

## Language Impairment in English-Speaking Patients with Alzheimer's Disease: A Role and Reference Grammar Contribution

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The linguistic aspects of Alzheimer's disease have received much less attention from qualitative viewpoints than from quantitative research perspectives. For this reason, the present article proposes the application of the linking algorithm provided by Role and Reference Grammar (RRG) to a corpus from English-speaking patients with Alzheimer's, namely the Pitt corpus. A sample of verb predicates from this corpus has been analyzed according to the steps provided by the grammar. Thus, the aims of this article are, on the one hand, to identify and describe the linguistic deficits found in the early stage of Alzheimer's disease and, on the other, to show the feasibility of this grammar in the description and possible early diagnosis of this neuro-degenerative disease. The results manifest a greater proportion of simple sentences with respect to coordinate, cosubordinate and subordinate sentences, as well as compensation strategies and problems with lexical retrieval.

Keywords: language impairment; Alzheimer's disease; Pitt corpus; Role and Reference Grammar; linking algorithm

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### El déficit lingüístico en pacientes anglohablantes con la enfermedad de Alzheimer. Una contribución desde la Gramática del Papel y la Referencia

Los aspectos lingüísticos de la enfermedad de Alzheimer han recibido mucha menos atención desde perspectivas cualitativas que desde investigaciones cuantitativas. Por ello, el presente

artículo propone la aplicación del algoritmo de enlace expuesto en la Gramática del Papel y la Referencia a un corpus de pacientes anglohablantes con Alzheimer; en concreto, utilizaremos el corpus Pitt. Analizaremos una muestra de los predicados verbales del corpus ateniéndonos a los pasos descritos en esta gramática. Así, los objetivos del artículo son, por un lado, identificar y describir los déficits lingüísticos de la primera etapa de la enfermedad y, por otro, demostrar la viabilidad de esta gramática en la descripción y el posible diagnóstico temprano de esta enfermedad neurodegenerativa. Los resultados indican una mayor proporción de oraciones simples respecto a oraciones coordinadas, cosubordinadas y subordinadas, así como estrategias de compensación y problemas de acceso léxico.

Palabras clave: déficit lingüístico; enfermedad de Alzheimer; corpus Pitt; Gramática del Papel y la Referencia; algoritmo de enlace

## 1. INTRODUCTION

Linguistics has permeated into other research fields, providing insight in areas such as political discourse (Fairclough and Fairclough 2012), education (Holme 2009), computer science (Manning 2015) and medicine (McAllister and Miller 2013). In this latter sense, clinical linguistics is the subarea of language science that analyzes and describes language disabilities in clinical environments (Crystal 1981, 1). In most studies in clinical linguistics, phonetics and phonology have received the greatest attention (Perkins 2011, 924-25). This has led Gallardo Paúls and Valles González (2008, 38) to demonstrate that there are studies that do not account for syntactic and semantic descriptions with respect to the deficits experienced by patients, only a phonological perspective. However, clinical linguistics is an essential component of linguistic research, for it provides tools to improve the living standard of patients (Gallardo Paúls and Valles González 2008, 47).

Alzheimer's disease is deemed the most common type of dementia in the world, accounting for roughly 70% of cases in people between 60 and 85 years old (World Health Organization; WHO 2021), and it affects women in a higher proportion (Martinkova et al. 2021). Furthermore, this disease is characterized by a gradual loss of cognitive functions, including language, as well as psychiatric disorders and difficulties in daily-life activities (Burns and Iliffe 2009, 467). Language impairment is generally present in all three stages of the disease: a) the pre-clinical or early stage; b) the intermediate stage; and c) the advanced, or late, stage (Zvěřová 2019, 5; WHO 2021). The most common symptoms start before diagnosis, and present as memory loss and disorientation, with more severe impacts seen in the late stage, where physical and social independence may be virtually non-existent (WHO 2021).

Despite the number of quantitative studies dealing with cognitive and linguistic deficits associated with Alzheimer's disease (Visch-Brink et al. 2004; Bäckman et al. 2005; Weiner et al. 2008; Guerrero et al. 2015), this article considers those studies

that have explored these impairments from a qualitative perspective (Malagón et al. 2005; Gayraud et al. 2011; Grasso et al. 2011; Rodríguez-Rojo et al. 2015; Pistono et al. 2018). Regarding recent investigations on Alzheimer's disease through linguistic means, most proposals stem from natural language processing by applying language models, machine learning or context-free grammars (Orimaye et al. 2014; Fraser et al. 2016; Eyigoz et al. 2020; Clarke et al. 2021). Those which fall within linguistic theories have been centered on Generative Grammar (Fyndanis et al. 2013), although other models are also found, such as propositional analysis, based on Case Grammar (King 2012) or Systemic Functional Grammar (Zhu and Huang 2020). Thus, we consider that the analysis of language in patients with Alzheimer's disease by means of theoretical linguistics may provide more depth to the detection and diagnosis of this disease, in the same line as Szatloczki et al. (2015). This research direction is based on the scarcity of linguistic theory within computational perspectives, an approach which allows the description and analysis of language deficits in these patients.

In this article we will follow a functionalist approach using the tools provided by Role and Reference Grammar (RRG) (Van Valin and LaPolla 1997; Van Valin 2005). This grammar combines a certain degree of syntactic and semantic formalization, including the pragmatic content, and is thus an appropriate model with which to study the disease. To date, however, this grammar has not been used in clinical environments in the English language (see Suárez-Rodríguez 2021, 2022). In this work, these tools will be applied to a corpus of transcriptions of English-speaking patients with Alzheimer's disease, namely the Pitt corpus (Becker et al. 1994). The aims of this study are, therefore, to provide a qualitative viewpoint within linguistic research on Alzheimer's, especially in the early stage, and to show that this grammar can be used for the description and possible early diagnosis of the linguistic deficits in such patients. As such, our aim is not to prove that there is an impairment in language production and comprehension, but to try to describe it by using the tools of RRG. To do so, we must first identify the types of verbs present and how they are distributed through the sample. However, providing an explanation for this distribution and frequency of *Aktionsarten* in the sample will be part of a future study.

The paper is structured as follows. In section 2, we briefly describe the theoretical background of RRG. In section 3, we present the corpus and, in section 4, we explain the methodology followed in the analysis of the sentences from the corpus with this grammar. Section 5 shows the analysis of samples of sentences using the method and the discussion of the results. In section 6, conclusions are presented.

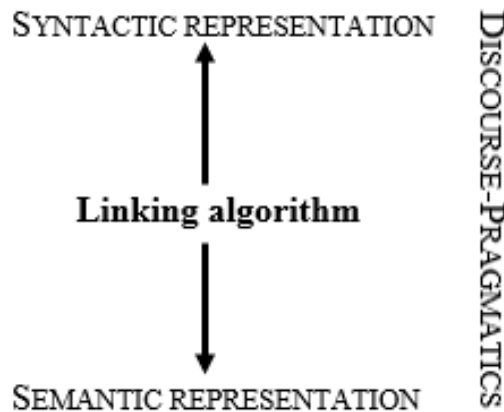
## 2. A BRIEF ACCOUNT OF ROLE AND REFERENCE GRAMMAR

RRG (Van Valin and LaPolla 1997; Van Valin 2005) is located within the functionalist approach in linguistic theory, as it considers language to be a system of communicative social action. This grammar is built on attempting to answer two questions:

- 1) How would linguistic analysis be realized from the perspective of languages such as Dyirbal or Lakhota rather than English or Spanish?
- 2) How can we encapsulate and explicate the syntax, semantics and pragmatics of grammatically distinct languages (Van Valin 2005, 1)?

