# Language-specific effects in Alzheimer's disease: Subject omission in Italian and English 

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#### Abstract

The aim of this study was to verify whether the repetition abilities in Alzheimer patients interact with the linguistic properties of individual languages, such that speakers will omit nominal referents more often only if the omission is a grammatical option in their language. Unlike English, where an overt nominal referent is always required in grammatical subject position, Italian allows grammatical subjects to be unexpressed. In Experiment 1, twelve Italian speakers with Alzheimer's disease (AD) and twelve age- and education-matched controls repeated sentences of varying length and complexity. As predicted, Italian AD speakers omitted sentence subjects in complex sentences while control participants very rarely did. In Experiment 2, ten English AD speakers, matched with the Italian $A D$ participants with respect to age and severity of the disease, and ten age- and education-matched controls repeated translation equivalent materials. Unlike the Italian AD participants, English AD participants did not omit sentence subjects. Italian and English AD participants, however, were comparable in their global ability to repeat sentences of varying length. Together these results indicate that the performance of AD speakers in repeating sentences interacts with language-specific properties.


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## 1. Introduction

A common observation about the language of patients with Alzheimer's Disease (AD) is that it is "empty", in that it contains a high proportion of words with low semantic content (Hutchinson \& Jensen, 1980; Kempler, 1995; Nicholas, Obler, Albert, \& Estabrooks-Helm, 1985; Ripich \& Terrell, 1988; Ulatowska, Allard, \& Donnell, 1988). One area where this is manifest is nominal reference. English speaking AD patients are reported to overuse pronouns instead of full Noun Phrases (NPs) (Almor, Kempler, MacDonald, Andersen, \& Tyler, 1999; Bschor, Kühl, \& Reischies, 2001; Kempler \& Zelinski, 1994; Nebes, 1989; Ripich \& Terrell, 1988), but no consensus exists as to why they do so. Explanations range from locating the deficit in central language processes, either related to working memory (Almor et al., 1999), or impoverished lexical-semantic representations (Altmann, Kempler, \& Andersen, 2001; Forbes, Venneri, \& Shanks, 2002; Venneri et al., 2008), to attributing this pattern to problems with discourse-pragmatics (Ripich \& Terrell, 1988; Ulatowska \& Chapman, 1995). In this paper, however, we do not address the nature of the cognitive deficit(s) underlying the lexical problems with NPs in AD. We focus instead on how the deficit interacts with the grammatical properties of the language of the speaker with AD. Methodologically, our study falls within the domain of crosslinguistic approaches to language disorders. This approach has a long tradition in aphasia (e.g., Bates, Wulfeck, \& McWhinney, 1994; Menn \& Obler, 1990) but is much less developed in the study of language in AD (but see Waleski, Sosta, Cappa, \& Ullman, 2009).

We hypothesize that the linguistic encoding of nominal referents in both normal and impaired speakers is affected by a number of factors operating simultaneously, including the grammar of the language and the grammatical role of the nominal in a clause, the speaker's cognitive resources, the informational content of each referent in the message, the communicative goals of the speaker, and the demands of the task. To tease these factors apart, independent studies have to be designed to study each factor independently (Valian, Prasada, \&Scarpa, 2006). In this study, we examined the effects of language grammar and sentence complexity on the encoding of nominals in grammatical subject position in AD. We examine two languages, English and Italian, that contrast minimally with respect to whether grammatical subjects are required (English) or optional(Italian). The contrast between the two types of languages is illustrated in(1) and (2). Without an overt third person subject (e.g., she), English (1) is ungrammatical, whereas the corresponding Italian (2) is fully grammatical. Languages like Italian are often referred to as null-subject languages (Chomsky, 1981; Rizzi, 1982). In these languages the null subject is assumed to be a phonologically silent, syntactically represented element with pronominal properties.
(1) * Walks on the beach
(2) Cammina sulla spiaggia

The prediction was that if null subjects are grammatical in a given language, all other things being equal, speakers should exploit the null-subject option when task demands are high, as for example is the case of long or complex sentences.

Evidence that use of the overt syntactic subjects is affected both by grammatical and performance factors comes from cross-linguistic studies in language acquisition. Two-year-olds acquiring American English use overt syntactic subjects almost twice as much as do Italian children at the same stage of development (Valian, 1991), indicating that both groups are sensitive to the grammatical properties of their native language. In languages that allow null subjects, in young children the use of overt subjects increases with age (Valian \& Eisenberg, 1996), while null subjects' use in adult grammars that allow null subjects appears to be negatively correlated with sentence length (Hyams \& Wexler, 1993; see also Rizzi, 2000), strongly suggesting a relation between grammatical options and language production both in children and adults.

In the work reported here, we used a repetition task to examine the effect of sentence complexity on the production of syntactic subjects by speakers with AD. English speaking AD patients have been shown to be sensitive to manipulations of sentence complexity (Biassou, Onishi, Hughes, D'Esposito, \& Grossman, 1996; Small, Kemper, \& Lyons, 2000); however, we do not know how sentence complexity affects their inclusion of particular syntactic constituents. This is the first experimental study in AD to 1) examine the effects of sentence complexity on the production of nominal referents in a particular
grammatical position (i.e., subject) and 2) compare the performance of English and Italian patients on the same task. By using the same task and matched materials with speakers of languages that contrast minimally on a grammatical property (i.e., obligatory overt subjects in English vs. optional overt subjects in Italian), we can tease apart the effects that are due to global repetition abilities from those that result from language-specific syntactic properties.

