# The comprehension of relative clauses in patients with Alzheimer's disease

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It is well known that patients affected by Alzheimer's Disease suffer from cognitive and linguistic deficits. This article briefly reviews the main symptoms of the disease, focussing mainly on language impairment. We also display the results of an experiment on the comprehension of relative clauses. A group of ten Italian speaking patients underwent a sentence-picture matching task, which included four different types of sentence; subject-verb-object simple sentences, subject relative clauses, object relative clauses, and passive object relatives (SVOs, SRs, ORs and PORs). Overall results from the experimental group displayed impairment on the comprehension of all sentence types, with an especially low performance on object relative clauses, probably as a consequence of their complex featural set.

## 1. Introduction

This article deals with the comprehension of relative clauses in elderly patients affected by Alzheimer's disease (AD). This study arises and is motivated by an interest in two separate fields of inquiry, namely: *(i)* the cognitive and linguistic deficits in patients affected by Alzheimer's disease, and *(ii)* the processing of relative clauses by different speaker profiles.

Alzheimer's disease and similar forms of dementia affect around 35.5 million elderly adults in the world, and the number is expected to increase to 115.4 million by the end of 2050, considering the rate at which the population is aging (*Rapporto Mondiale Alzheimer 2010*[1]). Accordingly, Alzheimer's disease can be considered a world health emergency. The high incidence of Alzheimer's disease appears even more dramatic if we consider the lack of effective treatments and reliable diagnostic methods. Neuropsychologists are working on the creation of accurate techniques and tests to screen for Alzheimer's disease, a diagnosis, that at present, can only be confirmed by a *post mortem* examination. To achieve this, there is a need for much more detailed descriptions of the symptoms of Alzheimer's disease, including comprehensive descriptions of the major cognitive deficits exhibited by Alzheimer's patients. This study can therefore be considered a modest contribution

[1] *Rapporto Mondiale Alzheimer 2010* is the Italian version of the original *Alzheimer's Disease International 2010*.

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to the attempts made to detect the linguistic deficits caused by Alzheimer's disease, with a specific focus on sentence processing.

This study also provides the possibility of sampling the comprehension of relative clauses in a new segment of the population (AD patients) other than those we can read about in the existing literature. Recently, researchers have been working on the acquisition and processing of relative clauses, and their experimental works lead to interesting and challenging insights regarding the syntactic configurations and movements involved in relative clauses. This study relies on the account, first formulated in Friedmann, Belletti, Rizzi (2009), of the involvement of feature set analysis in relative clause computations.

The first part of this study provides an overview of recent studies on relative clauses. A brief overview of Alzheimer's disease and its subsequent deficits then follows. In the last section, an experiment on the comprehension of relative clauses in AD patients is presented.

## 2. Relevant background on relative clauses

Relative clauses are syntactically complex structures which function as modifiers. They are implemented through an operation of abstraction starting from an internal position of the clause, to some element of the main clause to be modified. The modified element is named "head of the relative"; while the "relativization site" is the position from which the element is moved. Depending on the position from which the movement begins, namely the "relativization site", the clause can either result in a subject relative, or in an object relative.

Previous studies have already confirmed that the two different structures do not display the same degree of difficulty, with ORs being more demanding and expensive than SRs, from the computational point of view. Early data came from cross-linguistic studies on L1 acquisition. Subject relatives are readily comprehended and produced even in pre-school children, while object relatives require a few more years to be mastered.

In Friedmann, Belletti, Rizzi (2009) Hebrew speaking children under the age of five were tested on the comprehension of relative clauses through a picture and scenario-sentence matching task. While SRs were well comprehended (90% accuracy), the performance on ORs did not exceed the chance threshold (55%), a clear sign that children could not understand the latter type of configuration.

Elicitation tasks on Italian speaking children of different ages revealed a similar pattern (Utzeri 2007; Belletti, Contemori 2010). Accuracy rates vary depending on age, but SRs are already being well produced by the age of four, while a clear difficulty with ORs persists. Children tend to avoid the production of ORs by developing a variety of strategies (Belletti, Contemori 2010). They resort to verb changes, invert characters (which actually leads one to think they misunderstand the task), and most of all, they convert ORs into SRs by adopting a passive voice structure. This last strategy is particularly and increasingly adopted after the age of six, which corresponds to the age at which children master the use of passive structures in L1. What is most striking is that the very same strategy was even preferred by a group of adult speakers. Belletti and Contemori (2010) included a control group of twenty-eight adults, aged 20-28, in their study, who displayed a



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clear tendency to produce subject relatives with a passive voice in most of the trials (88%) where a target object relative was elicited. The linguistic attitude of adult speakers then allows us to reinterpret children's performances and their tendency to increasingly use passives in order to avoid ORs. We can then compare both adult and child performances and consider the latter as a progressive approach to the adult system.

Basing the discussion on this data, Belletti (2009) labelled the structure mentioned above as passive object relative. This definition refers to the use of the passive voice in an SR in order to reproduce the semantic equivalent of an OR.

