irrelevant propositions or selecting only relevant propositions.	The pretty girl who was wearing a red coat was going to her grandmother's house to pay her a visit. ↓ The girl was going to her grandmother's house to visit her.
Generalization	It reduces the sentences to propositions that provide their general concept, by taking steps such as grouping individual participants of the narrative.	The table was full of doughnuts, cakes, cupcakes and cookies. ↓ The table was full of baked sweets.
Construction	It gathers the propositions present in the text to create a new one that provides the global idea of the sequence.	The worker went to the train station in the morning and bought a ticket. ↓ The worker took the train to work.

Source: the author.

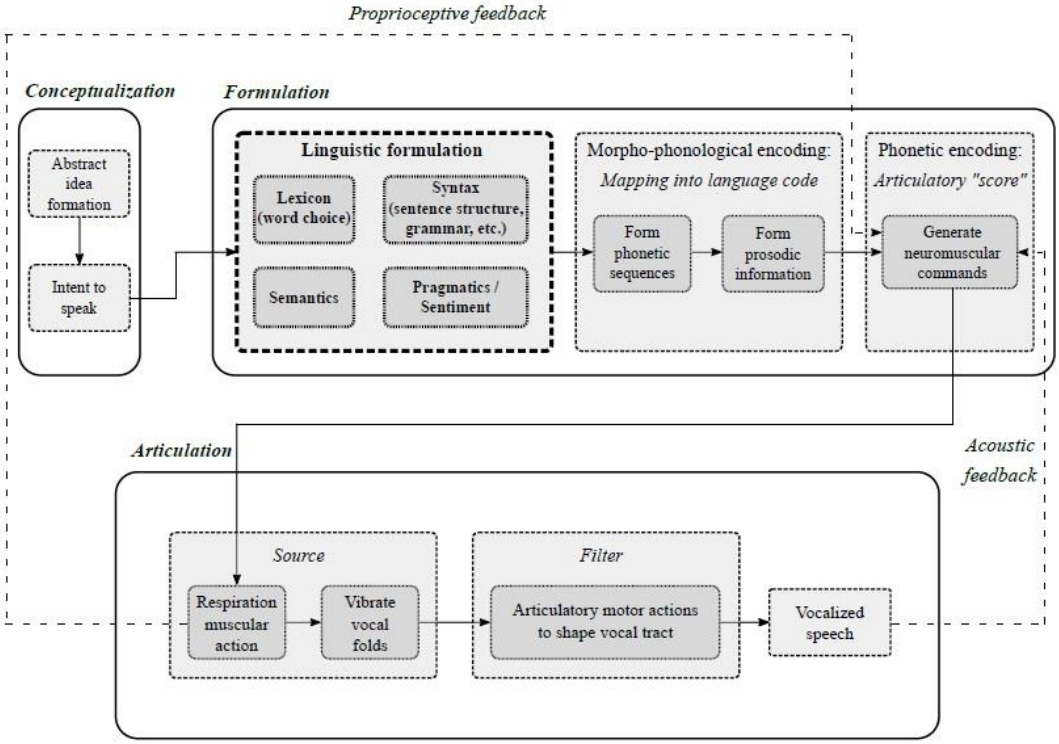
Kintsch and van Dijk (1978) proposed a general model on the stages of discourse processing. The steps presented by the authors are expected to be followed by individuals without any cognitive impairment. Changes in this model are expected to be observed in cognitively impaired individuals, such as individuals diagnosed with Alzheimer' Disease.

Arguing that speech production is a process that relies on a simultaneous engagement of cognitive planning and motor ability, Cummins *et al.* (2015) propose a model of speech production that accounts the process from the linguistic planning phase to the actual vocalization of the utterance. The authors defend that the process of speech production begins with the speaker's communicative intention. In the present studies, the expected communicative intention of the speakers was the reproduction of an event (presented in a narrative form) they were previously told. After the establishment of the communicative intention, phonetic and prosodic information associated with this intent are setup and stored in working memory. According to the authors, during this storage in working memory, the phonetic and prosodic information are transformed into representations, leading to the motor part of speech production.

Voleti, Liss and Berisha (2019), adapting the concept of speech production by Cummins *et al.* (2015), propose that it is separated in three stages: *conceptualization*, during which occurs the formation of ideas about the intended message to be produced; *formulation*,

where the exact linguistic construction for the utterance is formed; and *articulation*, the actual production of the utterance. In figure 1, Voleti, Liss and Berisha (2019), through an adaptation of Cummins *et al.*'s (2015) diagram, illustrate their proposed model of language production.

Figure 1. Voleti, Liss and Berisha's (2019) speech production diagram, adapted from Cummins *et al.* (2015).



Source: Voleti, Liss and Berisha (2019).

According to Voleti, Liss and Berisha (2019), the first stage of language production – *conceptualization* – is responsible for the formation of pre-verbal ideas that result in the concept to be expressed by the utterance. Then, in the *formulation* stage (divided in three processes: *linguistic formulation*, *morpho-phonological encoding*, and *phonetic encoding*), the linguistic structure of the utterance is established. First occurs the selection of features such as the lexical items and the syntactic structure most adequate to transmit the idea formed during the conceptualization stage. Then, the phonetic and prosodic information of the features selected during linguistic formulation are created. The morpho-phonological encoding is followed by phonetic encoding, where a set of "instructions" that are to be followed during the *articulation* stage is established.

Kintsch and van Dijk (1978) and Voleti, Liss and Berisha (2019) propose a general model for discourse processing and production. These models were designed to address the processes behind discourse ability of individuals without cognitive impairment. As language

is also a cognitive process, however, changes in this model are expected to be observed in cognitively impaired individuals, such as individuals diagnosed with Alzheimer's Disease. In the following sections, we are going to discuss changes in discourse processing related to aging and to cognitive disorder, to understand whether language impairment can be observed at the discourse level, and what characteristics may be affected.

1.2 LANGUAGE IN HEALTHY AGING AND THE IMPACT OF COGNITIVE RESERVE

The aging process is commonly linked to a decline in cognitive processing. Cognitive abilities are usually divided in domains such as attention, memory, executive cognitive function, visuospatial processing, processing speed, and language (HARADA; NATELSON LOVE; TRIEBEL, 2013; MURMAN, 2015). Attention and processing speed are negatively affected by aging, with older individuals showing a decrease in processing speed and difficulty performing complex attentional tasks, such as selective focus and multitasking (HARADA; NATELSON LOVE; TRIEBEL, 2013). Executive functioning also suffers a negative impact from the aging process, with older adults showing signs of decline in abstraction, mental flexibility and inhibition (HARADA; NATELSON LOVE; TRIEBEL, 2013; SALTHOUSE, 2009; WECKER *et al.*, 2000). Memory is partly affected by aging. While nondeclarative (implicit) memory seems to remain stable throughout the lifespan, declarative (explicit) memory is negatively impacted by the aging process (HARADA; NATELSON LOVE; TRIEBEL, 2013). Visuospatial processing, on the other hand, remains stable during aging (HARADA; NATELSON LOVE; TRIEBEL, 2013). Language processing, like memory, presents an asymmetric pattern. Language comprehension remains largely stable in aging, whereas language production is affected by aging (BURKE; MCKAY; JAMES, 2000).

One of the most noticeable and documented deficits of language production in aging is word-retrieval. Reports indicate that one of the main linguistic complaints of older adults is the tip-of-the-tongue (ToT) effect, showing difficulty retrieving known words (BROWN; MCNEILL, 1966). The ToT effect becomes more prominent with increasing aging, as a result of a phonological retrieval deficit (BURKE *et al.*, 1991). Aging is also correlated with an increase in speech dysfluencies. More specifically, older adults produce more lexical and nonlexical dysfluencies than younger adults, indicating an age-related word retrieval deficit (MORTENSEN; MEYER; HUMPHREYS, 2006).

Discourse performance is also known to be affected by aging. Cognitive aging negatively affects discourse production aspects such as the number of propositions and the

time needed for summarizations (NORTH *et al.*, 1986). Regarding discourse complexity, aging leads to a deterioration in overall narrative quality, resulting in longer but simpler discourse (NORTH *et al.*, 1986). While older individuals' discourse is structurally more complex, with more embedded episodes, syntactically it is less complex, as it has fewer cohesive links than discourse produced by younger individuals (KEMPER *et al.*, 1990). Older adults also produce more words and sentences, although there is a decrease in informational content density, resulting in a verbose speech (JUNCOS-RABADÁN; PEREIRO; RODRÍGUEZ, 2005). It is worth pointing out, however, that not all aspects of language production are negatively affected by aging. As a result of their increased knowledge of the world, older adults often possess greater vocabulary, allowing them to produce more lexically diverse utterances (KEMPER; THOMPSON; MARQUIS, 2001). A more in-depth discussion of the effects of aging on discourse production will be presented in study 2.

Although the aging process is often accompanied by cognitive decline, not all individuals experience the same deficits. While some individuals report some or all the deficits presented above, others seem to retain an intact cognitive performance throughout the aging process. For the past decades, researchers have been investigating the reason why there is such a difference in cognitive abilities among older individuals. One of the most accepted hypotheses is the *cognitive reserve* theory proposed by Yaakov Stern (2002).

In an attempt to define *reserve*, Stern (2002) states that the concept of *reserve* is relevant to any situation involving brain damage. In his attempt to offer an acceptable definition of reserve, Stern (2002) proposes that reserve models can be conveniently subdivided into passive and active processes. In the passive process (*brain reserve, brain maintenance*), he suggests that some brains may have a stronger resilience against pathology, thus increasing the threshold of damage for clinical expression. In the active process (*cognitive reserve*), he suggests that the brain may take steps to compensate for damage. Stern and colleagues (2018) offer an explanation of these three models, discussing their particularities and limitations.

Brain reserve (BR) relates to structural characteristics of the brain. Stern *et al.* (2018) argue that the individual variation of brain structure, such as the number of neurons and synapses, works as a mechanism to cope with age-related cognitive changes and pathology. The main feature of the BR model is the concept of *brain reserve capacity* (BRC), which Stern first discussed in his 2002 paper on reserve. This reserve capacity is responsible for delaying symptoms of dementia. It is argued that there is a threshold that limits the amount of damage the brain can suffer before signs of impairment appear. The BRC is responsible for

establishing such a limit. As brain damage progresses, it reduces BRC. When this reserve level reaches a capacity below the threshold, deficits in cognition become apparent, and the higher the impact of brain damage, the more prominent the impairment. Brain reserve is considered a passive model, as it does not rely on the reorganization of brain functions, relying instead on the strength of brain structure (STERN *et al.*, 2018).

Regarding the *brain maintenance* concept (BM), Stern and colleagues (2018) propose that there is a reduction in the development of age-related brain changes over time. Such reduction may be the result of genetics or lifestyle. These factors contribute to individual differences in brain deterioration observed in healthy aging. The authors also suggest that lifestyle may have an impact on pathological changes, reducing the likelihood of their occurrence. The concept of brain maintenance is closely related to that of brain reserve. They differ, however, on their supposed benefits against brain damage. Brain reserve relates to the longitudinal effect pathology has on cognitive processing, while brain maintenance is related to the enhancing of the brain structure (STERN *et al.*, 2018).

As for the *cognitive reserve* model, Stern and colleagues (2018) postulate that it refers to the idea that cognitive abilities benefit from an adaptation process, where individuals cope with brain changes through an increased activation of cognitive networks or through the activation of additional networks to support processing. This adaptive ability is impacted by external factors, such as education and reading and writing habits, and by internal – genetic – factors, leading to individual differences in the efficiency of cognitive processing. The authors state that, when faced with difficult tasks, individuals either have an increased activation in areas responsible for processing those tasks or recruit additional areas that would normally not be involved. Thus, such activation is also related to individual abilities, with high-skilled individuals having a better performance than low-skilled ones. This difference in activation is found in both healthy and impaired individuals, suggesting it is a natural response to an increase in difficulty, regardless of impairment (STERN *et al.*, 2018).