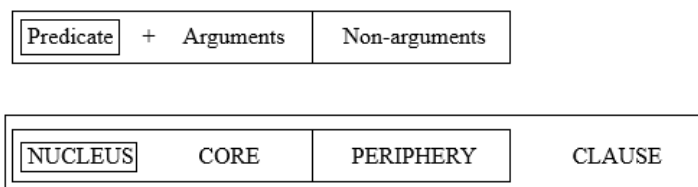
The first question accounts for the typological nature of RRG, whereas the second one is answered by means of the connection of the three linguistic elements—syntax, semantics and pragmatics—following three representations—respectively, syntactic structure, semantic content and sentence information. Furthermore, syntax and semantics are connected by a linking algorithm, which allows us to move from one representation to the other (figure 1).

FIGURE 1. General Structure of RRG (adapted from Van Valin 2005, 2)



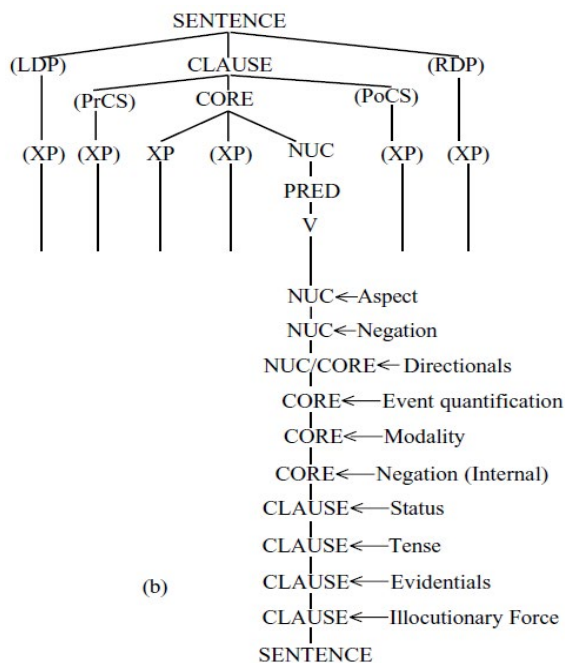
Syntactic representation in RRG is not based on abstract derivations, but rather on a sole level of analysis where syntax, semantics and pragmatics are represented. To avoid *ad hoc* explications of language differences, RRG postulates the layered structure of the clause, where syntactic units are defined semantically (Van Valin 2005, 4). This implies that there is no linear dominance and that the order of elements is language-specific (Van Valin 2005, 5). Thus, the clause is semantically built on the predicate and its arguments and non-arguments, i.e., adjuncts (Pavey 2010, 53). Syntactically, the NUCLEUS is realized as a predicate, which does not necessarily have to be verbal, and can also be adjectival or nominal (Van Valin 2005, 28); along with its arguments, this predicate constitutes the CORE, whereas the non-arguments form the PERIPHERY. Figure 2 shows how the syntax of simple sentences is conceptualized in RRG.

FIGURE 2. Representation of the Layered Structure of the Clause (adapted from Van Valin 2005, 4)



These syntactic units in the layered structure of the clause are represented by a constituent projection, which also contains other language-specific, pragmatically motivated positions: the pre- and post-core slots (PrCS and PoCS) and the left- and right-detached positions (LDP and RDP). Moreover, features like tense, negation, aspect and illocutionary force are considered operators in RRG and are thus represented in a different projection connected through the NUCLEUS (Van Valin 2005, 12). As figure 3 shows, there are three types of operators, depending on the level they affect—nuclear, core and clause operators—and only negation is to be found in all three levels (Van Valin 2005, 9).

FIGURE 3. Layered Structure of the Clause with Constituent and Operator Projections (adapted from Van Valin 2005, 12)



Because RRG does not assume a derivational approach to syntax, it posits the usage of syntactic templates, which are stored in a syntactic inventory. These templates are language specific and must comply with the *selection principle*, i.e., the number of semantic arguments must be equal to the number of syntactic arguments (Van Valin 2005, 130). In this way, the syntactic content in RRG is specific to each language, as opposed to the semantic content, which is universal, i.e., it may be applied to any language of the world (Van Valin 2005, 128).

In complex sentences, apart from coordination and subordination, which are the traditional types of nexus relations, RRG posits the usage of cosubordination (Van Valin 2005, 187; Van Valin 2021), which is considered a half-way point between coordination and subordination, as in *Sam sat playing the piano* (Van Valin 2005, 198). In doing so, RRG also includes three types of junctures which refer to “the nature of [syntactic] units being linked” (Van Valin 2005, 188): a) *nuclear junctures* contain several nuclei within a single core, as in *Kim painted the table red* (taken from Van Valin 2005, 190); b) *core junctures* contain several cores under a single clause (e.g., *Chris forced Diana to leave the party*, Van Valin 2005, 188); and, c) *clause junctures* contain several clauses under a single sentence, as in the example *Dana jogged through the park, and Kim waved to him* (Van Valin 2005, 228).

As for the semantic content, RRG bases it on the semantic representation of predicates, which are typically—but not exclusively—verbs, and this lexical representation requires a theory of verb classes (Van Valin 2005, 31). Consequently, RRG utilizes Vendler’s (1957) classification of *Aktionsart* or lexical aspect, which distinguishes states, activities, accomplishments and achievements, and at the same time RRG modifies the representational schema presented in Dowty (1979). Moreover, RRG adds semelfactives to its verb classes (Comrie 1976; Smith 1997), as well as active accomplishments (Van Valin and LaPolla 1997, 100; Van Valin 2005, 32). In doing so, we obtain six types of verb classes and their causative counterparts. These verb classes are defined according to four semantic features: [ $\pm$ static], [ $\pm$ dynamic], [ $\pm$ telic] and [ $\pm$ punctual].<sup>1</sup> To obtain the *Aktionsart* of each verbal predicate, RRG provides eight tests that, although far from perfect, when applied sequentially help to distinguish the verb classes by using the previous semantic features, as well as their causative counterparts (Van Valin 2005, 40). An explication and discussion of these tests can be found in Van Valin and LaPolla (1997, 93-97), Van Valin (2005, 35-41) and Cortés Rodríguez et al. (2012, 62-65).