If ORs are avoided, preferably through the production of PORs, we are allowed to infer that ORs demand high computational costs, which can be reduced by utilizing PORs.

The reasons for this phenomenon were explained by Belletti and Rizzi (2010), and earlier in Friedmann, Belletti, Rizzi (2009) by adopting a perspective based on the formulation of the Principle of Relativized Minimality elaborated by Rizzi (1990).

Given a configuration such as the following in (1), in which X, Z and Y represent positions characterized by abstract syntactical features, according to the Principle of Relativized Minimality (RM), a local relation between X and Y can hold only if Z does not intervene, that is to say only if Z is not a position of the same kind of X and therefore does not represent a valid candidate for the local relation:

(1) X….Z….Y

In other words, we need X and Z to carry slightly different features in order to permit a relation between Y and X, otherwise Z intervenes.

We should now try to reconsider what happens in terms of locality and features in the configuration of subject and object relative clauses. In the examples, [+N] represents the lexical restriction feature, while [+Rel] stands for the scope discourse feature able to attract the relative head.

(2) SR: Show me the dog that <the dog> is biting the cat

| X | Z | Y |
|---|---|---|
| [+N; +Rel] | <[+N; +Rel]> | [+N] |

(3) OR: Show me the dog that the cat is biting <the dog>

| X | Z | Y |
|---|---|---|
| [+N; +Rel] | [+N] | <[+N; +Rel]> |

basic adult grammar
* child grammar

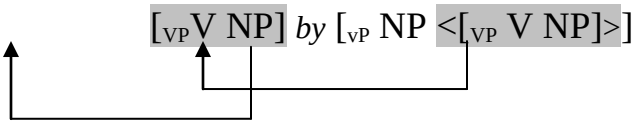


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As can be seen above, in the SR (2) the relation between the relativization site and the relative head holds, as no other element intervenes.

In the OR (3), problems arise as Z (the subject of the relative clause) shares the feature [+N] for a lexical restriction with X. The two positions then result in a relation of inclusion, in which they share a few features, except for the [+Rel] feature. Friedmann, Belletti and Rizzi (2009) claim, at this point in the analysis, that adults would be perfectly able to handle a configuration of inclusion in which two positions share a similar (yet still slightly different) set of features, while children would suffer from problems, as the analysis required to detect the difference in features is too sharp. In other words, children would apply a stricter version of the principle of RM; in their grammar the presence of a lexical restriction both in the attractor position (X) and in the potential intervener position (Z) would be problematic. Therefore children cannot properly parse ORs, as detected by tests on comprehension (Friedmann, Belletti, Rizzi, 2009) and on production (Belletti, Contemori, 2010).

PORs are the preferred option for adults speakers when ORs are elicited, and children seem to develop the same strategy as soon as passive becomes a valid and mastered option in their grammar (Belletti, Contemori, 2010). The reason for this can be explained by utilizing Collins' analysis (2005) for passive structures. According to Collins, the configuration in passive structure is realized through a *smuggling* operation, as given in (4) :

(4) 


The *smuggling* operation allows the VP-chunk (V and O-NP) to move as part of the vP, to a position higher than the one occupied by the subject (S-NP) of the matrix clause. By doing this, the original O-NP (and therefore the relativization site of the relative clause) achieves a higher position than the original S-NP, thus neutralizing the potential intervention.

Although apparently very expensive, the *smuggling* operation is actually an effective strategy as it allows the original object-NP to cross over the position of the subject-NP without triggering any potential intervention effect. When the [+Rel] operator in the main clause functions as an attractor for the adjunction of the relative clause, the O-NP is already in an optimal position, right above any other lexical element threatening intervention.

According to the theoretical and experimental data available on relative clauses, we could now set SRs, ORs and PORs along a scale of difficulty, in which SRs would be at one extreme as the easiest structure, and ORs at the other extreme as a very expensive configuration. PORs would be in between because they are easier than ORs for being a subject relative clause, yet still, to some extent demanding because of the *smuggling* operation involved.

From this perspective, the Principle of Relativized Minimality and the analysis of passive structures *à la* Collins provide a strong theoretical background to explain



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why ORs are expensive for adults and ungrammatical for children, and why PORs are the preferred alternative output.

**3. The linguistic deficit in Alzheimer's disease patients: An overview**

Alzheimer's disease is a form of senile dementia, determined by a neurodegenerative process. Causes are still unknown, however the disease is associated with the loss of neurons and the subsequent atrophy of parts of the brain. Brain damage begins within the hippocampus and the amygdala in the limbic system and then spreads to the neo-cortex. The loss of long-term memory is perhaps its most well known symptom, however daily living activities and cognitive functions are also progressively affected to the extent that the person becomes dependent.