Both the active and passive models have some limitations. One of the limitations from the passive model is the assumption that everyone experiences the same effects caused by brain damage, without accounting for individual differences in cognitive processing and disruption (STERN, 2002). As for the active model, concern has been raised to the lack of information on cognitive processing before impairment, to assess the impact of CR measures on coping with impairment (DÍAZ-ORUETA; BUIZA-BUENO; YANGUAS-LEZAUN, 2010). Stern (2002) also states that, since each model relies on different aspects of brain change, active and passive models may differ in their ability to explain differences in

cognitive processing. In this thesis, we adopt the CR model to assess AD-related changes in language to analyze and explain changes in cognitive processing without evaluating brain data.

Stern (2002) suggests that cognitive-stimulating activities, such as schooling, reading and writing habits and learning another language assist in keeping cognitive processing active, thus creating a cognitive reserve that prevents, or at least delays, cognitive decline caused by aging. This theory fostered investigations on the role variables related to cognitive reserve play on memory, executive functions and language.

Education seems to predict cognitive performance in tools for cognitive assessment, such as the Mini-Mental State Exam (MMSE) (ALBERT; TERESI, 1999) and subtests from the Wechsler Scale of Adult Intelligence, such as logical memory and digit span (ELIAS *et al.*, 1997), with individuals with higher levels of education achieving higher scores in the tests. As it affects cognitive processing, years of education assist in the establishment of cognitive reserve, with influence of education on cognitive performance being observed even decades after the completion of formal studies (SCHNEEWEIS; SKIRBEKK; WINTER-EBMER, 2014). Although the influence of education on overall cognitive performance is well-established in the literature, its effect on language production has still not been explored in depth. Among the studies addressing the relationship between education and performance on language production, there is evidence pointing to a positive influence of education in the number of words produced in spontaneous speech (ARDILA; ROSSELLI, 1996), and to an influence on the number of communicative strategies in picture-based narrative (JERÔNIMO, 2018). These findings indicate that higher levels of education lead to an increase in the quality of discourse.

Together with educational level, reading and writing habits, in terms of amount and quality, are also considered relevant for the establishment of cognitive reserve. Reading and writing, as a means of mental stimulation, result in a reduced risk of dementia (WANG *et al.*, 2006). Reading and writing habits also positively impact performance on cognitive tasks, such as attention, working memory and executive functions (PAWLOWSKI *et al.*, 2012). Regarding the influence of reading and writing habits on language production, there is a positive correlation between these variables and scores in language production tasks, including naming and oral comprehension (PAWLOWSKI *et al.*, 2012). However, the literature on the topic is still scarce, as it will be addressed in Study 2 in this thesis. Thus, more investigation must be conducted to understand the role of reading and writing habits on specific linguistic features.

From this brief review, it is observed that, although some linguistic abilities decline with aging, others remain stable or even show signs of improvement. Education and reading and writing habits, as cognitive stimulating factors, are also shown to improve overall cognitive performance, consequently improving linguistic processing as well. Still, little is known about such relationship, and more in-depth investigations must be conducted to understand the role of these cognitive stimulating factors on different aspects of linguistic processing. In the following section, an overview of the impact of Alzheimer's Disease is going to be presented to contribute to the discussion in study 1.

1.3 LINGUISTIC FEATURES OF ALZHEIMER'S DISEASE

Elderly individuals often report memory-related deficits, such as forgetting where they place things, or having difficulty producing some words in everyday speech (known as the tip-of-the-tongue phenomenon (ToT), already mentioned). Despite an understandable frustration with their changed cognitive performance, and the fear of developing the early stages of dementia, these individuals' complaints in general relate to natural consequences of our aging process. It is worrisome, however, when this cognitive decline occurs in a short time span and has a substantial impact on one's daily life. Such an abrupt decline suggests the existence of a brain disease involving the death of neuronal cells or the disruption of brain connectivity (KURZ; PERNECZKY, 2009).

One of the most common neurodegenerative diseases is Alzheimer's Disease (AD). First described in 1907 by the German psychiatrist Aloysius Alzheimer – after whom the disease is named –, AD is characterized by a gradual loss of memory and other cognitive functions. This loss is more exacerbated than the one seen in healthy aging, and results in deficits that affect the patients' daily life by reducing their functionality (AZEVEDO *et al.*, 2010). AD is usually diagnosed in patients over 65 years old (late onset), yet there are cases in which the disease is diagnosed earlier in life (early onset), around the fifties. Higher age and low level of education are considered some of the most important risk factors for late onset AD (HESTAD; KVEBERG; ENGEDAL, 2005). Other risk factors include head injuries and untreated cardiovascular diseases. Early onset, on the other hand, is believed to have a genetic etiology.

Alzheimer's Disease is categorized as a chronic form of dementia, meaning its evolution occurs during a time span of months or years. As it progresses, the patients' autonomy is reduced until their body essentially shuts down, thus leading to death. The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (APA, 2013)

presents a scale to determine dementia progress. This scale comprises three stages: mild, moderate and severe. At the mild stage of dementia, there is a noticeable deficit in patients' ability to perform instrumental activities of daily life, such as managing money, cooking and performing regular household chores. They still retain, however, judgment ability, personal hygiene, and the ability to perform basic tasks with no issues, thus still being capable of conducting an independent life. At the moderate stage, independent life becomes risky, with patients having difficulty to perform basic tasks, such as getting dressed and feeding on their own. At this point, they require a certain degree of supervision to preserve their integrity, though still capable of being left on their own for short periods without danger. At the severe stage, patients completely lose their independence. At this point, they require constant supervision, and rely on other individuals for the maintenance of a minimal level of nutrition and hygiene. When patients reach the severe stage of dementia, they also lose control of body functions, leading to cases of incontinence or mutism, thus being left in a vegetative state until their eventual death. Aside from presenting a scale on the general development of dementia, DSM-5 also presents specific criteria for the diagnosis of AD. It is stated that AD can be diagnosed when one or more of the following criteria is met: clear evidence of decline in memory and learning; gradual and progressive cognitive decline; and absence of other neurodegenerative or cerebrovascular diseases contributing for cognitive decline (APA, 2013).

Language is one of the cognitive abilities that is most affected by dementia. As the disease progresses, so do language deficits. At the early stages of AD, individuals show impairment mainly at the word level - in naming, including finding words and names of objects (KEMPLER, 1991). It does not mean, however, that they have lost the semantic knowledge, as in most cases the patients can describe the objects, but not name them (SCHWARTZ; MARIN; SAFFRAN, 1979). As a result, vocabulary becomes simplified, and verbal fluency performance decreases (MANSUR *et al.*, 2005). The early stages of AD are also marked by the occurrence of hypernyms (saying the category an object belongs to instead of the object itself, e.g. saying flower instead of rose) and semantic paraphasia (substitution of a word for another of a similar semantic category, e.g. saying bus instead of train) (SOARES; BRANDÃO; LACERDA, 2012). Individuals with AD have a deficit in the processing of abstract language. When presented to proverbs and idioms, they tend to interpret them literally (KEMPLER; VAN LANCKER; READ, 1988). At the moderate stage of AD, naming ability worsens. Individuals with AD also experience a deficit in comprehension of complex linguistic material, such as inferences (KEMPLER; VAN LANCKER; READ, 1988). In the

late stage of AD, speech becomes almost unintelligible, and comprehension is affected at all language levels. These deficits affect the individuals' interaction with the world, contributing to the development of mutism (KEMPLER; VAN LANCKER; READ, 1988; SOARES; BRANDÃO; LACERDA, 2012).

Discourse, as a complex linguistic function, is sensitive to dementia-related changes in cognitive processing. Research on the influence of AD on discourse structure indicates the occurrence of dysfluencies at the lexical level, such as word-finding difficulties, repetitions, revisions and phonemic paraphasias, and on syntactic index measures, including coordinated, subordinated and reduced sentences, as compared to typical aging (LIRA *et al.*, 2011). As for macrolinguistic aspects of narrative production, AD patients have worse performance in the production of macropropositions[4], producing fewer main idea units than the healthy adults. (LIRA *et al.*, 2018). Semantic and syntactic differences have also been observed in AD. Discourse of AD patients contains less words overall (TOMOEDA *et al.*, 1996) and is lexically less diverse (FRASER; MELTZER; RUDZICZ, 2015). Comparisons between AD patients and healthy adults indicate a negative effect of AD in syntactic complexity (AHMED *et al.*, 2012). A thorough review of dementia-related changes in discourse processing will be presented in study 1.

Language tasks, specially tasks involving production of discourse, are accurate tools for diagnosing cognitive disorders, as language is sensitive to changes in cognitive processing. It is not, however, practical to conduct a thorough analysis on discourse production in a clinical setting, as it is a laborious and time-demanding task. In the following section, an overview on tools for automatic assessment of linguistic data will be conducted, addressing the different types of analysis and their diagnostic accuracy.

1.4 AUTOMATIC ANALYSIS OF LINGUISTIC FEATURES

Narrative production is sensitive to age and dementia-related changes in cognitive processing (AHMED; GARRARD, 2012; JUNCOS-RABADÁN; PEREIRO; RODRÍGUEZ, 2005; KEMPER; THOMPSON; MARQUIS, 2001; LIRA *et al.*, 2011, 2018; TOMOEDA *et al.*, 1996). A complementary assessment of these changes can be developed by analyzing linguistic features extracted from the participants' production via specially designed software. This analysis can be conducted manually, following models such as the Quantitative Production Analysis (BERNDT *et al.*, 2001). Manual discourse analysis, however, presents

[4] Van Dijk (1980, p.41) postulates that macropropositions are propositions that are part of the macrostructure of the text, that is, the global information of the text, such as its gist or most important information.

some challenges. First, it is a laborious method of analysis, which can be impractical if the sample to be analyzed is too large. Besides, manual analysis demands that everyone involved in the process follows a single assessment standard, to ensure the reliability of the results. In addition to these two challenges, manual analysis, depending on the focus, demands in-depth linguistic knowledge to successfully analyze some linguistic features. To make discourse analysis more reliable, new methods have been developed in recent years. These methods adopt an automatic approach to the analysis of linguistic features, guaranteeing that results are consistent and that individuals with basic linguistic knowledge can conduct the analysis. The analysis can be conducted via audio analyses, via transcripts analyses, or a combination of both.

One method of automatic discourse analysis is through the recording of the participants' production – the *audio analysis*. This approach is more suitable for the analysis of speech fluency. Analysis through the recording of oral discourse focuses mainly on the number of voiced and voiceless segments and their length. Results from studies analyzing discourse through audio recordings indicate that, in comparison to healthy adults, discourse of AD patients has more voiceless segments, and the voiced segments are shorter (LÓPEZ-DE-IPIÑA *et al.*, 2015). Discourse from AD patients is also less continuous when compared to those of healthy adults, containing more pauses (KÖNIG *et al.*, 2015). Before being processed by the software, the audio recording must be cleaned by removing non-analyzable events such as laughter, coughing and overlapping speech, as current software cannot process these segments.

Although software applications capable of converting audio into text are available, they still need to be refined to fully deal with impaired language resulting from dementia, for example. Analysis of audio recordings may also be affected by age-related changes in speech production, such as breathiness, articulatory difficulties and decreased voice intensity (YOUNG; MIHAILIDIS, 2010).

Aside from an analysis of audio recordings, automatic speech analysis can be conducted from transcriptions of narrative tasks – the *transcript analysis*. In this method, transcripts of narrative productions are made manually. During this process, annotations regarding pauses and possible dysfluencies are added. Then, these transcripts are analyzed on software applications that provide an output with several features on different aspects of discourse, such as complexity, number of words and types and tokens ratio. Automatic analysis of transcripts allows for a deeper analysis of discourse performance, though data production is more laborious, as the audio must be manually transcribed and segmented

before being processed by the software, which requires a trained person to avoid biased transcripts.