This classification helps to formalize meaning in the form of logical structures, which are taken from formal semantics (Van Valin and LaPolla 1997, 102). In this way, each *Aktionsart* can be assigned one logical structure, so that predicates are viewed as constants, represented as bold face followed by a prime (**pred'**), and the arguments of the predicate are represented by variables ( $x, y, z...$ ); in the case of an unknown

<sup>1</sup> For a detailed description of this classification, see Van Valin and LaPolla (1997, 82-128) and Van Valin (2005, 31-49).

or underspecified argument, the symbol “ $\emptyset$ ,” for an empty set, is used (Pavey 2010, 114). The basic logical structures are states and activities, and the rest are derived from them by means of uppercase operators (BECOME, INGR, SEML, CAUSE). For instance, Van Valin (2005, 45) provides the sentence *The dog died*, which would be transcribed as BECOME **dead'** (x = dog). Notice that this semantic metalanguage is universal, despite the constants and operators being written in English (Van Valin 2005, 45). Furthermore, dynamicity is represented in the logical structures by means of **do'**, as in *The cat popped the balloon* in Pavey (2010, 114), transcribed as [**do'** (cat,  $\emptyset$ )] CAUSE [INGR **popped'** (balloon)], where the second argument of **do'** is unknown. The following examples of logical structures are taken from Van Valin (2005, 46-47):

## 1) State:

Pat is a fool. **be'** (Pat, [**fool'**])

## 2) Activity:

The children cry. **do'** (children, [**cry'** (children)])

## 3) Achievement:

The window shattered. INGR **shattered'** (window)

## 4) Semelfactive:

Mary coughed. SEML **do'** (Mary, [**cough'** (Mary)])

## 5) Accomplishment:

The snow melted. BECOME **melted'** (snow)

## 6) Active accomplishment:

Chris ran to the park. **do'** (Chris, [**run'** (Chris)]) & INGR **be-at'** (park, Chris)

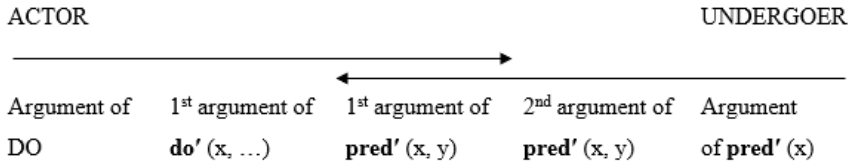
## 7) Causative:

Felix bounced the ball. [**do'** (Felix,  $\emptyset$ )] CAUSE [**do'** (ball, [**bounce'** (ball)])]

Each logical structure must be assigned at least one of the two semantic macroroles considered in RRG to generalize the traditional semantic roles: *actor* generalizes roles such as agent, experiencer, instrument, etc., whereas *undergoer* generalizes roles such as patient, theme, recipient, etc. (Van Valin 2005, 53; Van Valin 2006, 270-71). These macroroles are assigned following a hierarchy (see figure 4), where the first arguments of dynamic predicates receive the actor macrorole and the first arguments of stative predicates receive the undergoer macrorole (Van Valin 2005, 60; Van Valin 2006, 270-71). The direction of arrows indicates a decreasing realization of macroroles. Apart from this hierarchy, RRG propounds an assignment principle, where a) the number of

macroroles is less than or equal to the number of arguments in the logical structure (two macroroles for verbs with more than one argument; one macrorole for verbs with only one argument); and b) in one-argument verbs, if it is an activity verb, the macrorole is actor; otherwise, the macrorole is undergoer (Van Valin 2005, 63; 2006, 270-71).

FIGURE 4. Assignment Hierarchy of Macroroles (taken from Van Valin 2005, 61)



Lastly, RRG is best recognized for its linking algorithm: a series of sequential steps that connect the syntactic content and the semantic content of sentences or utterances (Van Valin and LaPolla 1997, 317-18; Van Valin 2005, 129). It is a bidirectional connection, and it allows connections to be made between language production and language comprehension (Van Valin 2005, 129). In a similar fashion to syntactic templates, the linking algorithm must obey a “completeness constraint” whereby the number of syntactic arguments must be equal to the number of semantic arguments (Van Valin 2005, 129-30; Van Valin 2006, 273-74). One important aspect is the identification of the privileged syntactic argument (PSA), which generalizes the syntactic subject.<sup>2</sup> The selection of the PSA is similar to the Actor-Undergoer Hierarchy shown in figure 4 and it can be stated as follows (adapted from Van Valin 2005, 100):

arg. of DO > 1<sup>st</sup> arg. of do' > 1<sup>st</sup> arg. of pred' (x, y) > 2<sup>nd</sup> arg. of pred' (x, y) > arg. of pred'

where the left-most argument is the highest-ranking argument and, therefore, the default choice for PSA.

Below we offer a simplified version of both parts of the algorithm.<sup>3</sup>

A) Linking algorithm: semantics → syntax (language production)

1. Construct the semantic representation (logical structures).
2. Assign macroroles according to hierarchy.
3. Determine the morpho-syntactic codification of arguments (PSA, grammatical case, agreement).
4. Select suitable syntactic templates.
5. Assign arguments to syntactic positions.

<sup>2</sup> A further explanation is provided in Van Valin (2005, 94-107).

<sup>3</sup> For the specificities of the linking algorithm, see Van Valin and LaPolla (1997, 623-26) and Van Valin (2005, 279-81).



B) Linking algorithm: syntax → semantics (language comprehension)

1. Determine the macroroles and other core arguments.
2. Assign the macroroles to the logical structure, according to hierarchy.
3. Link the core arguments from 1 and 2.
4. In non-subordinate core junctures, link the arguments of the main core with argument positions of the subordinate logical structure.
5. Assign the adjuncts to the periphery (core or clause) in the logical structure.
6. If they exist, assign the elements of the pre- or post-core positions.

### 3. THE PITT CORPUS

From 1983 to 1988, the Alzheimer Research Program of the University of Pittsburgh recruited 319 volunteers, either healthy or with Alzheimer's disease (AD), "to evaluate the full spectrum of behavioral neurologic factors" in AD patients (Becker et al. 1994, 585). This study was supported by the National Institute of Aging grants AG03705 and AG05133. These people received "an extensive neuropsychiatric evaluation," as well as laboratory tests, in order to "provide a carefully screened and uniformly evaluated cohort of AD patients" (Becker et al. 1994, 586). If any patient could not understand what was being evaluated, they would be excluded. As a result, from the 319 individuals selected for study, 102 were allocated to the control group, and 204 were AD patients; thirteen people were considered *special* and were not included in the study (Becker et al. 1994, 586).

After four years, 75 patients had died, 43 of whom were diagnosed as having *definite AD* when autopsies were held; thus, the final group consisted of 181 who are "probable and definite patients with AD" (Becker et al. 1994, 586). The average age of the AD final group was 71.4, with a standard deviation of 8.3 (Becker et al. 1994, 587), i.e., there were patients closer to 60 or 80 than to 70. As expected, most patients were women: 121 out of 181, which comprises 66.85% of the group (Becker et al. 1994, 587). Moreover, patients are identified by three numbers, a dash and another number between zero and three, which signals the order of visits by researchers. For instance, 283-0 refers to the first visit to patient number 283, while 051-1 and 051-2 correspond to the second and third visits to patient 051.

In this study, the neuro-psychological evaluation was obtained through the Mini-Mental State Examination (MMSE), in which only "the cognitive aspects of mental functions" are tested, given that it is not concerned with "mood, abnormal mental experiences and the form of thinking" (Folstein et al. 1975, 189). The scale consists of two parts: a) a section that "requires vocal responses only and covers orientation, memory and attention," where the maximum score is twenty-one points; and b) another section that analyzes the "ability to name, follow verbal and written commands, write a sentence spontaneously, and copy a complex polygon" with a maximum of nine points (Folstein et al. 1975, 190); thus, the maximum score is thirty points. According to Folstein et al. (1975, 196), a total score below twenty is "found essentially only in patients

with dementia, delerium [*sic*], schizophrenia or affective disorder.” Furthermore, the Cochrane Collaboration assigns a maximum score of twenty-four points to detect cognitive problems (Creavin et al. 2016) and the Alzheimer’s Association (n.d.) establishes a score between twenty and twenty-four points to be in the early stage.