The faculty of language is also affected by a form of fluent aphasia, with anomia being its first and most evident symptom. AD patients experience problems in comprehension and in production because of a difficulty in retrieving words and understanding their meaning. The first episodes usually occur with low frequency and semantically rich words; later, high frequency words of ordinary use are increasingly involved. The phenomenon has been deeply investigated and seems to be generated by the loss of information stored in the semantic network of our lexicon (Chertkow, Bub, 1990). The semantic knowledge impairment causes the underspecification of the meaning of words, so that once the core semantic information is lost, patients are not able to use the correlated words anymore. This hypothesis is based on the assumption of a strong correlation between *Naming* and *Knowing* (Chertkow, Bub, 1990). According to this assumption, the faculty of naming an object is based on the quantity of information the mind holds for the definition of an item. For example, to be able to name a "fork", the patient must keep in mind the core information related to the object, that is to say its function, shape, material and use. Once this kind of basic information is lost, the person is no longer able to name the item.

Taking into account Pinker's formulation (1999) of a dual system in which a declarative system and a procedural system can be distinguished as two processing mechanisms, the mental lexicon (declarative system) of AD patients suffers significant damage, unlike mental grammar (procedural system), which suffers less and remains unaffected longer. This framework was confirmed through tests on verbal morphology (Walensky et al. 2009; Colombo et al. 2009). Not surprisingly, AD patients displayed impairment when inflecting irregular verbs, as this ability is based on the mental lexicon, where irregular verbal forms are normally stored. In the same tests, the use of regular verbal morphology not only remains generally intact, however it even appears to be still productive. AD patients manage to inflect novel verbs, provided that the input can suggest that the verb belongs to a regular class verb, like the Italian verb class in *–are* (Walensky et al. 2009). This last point is particularly surprising, as it can be seen as a strong confirmation of the fact that the disease leaves the procedural aspects of processing intact (at least during the first stages, before dementia becomes severe).

One important aspect of language faculty in AD patients still remains unclear to researchers: sentence processing. As mentioned before, patients mostly display a



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form of fluent aphasia in which sentence production apparently seems unimpaired (at least in the first stages of the disease). Nevertheless, there are indications which suggest that this might not be the case. Patients clearly tend to simplify their language by overusing basic sentence structures; moreover, data on comprehension has revealed a slight impairment.

Sentence processing is known to be a very complex mechanism, which includes many components and involves a variety of extra-linguistic cognitive resources; not only are the lexical-semantic network and the syntactic parser activated, but working memory, short-term memory, processing speed, visual perception and mapping to extra-linguistic reality (to give a few examples) are required too. As a consequence, investigations in this field might be very demanding; any time a problem in production or in comprehension is detected, it has to be determined which specific part of the mechanism failed. This makes designing experiments challenging for researchers. Nevertheless, we can certainly claim that AD patients suffer from a general deficit in cognitive resources like working memory, the inhibitions of alternatives and attention span, and this inevitably affects sentence processing; furthermore, patients appear to be sensitive to different levels of grammatical difficulty.

For reasons of space, we cannot provide an extended overview of all syntactic structures and extra-linguistic cognitive resources tested so far; for the sake of illustration, in the next paragraph, we will limit our attention to the data available on the processing of relative clauses, this being our focus of interest.

## 4. Relative clauses in patients with Alzheimer's disease

Previous research on the processing of relative clauses by AD patients were mainly developed in the late 1990s. Although relative clauses were not the main focus of research in any of those studies, relatives were still introduced as a factor of grammatical difficulty. Therefore we can gather the data collected and review those aspects concerning relative clauses.

Kempler et al. (1998) test the comprehension of sentences characterized by different levels of grammatical difficulty. Through a sentence-picture matching task, they assess patients' ability to correctly process four different types of sentences; simple active sentences, simple active plus an adjunction sentences, passive sentences, and active sentences followed by a relative clause. This last condition leads to the highest number of mistakes, with accuracy of 66%, despite the 90% in simple active sentences. Authors therefore claim that patients are sensitive to the index of grammatical complexity, which would mean that their syntactic parser suffers from some kind of impairment. However, their interpretation of data could go no further than citing grammatical complexity as the main factor of comprehension failures, without exactly explaining what these consist of.

The same type of task, a sentence-picture matching task, is also used in Waters, Rochon and Caplan (1998). In this case, the authors combine three factors of grammatical complexity to manipulate sentences; the number of arguments (2 or 3), the canonicity of theta roles, and the number of verbs/propositions given in one sentence. The manipulation results in nine different types of sentences, two of



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which include a relative clause; one is of the OS type (subject relative with right-branching) and the other one is of the SO type (embedded object relative, left-branching). Both conditions are among the three which lead to the poorest outcome, as the percentage of accuracy is around 65% for OS and 55% for SO, while all other conditions have percentages of comprehension well above 80%, except for the condition in which two simple active clauses are adjunct in the same sentence. Thus, authors interpret the data by attributing the main factor of difficulty to the number of verbal phrases, in consideration of the fact that the three conditions with the lowest percentage of accuracy (two of the relative type and one with adjunction) all share the same feature: they are composed of two propositions.