In Experiment 1, we report the performance of Italian speakers with AD in repeating sentences that differ in length and number of clauses. We predicted that Italian AD speakers would omit more sentence subjects in complex sentences containing two clauses than in shorter sentences containing only one clause. In Experiment 2, we report the performance of English speakers with AD on an identical task and matched materials. We predicted that English AD patients would produce fewer, if any, null subjects in both long and short sentences. We then compared the global repetition abilities of Italian and English participants to ensure that both groups of patients were sensitive to length manipulations to a comparable degree, and to verify that the presence of null subjects was due to a genuine difference between the grammars of the two languages.

## 2. Experiment 1: Italian

### 2.1. Method

### 2.1.1. Participants

Twelve participants (three males) diagnosed with probable Alzheimer's disease and twelve healthy age- and education-matched controls (six males) participated in the study. The AD participants were recruited through the Istituto Triestino per gli Interventi Sociali (I.T.I.S.), Trieste, Italy. AD participants met the NINCDS-ADRDA criteria for probable Alzheimer's Disease (McKhann et al., 1984) and were mild to moderate in severity, as assessed by the Mini-Mental State Examination (MMSE; Folstein, Folstein, \& McHugh, 1975). AD participants and controls did not differ significantly in age or years of education. All participants gave their informed consent. Human subjects research approval was obtained from the research ethics committee of the University of Trieste and Hunter College, CUNY. See Table 1 for participant information.

### 2.1.2. Stimuli

The stimuli were a set of eighteen grammatical sentences for each of three conditions: One Clause with simple tense (One-Clause Condition), One Clause with complex tense (One-Clause-Auxiliary Condition) and Two-Clause sentences (Two-Clause Condition), for a total of fifty-four sentences. The experimental manipulations were number of clauses (complexity manipulation) and length. OneClause sentences were 6-7 words long and contained a subject, a main verb in the future tense, a direct object followed by an adjectival modifier or a prepositional phrase modifier. One-Clause-Auxiliary sentences were 7-8 words long and contained the same syntactic constituents as the One-Clause sentences except that the verb was in the future perfect form, which in Italian is a periphrastic form consisting of the auxiliary have in the future tense and the past participle of the main verb. Two-Clause sentences were 10-11 words long and contained a main clause with a subject and a verb followed by a subordinate clause introduced by the complementizer che ("that"). The subordinate clause was identical to the clause in the One-Clause sentences.

Thus, One-Clause and One-Clause-Auxiliary sentences contained one subject, a verb, and a direct object. In the Two-Clause sentences there were two subjects (one main-clause subject, one subordi-nate-clause subject), two verbs (main and subordinate) and one direct object (subordinate). Below is an example of each condition. A list of all experimental materials is given in Appendix 1.

Table 1
Demographics for Italian participants: means (and ranges) for age, Mini Mental Score, and education.

| Population | Age | MMSE | Education |
| :--- | :--- | :--- | :--- |
| AD | $71(55-84)$ | $21(17-24)$ | $6(5-13)$ |
| Control | $70(58-81)$ | $30(28-30)$ | $6(5-13)$ |

## One-Clause Condition:

| Il | ciclista perderà | la corsa regionale <br> the |
| :--- | :--- | :--- |

'The cyclist will lose the regional race.'
One-Clause-Auxiliary Condition:

| Il ciclista avrà | perduto | la corsa regionale |
| :--- | :--- | :--- |
| the cyclist will | lost-PAST-PARTICIPLE | the race regional |

'The cyclist will have lost the regional race.'
Two-Clause Condition:

| Il reporter <br> the reporter | prevede | che il ciclista perderà | la corsa regionale |
| :--- | :--- | :--- | :--- |
| predict.3SINGULAR.FUTURE | that the cyclist lose.3SINGULAR.FUTURE | the race regional |  |

'The reporter predicts that the cyclist will lose the regional race.'

### 2.1.3. Procedure

Participants were tested individually. The fifty-four sentences were arranged in a pseudo-random order and divided into three session blocks such that sentences in different conditions but containing the same lexical items did not occur in the same session. The experimental materials were presented in three different sessions on different days. During each session, the participant and the experimenter sat across from each other at a table. The experimenter read the sentence with normal rate and prosody and asked the participant to repeat it. Sentences were read a second time if needed. The experimenter took detailed notes of each participant's repetition on a score sheet containing all of the sentences in the order of presentation by crossing out words that were omitted in the repetition and marking any substitutions above the corresponding word.

Approximately 30 min after the sentence repetition task, participants were given the sentences again in a reading task. Because performance by AD participants in this task was at ceiling in all conditions, we do not discuss the reading results further.

### 2.1.4. Coding of repetitions

Two coders (the first and second authors) independently scored participants' repetitions. Intercoder agreement was high ( $>98 \%$ ); disagreements were resolved by discussion.