As shown in the transcriptions of the corpus, there are four tests, patients receiving a different one on each of the visits by a researcher. All patients received at least one of the four tests to assess their cognitive abilities by means of a guided interview. The first test consists of a picture of two children trying to take a cookie from a jar without their mother realizing. The second test checks the patients’ fluency by naming entities like animals or plants. The third test analyzes the degree of recall the patient has in that patients need to retell a story provided by the researcher. Finally, in the fourth test, the researcher asks the patient to create a sentence based on some given words. These tests are tagged in the corpus as “cookie,” “fluency,” “recall” and “sentence,” respectively. There are 1,047 transcriptions in the corpus, of which 309 are cookie, 238 fluency, 262 recall and 238 sentence. From the transcriptions it is also clear that not all patients speak for the same amount of time, with some patients having short transcriptions of less than 30 lines and others long transcriptions of more than 200 lines.

With respect to the results of the study, AD patients not only showed typical symptoms such as olfactory impairment or unawareness of their own memory loss, but also psychiatric symptoms such as anxiety, depression, hallucinations, phobias and paranoia (Becker et al. 1994, 588). As for language, AD patients generally scored worse than the control group on at least three tests: a) an entity name task; b) language production; and c) semantic correction. The results for these tests are shown in table 1.

TABLE 1. Results of the Study with Respect to Language (Becker et al. 1994, 590)

	Entity naming	Language production	Semantic correction
Healthy subjects	11.40 (7-12 points)	18.60 (6-29 points)	9.77 (0-10 points)
Alzheimer’s disease patients	5.95 (0-12 points)	5.82 (0-21 points)	7.48 (0-10 points)

#### 4. METHOD

Employing the MMSE scale and the classification of patients in the Pitt corpus—probable, possible, mild cognitive impairment (MCI), vascular and other—, the method we have followed to select the patients complies with the following conditions.

First, patients need to have twenty-four or less points on the MMSE scale: this guarantees that patients have, at least, mild cognitive impairment, regardless of the type of dementia or its cause. Second, as we set an upper bound, we require patients to score

more than nineteen points in the MMSE scale to make sure that individuals are not in the intermediate or late stages. These two conditions are based on the scores assigned by Folstein et al. (1975, 196), Creavin et al. (2016) and the Alzheimer's Association (n.d.). Third, to further ensure that patients are diagnosed with Alzheimer's, we will select those individuals that have been assigned the "probable AD" tag in the corpus. This last condition is set because the "possible AD" tag in the corpus is not sufficiently accurate in its diagnosis, i.e., there are patients that show signs of dementia compatible with AD, but these signs are not enough to state that patients have AD. At the same time, if patients that suffer from dementia are tagged in any other fashion (vascular, MCI or other), it does not ensure that the patient really suffers from AD, nor does it guarantee the stage at which the patient may be. In fact, there are several patients with no MMSE score, some who have a score but no tag and some who suffer from MCI, vascular or other form of cognitive impairment and score higher than twenty-five out of thirty in the MMSE scale. Therefore, we will select only those patients who have between nineteen and twenty-four points on the MMSE scale and only those who have the "probable AD" tag.

As such, then, the number of patients that we will consider based on the previous conditions is 74 AD patients out of the 181 individuals, although the number of patients vary in each test: 74 in the cookie test, 113 in the fluency test, 57 in the recall test and 51 in the sentence test. As can be observed, not all patients received the four tests and many patients have more than one visit per test, especially in the cookie test. There are patients whose score decreased when interviewed; for instance, patient 007 scored twenty on the first visit and nineteen on the second, but fifteen on the fourth—there is no record of a third visit in this case.

Since this article utilizes the RRG postulates, our analysis is based on the verbal predicate, which implies counting the predicates present in the transcriptions of these AD patients. The total number of predicates is 6,646, although the number of predicates found in each test varies: there are 2,632 predicates in the cookie test, 986 in the fluency test, 1,979 in the recall test and 1,049 in the sentence test. We will not analyze the fluency test, since it contains the lowest number of predicates due to it being a name-entity type of test where answers consist of one or a few words, mainly nouns; hence, we will consider 5,660 of the total 6,646 predicates. Besides, we will not analyze auxiliary and modal verbs, nor secondary verbs of constructions such as "have to [infinitive]" or "be about to [infinitive]," since all of them would be part of the operator projection. Idioms will not be analyzed either. Furthermore, we will not include information structure, since although it is relevant in the linguistic analysis, it is beyond the scope of this article.

In this way, the early stage contains 2,833 predicates: 1,353 predicates in the cookie test, 972 in the recall test and 508 in the sentence test. By only considering the early stage, we will be able to identify the specific impairments of these patients with respect to healthy individuals. Taking samples from each test, the number of predicates is 300, 276 and 231, respectively, which amounts to 807 predicates. These samples have been obtained by applying statistical methods to determine the minimum number of predicates

per patient to be analyzed so that the representative sample falls within a 95% confidence interval (Altman et al. 2000, 22). As a result, we needed to consider between three and four predicates per patient in each of the three tests. In cases where a patient provides less than three predicates, we have considered more predicates in the next patient.

These predicates are analyzed by applying the linking algorithm described at the end of section two. The semantics-to-syntax algorithm first requires the identification of the *Aktionsarten*, thus in the sample we find the following lexical classes: 253 states, 195 activities, 45 achievements, 10 accomplishments, 186 active accomplishments, 1 causative activity and 26 causative accomplishments. Then, in step one, we build the logical structures of each sentence. Regarding step two of the algorithm, we do not find any irregular assignment of macroroles, i.e., all macroroles align with their unmarked positions. Following steps three, four and five, we determine the privileged syntactic argument, we select the templates for each logical structure and we assign arguments to the syntactic positions. In the reverse direction, the syntax-to-semantics algorithm states that we determine the macroroles and core arguments, then assign the macroroles to the logical structure and link the core arguments (steps one to three). As for step four, we link the arguments of subordinate logical structures to the main core arguments of the non-subordinated core junctures. Then we assign the periphery adjuncts and, when needed, we assign the extra-core slots (PrCS and PoCS) and the detached elements (LDP and RDP). In figures 5-10, we provide a simplified version of the algorithm (see Van Valin 2005, 140 for a full representation) by using examples of each *Aktionsart*, where the continuous lines and arrows refer to the semantics-to-syntax algorithm and the discontinuous lines and arrows refer to the syntax-to-semantics algorithm. Figure 5 illustrates the examples of verbs *know* (state) and *do* (activity).