Small et al. (2000) tackle the problem from a different perspective and decide to adopt a sentence repetition task. This type of task is supposed to trigger syntactic parsing as a requirement for being able to repeat the sentence; without parsing and understanding the sentence, speakers should fail in correctly repeating the input. The test includes six different types of input created by combining three factors: *(i)* canonicity of theta role assignment, *(ii)* number of propositions (sentence with/without a relative clause), and *(iii)* branching direction (left/right) for relative clauses. Canonicity in theta role assignment and right-branching seem to be the two factors which make sentences easier, while patients experience more difficulty when the input contains a non-canonical assignment of theta roles or a left-branching relative clause. Canonicity and right-branching would then lose their assistive effect whenever respectively combined with left-branching and non-canonical assignment of theta roles (So that SS are more difficult than OS sentences, and OO more than OS). Authors explain the results by adopting the Resource Capacity Theory. According to this theory, speakers have a limited amount of available cognitive resources to parse sentences. In AD patients this quantity would be reduced and therefore not sufficient to fulfil all requirements, so that when more than one factor of difficulty occurs at the same time, there is competition for those computational resources. Whenever the available cognitive resources are not sufficient, speakers fail to properly parse, remember and repeat the input.

Overall, the three studies manage to detect an impairment in the processing of relative clauses, however they all fail to give an exact description of why these types of clauses are so problematic for patients with AD. What is missing is an up to date analysis of the configurations and movements involved in relative clauses. For this reason, we utilize the background literature on relative clauses reviewed in section 2 in order to design a suitable task to test AD patients on the comprehension of relative clauses.

## 5. The experiment

The experiment samples the comprehension of several types of relative clauses by elderly patients affected by Alzheimer's disease.

A sentence-picture matching task was chosen for this purpose because of the advantages offered by this technique when used with elderly people. It makes reasonable demands on AD patients' on-going memory, trials require a short time to



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be completed, and deficits of attention and short-term memory are counterbalanced by the images provided[2].

*5.1 Participants*

The experimental group was composed of ten subjects, all referred to us by a nursing home in Siena, Italy. Patients underwent neurological and neuropsychological assessments and results showed that they met the NINCDS-ADRDA criteria for probable Alzheimer's disease. The diagnosis was made despite the absence of laboratory assessments. Exclusionary criteria included previous history of psychiatric disorders, strokes or alcoholism, and the presence of other neurodegenerative conditions such as Parkinson's disease or vascular dementia.

The group included nine women and one man, aged 73;5 - 95;2 (M=82;2).

To evaluate the severity of their cognitive dementia, patients were tested with the Mini Mental-State Examination[3] (MMSE); therefore only patients who scored above 14/30 were included in the experiment. Overall results showed patients to have a mild to severe impairment, with MMSE scores in a range between 14 and 24 (M=17,2).

Five subjects in a similar age bracket were then recruited to create a control group (CO). Participants were between 75;5 and 88;1 years old (M=81;7). Their cognitive abilities were verified with the MMSE where they achieved scores above 27/30.

Both AD and CO subjects had a poor level of education (3-5 years), except for one member in the experimental group, who had completed a higher level of education (approximately 13 years in total).

The data summarized below shows that participants with AD and those of the control group did not display significant differences in age or education. MMSE average scores are provided as well. Detailed data for each participant is reported in Appendix A.

[2] The presence of disorders of visual perception in AD has been suggested by different authors (Hodges et al. 1991; Silveri and Leggio, 1996), however the phenomenon has not been definitively confirmed so far, at least in the first stages of the disease. For this reason, in designing the experiment, we did not take into account the use of images as a relevant bias.

[3] The Mini Mental-State Examination is a test based on thirty items, created to screen for cognitive impairment. It samples functions and abilities including spatial and temporal orientation, language, memory, arithmetic and constructional apraxia. Any scores above 26 correspond to an intact cognitive system. Scores below 26 indicate very severe (<5), severe (6-9), moderate (10-20) and mild (21-25) cognitive impairment conditions.



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**Table 1: ADs in comparison to COs**

| | AD | | CO | |
|---|---|---|---|---|
| | Average | Range | Average | Range |
| **Age** | 82;2 | 73;5 - 95;2 | 81;7 | 75;7 - 88;1 |
| **Men** | 1 | - | 1 | - |
| **Women** | 9 | - | 4 | - |
| **MMSE** | 17;2 | 14 – 24 | 28,8 | 27 – 30 |
| **Education**[4] | 5 | 2;5 – 13 | 4;6 | 3;1 - 5 |

*5.2 Design and Materials*

The material used for the sentence-picture matching task were adapted from BAMBI (Friedmann, Novrogrodsky, 2002), an experiment originally designed to test the comprehension of relative clauses in young, Hebrew speaking children.

The material was then tailored in consideration of the specific characteristics of the participants to be tested; characters like a hippopotamus, a penguin and a dwarf were eliminated from the materials as, according to the experimenter and the medical commission from the nursing home, they might have proven unfamiliar to the patients. In that case, a problem of anomia could have interfered with the performance on comprehension. After the selection, fifteen paperboard cards were included in the experiment.