Studies have increasingly adopted automatic analyses to assess impaired language production. For example, Marcotte *et al.* (2017) have found differences in syntactic features between healthy adults and patients diagnosed with the non-fluent variant of Primary Progressive Aphasia (nfvPPA), and a semantic difference between healthy adults and patients diagnosed with the semantic variant of PPA (svPPA). Regarding differences between AD patients and healthy adults, automatic transcript analysis points to semantic, syntactic and information impairment, as well as acoustic abnormalities (FRASER; MELTZER; RUDZICZ, 2015). Semantically, AD patients' discourse contains less diverse and more generic vocabulary, and shorter and more frequent words. Syntactically, AD patients produce fewer verbs and more sentence fragments, as well as more word variations, such as paraphasias[5] and distortions, when compared to healthy adults. Regarding information aspects, discourse from AD patients presents decreased informativeness, missing key concepts from narratives, and lower level of details.

Evidence on the accuracy of software applications for automatic analysis of discourse transcripts indicates that they produce reliable results. In the study by Fraser, Meltzer and Rudzicz (2015), there was a reported accuracy of 81% of automatic analysis of speech. Treviso *et al.* (2018) investigated the applicability of a fully automated system of narrative analysis to detect dementia-related changes in language. In this study, they focused on changes in individuals with mild cognitive impairment (MCI), which may represent a pre-clinical state of dementia. After the automatic and manual segmentation and annotation of the narratives, Treviso and colleagues ran them on Coh-Metrix-Dementia[6], observing the syntactic metrics of Yngve's complexity, Frazier's complexity, mean clauses per sentence, noun phrase incidence, modifiers per noun phrase, and pronouns per noun phrase. Their results indicated that the feature for modifiers per noun phrase had a significant difference when comparing manual and automatic methods of analysis. When comparing the results from the control and the MCI groups, the metric of Frazier complexity showed a significant difference. The results obtained by Treviso and colleagues (2018) and Fraser and colleagues (2015) indicate that software-based analysis of narratives is a reliable and efficient tool for the

[5] Paraphasia is a type of language production error characterized by mispronunciation of words or the utterance of inappropriate words for the context.
[6] Access in: http://143.107.183.175:22380/

detection of discourse impairment, also functioning as a monitor of linguistic decline in dementia.

Throughout this chapter, we addressed changes in discourse processing related to aging and to AD, as well as the effects of education and reading and writing habits on discourse processing in healthy aging. There is a lack of literature, however, regarding the effects of aging and AD on linguistic aspects of narrative recall, a fundamental ability for daily communication. In the following chapters, we are going to present two studies in an attempt to contribute with this topic. In the first study – Automatic Assessment of Syntactic, Lexical and Semantic Aspects of Narrative Recall in Alzheimer's Disease –, we are going to investigate AD-related changes on syntactic, lexical and semantic aspects of narrative recall. In the second study – Education and Reading and Writing Habits as Predictors of Narrative Recall Performance in Healthy Aging –, we are going to investigate whether the same linguistic features adopted in the first study assessing language deficits in AD can detect changes in cognitive processing related to cognitive stimulating factors, specifically education and reading and writing habits.

2 STUDY 1: AUTOMATIC ASSESSMENT OF SYNTACTIC, LEXICAL AND SEMANTIC ASPECTS OF NARRATIVE RECALL IN ALZHEIMER'S DISEASE

2.1 INTRODUCTION

Alzheimer's disease (AD) is characterized mainly by a decline in several cognitive abilities, such as memory, attention, processing speed, executive functions and language (AZEVEDO *et al.*, 2010; HUNTLEY; HOWARD, 2010; MARCOTTE *et al.*, 2017). Discourse is a complex linguistic component that comprises morphosyntactic and lexico-semantic aspects of language processing. The aim of this study is to investigate the impact of AD on discourse processing, with a focus on discourse production, measured via a software that automatically assesses oral production. A brief review of evidence on the effects of AD on syntactic, lexical and semantic processing linked to discourse production will be presented. Some of these studies include the use of an automatic procedure to assess discourse. Automatic assessment is conducted via specialized software, which extracts the linguistic metrics of spontaneous or induced discourse (e.g., morphossyntactic, lexical and semantic information, and pragmatic features).

Syntactic changes

Studies on the impact of AD on syntactic features have produced diverging results. Some studies indicate a reduction in the mean length of sentences produced by AD patients when compared to healthy controls (HIER; HAGENLOCKER; SHINDLER, 1985), while others have not found differences between the groups (CUETOS *et al.*, 2007). Although there seems to be an influence of AD on the length of the sentences produced, studies report that there is no observable deficit in AD regarding the total number of sentences produced (CHOI, 2009; CUETOS *et al.*, 2007; ORIMAYE *et al.*, 2017). The same inconsistency is found on measures of dependency distance, which assess complexity through the distance between a word and its dependency head in a sentence. Some studies point to an impact of AD on dependency distance (LIU; ZHAO; BAI, 2020), while other studies have failed to find a difference between AD and healthy controls on this feature (ARAMAKI *et al.*, 2016; ORIMAYE *et al.*, 2017). In addition, some studies report a negative impact of AD on other syntactical features, such as the proportion of subordinate clauses (CROISILE *et al.*, 1996; HIER; HAGENLOCKER; SHINDLER, 1985) and the Yngve score, which measures syntactic complexity by means of the number of left-branches in a sentence (ROARK *et al.*, 2011).

Lexical changes

Similarly to the case of syntax, the evidence of lexical changes on discourse production in AD is somewhat contradictory. For example, studies on the number of words produced by AD patients and healthy controls in discourse tasks have found mismatching results. While some report a reduction in the total number of words produced by AD patients (HIER; HAGENLOCKER; SHINDLER, 1985; LIRA *et al.*, 2014), others have not found any differences for the number of words produced (AHMED *et al.*, 2013a; KAVÉ; DASSA, 2018). Kavé and Dassa (2018) have found that AD patients produced significantly more words than healthy controls, though they argue that it might be the result of encouragement given to AD patients by the examiners, who deemed their descriptions incomplete. The changes in the type and amount of word classes produced by AD participants have also been studied to measure cognitive decline. AD patients produce more function words than content words; conversely, healthy participants produce more content words (JIN; CHOI; LEE, 2016; KAVÉ; GORAL, 2016; YANCHEVA; FRASER; RUDZICZ, 2015). This indicates a poorer, more empty speech in AD persons. The ratio of word classes also seems to change in AD participants. AD patients produce proportionally less nouns, pronouns, adjectives, verbs and adverbs than healthy older adults (AHMED *et al.*, 2013b; CROISILE *et al.*, 1996; FRASER; MELTZER; RUDZICZ, 2015; KAVÉ; GORAL, 2016; YAMADA; SHINKAWA; SHIMMEI, 2020).

Some word properties are sensible to cognitive decline in AD, as is the case of word frequency. Patients with AD tend to produce more frequent words as compared to less frequent ones as impairment progresses (CUETOS *et al.*, 2017; HERNÁNDEZ-DOMÍNGUEZ *et al.*, 2018; KAVÉ; GORAL, 2016). The effect of AD on word length, however, is not clear. Kavé and Goral (2016) have found that individuals with dementia produced shorter words, while Cuetos and colleagues (2017) have found comparable word length production between AD patients and healthy controls.

Semantic changes

Changes in the semantic aspects of discourse production have also been observed in AD patients in comparison to healthy older adults. In an analysis conducted with automatic assessment of spontaneous speech, differences can be found in Brunét's index (an index of type/token ratio less sensible to text size), Honoré's statistic (an index of the proportion of words used once in relation to the total number of words), and type-token ratio (TTR). This indicates that healthy older adults produce a semantically richer speech in comparison to AD

patients' oral production (BUCKS *et al.*, 2000; HERNÁNDEZ-DOMÍNGUEZ *et al.*, 2018; KAVÉ; GORAL, 2016; YANCHEVA; FRASER; RUDZICZ, 2015). Semantic impairment in AD have also been observed in other psycholinguistic semantic variables such as age of acquisition, familiarity, imageability and concreteness. More specifically, studies show that AD patients produce more easily words acquired early in life, words that are more familiar and more imageable (CUETOS *et al.*, 2012; HOLMES; JANE FITCH; ELLIS, 2006; IVANOVA; SALMON; GOLLAN, 2013). Evidence also suggests that abstract concepts deteriorate faster in AD as compared to concrete concepts, thus leading to a deficit in the production of abstract words in AD (GIFFARD *et al.*, 2015).

Reduced content density has also been described in AD patients. Content density is determined by the mean proportion of content words (nouns, verbs, adjectives and adverbs) to the number of function words (pronouns, prepositions, conjunctions *et al.*) in a sentence. AD patients showed lower scores in content density when compared to healthy individuals (ROARK *et al.*, 2011). Finally, the diversity of lexical items is also reduced in AD, as patients' discourse presents with more instances of word repetitions than the discourse of healthy individuals (GUINN; HABASH, 2012).

The brief review presented here provides evidence that AD-related changes in discourse production occur at the syntactic, lexical and semantic levels. Although there are some divergences about which linguistic features are specifically affected, the consensus is that there is a reduction in discourse complexity associated with AD.

Automatic assessment of discourse features

The use of automatic feature analyses of discourse via software to compare clinical and healthy populations has increased. For instance, Marcotte *et al.* (2017) compared the spontaneous speech of the participants diagnosed with the non-fluent and semantic variants of primary progressive aphasia (PPA) to the speech production of healthy adults. They have found that participants diagnosed with non-fluent variant of PPA differed from the control group on a syntactic level, as they produced more sentences, T-units and clauses. The length of these features, however, as well as the length of words, was reduced in comparison to the control group. Differences between participants with semantic variation of PPA and controls were observed on syntactical, lexical and semantic levels. Participants with semantic variation of PPA produced fewer nouns and words overall than the control group. Production from the patient group also featured lower proportion of nouns and pronouns, higher proportion of verbs and adverbs, and a lower type-token ratio. Measures of lexical richness such as Brunét's

index and number of words also distinguished the group of participants diagnosed with semantic variation of PPA from the control group. Similarly, Roark *et al.* (2011) compared the performance of participants diagnosed with MCI on an immediate and delayed narrative recall task to the performance of healthy participants. They have found that, on language measures, participants with MCI produced less words per clause and lower content density during the immediate recall stage of the task. On the delayed stage, recall by participants with MCI was marked by even less words per clause, lower Yngve score, shorter dependency length and even lower content density. The analysis of speech measures indicated that participants with MCI had lower standardized pause rates both on immediate and on delayed narrative recall.

This study aims at verifying whether there were differences in the oral recall of a short narrative comparing AD participants and a control group of healthy elderly adults. Participants were asked to listen carefully to a short narrative, and to retell the story with the maximum amount of details as possible. Syntactic, lexical and semantic features were assessed via the NILC Metrix software. In the present study we follow the selection of features adopted by Marcotte *et al.* (2017). We put forward the hypotheses that the linguistic changes in the recalls of AD participants would be observed in syntactic, lexical and semantic features in the comparison to healthy controls' recalls. We argue that the recall produced by AD patients would be marked by a reduction in the length of sentences and in syntactic complexity at the syntactic level; by a reduction in the number of words, in the proportion of content words and in properties such as frequency at the lexical level; and by a reduction in diversity at the semantic level.