FIGURE 5. Linking Algorithm for the Sentence *You know what I did*

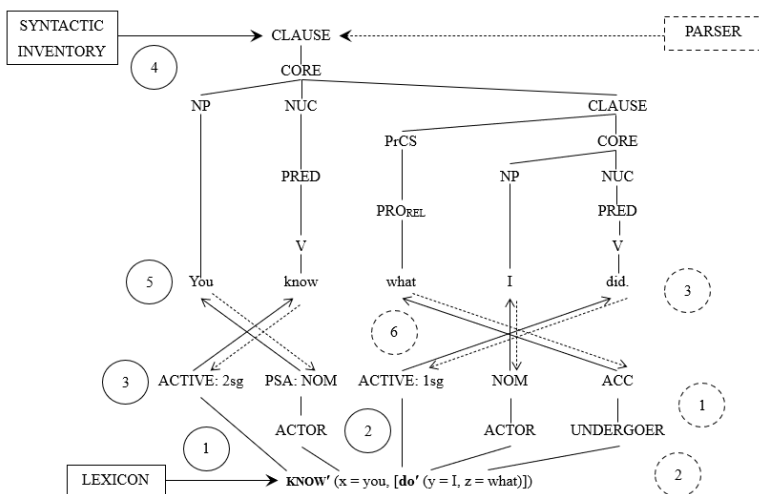
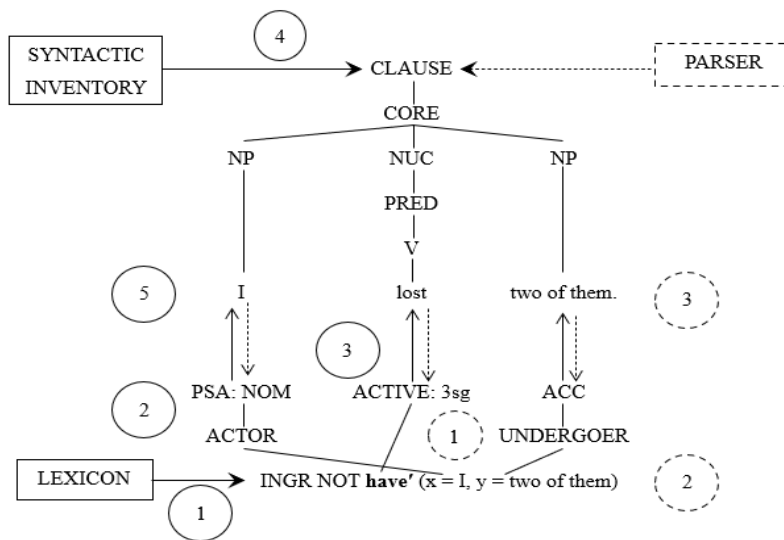


Figure 6 exemplifies the linking algorithm for a sentence that includes the verb *lose* (achievement).

FIGURE 6. Linking Algorithm for the Sentence *I lost two of them*



In figure 7, a sentence with the verb *fall down* (accomplishment) is given as an example.

FIGURE 7. Linking Algorithm for the Sentence *The stool is falling down*

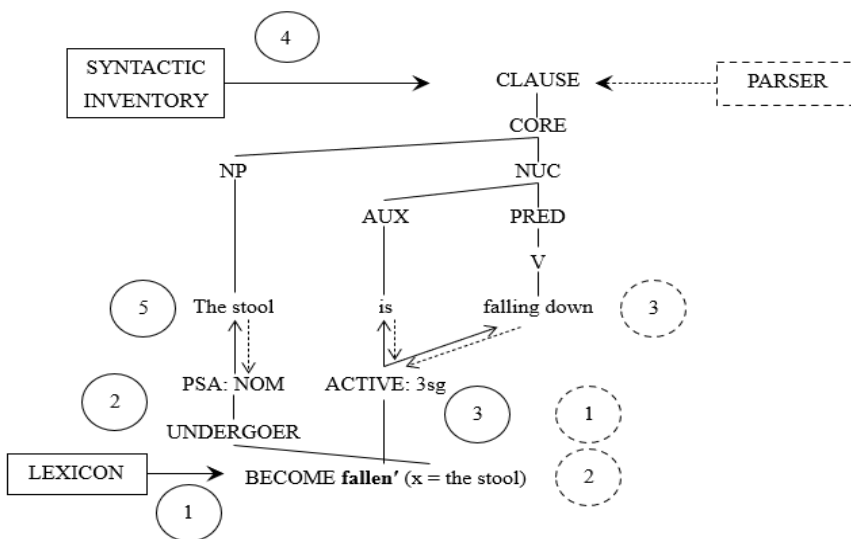


Figure 8 illustrates how an active accomplishment like the verb *go* (*to a place/somewhere*) is realized following the linking algorithm.

FIGURE 8. Linking Algorithm for the Sentence *They were going to somebody's house*

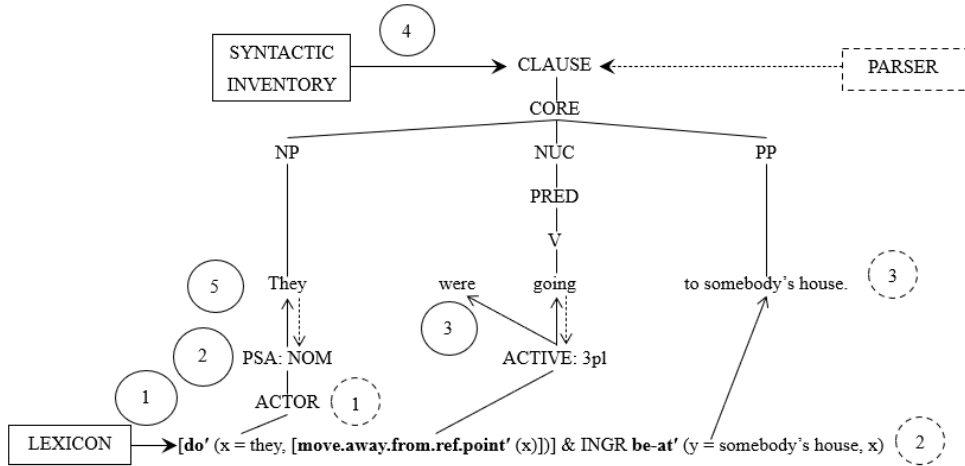
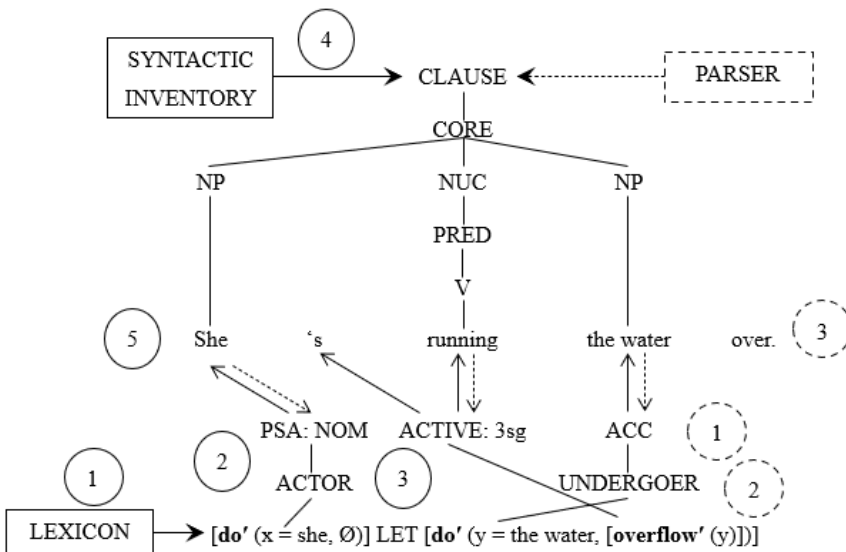
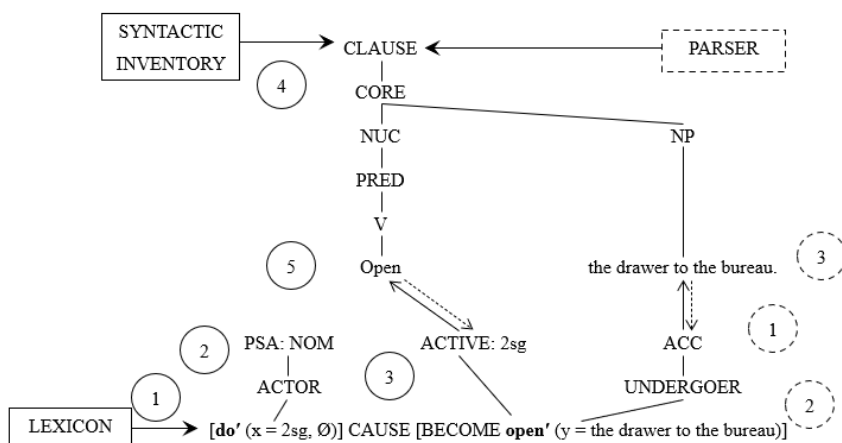


FIGURE 9. Linking Algorithm for the Sentence *She's running the water over*



Finally, in figure 10, a causative accomplishment is illustrated with the sentence containing the verb *open*.