A total of sixty sentences were orally presented to the participants in combination with two images. The images depicted two characters involved in the same action; with the roles reversed in the second image. The participants were then requested to point to the image which corresponded to the scenario described in the sentence. Only one of the two images (the target) could precisely match the oral input, while the other one functioned as a syntactic foil, as it represented an identical action but with reversed thematic roles.

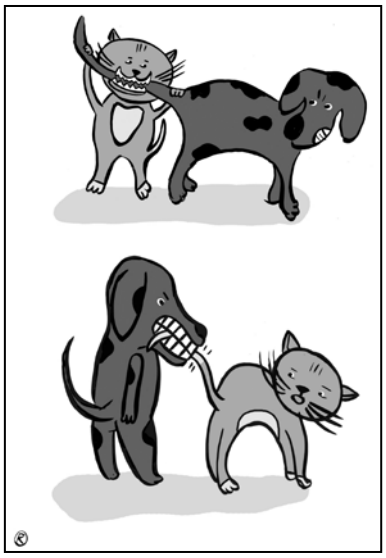
Each pair of images was presented four times in combination with four different sentences, each corresponding to a different grammatical condition. As an example, see Figure 1 below, presented in combination with the sentences in the examples (5)a to (5)d:

[4] The value refers to the number of years of formal education the participants had.



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**Fig. 1**



(5)a Il cane morde il gatto
The dog bites the cat
"The dog is biting the cat"

(5)b Mostrami il cane che morde il gatto
Show-me the dog that bites the cat
"Show me the dog that is biting the cat"

(5)c Mostrami il cane che il gatto morde
Show-me the dog that the cat bites
"Show me the dog that the cat is biting"

(5)d Mostrami il cane che è morso dal gatto
Show-me the dog that is bitten by-the cat
"Show me the dog that is bitten by the cat"

The sentence in (5)a represents the basic condition with a simple present active tense in subject-verb-object word order, which corresponds to the unmarked sentence structure in Italian. The three following conditions all include a main clause at the imperative mood ("*Mostrami*"/"Show me"), followed by a relative clause. The three conditions correspond to the three different types of relatives we have considered above. In (5)b there is a subject relative, in (5)c an object relative, and in (5)d, what has been labelled as a passive object relative (Belletti, 2009).

We would also like to underline that the introductory sentence ("Show me…") had the function of frequently reminding the patients the nature of the task to be fulfilled. Concerning sentences like (5)a, we decided they should be presented without any introductory pattern to sound as natural as possible. Indeed, the use of an explicit request to point to the correct target picture would have considerably



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changed the grammatical structure of the condition, or would have made it sound less natural. In this condition, subjects were nevertheless expected to be able to complete the task, thanks to its repetition.

As mentioned before, each pair of images (as the one given in Fig.1) was presented four times during the experimental section, in alternated combinations with one of the four sentence types as in the example (5)a to (5)d. This resulted in a total number of sixty trials, which were randomized and divided into four blocks of fifteen. The random order was then revised so that each couple of pictures was presented only once per block and the sentence types were equally distributed throughout the blocks, which resulted in a variable number of three to four sentences per type in each block (see Appendix B for more examples).

There was no correlation between the target picture and its position on the page, so the target could consecutively appear in the same position on the page more than twice. However, the same sentence type was never presented more than twice in a row.

Each block was preceded by a training trial, which was not included in the analysis of the results.

*5.3 Procedure*

AD patients were tested at the nursing home where they were living. A few measures were taken to prevent them from feeling under pressure or uncomfortable. A quiet room in a silent area was chosen as the location for the experiment. Experiment sessions usually took place in the morning, based on the recommendations of the medical staff, as this is the time of the day in which patients seem to suffer from behavioural fluctuation less. Tests were usually performed by the experimenter with the presence of a person familiar to the patients (usually a member of the nursing staff), for the same reasons described above.

All patients managed to complete the four blocks in one section, with a single five minute break between the second and the third block. Additional breaks were allowed any time a patient asked for one or showed evident signs of attention deficit.

Subjects from the control group were interviewed at their private home. In this case, the session started with the MMSE test to verify their cognitive abilities were intact, as a binding requirement to enter the control group.

Regarding patients, their MMSE scores were provided by the medical staff at the nursing home, according to the results obtained during the latest neuropsychological assessment[5].

All tests were conducted by the same experimenter, who was responsible for presenting the oral input in combination with the images and for taking note of the patients' performance. Upon participants' request, the input sentences could be repeated up to a maximum of two times. After that, further requests for repetition were allowed, however the trial was classified as failed, even in the event of a correct answer. In case of incertitude, the subject was kindly invited to move on to the following trial. No feedback was given about the accuracy of the answers.

[5] In case the available data referred back to a period of time two months previous, the assessment was repeated, to obtain an up to date evaluation.



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Except for instructions on the task, no information or explanation about the experiment or its goal were provided at the beginning. Any other question was answered at the end of the session.

*5.4 Results*

All participants managed to comprehend and complete the task.