2.2 METHODS

Participants

Ten elderly adults diagnosed with Alzheimer's Disease (AD) participated in the study, matched with 20 healthy controls by age, education, gender, reading and writing habits, and socioeconomic status (Table 1). All participants in the clinical group had a dementia rating (CDR) score of 1, indicating they were in the early stage of dementia. Five from the initially 15 participants recruited for the patient group were excluded due to their inability to complete the narrative recall task. Their recalls contained only statements reporting their inability to remember any excerpt of the story they were asked to recall. AD participants were recruited from the neurology ambulatory at the hospital affiliated to the university PUCRS. Control participants were recruited at general courses offered for members of the community at the

university PUCRS and at community centers close to the university. All participants were native speakers of Brazilian Portuguese and did not speak other languages. Exclusion criteria for participants included a known history of substance abuse and/or neurological or psychiatric illness. The possible presence of other illnesses was assessed through a general health questionnaire, while depression symptoms were assessed through the Geriatric Depression Scale (GDS) (YESAVAGE *et al.*, 1982), and participants with untreated depression were not recruited for the study. General cognitive performance was assessed with the Mini-Mental State Examination (MMSE) (FOLSTEIN; FOLSTEIN; MCHUGH, 1975). We used the scoring that considers education and literacy levels developed by Laks *et al.* (2003).

The study was approved by the Research Ethics Committee of PUCRS, under report number 560.073, CAAE registry number 21006913.0.0000.5336. Participation in the study was voluntary, and participants signed an informed consent to join the study. All participants underwent a battery of linguistic tasks as part of a larger study to map age and dementia-related changes in language processing (BALE - Battery for Language Assessment in Aging) (HÜBNER *et al.*, 2019).

Table 2. Participants' demographic and neuropsychological data

	Controls (n=20, F=16) M (SD)	**AD (n=10, F=6) M (SD)**	**Group Effect**
Age	76,20 (2,546)	77,50 (5,017)	ns
Socioeconomic Status	22,29 (4,659)	23,56 (5,946)	ns
Education	5,60 (3,267)	6,10 (2,025)	ns
Reading Habits	5,60 (3,393)	3,50 (3,408)	ns
Writing Habits	3,70 (3,164)	1,40 (2,797)	ns
MMSE	26,75 (2,807)	21,10 (3,281)	***

Note: *** $p < .001$; ns = not significant.

Narrative recall task.

The narrative recall task adopted in this study is known as Lucia's story, a subtest of the battery BALE (HÜBNER *et al.*, 2019). It reports the story of a lady who needs to travel to another city for a work appointment. She takes a ride with a friend to go the bus station, but a flat tire forces her to take a taxi to reach the station in time to get the bus. This short narrative is read by the examiner, who instructs the participant to listen attentively to the story, told only once. After listening to the story, participants were given this instruction: "Now I'm

going to ask you to tell me this story with as many details as you can remember." Their recall was recorded for further transcription. If the participants' recall omitted information from the narrative, general encouragement for additional information was provided, such as "what else do you remember?" and "what happened after that?." After the recall, participants were asked a series of questions to assess their comprehension of the narrative. As this study focuses on the structure of the narrative produced by the participants during the production step of the narrative recall task, we will not address participants' performance on the comprehension questions in this study.

Analysis of narrative recall

The recorded narrative production was transcribed by researchers from the Group of Studies in Neurolinguistics and Psycholinguistics (GENP). The transcripts were segmented in utterances, as proposed by Thompson *et al.*, (2012). Thompson and colleagues define utterances as being a group of words expressing a complete thought. For software identification purposes, a full stop marked the end of each utterance. An example of the segmented transcripts used in this study can be found in Table 5. We then used the automatic narrative recall assessment, developed by the software NILC Metrix, to analyze the narrative production of participants. This software automatically extracts 178 linguistic features from texts. This software does not require a minimum number of words to analyze a text, so we did not need to complement transcripts with additional speech samples.

Following Marcotte *et al.* (2017), we narrowed the number of features to a total of 35 features organized into three categories: syntactic, lexical and semantic. Since different softwares were used in the present study and that of Marcotte *et al.* (2017), only 17 features were equivalent between the two studies. The other 18 features were selected because of their presence in previous studies which investigated clinical populations (HERNÁNDEZ-DOMÍNGUEZ *et al.*, 2018; ROARK *et al.*, 2011). A description of the features analyzed in this study can be found in Table 3.

Table 3. Description of linguistic features extracted from narrative transcripts

Linguistic Features	Explanation	Interpretation
Syntactic features		
sentences	Number of sentences in the text	Higher values indicate higher complexity
words_per_sentence	Number of words divided by the number of sentences	Higher values indicate higher complexity
clauses_per_sentence	Mean number of clauses per sentence	Higher values indicate higher complexity

Linguistic Features	Explanation	Interpretation
yngve	Mean number of left-branch ramifications per sentence	Higher values indicate higher complexity
frazier	Mean number of bottom-up knots per sentence	Higher values indicate higher complexity
subordinate_clauses	Proportion of subordinate clauses, relative to the number of clauses in the text	Higher values indicate higher complexity
dep_distance	Mean distance between a word and its dependency head	Higher values indicate higher complexity
Lexical features		
noun_ratio	Proportion of nouns, relative to the number of words in the text	The relationship between the feature and text complexity is not clear
verbs	Proportion of verbs, relative to the number of words in the text	The relationship between the feature and text complexity is not clear
prepositions_per_sentence	Mean number of prepositions per sentence	The relationship between the feature and text complexity is not clear
adjective_ratio	Proportion of adjectives, relative to the number of words in the text	Higher values indicate higher complexity
adverbs	Proportion of adverbs, relative to the number of words in the text	The relationship between the feature and text complexity is not clear
pronoun_ratio	Proportion of pronouns, relative to the number of words in the text	Higher values indicate higher complexity
function_words	Percentage of functional words, relative to the number of words in the text	The relationship between the feature and text complexity is not clear
content_words	Proportion of content words, relative to the number of words in the text	The relationship between the feature and text complexity is not clear
cw_freq	Mean value of the absolute frequency of content words in the text	Higher values indicate lower complexity
syllables_per_content_word	Mean number of syllables per content word	Higher values indicate higher complexity
words	Number of words in the text	Higher values indicate higher complexity
personal_pronouns	Proportion of personal pronouns, relative to the number of words in the text	The relationship between the feature and text complexity is not clear
conn_ratio	Proportion of connectives, relative to the number of words in the text	The relationship between the feature and text complexity is not clear
Semantic features		
imageabilidade_mean	Mean value of imageability of content words in the text	Lower values indicate higher familiarity and lower text complexity
idade_aquisicao_mean	Mean age of acquisition of content words in the text	Lower values indicate lower age of acquisition and lower text complexity
familiaridade_mean	Mean value of familiarity of content words in the text	Lower values indicate higher familiarity and lower text complexity
ttr	Types (words without repetition) to tokens (total words including repetition) ratio	Higher values indicate higher complexity
brunet	Type/token ratio less sensible to text size	Lower values indicate more lexical richness

Linguistic Features	Explanation	Interpretation
honore	Proportion of words used once, relative to the total number of words	Higher values indicate more lexical richness and higher complexity
dalechall_adapted	Readability through the number of nonfamiliar words per mean number of words in a sentence	Higher values indicate higher complexity
content_density	Mean proportion of content words, relative to the number of function words in a sentence	The relationship between the feature and text complexity is not clear
concretude_mean	Mean value of concreteness of the content words in the text	Higher values indicate lower complexity
content_word_diversity	Proportion of types of content words, relative to the number of tokens of content words in the text	Higher values indicate higher complexity
function_word_diversity	Proportion of types of function words, relative to the number of tokens of function words in the text	The relationship between the feature and text complexity is not clear
noun_diversity	Proportion of types of nouns, relative to the number of tokens of nouns in the text	Higher values indicate higher complexity
pronoun_diversity	Proportion of types of pronouns, relative to the number of tokens of pronouns in the text	Higher values indicate higher complexity
preposition_diversity	Proportion of types of pronouns, relative to the number of tokens of pronouns in the text	The relationship between the feature and text complexity is not clear
abstract_nouns_ratio	Proportion of abstract nouns, relative to the number of words in the text	Higher values indicate higher complexity

Source: the author.

Statistical analysis

Following Marcotte *et al.* (2017), performance between AD patients and healthy participants for each of the 35 features was compared using independent-samples t-tests.

2.3 RESULTS

We have found significant differences between the performance of AD participants and healthy controls for 11 of the 35 features. Table 4 presents these variables divided by type of linguistic features (syntactic, lexical and semantic).

Syntactic features

The results from the analysis of the syntactic features indicate that AD patients produced significantly less sentences, $t(28) = 3{,}345$, $p < 0{,}01$; less words per sentence, $t(28) = 2{,}190$, $p < 0{,}05$; and had lower Yngve scores, $t(28) = 2{,}355$, $p < 0{,}05$. Lower Yngve scores indicate less left-branches in the sentences, which represent poorer complexity. These results

indicate that the narrative production of AD patients is syntactically less complex than the production of healthy controls.

Lexical features

The analysis of lexical features reveal that the AD group produced proportionally more content words, $t(28) = -2{,}721$, $p < 0{,}05$; less function words, $t(28) = 2{,}721$, $p < 0{,}05$; and less words overall, $t(28) = 3{,}289$, $p < 0{,}01$, than the control group. This suggests a more complex production in the narrative recall task. Results from the analysis of lexical features also show that the mean frequency of content words produced by AD patients is higher than that of the control group, $t(28) = -2{,}557$, $p < 0{,}05$. In this feature, lower values indicate more complex texts. The results from the lexical features subset suggest that the control group produced lexically more complex narratives, resulting in better performance in this category, concerning these four features, out of 13 analyzed at this level.

Semantic features

Differences between the groups in semantic features were observed in type-token ratio (ttr), $t(28) = -2{,}366$, $p < 0{,}05$; Brunét's index, $t(28) = 3{,}646$, $p < 0{,}001$; content density, $t(28) = -2{,}603$, $p < 0{,}05$; and function word diversity, $t(28) = -2{,}889$, $p < 0{,}01$. Type-token ratio measures the proportion of repeated words in the text. Our results on this variable indicate that the recall produced by the AD patients presented with fewer repetitions than the recall by healthy controls. The same is observed in the feature measuring function word diversity. Our results suggest that the function words produced by the control group are proportionally less diverse in comparison to the AD group. There is also a significant difference between groups in Brunét's index. Lastly, a significant difference is observed in the content density feature, with the control group also achieving lower results. The impact of these and other semantic features on text complexity, however, is still not clearly established. The discussion section will discuss the interpretation of these results, since the lower scores observed in the control population may not represent lower performance.