FIGURE 10. Linking Algorithm for the Sentence *Open the drawer to the bureau*

Lastly, during the analysis of each patient's transcription in the sample, we have added some comments related to the relevant aspects we have encountered. For instance, whether the patient misuses a word, like using *chair* instead of *stool*. In some cases, patients change register and introduce contractions such as *ain't* or the transcription accounts for the literal utterance, as in *hafta*. In the next section, we provide the results of the analysis with examples of these comments.

## 5. RESULTS AND DISCUSSION

As stated before, the analyzed sample consists of 807 predicates distributed across three tests. We have applied the linking algorithm provided by RRG, which begins by identifying the *Aktionsarten*. Note that the examples and syntactic representations follow the most appropriate punctuation rules in accordance with the transcriptions in the corpus, although different meanings may arise with different punctuation. The results will be presented considering the following linguistic aspects: first, all types of verbal classes as defined by their *Aktionsarten*, then the types of sentences and junctures are identified and finally the most common linguistic anomalies. We include examples with the logical structures for each test, along with the patient's identification code. We also provide some transcriptions and syntactic representations of constituents as an illustration of the final step of the semantics-to-syntax algorithm.

As table 2 shows, states are the most frequent *Aktionsart*, followed by activities, active accomplishments, accomplishments, achievements and the causatives. In the causatives, we find one causative activity and twenty six causative accomplishments. In the cookie test, activities are the most common *Aktionsart*, but in the recall and sentence tests, states and active accomplishments are more frequent. As stated in the

introduction, the consequences of these results and potential explanations for them will be presented in a future paper.

TABLE 2. *Aktionsart* Frequency in the Sample

	State	Activity	Achiev.	Semelf.	Accomp.	Act. accomp.	Causatives
Cookie	58	87	16	0	60	58	21
Recall	127	55	21	0	24	49	0
Sentence	68	53	8	0	17	79	6
Total	253	195	45	0	101	186	27

If we look at the sentences, there are 665 in total in the three tests. Table 3 shows that most sentences are simple sentences (63.01%, examples 1, 2 and 3). Example 1 is represented in figure 11; notice the pause “&uh” in the middle of the sentence. In example 2, we use the logical structure proposed in Van Valin and LaPolla (1997, 116-18) to account for a generalized version of *verba dicendi*; we also introduce the internal variable  $\gamma$  for language, although it is not necessary.

TABLE 3. Types of Sentences in the Sample

	Simple	Coordinate	Subordinate	Cosubordinate	Juxtaposed	Total
Cookie	131	30	36	28	3	228
Recall	140	7	57	32	0	236
Sentence	148	13	24	12	4	201
Total	419	50	117	72	7	665

(1) This lady is dryin' dishes. (cookie test, 181-0)

{do' (x = this lady,  $\emptyset$ )} & INGR dried' (y = dishes)<sup>4</sup>

(2) No, I can't tell you anything. (recall test, 005-2)

do' (x = I, [express( $\alpha$ ).to.( $\beta$ ).in.language.( $\gamma$ )' (x, y = you)]), with  $\alpha$  = anything,  $\beta$  = you and  $\gamma$  = English

<sup>4</sup> These symbols are taken from formal logic and stand for the conjunction “&” (“and then,” but also two sequential states of affairs) and conjunction “^” (“and,” but also two concurrent states of affairs). Other symbols are the inclusion “ $\supset$ ” for conditional sentences and “+” for an unexpressed temporal relation between two states of affairs.



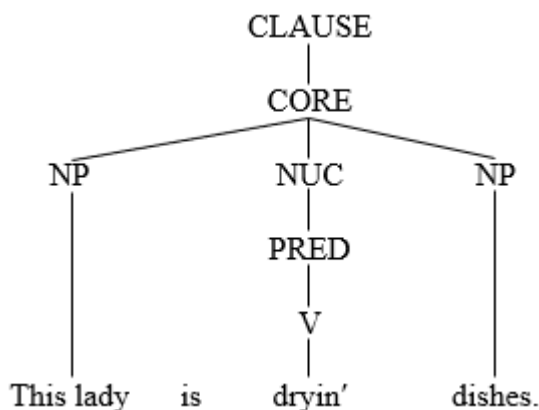
(3) My neighbor hadta take his child to the hospital. (sentence test, 010-1)

do' (x = my neighbor, [take' (x, y = his child)]) & INGR be-at' (z = the hospital, y)

The frequent use of simple sentences in this corpus may respond to the nascent cognitive impairment due to Alzheimer's disease experienced by the patients, something we describe in the introduction. The reason for this is that syntactic realizations tend to show how the desired semantic content of states of affairs is construed, and thus simple sentences are rendered as the preferred option when expressing situations or ideas. In other words, the way patients conceptualize situations or ideas determines the way they articulate sentences and, as we will see, the pragmatic content acts as an intermediary in the patients' interventions. In the case of this corpus, patients have some limitations in the sense that they cannot speak freely, since it is a guided interview and they are not allowed to digress.

FIGURE 11. Transcription and Syntactic Representation of Example 1

\*PAR: this lady is &uh *dryin(g)* [active accomplishment] dishes.



Next, we will consider subordinate sentences as they are the second most used type (17.59%). At the same time, junctures are realized at the core level, as in examples 4, 5 and 6. These three examples show the class of verbs related to propositional attitudes as part of the matrix clause. Figure 12 represents example 5.

(4) I assume she's drying a dish. (cookie test, 270-2)

BELIEVE' (x = I, [[do' (y = she, Ø)] & INGR dried' (z = a dish)])<sup>5</sup>

<sup>5</sup> Whereas "predicate" represents those verbs strictly related to its meaning (know', be', believe'...), "PREDICATE" represents those verbs related to a class of verbs (propositional attitude, reason, jussive...).