After the editing process described in 5.2, all the remaining characters depicted in the images were recognizable and familiar to the subjects. Nevertheless, one of the pictures still caused misunderstandings among the participants. This was the image with a young girl and a monkey involved in an embrace. A few subjects needed to carefully analyze the images before being able to answer; others commented that the two images could equally match to the sentence because in both images the girl and the monkey were embracing each other, while others admitted they could not provide an answer in spite of understanding the meaning of the sentence, as they could not distinguish the difference between the two images. Not surprisingly, the comprehension of the matched sentences was very poor, with a high percentage of incorrect answers in all four conditions. Thus, the corresponding trials were omitted from the analysis.

All participants managed to complete the experiment in one single session; only patient G.B. repeated the test twice. During the first appointment G.B. appeared to be in a more severe confused mental state than was expected based on her MMSE score (21.4). Indeed, after completing the task, her glycaemia was checked and abnormal values were detected. The performance could therefore not be considered representative of the patient's skills and we decided to repeat the test the following week. On that second occasion, the patient appeared calm and lucid and showed no memory of having attempted the same task before, therefore the experiment was repeated. The second performance though, presented other peculiarities; the percentage of correct answers showed considerable differences in comparison with all other participants. ORs were well mastered (correct comprehension of twelve sentences out of fifteen), unlike SVOs (8/15), SRs (9/15) and, with the lowest results, PORs (7/15). As no other participant (neither in the experimental nor in the control group) showed a similar pattern and in consideration of the exceptional situation already associated with the subject, we decided to exclude the data of patient G.B. from our discussion.

The table below summarizes the performances of our patients for each type of clause; the scores correspond to the number of correct answers per type out of fourteen[6]. In the last two columns, the total number of correct answers and their counter value in percentage are given.

[6] The total number of trials per type of sentence is now fourteen, as we excluded trials corresponding to the image of a girl and a monkey embracing each other for the reasons described above.



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**Table 2: Results of the experimental group (AD).**

| | Correct answers per sentence type (AD) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | B. M. | Be. I. | Bi. I. | B. L. | P. M. | S. R. | S. E. | V. C. | Z. A. | Total | % |
| **SVO** | 8 | 11 | 10 | 12 | 14 | 14 | 12 | 14 | 14 | 109/126 | 86.50% |
| **SR** | 6 | 12 | 13 | 11 | 9 | 13 | 12 | 13 | 14 | 103/126 | 81.70% |
| **OR** | 7 | 5 | 7 | 5 | 9 | 11 | 10 | 12 | 6 | 72/126 | 57.10% |
| **POR** | 7 | 9 | 10 | 12 | 9 | 13 | 12 | 13 | 12 | 97/126 | 77.00% |

The results gathered from the control group are reported in Table 3. As this group was composed of five members, seventy trials were performed by the group per sentence type in total.

**Table 3: Results of the control group (CO).**

| | Correct answers per sentence type (CO) | | | | | | |
|---|---|---|---|---|---|---|---|
| | C. L. | F. G. | F. M . | M. C. | Z. S. | Total | **%** |
| **SVO** | 14 | 14 | 14 | 14 | 14 | 70/70 | 100% |
| **SR** | 14 | 14 | 14 | 13 | 14 | 69/70 | 98.60% |
| **OR** | 14 | 13 | 13 | 12 | 13 | 66/70 | 94.30% |
| **POR** | 14 | 13 | 13 | 14 | 14 | 68/70 | 97.10% |

We would now like to compare the results from the AD and the CO groups, by considering the percentages of accuracy per sentence type in the two groups (Table 4); the data is also illustrated in a graph (Figure 2).

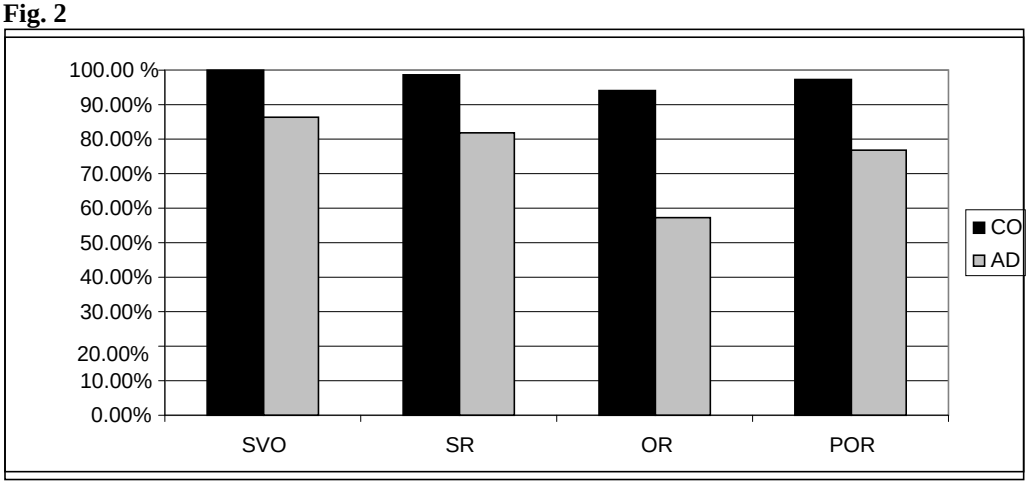
**Table 4: Performance of AD and CO in comparison.**

| | **AD** | **CO** |
|---|---|---|
| **SVO** | 86.50% | 100 % |
| **SR** | 81.70% | 98.60% |
| **OR** | 57.10% | 94.30% |
| **POR** | 77.00% | 97.10% |



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**Fig. 2**




*5.6 Discussion*

Overall, subjects in the control group displayed a proficient comprehension of all four types of sentences; performances were not above the ceiling, and a low percentage of mistakes were reported, which means the task was not completely undemanding, however, it was still suitable to the cognitive and linguistic skills of elderly adult speakers in the selected age range.