Table 4. Comparison of the groups' performance on linguistic features

Linguistic Features	**Controls (n=20)**	**AD (n=10)**	**Group Effect (p)**
Syntactic features			
sentences	5,750 (1,803)	3,400 (1,838)	**
words_per_sentence	6,028 (1,476)	4,797 (1,397)	*

Linguistic Features	Controls (n=20)	AD (n=10)	Group Effect (p)
clauses_per_sentence	1,950 (0,690)	1,567 (0,351)	ns
yngve	1,676 (0,194)	1,504 (0,177)	*
frazier	6,320 (0,552)	6,311 (0,474)	ns
subordinate_clauses	0,234 (0,161)	0,190 (0,181)	ns
dep_distance	7,298 (2,830)	5,443 (2,451)	ns
Lexical features			
noun_ratio	0,283 (0,043)	0,299 (0,127)	ns
verbs	0,261 (0,046)	0,281 (0,086)	ns
prepositions_per_sentence	1,410 (0,811)	0,933 (0,473)	ns
adjective_ratio	0,001 (0,004)	0,000 (0,000)	ns
adverbs	0,018 (0,021)	0,053 (0,077)	ns
pronoun_ratio	0,074 (0,051)	0,039 (0,060)	ns
function_words	0,437 (0,053)	0,367 (0,088)	*
content_words	0,563 (0,053)	0,633 (0,088)	*
cw_freq	181382,489 (140550,687)	381395,030 (291856,532)	*
syllables_per_content_word	2,520 (0,177)	2,630 (0,304)	ns
words	35,250 (15,252)	17,200 (11,555)	**
personal_pronouns	0,056 (0,039)	0,027 (0,052)	ns
conn_ratio	0,091 (0,046)	0,100 (0,061)	ns
Semantic features			
imageabilidade_mean	4,958 (0,166)	4,976 (0,251)	ns
idade_aquisicao_mean	3,480 (0,387)	3,439 (0,390)	ns
familiaridade_mean	5,077 (0,240)	5,059 (0,233)	ns
ttr	0,788 (0,095)	0,879 (0,106)	*
brunet	7,636 (1,174)	5,711 (1,695)	***
honore	776,883 (313,873)	845,950 (310,124)	ns
dalechall_adapted	8,262 (1,130)	8,366 (3,965)	ns
content_density	1,325 (0,325)	1,914 (0,917)	*
concretude_mean	4,798 (0,213)	4,783 (0,387)	ns
content_word_diversity	0,899 (0,086)	0,929 (0,082)	ns
function_word_diversity	0,660 (0,146)	0,834 (0,174)	**
noun_diversity	0,897 (0,101)	0,834 (0,315)	ns
pronoun_diversity	0,455 (0,317)	0,367 (0,483)	ns
preposition_diversity	0,814 (0,178)	0,825 (0,334)	ns
abstract_nouns_ratio	0,028 (0,027)	0,058 (0,083)	ns

Note: * p < .05 ** p < .01 *** p < .001; ns = not significant.

2.4 DISCUSSION

In the present study, we explored changes in performance in syntactic, lexical and semantic aspects of narrative recall of AD patients in comparison to elderly subjects without cognitive impairment. To do so, we performed an independent samples t-test analysis to

compare the performance of the two groups on a series of linguistic features measuring discourse complexity.

Syntactic features

In our analysis, we observed that AD patients had lower mean scores in syntactic features, as measured by three syntactic variables: the total number of sentences produced, the mean number of words per sentence, and the Yngve score. This can be interpreted as the narrative production of AD patients being syntactically less complex than the production of healthy controls. The narrative recall produced by the AD patients had less and shorter sentences, and their sentences had less syntactic ramifications. Our results of the total number of sentences contrast with previous literature on narrative production. For example, Choi (2009) and Cuetos *et al.* (2007) have not found differences in the number of sentences produced by AD patients and healthy controls on a picture description task. The mismatching results could possibly result from the type of task adopted to elicit discourse production. Picture description tasks rely on the individual telling a story while looking at the stimulus, while in narrative recall tasks the participants did not have access to the stimulus while producing their narratives. Recall tasks rely more heavily on working and episodic memory, which are impaired in AD patients (HUNTLEY; HOWARD, 2010). Thus, the ability to completely recall a narrative from memory is impaired in AD, leading to a reduction in discourse length.

The difference in the mean number of words per sentence observed in our study supports the findings from Hier, Hagenlocker and Shindler (1985), who adopted a picture description task. Again, this result is expected due to the nature of the task and its reliance on memory ability. We observed that AD patients had difficulty recalling details from the narrative, as their recalls consisted mostly of the gist of the story. As such, their utterances were simpler than the utterances produced by healthy controls. Conversely, our results did not reproduce the results from Cuetos *et al.* (2007), who also adopted a picture description task, but have not found a difference in the number of words per sentence. This could have occurred because their patient group did not present clinical signs of AD. Thus, their preserved memory ability allowed them to produce more informative sentences.

The difference in the Yngve score observed in this study contrasts with the results found by Roark *et al.* (2011). Although a similar recall task to the one adopted in this study was adopted by them, Roark and colleagues have not found a difference in Yngve score in the immediate recall step of the narrative task. They have found, however, a difference in the

delayed recall step of the task. This difference can be explained by differences in the participants' profile between the studies. Roark *et al.* (2011) evaluated performance from individuals with Mild Cognitive Impairment (MCI). As MCI is seen as a pre-AD stage – thus still not presenting signs of impairment that affect daily life –, participants from the study by Roark *et al.* (2011) did not have problems producing more left-branching sentences. Their findings on a difference at the delayed recall as compared to the immediate recall may indicate, however, that when associated with a memory load, the ability of MCI participants to produce such sentences reduces. As AD is marked by more severe memory deficits, differences in Yngve score may already be observable in immediate recalls.

The syntactic differences observed in this study were also observed by Marcotte *et al.* (2017). In their study, Marcotte and colleagues have found that participants diagnosed with the non-fluent variant of PPA produced shorter sentences than the control group did, while both the participants diagnosed with non-fluent and semantic variations of PPA achieved lower mean Yngve scores. These findings indicate similar patterns of language impairment at the syntactic level between AD and the non-fluent variant of PPA individuals. They also indicate that number of words per sentence and Ygnve score features are sensitive to detect different neurodegenerative conditions. Marcotte *et al.* (2017) have also found a difference in the number of sentences produced by participants diagnosed with the non-fluent variant of PPA. Their results, however, indicate that participants diagnosed with this condition produced more sentences than the control group. In this study, on the other hand, AD patients produced fewer sentences than the control group. Further investigation is needed to understand this difference.

Lexical features

AD patients produced fewer words overall than the control group, and the mean frequency score of the words produced by them was higher, indicating a less complex narrative. Both results corroborate findings of previous studies (HERNÁNDEZ-DOMÍNGUEZ *et al.*, 2018; HIER; HAGENLOCKER; SHINDLER, 1985; KAVÉ; GORAL, 2016; LIRA *et al.*, 2014). Regarding the proportion of content words and function words, our data suggest an opposite effect than what is described in the literature. Jin, Choi and Lee (2016) have found that AD patients produced fewer content words than healthy individuals, a finding corroborated by Kavé and Goral (2016). In our study, however, the opposite was true, with AD patients producing more content words and healthy controls producing more function words. We argue that our findings might result from the length of the recall produced

by the healthy controls recruited for this study. While they recall a narrative, they may use function words such as pronouns to make anaphoric references. AD patients, on the other hand, do not make as many references because their recall is shorter. It is important to state that some of the possible reasons why other studies assessing narrative production through automatic assessment obtain mismatched results are the task adopted and the cohort recruited. Specifically, Hernández-Domínguez *et al.* (2018) adopted a picture description task, which does not rely as much on memory as narrative recall does, thus allowing for a more "open" and informative production. Roark *et al.* (2011) adopted a narrative recall, but because they analyzed the recall of participants diagnosed with MCI, and the length of the recall produced by them was similar to the recall produced by healthy controls, similar proportions of content to function words were found between groups. The mismatching findings between studies should be further explored.

None of the features indicating performance differences between the groups in this study correlate with the features found by Marcotte *et al.* (2017). This discrepancy indicates that, at the lexical level, narrative production in AD differs from narrative production in PPA, considering the two variants analyzed (semantic and non-fluent variants). However, the analysis of performance of AD patients in a topic-directed interview task, as adopted by Marcotte *et al.* (2017), must be conducted to investigate whether differences in features between different the two neurodegenerative profiles (AD and PPA) remain uncorrelated.

Semantic features

The analysis of the semantic features adopted for this study produced results to be carefully analyzed. Considering the four features that differed between AD and healthy controls, none is in accordance with findings from previous studies. In our analysis we observed that AD patients achieved higher scores in the type-token ratio feature, and lower scores in Brunét's index. Both features measure the proportion of types in relation to tokens in a text. Higher TTR scores correlate with better performance, resulting in a more complex text. Interpretation from Brunét's index, on the other hand, indicates that lower scores correlate with better performance, also indicating an increase in linguistic complexity. Thus, our findings suggest that AD patients produced semantically more complex recalls than healthy controls. Studies developed by Hernández-Domínguez *et al.* (2018) – who adopted automatic assessment –, and Bucks *et al.* (2000) showed that the control group performed better than the AD group on these features. The results from the analysis of content density and function word diversity indicate that the AD group produced denser recalls information-wise and more

diverse function words. Our results on content density contrast with the results from Roark *et al.* (2011), who have found that, as stages of dementia advanced, content density scores declined. Our findings on function word diversity also contradict the literature, as results from the study conducted by Hier, Hagenlocker and Shindler (1985) demonstrated a decline in lexical diversity in AD patients relative to healthy controls' production.

The mismatching results found in our analysis of semantic features may be due to task typology. In this study, the recall of a short narrative was adopted, while an oral narrative production based on a picture and topic-directed interview were adopted in these comparable studies. As the objective in narrative recall tasks is to reproduce a story that was previously heard or read, the linguistic universe is restricted, preventing lexical and semantic variability. Since healthy controls produced a longer narrative, they eventually repeated words from the narrative, thus reducing the type-token ratio. The AD group, on the other hand, produced shorter narratives, some of which consisted of a single sentence. Consequently, their recalls included fewer or no repetitions. This difference is best explained by Heaps' law (HEAPS, 1978). According to this law, as texts increase in length, the likelihood of producing new words decreases, thus making it look as if the text is less diverse. Such effect interferes with features such as TTR and Brunét's statistics, as they both assess language through the proportion of types (every word entry in the text) to tokens (unique entries in the text). Table 5 provides an example of a transcript from an AD patient and from a healthy control.

Table 5. Transcript samples from the narrative recall task

AD patient	**Healthy Control**
Lúcia foi pro trabalho com um amigo . pegou o ônibus . e furou o pneu .	Lúcia mora no interior numa cidade do Paraná . precisou viajar pra uma outra cidade à procura de emprego . ela pegou um carro . passou um buraco . quebrou o carro . e pegou um ônibus pra ir pra rodoviária pra não perder o ônibus .

Source: the author.

As the transcripts in Table 5 illustrate, by being longer and including more content, the recall produced by the healthy control participant contains some word repetitions. In the AD patient's recall, each word appears only once. Such difference leads the software conducting the automatic analysis to interpret the longer transcript as being less complex, as predicted by Heap's law. Again, it is important to consider task typology. Hier, Hagenlocker and Shindler (1985) also assessed lexical diversity, and their results indicated that the narrative produced by participants with cognitive disorder was less diverse than the narratives produced by

healthy controls. In their study, however, Hier, Hagenlocker and Shindler (1985) adopted a picture description task, which has a less restrictive linguistic universe than a narrative recall task, a context in which the participant has to replicate what was heard or read.

Another explanation to the discrepancy observed in our findings compared to previous literature lies on the importance of memory for recall tasks. Narrative recall relies heavily on memory performance, as the participant does not have access to the stimulus during the execution of the task. In narrative tasks where participants have access to the stimulus while producing the narrative, such as "here-and-now" picture description, this reliance on memory is reduced (ASP; DE VILLIERS, 2010). We observed that when AD patients failed to retrieve information from the narrative, they made-up information related to the narrative's semantic universe, such as saying that Lúcia had to take a bus to travel instead of saying she had to take the bus to go to a job interview. By adding information that was not part of the original narrative, AD patients inadvertently increased the linguistic universe of the task. The production of new words could have then contributed to an increase in lexical diversity.

Considering our results, a careful analysis should be done when explaining data of semantic features analyses with automatic language assessment. Users should consider the characteristics of each sample being analyzed and interpret the results accordingly. Thus, in similar cases to the one in this study, which generated a length discrepancy in oral narratives produced by the groups with cognitive decline, the interpretation of features measured in ratio should be carefully done. Still, further investigation is needed to assess the impact of types of oral narrative production on language automatic assessment.