(5) You know what I did. (recall test, 212-3)

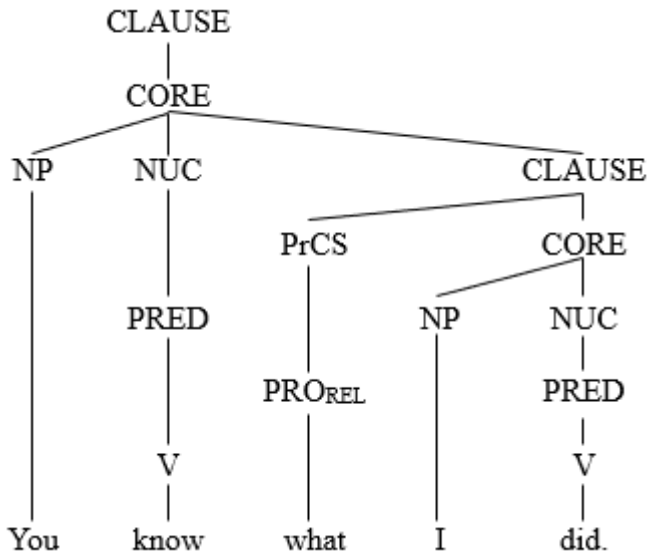
**KNOW'** (x = you, [do' (y = I, z = what)])

(6) I thought we was getting it. (sentence test, 164-1)

**BELIEVE'** (x = I, [BECOME have' (y = we, z = it)])

FIGURE 12. Transcription and syntactic representation of example 5

\*PAR: you *know* [state] what I *did* [activity]. [+ exc]



As for cosubordinate sentences, they represent 10.83%. We observe that they appear in different constituent levels, as in examples 7, 8 and 9. This is directly related to the type of juncture in use: core juncture (examples 7 and 9) or nuclear juncture (example 8). In example 7 (see figure 13), the second argument (“cookie”) lacks a definite article or the final -s required for regular plural nouns in English. In example 9, the patient confuses phonetically similar words like “ride” and “write,” which may signal difficulties in lexical retrieval.

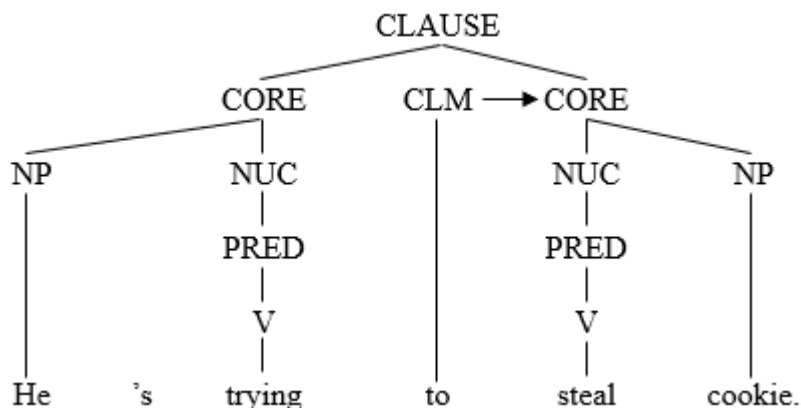
(7) He’s trying to steal cookie. (cookie test, 005-0)

**do'** (x = he, [try' (x, [[do' (x, Ø)] CAUSE [BECOME NOT have' (y = Ø, z = cookie) & BECOME have' (x, z)])]])

- (8) They went fishing. (recall test, 282-1)  
 [do' (x = they, [move.away.from.ref.point' (x)])] & [do' (x, [fish' (x)])]
- (9) I like to ride the... write with a pencil. (sentence test, 051-2)  
 do' (x = I, [write' (x)]) ^ do' (x, [use' (x, y = a pencil)])

FIGURE 13. Transcription and Syntactic Representation of Example 7

\*PAR: he's *trying* [activity] to *steal* [active accomplishment] cookie.

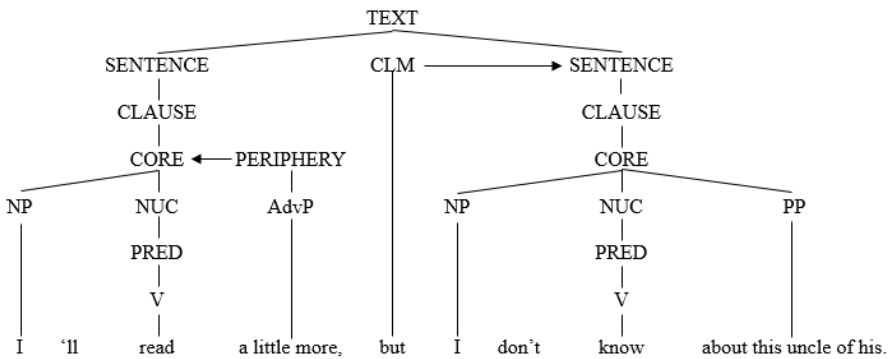


Coordinate sentences constitute 7.52% of the total, and they are all accompanied by their clause-linking markers (CLM), as are “and” and “but” in examples 10, 11 and 12. Figure 14 shows the transcription and syntactic representation of example 11. In these cases, coordination is realized at the sentence level only in example 10, examples 11 and 12 being instances of clausal coordination.

- (10) Well, he's into the cookie jar and the stool is falling down. (cookie test, 279-1)  
 [like' (x = he, y = the cookie jar)] ^ [BECOME fallen' (z = the stool)]
- (11) I'll read a little more, but I don't know about this uncle of his. (recall test, 134-1)  
 [more' (do' (x = I, [read' (x)]))] ^ [know' (x, y = about this uncle of his)]
- (12) The leaves are dropping from the tree... and they should run. (sentence test, 035-1)  
 [INGR dropped' (x = the leaves) ^ NOT be-on' (y = the tree, x)] & [do' (x, [run' (x)])]

FIGURE 14. Transcription and Syntactic Representation of Example 11

\*PAR: I'll *read* [activity] a\_little more but I don't *know* [state] about this uncle of his.



Parataxis is the least used type of sentence (examples 13, 14 and 15) and they represent 1.05% of them. In example 13, there are three cores with three nuclei (“slant,” “ready” and “topple”) as an ad-nuclear subordination of the noun phrase. In figure 15, we provide the representation of example 14. We did not find any juxtaposed sentences in the recall test.

(13)The chair slanting, ready to topple. (cookie test, 089-0)

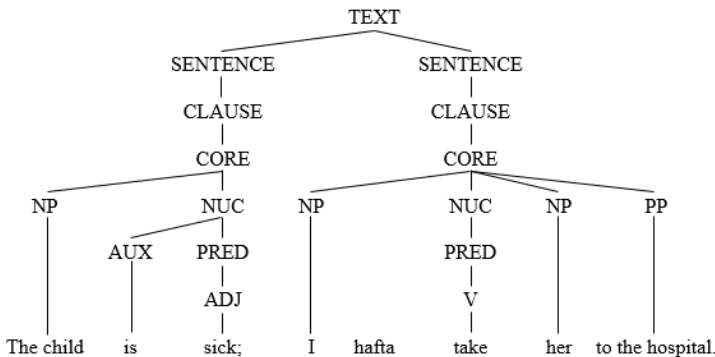
{BECOME *slanted'* (x = the chair)} ^ {INGR *fallen'* (x)}

(14)The child is sick; I hafta take her to the hospital. (sentence test, 472-0)

{*sick'* (x = the child)} & {[*do'* (y = I, [*take'* (y, x)] & INGR *be-at'* (z = the hospital, x))}

FIGURE 15. Transcription and Syntactic Representation of Example 14

\*PAR: the child is: sick, I hafta *take* [active accomplishment] her to the hospital.