In the results of the control group, the SVO condition displayed the highest percentage of accuracy (100%), which means that all SVO sentences were correctly interpreted and matched to the target image. A few mistakes occurred in the SR and POR conditions, while ORs registered the lowest performance, as comprehension only reached 94.3%. In the control group, OR is the condition with the highest number of inaccuracies, which probably reflects how expensive this kind of clause is in terms of computation, for the reasons described in section 2. Currently, there is no available data on the comprehension of ORs by young adults, however the clear tendency to avoid the production of ORs in elicitation tasks, seems to correlate to data from comprehension in elderly people.

Results from the control group confirm that the task was reasonable and adequate for a population segment of elderly adult people. Therefore, we may suggest that the different and overall lower performance detected in AD patients as a group compared to the control group can be reasonably considered as a product of the neurodegenerative disease and its subsequent cognitive deficit, rather than an effect of normal aging.

All subjects in the experimental group managed to understand and fulfil the task throughout the complete session, however results showed considerable differences among the four sentence types, which means patients were sensitive to the grammatical manipulation we introduced. If we had found similar low levels in all conditions, several hypotheses could have been made (patients did not understand the task, the lexicon was unfamiliar, the pictures lead to misunderstanding); however, this was not the case, because differences in



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comprehension of the four sentence types clearly reflects an altered parser, challenged by syntactic complexity.

As expected, the performance of our patients was best on SVO sentences, with 86.5% accuracy; SRs, PORs and ORs follow in this order. SVOs, SRs and PORs are clearly understood above chance level results, with results all higher than 75%, which reveals the comprehension skills of AD patients to be weaker, yet still comparable to those displayed by the control group.

The theoretical and experimental backgrounds we outlined above can now suggest an explanation for the current data from the performance of AD patients. SVO sentences reproduce the unmarked subject-verb-object word order, do not require any specific movement, and can therefore be considered inexpensive configurations. Indeed, SVOs were successfully comprehended. The control group did not have any difficulties with them, and AD patients seemed to be able to cope with them as well, although with a lower degree of accuracy (86.5%).

Subject relatives immediately follow in the rank of comprehension; this is probably due to the A' movement they require to move the subject of the relative clause to the main clause. This movement does not entail any violation of the Relativized Minimality theory as it does not cross over any other lexical element, however it still displays a more complex structure than the simple SVO sentence.

POR sentences are structurally similar to SRs, as they are based on a subject relative clause, however their computational cost is increased by a *smuggling* movement, which is required to facilitate a passive voice structure.

The data which stood out the most regards the comprehension of OR clauses. This condition is the most challenging for our patients, who indeed achieved chance level scores. While SVOs, SRs and PORs are all within a 10 point range (86.5% to 77.1%) and are well above chance level, OR results (57.1%) are 20 points lower than POR results.

The considerable gap between PORs and ORs (on average around 20 points), can be explained by considering the data collected from adult speakers reacting to elicitation tasks. According to Belletti and Contemori (2010), most adult speakers tend to avoid the production of OR clauses and prefer to adopt passive object relatives as a semantic equivalent, yet less expensive, alternative. This point was confirmed in the performance of young speakers; children gradually conform to adult behaviour as soon as they master the use of the passive (Belletti 2009). *Smuggling* clearly appears to be easier and less expensive than the A' movement required in ORs. For these reasons PORs are preferred whenever available as a valid, semantically equivalent alternative. We suggest that the syntactic parser of patients with AD could be able to bear the cost of *smuggling* to compute sentences in a passive voice, while this is not the case when it comes to computing ORs. The computation of a configuration which involves a movement across a position similar in features to the target position would generate an effect of locality violation in AD patients, who would then not be able to conduct a detailed analysis of the features involved and their configuration.

The computational system of our patients seems much more similar to the one detected in children during L1 acquisition, rather than to an adult system. In Belletti (2012), children under the age of seven correctly interpreted 64% of OR clauses and



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79% of sentences with a POR structure, while our patients scored 57% and 77%, respectively. The percentage of accuracy in comparable materials in the two groups is therefore almost equivalent. We hypothesize that patients affected by Alzheimer's disease could suffer from a weaker parser, and consequently could be forced to restrict themselves to a simpler system, similar to the one adopted by children.