Some of the semantic features that distinguished the groups in this study also distinguished groups in the study by Marcotte *et al.* (2017). The findings from Marcotte and colleagues, however, are the opposite from the findings from this study. In their study, Marcotte *et al.* (2017) have found that participants diagnosed with the semantic variant of PPA had lower scores in TTR and higher scores in Brunét's index as compared to healthy controls' scores, indicating that the discourse produced by the participants diagnosed with semantic variation of PPA was less lexically rich. Our results do not corroborate the results by Marcotte *et al.* (2017). Again, this may be explained by the difference in task typology mentioned above. The task adopted by Marcotte *et al.* (2017) consisted of topic-directed interviews, allowing participants to produce unconstrained discourses, as opposed to narrative recall tasks that are more verbatim in nature.

2.5 FINAL CONSIDERATIONS

Our analysis of linguistic features with the use of automatic assessment showed impaired narrative recall in AD patients relative to healthy controls in the three linguistic levels investigated: syntactic, lexical and semantic. Results from the automatic assessment of linguistic features that provide opposite results from what is proposed in the literature indicate the need of carefully interpret the results when it comes to ratio data, mainly in the semantic domain. Attention should also be given to studies including different clinical groups, as in this study we only addressed the effects of AD. Moreover, task typology is another aspect to be observed, and results may not allow for generalization of interpretations across studies which used different types of tasks to generate oral narrative production.

Automatic language assessment is a promising tool for researchers and clinicians, as it provides data to detect language impairment and characterize groups according to their linguistic performance, such as in high compared to low educational level groups (TREVISO *et al.*, 2018). In this study, automatic language assessment was useful in differentiating AD patients from healthy elderly adults. Still, this study has some limitations that should be addressed in future studies. Our main limitation was group size. Although we successfully differentiated AD patients from controls, the number of AD patients in our study was small, making it hard to make strong assumptions on their performance on a narrative recall task. Additionally, our narrative samples had significant differences in length. Although this is an important finding, length differences can impact analysis of some features that are length sensitive.

For future studies, we suggest that results from this study be compared to the automatic assessment of performance of AD patients on other oral narrative tasks, such as single and multiple picture description and autobiographical narrative, to assess whether the features described in this study would also be relevant to differentiate groups in these other tasks. We also suggest that the input method adopted for this study (listening to the story) could compared to another input modality (reading) to assess the influence of the input in the performance in a narrative recall task. Furthermore, we suggest that these findings are correlated with performance on memory tests to assess the role of each type of memory on different linguistic features.

3 STUDY 2: EDUCATION AND READING AND WRITING HABITS AS PREDICTORS OF NARRATIVE RECALL PERFORMANCE IN HEALTHY AGING: A STUDY WITH AUTOMATIC ASSESSMENT

3.1 INTRODUCTION

The aging process is associated with a decline in cognitive functions. Cognitive skills such as attention, processing speed, executive functioning and memory are known to be negatively affected by aging (HARADA; NATELSON LOVE; TRIEBEL, 2013; SALTHOUSE, 2009; WECKER *et al.*, 2000). Language, as a cognitive function itself, is also affected by aging, albeit asymmetrically. For example, evidence suggests that language comprehension remains largely intact, while language production is shown to be affected (BURKE; MCKAY; JAMES, 2000).

Indeed, age-related language deficits have been observed in language production. Some findings point to a negative effect of age on spontaneous discourse production (ARDILA; ROSSELLI, 1996). Several studies present evidence indicating that the syntactic aspects of discourse, such as number of subordinate and left-branching clauses, decrease with age (KEMPER; THOMPSON; MARQUIS, 2001; MARINI *et al.*, 2005). Differences were also observed in abilities such as word-finding and the production of complex utterances (ALBERT *et al.*, 2009; MARINI *et al.*, 2005). As for the lexical aspects of discourse, changes that correlate with aging have also been observed. Although vocabulary knowledge increases with age (KEMPER; THOMPSON; MARQUIS, 2001), access to lexical information seems to be impaired, as evidence indicates that there is an increase in word finding difficulties noticeable in older adults, as older adults experience more tip-of-the-tongue states during discourse production (MARINI *et al.*, 2005). This word-finding difficulty experienced by older adults seems to affect their performance in discourse (BURKE *et al.*, 1991). Despite these deficits in lexical access, older adults' discourse is marked by more diverse vocabulary as compared to young adults (KEMPER; SUMNER, 2001). Changes in the semantic aspects of discourse production have also been observed in aging. Older adults produce less information units than younger adults (CAPILOUTO; WRIGHT; WAGOVICH, 2005; CHOI, 2012). Older adults also take longer to access late-acquired words than early-acquired words (MORRISON *et al.*, 2002).

Much has been discussed about the effects of external factors on cognitive improvement. Stern (2002) and Stern *et al.* (2018) propose that cognitive-stimulating activities such as formal education and reading and writing habits may assist in the creation of

a cognitive reserve that attenuates cognitive decline and postpone the clinical manifestation of signs of (major) cognitive disorder. Several studies have reported that higher levels of education are associated with better performance in attention, processing speed, memory and executive functions tasks (CONSTANTINIDOU; CHRISTODOULOU; PROKOPIOU, 2012; COTRENA *et al.*, 2016; DARWISH *et al.*, 2018; LE CARRET *et al.*, 2003). Findings on the impact of reading and writing habits on cognitive performance, though still scarce, point to an impact of these variables on cognitive processing. Increased reading and writing habits improve performance on attention, executive functions, working memory and language tasks (BRANCO *et al.*, 2014; GALLUCCI *et al.*, 2009; JEFFERSON *et al.*, 2011; PAWLOWSKI *et al.*, 2012).

Studies on the impact of cognitive reserve measures in language production support this relationship. More years of education are associated with better performance on the lexical aspects of discourse, such as the number of words produced in a narrative (ARDILA; ROSSELLI, 1996; LE DORZE; BÉDARD, 1998). An impact of education has also been observed in the semantic aspects of discourse, as higher levels of education contribute to a better performance on features such as content word diversity (LE DORZE; BÉDARD, 1998). To our knowledge, however, there are no studies assessing the relationship between education and syntactic aspects of discourse production, and studies on the effects of reading and writing habits on discourse production are still scarce.

Research has investigated the impact of Alzheimer's Disease on syntactic (HIER; HAGENLOCKER; SHINDLER, 1985; ORIMAYE *et al.*, 2017; ROARK *et al.*, 2011), lexical (AHMED *et al.*, 2013b; LIRA *et al.*, 2014; YANCHEVA; FRASER; RUDZICZ, 2015) and semantic (BUCKS *et al.*, 2000; HERNÁNDEZ-DOMÍNGUEZ *et al.*, 2018; KAVÉ; GORAL, 2016) aspects of discourse production. However, there is a lack of studies addressing the impact of education and reading and writing habits on these linguistic features. In an attempt to fill this gap, this study investigates the impact of education and reading and writing habits on syntactic, lexical and semantic features in normal aging. We assessed these features by means of software of automatic feature analyses. Automatic feature analyses have shown to be a valuable tool to distinguish healthy from clinical groups, such as AD, mild cognitive impairment (MCI) and primary progressive aphasia (PPA) (HERNÁNDEZ-DOMÍNGUEZ *et al.*, 2018; MARCOTTE *et al.*, 2017; ROARK *et al.*, 2011). It also is a promising tool to study normal aging. The aim of the study, thus, is to verify whether these cognitive stimulating conditions (i.e., education and reading and writing habits) impact on narrative recall performance in normal aging.

3.2 METHODS

Participants

Seventy-four healthy elderly adults participated in this study. They were recruited at groups attending courses at the university delivered for the community, as well as at community centers. Table 1 presents their demographic and neuropsychological characterization. Their ages ranged from 65 to 82 years (71,80/4,444), and education ranging from 2 to 20 years (10,09/5,465) of formal education. Their socioeconomic status ranged from lower class to upper middle class (24,19/5,972). The participants' score on the reading habits questionnaire ranged from 0 to 16 points (7,64/3,866), and on the writing habits questionnaire ranged from 0 to 14 points (4,65/3,258). All participants were native speakers of Brazilian Portuguese and did not speak other languages. They did not present a history of substance abuse and/or neurological or psychiatric illness. They did not have depression symptoms, as measured by the Geriatric Depression Scale (GDS) (YESAVAGE *et al.*, 1982). Their general health status was assessed through the Mini-Mental State Exam (MMSE). Their scores on MMSE ranged from 22 to 30 (27,80/1944), indicating that none of the participants was cognitively impaired.

Table 6. Demographic and neuropsychological data of the participants of the study

N=74 (F=60)	Min	Max	Mean	SD
Age	65	82	71,80	4,444
SES	13	40	24,19	5,972
Education	2	20	10,09	5,465
RH	0	16	7,64	3,866
WH	0	14	4,65	3,258
MMSE	22	30	27,80	1,944

Note: N = number of participants; SES = Socioeconomic Status; RH = Reading Habits; WR = Writing Habits; MMSE = Mini-Mental State Exam. SES classes: lower = 0 to 16; middle = 17 to 28; upper middle = 29 to 44; upper = 45 to 100.

Source: the author.

This study was approved by the Research Ethics Committee of PUCRS, under report number 560.073, CAAE registry number 21006913.0.0000.5336. Participation on the study was voluntary, and participants gave written informed consent before joining the study.

All participants underwent a battery of linguistic tasks as part of a larger study to map age and cognitive disorder-related changes language processing (BALE - Battery for Language Assessment in Aging) (HÜBNER *et al.*, 2019). Its tasks were validated and

adjusted to be adequate to the participants' linguistic and sociocultural reality. General cognitive performance was assessed through the Mini-Mental State Examination (MMSE) (FOLSTEIN; FOLSTEIN; MCHUGH, 1975), following the scoring interpretation provided by Laks and colleagues (2003).

Narrative recall task and linguistic features

The procedure for data collection and assessment of narrative recall, as well as the description of the grouped types of features analyzed in this study, are the same as those adopted in Study 1 (please to refer to section 2.2 in this thesis).

Statistical analysis

A step-wise linear regression analysis was conducted with narrative recall scores obtained through automatic analysis as dependent variable and age, socioeconomic status, education and reading and writing habits as regressors on three sets of linguistic features (syntactic, lexical and semantic). First, we inspected the data for skewness and multicollinearity, and there was no need to correct any variable. Then, the variables were grouped in the regression models in two separate steps: Step 1 included age and socioeconomic status, and Step 2 included education, reading habits, and writing habits. In this way, in Step 1 we controlled for the effect of age and socioeconomic status, and in Step 2 we focused on the contribution of our variables of interest (education, reading habits, and writing habits) to narrative recall.

3.3 RESULTS

Results from the regression analysis on the effect of education and reading and writing habits on syntactic, lexical and semantic features can be found in Tables 7, 8 and 9.

Syntactic features

In the first step of the analysis, socioeconomic status was a significant predictor of performance on the feature measuring overall number of sentences, $\beta = 0.311$, $p < .01$, meaning higher socioeconomic status resulted in a higher number of sentences. Socioeconomic status did not predict any other features. Age was not a significant predictor of any of the syntactic features. After controlling for the effect of age and socioeconomic status, education significantly predicted performance on number of sentences, $\beta = 0.508$, $p < .001$; words per sentence, $\beta = 0.354$, $p < .05$; clauses per sentence, $\beta = 0.368$, $p < .05$; and

dependency distance, $\beta = 0.362$, $p < .05$. The results indicate that, as education increased, so did the production of sentences, words per sentence and clauses per sentence. They also indicate that the mean dependency distance in sentences increased with more years of education. Reading and writing habits did not show an influence on syntactic features.