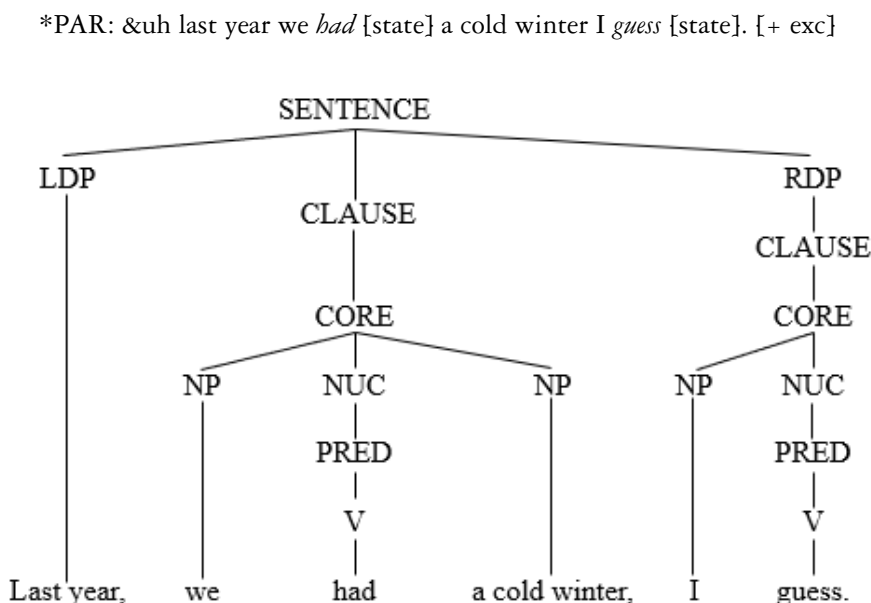


In the case of intra-clausal elements, pre-core slots appear in low numbers, mainly as direct questions (example 15) but also as subordinate sentences like in example 5 (“You know what I did”)<sup>6</sup>. Regarding extra-clausal elements, the LDPs appear as in example 10 (“Well, [...]”), although they also appear as time adverbials, such as in example 16. RDPs are less common, especially when used as simple sentences like “I think” or “I presume,” along the lines of the simple sentence in example 16 (see figure 16). We also note the use of pauses in many sentences, realized in the transcription of example 16 as “&uh” at the beginning of the sentence.

(15) What do you want here? (cookie test, 470-1)  
**here'** (**want'** (x = you, y = what))

(16) Last year, we had a cold winter, I guess. (sentence test, 357-0)  
**BELIEVE'** (z = I, [**last.year'** (**have'** (x = we, y = a cold winter))])

FIGURE 16. Transcription and Syntactic Representation of Example 16



These sentences have their extra-core slots and detached phrases within their canonical positions, i.e., pre-core slots are placed before the cores and LDP and RDP are placed either before or after the clause, with no misplacements. Likewise, peripheries are uttered

<sup>6</sup> Post-core slots are not filled in English, but they are in other verb-final languages such as Japanese (Van Valin 2005, 5-6).

in their canonical positions, since all periphery slots are placed adjacent to the modified elements, that is, they are near the appropriate constituent level and they modify it as expected. This may be due to the strict syntax of English (as compared to Spanish, for instance; see Suárez-Rodríguez 2021, 127; 2022, 166), where a slight change in the syntactic structure that is not meant as emphasis or to indicate a more formal register is quickly recognized and sometimes resolved by the patient himself or herself.

Finally, with respect to anomalies, we find many cases where patients produce pauses inside the sentences, as in the transcription of example 16. We observe as well that there are patients who use verbs in a different way than would be expected for a healthy individual (example 17) or they drop parts of the sentence such as the entire subject noun phrase or just part of a phrase, as in example 7 (“He’s trying to steal cookie”). Example 18 represents those cases where the head of a phrase or an entire argument is missing. In this case, this may signal a dependency on the context, since the task is related to a girl and a man.

(17) She’s running the water over. (cookie test, 005-2)

(18) Went to visit her grandfather. (recall test, 357-0)

In example 6, the patient utters a non-standard use of the auxiliary verb (“we was getting”). However, all these anomalies may be understood as instances of colloquial register, because they are not common among patients in the corpus. In example 19, we can observe how the definite article is not used, in a similar fashion to example 18. We also find that there are patients who utter “chair,” “ladder” or “step,” instead of “stool,” or they do not even remember the name for the object and utter “jar” instead (example 20).

(19) Little boy’s gettin’ into the cookies. (cookie test, 450-0)

(20) Wowie, the boy’s going up on a cookie jar to get cookies and he’s falling off the jar [...]. (cookie test, 010-0)

Furthermore, we observe how transcriptions record sentences where there is no agreement (example 21) or sentences that appear to make no sense (example 22).

(21) Yes, there’s a few accidents. (cookie test, 610-0)

(22) I sit in the chair and for the doctor. (sentence test, 310-0)

The most salient feature may be the semantic aspect of words. We highlight the large number of transcriptions where patients state that they do not know or remember

a word or a situation, even explicitly asking the researcher what is needed to complete the task (example 15, “What do you want here?”). Moreover, patients in the cookie test tend to confuse “stool” with “chair,” “step” or even “jar,” as in example 20. This anomaly may respond to impairments linked to Alzheimer's disease, because it is a recurring aspect in a number of patients and hence it may be the consequence of the beginning of the illness. Not only do patients confuse words of the same lexical domain, but they also use constructions like example 22, where “for the doctor” makes no sense in the sentence nor in the previous or subsequent participations in the interviews. Moreover, the use of pauses and fillers, such as that shown in the transcription of example 16, signals that patients may require more time for language processing and lexical retrieval, again as a consequence of the symptoms associated with Alzheimer's disease, demonstrating how patients tend to compensate for a lack of lexical-semantic processes with pragmatic features, such as pauses (Pistono et al. 2019, 140-41).

Lastly, and given the fact that these are guided interviews, the pragmatic content may play a greater role in the syntax-semantics interface than initially expected, especially in Alzheimer's disease. This interpretation arises from the way patients express meaning in the cookie test, the recall test and the sentence test. As stated before, what is realized syntactically may not have a one-to-one correspondence with what a patient wants to express, i.e., the semantic content, and thus they may tend to rely more on context to achieve this goal and to use compensation strategies.

## 6. CONCLUSION

We have analyzed 807 verb predicates from a sample of the Pitt corpus of patients with Alzheimer's disease by means of the linking algorithm provided by RRG. The results manifest a greater proportion of simple sentences with respect to coordinate, cosubordinate and subordinate sentences, as well as several instances where patients misuse a word or cannot remember the required word. Although syntax is mostly unimpaired, the semantic and pragmatic contents show that patients have problems with their lexical retrieval and that they compensate for this deficiency by relying on pauses and fillers.

In this paper we have aimed at describing the language production and comprehension of a sample of patients diagnosed with early-stage Alzheimer's by means of RRG. Our results suggest that this grammar may be useful as a descriptive tool in clinical linguistics, since its syntax-semantics interface may help to better account for the type of language impairment a patient experiences. Moreover, this linguistic theory may well become a way to improve the diagnosis of language-specific problems of Alzheimer's disease. The sample is restricted to patients in the early stage of the disease; more research is therefore needed regarding healthy individuals and the intermediate and advanced stages. Further investigations may also account for quantitative features or a quantitative-qualitative approach, as well as contribute to a deeper understanding of the role of information structure in reference to an early diagnosis.

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