According to Grillo (2009), aphasic patients also experience feature set misinterpretations, when challenged with configurations that require a detailed feature analysis, like OR clauses, for example. Grillo hypothesizes that aphasic patients suffer from reduced cognitive resources, which would make their syntactic parser weaker and unable to give a proper analysis of the elements. Syntactic information associated with lexical items would activate more slowly and then decay faster than normal, resulting in an impoverished feature make-up. In other words, patients could not activate all features simultaneously and for a period of time long enough to allow for sentence processing. As a consequence, parsing operations would be held on a reduced set of features, as some of those features are omitted. The omission of one feature can convert a grammatical configuration into a violation of locality; if, for example, the simplified feature make-up ignores the [+Rel] feature which characterizes the attractor in relative clauses. Positions like the target and the potential intervener result in having an identical feature set and intervention effects follow.

Setting aside the different causes behind these cognitive deficits, we can now compare AD patients to aphasic patients. We suggest that the poor performances of AD patients on the test (especially regarding the OR condition), could be determined by a simplified computational system, unable to execute proper analyses of all features involved, similar to that which theoretically occurs in aphasics patients. Limited cognitive resources could manage to compute configurations in which there is a clear disjunction in features, while they would experience difficulty in situations of inclusion, which are re-analyzed as identity (and therefore refused as ungrammatical).

In conclusion, we can say that the performance of AD patients can be compared to that of the other two groups: young children and aphasic patients. What is clear is that the three groups display a different syntactic parser with respect to the normal adult one, even though as a consequence of completely different causes. As a result, subjects are unable to analyze subtle featural sets and fall back to a simplified system, in which either a stricter version of the principle of Relativized Minimality is adopted (as in child grammar) or in which some features are omitted (as by aphasics).

## 6. Conclusion

Basing the discussion on the data displayed above, we suggest that AD patients perform differently than controls when tested on the comprehension of several types of relative clauses. Percentages of accuracy were lower than in the control group, thus revealing a deficit in sentence processing, with selective responses to manipulations on grammar difficulty. By increasing the difficulty of the configurations involved, patients displayed a subsequent decrease in their



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comprehension ability. In particular, they could not perform above chance level in the processing of OR sentences. This kind of relative clause could be too expensive to be processed, because of the detailed analysis of the subtle featural set required. Therefore, the performance of AD patients could be compared to that of young children during L1 acquisition (Friedmann, Belletti, Rizzi, 2009; Belletti, Contemori, 2010) and that of aphasics with agrammatism (Grillo, 2009). In both groups, problems with the analysis of subtle sets of features have been detected, although on the bases of different causes and mechanisms. Children may adopt a stricter version of the RM principle and be more sensitive to locality violations, while aphasics may be unable to include the complete set of features in their analysis. At the moment, we cannot say exactly where this explanation for the phenomenon found in AD patients will, or should lead. Nevertheless, we can certainly claim that their incapacity to properly analyze complex featural sets explains their poor performances regarding ORs. Further research should now be designed with the specific goal of detecting how Alzheimer's patients handle complex feature set analysis.

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## Appendix A

| AD GROUP (1/2) | | | | | |
|---|---|---|---|---|---|
| Subject | B. M. | Be. I. | Bi. I. | B. G. | B. L. |
| Age | 80;2 | 79;11 | 73;5 | 95;2 | 86;1 |
| Sex | F | F | M | F | F |
| MMSE | 14 | 15 | 15,3 | 21,4 | 16,2 |
| Years of education | 8 | 2 | 5 | 3 | 5 |

| AD GROUP(2/2) | | | | | |
|---|---|---|---|---|---|
| Subject | P. M. | S. R. | S. E. | V. C. | Z. A. |
| Age | 82;3 | 81;6 | 84;1 | 85;3 | 74;9 |
| Sex | F | F | F | F | M |
| MMSE | 14,7 | 14,7 | 15 | 22 | 24 |
| Years of education | 3 | 13 | 3 | 3 | 5 |

| CO GROUP | | | | | |
|---|---|---|---|---|---|
| Subject | C. L. | F. G. | F. M . | M. C. | Z. S. |
| Age | 75;7 | 82;4 | 88;1 | 84;4 | 78;6 |
| Sex | M | F | F | F | F |
| MMSE | 30 | 29 | 28 | 27 | 30 |
| Years of education | 5 | 5 | 3 | 5 | 5 |

## Appendix B

Example 1

SVO Il bambino bacia il nonno
*The child is kissing the grandfather*

SR Mostrami il bambino che bacia il nonno
*Show me the child that is kissing the grandfather*

OR Mostrami il bambino che il nonno bacia
*Show me the child that the grandfather is kissing*

POR Mostrami il bambino che è baciato dal nonno
*Show me the child, that is kissed by the grandfather*



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Example 2

SVO La bambina dipinge la mamma
*"The child is painting the mother"*

SR Mostrami la bambina che dipinge la mamma
*"Show me the child, that is painting the mother"*

OR Mostrami la bambina che la mamma dipinge
*"Show me the child, that the mother is painting"*

POR Mostrami la bambina che è dipinta dalla mamma
*"Show me the child, that is painted by the mother"*



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