Lexical features

In Step 1, socioeconomic status was a significant predictor of performance on syllables per content word, $\beta = 0.307$, $p < .01$, and total words produced, $\beta = 0.296$, $p < .05$. The results indicate that the number of words produced and the mean number of syllables per content word increased with age. In step 2, education predicted noun ratio, $\beta = -0.408$, $p < .01$; function words produced, $\beta = 0.429$, $p < .01$; content words produced, $\beta = -0.429$, $p < .01$; and total words produced, $\beta = 0.583$, $p < .001$. The results from Step 2 indicate that an increase in education resulted in an increase on the percentage of function words produced and on the number of words produced. Conversely, an increase in education resulted in a decrease on noun ratio. Reading and writing habits did not predict any of the 15 lexical features.

Semantic features

In step 1, age significantly predicted mean imageability value, $\beta = 0.328$, $p < .01$; and mean age of acquisition value, $\beta = -0.276$, $p < .05$. The results indicate that an increase in age resulted in the production of words acquired earlier in life and that are more imageable. In step 2, level of education significantly predicted Brunét's index, $\beta = 0.561$, $p < .001$; type-token ratio, $\beta = -0.402$, $p < .01$; content density, $\beta = -0.428$, $p < .01$; and function word diversity, $\beta = -0.441$, $p < .01$. The results indicate that an increase in years of education is associated with a decrease in overall word diversity. Reading and writing habits did not significantly predict any semantic feature.

Table 7. Standardized βs, R^2s, and ΔR^2s for the regression analyses of syntactic features

Step		sentences	words_per_sentence	clauses_per_sentence	yngve	frazier	subordinate_clauses	dep_distance
Step 1	Age	-0.002	-0.018	0.145	0.021	0.222	-0.101	0.018
	SES	0.311**	0.140	0.134	0.132	0.051	-0.076	0.083
	R^2	0.097	0.021	0.029	0.016	0.046	0.012	0.006
	ΔR^2	0.097*	0.021	0.029	0.016	0.046	0.012	0.006
Step 2	Ed	0.508***	0.354*	0.368*	0.244	0.180	0.385	0.362*
	RH	-0.031	0.120	0.131	0.149	0.149	-0.007	0.090
	WH	0.151	-0.081	0.008	-0.110	-0.123	-0.145	-0.055
	R^2	0.339	0.136	0.180	0.086	0.092	0.105	0.119
	ΔR^2	0.242***	0.115*	0.152**	0.070	0.047	0.093	0.113*

Note: SES = Socioeconomic status; Ed = Education; RH = Reading Habits; WH = Writing Habits.

ΔR^2 is the incremental increase in the model R^2 that results from the addition of a predictor or set of predictors in a new step of the model.

*p < .05 ** p < .01 *** p < .001

Table 8. Standardized βs, R^2s, and ΔR^2s for the regression analyses of lexical features

Step		noun_ratio	verbs	prepositions_per_sentence	adjective_ratio	adverbs	pronoun_ratio	function_words	content_words	cw_freq	syllables_per_content_words	words	personal_pronouns	conn_ratio
Step 1	Age	-0.049	0.164	-0.056	0.046	-0.103	0.085	-0.071	0.071	-0.129	-0.196	-0.004	0.133	0.063
	SES	-0.006	-0.117	0.084	0.024	0.054	0.102	0.088	-0.088	-0.209	0.307**	0.296*	0.112	0.243
	R^2	0.002	0.051	0.013	0.002	0.016	0.013	0.016	0.016	0.046	0.165	0.088	0.022	0.055
	ΔR^2	0.002	0.051	0.013	0.002	0.016	0.013	0.016	0.016	0.046	0.165**	0.088*	0.022	0.055
Step 2	Ed	-0.408**	-0.074	0.225	-0.089	0.068	0.386	0.429**	-0.429**	0.203	0.027	0.583***	0.265	0.088
	RH	0.092	-0.034	0.148	0.063	-0.115	-0.091	-0.018	0.018	-0.243	-0.070	0.024	0.077	-0.055
	WH	-0.076	0.091	-0.091	0.199	-0.009	0.015	-0.037	0.037	-0.115	-0.075	0.060	-0.039	0.210
	R^2	0.122	0.058	0.076	0.045	0.027	0.106	0.138	0.138	0.118	0.177	0.374	0.086	0.101
	ΔR^2	0.120*	0.008	0.064	0.043	0.010	0.093	0.122*	0.122*	0.072	0.012	0.285***	0.064	0.046

Note: SES = Socioeconomic status; Ed = Education; RH = Reading Habits; WH = Writing Habits.

ΔR^2 is the incremental increase in the model R^2 that results from the addition of a predictor or set of predictors in a new step of the model.

Table 9. Standardized βs, R^2s, and ΔR^2s for the regression analyses of semantic features

Step		imageabilidade_mean	idade_aquisicao_mean	familiaridade_mean	ttr	brunet	honore	dalechall_adapted	content_density	concretude_mean	content_word_diversity	function_word_diversity	noun_diversity	pronoun_diversity	preposition_diversity	abstract_nouns_ratio
Step 1	Age	0.328**	-0.276*	0.164	-0.139	0.020	-0.222	-0.139	0.073	0.264	-0.142	-0.127	-0.126	-0.194	0.019	0.103
	SES	0.139	0.060	-0.008	-0.144	0.261	0.102	-0.072	-0.107	0.162	0.026	-0.245	0.121	-0.049	0.056	0.004
	R^2	0.103	0.089	0.028	0.029	0.066	0.072	0.019	0.021	0.073	0.023	0.059	0.039	0.035	0.003	0.010
	ΔR^2	0.103*	0.089*	0.028	0.029	0.066	0.072	0.019	0.021	0.073	0.023	0.059	0.039	0.035	0.003	0.010
Step 2	Ed	-0.219	0.111	-0.010	-0.402**	0.561***	-0.217	0.044	-0.428**	-0.156	-0.170	-0.441**	-0.189	-0.037	-0.282	0.082
	RH	-0.084	-0.139	0.205	-0.071	0.056	-0.109	0.008	0.024	-0.144	-0.122	-0.047	-0.163	-0.003	-0.049	-0.088
	WH	-0.003	-0.059	0.059	0.192	0.006	0.258	-0.056	0.017	-0.052	0.350	0.007	0.338	0.104	0.062	-0.281
	R^2	0.158	0.111	0.078	0.148	0.324	0.136	0.022	0.144	0.140	0.111	0.217	0.128	0.043	0.064	0.099
	ΔR^2	0.055	0.022	0.050	0.118*	0.258***	0.064	0.003	0.123*	0.067	0.088	0.157**	0.089	0.008	0.061	0.089

Note: SES = Socioeconomic status; Ed = Education; RH = Reading Habits; WH = Writing Habits.

ΔR^2 is the incremental increase in the model R^2 that results from the addition of a predictor or set of predictors in a new step of the model.

3.4 DISCUSSION

The aim of this study was to verify whether cognitive stimulating conditions, more precisely education and reading and writing habits, impact on narrative recall performance in normal aging, as assessed by automatic language assessment. To do so, we performed a regression analysis to assess the impact of education and reading and writing habits of healthy elderly people on syntactic, lexical and semantic features related to discourse complexity.

Syntactic features

The first step of the regression analysis of syntactic features provided interesting results. Unlike what has been found in other studies, such the ones conducted by Marini and colleagues (2005) and Kemper and colleagues (2001), in our study age did not predict performance on any of the adopted linguistic features. This result could possibly be interpreted as an effect of the type of task adopted in each study. Marini *et al.* (2005) obtained language samples from a picture description, and Kemper *et al.* (2001) obtained language samples from a series of discourse elicitation questions. In both cases, the participants' language production is spontaneous. In the present study, a narrative recall task was adopted. Since in this task participants were expected to provide a recall of a story they had just heard, participants had contextual restraints given by the context of the story they heard. Thus, it can have attenuated the age-related effects in syntactic processing. Moreover, in a recall task the story is presented orally as a model to be followed and repeated, differently from spontaneous speech production (ASP; DE VILLIERS, 2010). We did find that socioeconomic status predicted the number of sentences produced, meaning that an increase in socioeconomic status resulted in more sentences being produced. While socioeconomic status is associated with children's language development (HOFF; TIAN, 2005; PUNGELLO *et al.*, 2009), there seems to be no studies, to our knowledge, on the relationship between socioeconomic status and linguistic performance in aging. Thus, further studies must be conducted to address this effect.

Once the effects of age and socioeconomic status were controlled for, our results from the second step of the analysis of syntactic features showed education as a predictor of the number of sentences produced, meaning that more educated participants produced more sentences. Education also significantly predicted the mean number of words per sentence, the mean number of clauses per sentence and the dependency distance between words in a sentence. The results indicate that an increase in education results in longer and more complex sentences. While there is no previous literature on the relation of syntactic aspects of language

production and education to discuss our findings, it is well established that education assists in cognitive processing. We argue that, even though our participants would have no difficulty reproducing successfully a story told to them, as opposed to spontaneously producing one, the ones with higher education are able to produce more syntactically complex recalls.

Lexical features

In the first step of the analysis of lexical features, socioeconomic status was a predictor of the features measuring mean syllables per content word and total number of words. The results indicate that an increase in socioeconomic status resulted in an increase in the number and in the length of words produced during recall. The lack of an effect of age on lexical features is surprising, as one of the age-related language deficits that has been most documented is word finding difficulty, as reported by Marini *et al.* (2005) and Burke *et al.* (1991). As argued in the discussion of syntactic features, the lack of a correlation between age and lexical aspects could be a consequence of the task adopted in the study. Thus, one hypothesis to explain sustained ability in word finding is that listening to the story right before recalling it reduced word-finding difficulties commonly experienced by older adults.

The second step of the analysis showed that education was a predictor of the total number of words and the ratio of function words produced, indicating that the number of words and the ratio of function words increased with education. Interestingly, though, education predicted a decrease in the production of content words and nouns. The effect of education on the number of words follows previous findings in the literature, such as those from Le Dorze and Bédard (1998) and Ardila and Rosselli (1996). In both cases, higher levels of education were associated with higher number of words produced during discourse tasks. The negative effect of education on the ratio of nouns and the increase of function words over content words, on the other hand, are not consistent with the literature, and may be a limitation related to the length of the recall produced by the more educated participants in this study. Function words such as pronouns can be prominent in narrative tasks as the speakers make anaphoric or cataphoric references. We observed that an increase in education resulted in an increase on the length of recall. Thus, it is expected that longer recalls have more referencing instances, increasing the proportion of content words. This can also explain why there was a reduction in noun ratio, as there would be an increase in the number of entries of other lexical categories.

Semantic features

The first step of the analysis of semantic features indicates that age is a predictor of imageability. More specifically, older participants produced words with higher imageability. Also, age predicted age of acquisition measures. This can be interpreted as older adults producing more words acquired earlier in life than words acquired later in life. The age-related decline in the mean age of acquisition value is in line with previous findings indicating that older adults have more difficulty activating words acquired later in life. Morrison and colleagues (2002), for example, have found that older adults made more errors and took longer to name late-acquired words in a picture naming task, indicating that words acquired early are more crystallized in memory.

In the second step of the analysis, our results indicate that education negatively affects type-token ratio, content density and function word diversity. The results indicate that the recall of more educated participants was less diverse in function words, had a lower proportion of content words relative to function words, and had more repetition of words. Education also had a negative effect on Brunét's index. The results from the regression analysis indicate that increased education resulted in increased Brunét's index scores, but since higher scores on Brunét's index indicate lower performance, the result from the regression analysis indicate that recall from participants with more education had more word repetition. These results do not corroborate the findings from Le Dorze and Bédard (1998), who have found that education contributes to more diverse discourses.

We argue that the discrepancy on results of semantic features observed between the studies is related to the type of task adopted. Le Dorze and Bédard (1998) adopted a picture description task to elicit narratives from healthy participants. Although there is a stimulus guiding the production of narrative, picture description tasks allow participants to develop a somewhat more unconstrained narrative. Conversely, narrative recall tasks already provide participants with the linguistic set necessary for the execution of the task, which consists of repeating a story already read or heard (as in our study). As proposed by Heap's law (HEAPS, 1978), larger language samples suffer a reduction in diversity due to an increased chance of word repetition. This law applies specially to narrative recall tasks. The purpose of a narrative recall task is to reproduce a narrative previously told or read, so participants are expected to work with a restricted linguistic universe, reducing the likelihood of the production of new words. Table 10 provides an example of the effect of narrative length on lexical diversity.

Table 10. Transcript samples from the narrative task

Participant with low education	Participant with high education
a Lúcia tem que viajar . pegou um táxi . o táxi furou um pneu . ela chamou o Pedro .	Lúcia morava no interior do Paraná . veio para a capital pra fazer um teste pra emprego . quem levou ela foi de carona o seu amigo . esse amigo levou . na estrada deu um problema com o pneu . furou o pneu . e ela pensou que ia se atrasar pra pegar o ônibus na rodoviária . ela pegou um taxi . e chegou ainda a tempo de pegar o ônibus . e se reportar para a capital .

Source: the author.

As evidenced in Table 10, although the production from the participant with high education is unquestionably richer in content, it contains more word repetitions than the recall produced by the participant with low education. While the participant with low education only repeats the word *táxi* once, the participant with high education repeats several words, such as *levou* (took), *pneu* (tire), *ônibus* (bus), *capital*, and *ela* (she). So, even though the participant with high education produced a better recall, lexical diversity measures such as TTR and Brunét's index are negatively affected by length, identifying larger speech samples as less complex. Thus, when conducting an automatic assessment of semantic features measuring diversity, it is imperative that task type and sample size are accounted for when interpreting results.

Education has been associated with an increase in overall cognitive performance (ALBERT; TERESI, 1999; ELIAS *et al.*, 1997; SCHNEEWEIS; SKIRBEKK; WINTER-EBMER, 2014). Still, few studies have addressed its impact on discourse production. In this study, results indicate that education predicted performance on features assessing the length of recall. Results point to an increase in number of sentences, mean number of words per sentence and total number of words associated with an increase in education. These results corroborate the results from Ardila and Rosselli (1996), who have found that education correlated with an increase in spontaneous language production.

Our analysis also identified some predictions that, to our knowledge, have not been reported in literature yet. Results indicate that increased education is associated with increased clauses per sentence and dependency distance. These findings suggest that elderly participants with higher education produce more syntactically complex sentences. And though the results of semantic features are biased due to length disparity, four features measuring word diversity were predicted by age. While there are no studies to corroborate our findings on linguistic features, the results obtained in this study corroborate the argument that education contributes

to the establishment of a cognitive reserve. Also, the fact that reading and writing habits did not predict performance on any feature provides evidence on the importance of education as key for the increase of overall of cognitive performance.

3.5 FINAL CONSIDERATIONS

Linguistic features analyses showed that education predicted performance on variables in all three groups of features (syntactic, lexical and semantic), while the influence of reading and writing habits was not found in any group of features. Thus, we can infer that, to what concerns this sample of participants, education was a more effective cognitive reserve than were reading and writing habits in the narrative task production of recall. Therefore, governmental efforts should be done mainly in underdeveloped countries so to foster the access of their population, mainly the elderly extract, to formal education, since it represents a valuable source of cognitive reserve, improving linguistic performance.

Automatic assessment analyses have increasingly been adopted in studies designed to detect group characterizations and detect language impairment in clinical populations compared to healthy ones (MARCOTTE *et al.*, 2017; ROARK *et al.*, 2011). The software to develop these analyses have improved largely and their adoption as a complementary tool for language assessment by clinicians and researchers has increased largely. It is important to note that attentive interpretation must be taken when analyzing data according to samples' characteristics and to task typology, since they can lead to biased results in some features, as it was the case of some semantic features in the present study.

There are limitations in this study that should be addressed in future studies. Our narrative samples differed in length, which could have lead to biased results in some of the features assessed in this study. Also, as there is a lack of literature on the influence of education and reading and writing habits on narrative production in healthy aging, especially when it comes to the use of automatic assessment, we could not discuss some of our findings as there were no comparable studies.

For future studies, we suggest that results from this study be compared to the automatic assessment of performance of healthy elderly adults on other narrative tasks, such as single and multiple picture description and autobiographical narrative, to assess whether the features described in this study would also be relevant to other tasks. We also suggest that these findings are correlated with performance on memory tests to assess the role of each type of memory on different linguistic features.

4 CONCLUSIONS

The present thesis aimed at investigating performance of healthy elderly adults as a function of schooling and reading/writing habits and elderly adults diagnosed with Alzheimer's Disease on language production assessed through a narrative recall task. To reach this aim, the thesis was divided into two studies.

The first study compared the production of syntactic, lexical and semantic features in a narrative recall task of AD participants and healthy elderly controls, as measured by automatic assessment. Participants recalled a short narrative presented orally. The recalls produced by the participants were then automatically analyzed via a software that extracted a series of linguistic features grouped in syntactic, lexical and semantic features. Differences were found between the AD and the control group' performance across all three groups of features. The findings from this study support the literature, indicating that discourse production tasks are an adequate measure for clinical assessment, as they seem to effectively detect cognitive changes via linguistic assessment.

Regarding the applicability of tools for automatic assessment of language, results indicate a limitation related to the length of recall. Although the automatic analysis successfully distinguished AD patients from healthy elderly adults, corroborating the findings from previous studies, the analysis of semantic features provided opposite results to what was expected. In the sample analyzed in this study, results from all the semantic analysis suggest that AD patients produced better recalls than the control groups did. This mismatching result could possibly be related to the type of task adopted in this study. Narrative recall tasks rely more heavily on memory capacity – reduced in AD samples, and are more constrained in terms of the semantic context as compared to free speech and picture-based narratives. Thus, careful interpretation of semantic features should be taken when adopting narrative recall as the task to elucidate oral narrative production.

The second study assessed the effect of education and reading and writing habits on syntactic, lexical and semantic features of a narrative recall produced by healthy elderly adults. The same set of grouped syntactic, lexical and semantic features adopted in Study 1 was used in Study 2, in order to verify whether features that were sensitive to characterize AD would also be sensitive to reflect the impact of cognitive stimulating factors (schooling and reading/writing habits). Results from this study showed that several features that indicated cognitive decline also indicated an effect of education. Although there is a lack of literature to compare with these findings, these results corroborate the hypothesis that education is associated with an improvement in overall cognitive processing, including linguistic

processing. Our results indicate that participants with higher education produced better recalls syntactically, lexically and semantically, suggesting that education strengthens cognitive processing. Interestingly, semantic features also provided results in opposition to what was expected, indicating that participants with lower education performed better than participants with higher education. The fact that, in both studies, semantic features provided unexpected results corroborates the hypothesis that these results may be task driven. Therefore, semantic features of narrative recall must be addressed carefully in future analyses, with further studies investigating the impact of task typology on the interpretation of semantic feature analyses.

Table 11 illustrates the features that significantly distinguished the groups in both studies. This comparison indicates that measures related to length such as number of sentences and mean number of words per sentence are especially sensitive to detect both an increase and a decrease in cognitive abilities, as they predicted performance in our study and others (ARDILA; ROSSELLI, 1996; FRASER; MELTZER; RUDZICZ, 2015; LE DORZE; BÉDARD, 1998; TOMOEDA *et al.*, 1996). The results are also similar in both studies regarding semantic features. This could be an indicator of a semantic changes in discourse processing, but since our results did not corroborate those found in the literature, further studies must be conducted to assess whether the differences observed by us result from differences in cognitive performance or from a task condition.

Table 11. Comparison of the results from the two studies

Features	Explanation	Interpretation	S1	S2
Syntactic features				
sentences	Number of sentences in the text	Higher values indicate higher complexity	X	X
words_per_sentence	Number of words divided by the number of sentences	Higher values indicate higher complexity	X	X
clauses_per_sentence	Mean number of clauses per sentence	Higher values indicate higher complexity		X
Yngve	Mean number of left-branch ramifications per sentence	Higher values indicate higher complexity	X	
dep_distance	Mean distance between a word and its dependency head	Higher values indicate higher complexity		X
Lexical features				
noun_ratio	Proportion of nouns, relative to the number of words in the text	The relationship between the feature and text complexity is not clear		X

Features	Explanation	Interpretation	S1	S2
function_words	Percentage of functional words, relative to the number of words in the text	The relationship between the feature and text complexity is not clear	X	X
content_words	Proportion of content words, relative to the number of words in the text	The relationship between the feature and text complexity is not clear	X	X
cw_freq	Mean value of the absolute frequency of content words in the text	Higher values indicate lower complexity	X	
words	Number of words in the text	Higher values indicate higher complexity	X	X
Semantic features				
ttr	Proportion of types (words without repetition) to tokens (total words including repetition)	Higher values indicate higher complexity	X	X
brunet	Type/token ratio less sensible to text size	Lower values indicate more lexical richness	X	X
content_density	Mean proportion of content words, relative to the number of function words in a sentence	The relationship between the feature and text complexity is not clear	X	X
function_word_diversity	Proportion of types of function words, relative to the number of tokens of function words in the text	The relationship between the feature and text complexity is not clear	X	X

Narrative recall and discourse production model

The results from the studies conducted in this thesis indicate a relation between cognitive processing and performance on syntactic, lexical and semantic features of discourse. These findings corroborate the hypothesis that, although errors in language production may result from an age-related deficit in phonological retrieval, as stated by Burke and colleagues (1991), they may result from deficits already present at early stages of production, such as in the linguistic formulation step in the model proposed by Voleti, Liss and Berisha (2019). The linguistic formulation step of the speech formulation model is responsible for the selection of features such as the lexical items and the syntactic structure most adequate to transmit the idea formed during the conceptualization stage. Both studies from this thesis present differences on

syntactic, lexical and semantic features, indicating that this selection step is sensitive to all changes in cognitive processing.

Results from both studies also show that changes in cognitive processing – resulting from cognitive decline in AD or from cognitive improvement in higher education - may affect the processing of narrative structure. This can be interpreted by the results obtained from features assessing the length of recall, such as number of words, number of sentences and mean length of sentences. These results indicate cognitive changes affect, for the good and the bad, the processing of discourse structure as proposed by Kintsch and van Dijk (1978). Their model proposes that an efficient discourse processing involves the organization of conceptual information into complete discourses. From the results of Study 1, we hypothesized that a neurodegenerative disease (AD) would cause a deficit in this processing, whereas in Study 2 we hypothesized that higher education would strengthen the network responsible for discourse processing, allowing for a more successful outcome. Our hypotheses were confirmed by the analyses of syntactic, lexical and semantic features with the use of automatic assessment. Thus, the analyses of the structure of discourse production can also be adopted as an indicator of cognitive performance, distinguishing cognitively impaired groups (such as in AD) from healthy elderly groups, and groups with varying educational levels.

Future directions

In this thesis, we attempted to fill two gaps found in the literature. One of the gaps is the lack of studies on the impact of AD on linguistic features related to narrative recall performance. This is an important area to be investigated, as discourse reproduction is as important as discourse production for social communication. The other gap is the lack of studies on the impact of education and reading and writing habits, factors known to assist in the establishment of cognitive reserve, on performance on narrative recall tasks. We also assessed the accuracy of automatic linguistic analysis for distinguishing individuals with different cognitive profiles. Our results indicate that aspects that affect cognitive processing both positively and negatively impact roughly the same aspects of discourse. For future studies, we suggest a comparison of results on narrative recall with results from other discourse tasks, such as picture description and interviews, to fully map discourse performance in healthy aging and in AD. We also suggest a correlation with memory performance, to investigate the types of memory associated with each linguistic feature.

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