Participants' repetitions were examined in two ways. First, global repetition ability was examined via the percentage of correct words repeated in a sentence, irrespective of word position or grammatical role in the repetition. The second measure examined sentence repetitions for the presence of null subjects.
2.1.4.1. Percent correct. This measure was the number of words correctly repeated by the participant, irrespective of its position or grammatical role in the sentence. A target word was considered correctly repeated if this was identical to the one presented in the target, but it did not matter whether it was repeated in the same position or with the same grammatical role as the target. No synonyms, and no substitutions of number (e.g., a singular form instead of a plural), gender (e.g., a masculine form instead of a feminine form), nor tense (e.g., a past instead of a future) were allowed. For example, if the target sentence was "The grandmother will bring the Christmas presents" the percent correct scoring for a repetition such as "Grandma will bring the presents" would not count "Grandma" as a correct repetition, and the repetition would receive a percent correct score of .57 (4/7). A repetition such as "presents will be brought by the grandmother" would also receive a correct score of .57 (4/7).
2.1.4.2. Scoring of error types for null-subject analysis. Before scoring for the presence of null subjects, responses were first divided into two categories: 1) same sentence as the target; 2) different sentence from the target. A description of the initial scoring criteria is given below.

1) Same sentence. A response was scored as 'same sentence' if: a) the repetition was a verbatim repetition of the target (i.e., identical in syntax and containing the same lexical items of the target), or b) the repetition had the same syntax as the target, but contained one or more lexical substitutions. Substitutions were only acceptable if they involved a word of the same syntactic category as the target and with a similar meaning: e.g., "the cyclist" instead of "the athlete", "finish" instead of "end". Instances in which a determiner was followed by a pause but was missing the noun were also included (e.g., "The... said that the athlete would win the race"). Because of the presence of the determiner, these repetitions were not considered instances of null subjects, but rather, omissions of the lexical content of the grammatical NP.
2) Different sentence. For a production to count as a 'different - scorable - sentence’ (see below for the detailed scoring) it had to contain at a minimum: an inflected verb and one nominal referent in the case of One-Clause sentences, and at least 2 verbs and a nominal referent (either one of the subjects, or the subordinate object) in the case of the Two-Clause sentences.

After this initial scoring, all of the sentences in category 2 - scorable sentences that differed from the target - were further examined for the presence of null subjects.
2.1.4.3. Scoring of null subjects. All of the productions that were classified as different sentences from the target were subsequently scored for the presence of null subjects. The criteria for each type of null subject are described below.

Subject-drop-main: the main-clause subject was omitted, ${ }^{1}$ while the remaining constituents in the main clause and the entire subordinate clause (if present) were overtly expressed (e.g., "The reporter predicts that the athlete will win the race").

Subject-drop-subordinate: the subordinate-clause subject was omitted while all other constituents were expressed (e.g., "The reporter predicts that the athlete will win the race").

Subject-drop-both: Both the main- and subordinate-clause subject were omitted while all other constituents were expressed (e.g., "The reporter predicts that the athlete will win the race").

### 2.2. Results

Our primary predictions for Italian were that, with longer sentences, AD speakers 1) would be less accurate in correctly repeating words from the target sentence, and 2 ) would produce repetitions containing null subjects. We thus report patients' and controls' mean percent words correctly repeated (percent correct words) and their mean percent repetitions containing null subjects (percent null subjects). For both measures separate analyses were performed treating participants ( $F_{1}$ ) and items ( $F_{2}$ ) as random effects. Statistical analyses were also performed on the arcsine-transformed proportions of responses, which produced the same pattern of results as analyses of raw proportions. We present statistics on raw proportions because they are easier to interpret than arcsines (Studebaker, 1985). All proportions are computed with unweighted means.

### 2.2.1. Percent correct

Table 2 shows the mean percent words correctly repeated by Italian AD participants and controls in the One-Clause, One-Clause-Auxiliary, and Two-Clause conditions. A 3 (condition) $\times 2$ (population) mixed ANOVA showed significant main effects of condition ( $F_{1}(2,44)=80$, MSE $=.2, p<.0001$, $F_{2}(2,17)=107.04$, MSE $\left.=.36, p<.0001\right)$, population $\left(F_{1}(1,22)=31.5\right.$, MSE $=.4 ; p<.0001$;

[^1]Table 2
Italian percent correct results: mean percentage of correct words produced in each condition, by population.

| Population | One Clause | One-Clause-Auxiliary | Two Clauses |
| :--- | :--- | :--- | :--- |
| AD | .94 | .91 | .64 |
| Control | .99 | .99 | .93 |

$\left.F_{2}(1,17)=149, \mathrm{MSE}=.54, p<.0001\right)$ and a significant condition $\times$ population interaction $\left(F_{1}(2,44)=51.6, \mathrm{MSE}=.13, p<.0001 ; F_{2}(2,34)=121, \mathrm{MSE}=.16, p<.0001\right)$. Because of the significant condition $\times$ population interaction, we followed up with separate one-way ANOVAs for AD participants and controls. For the AD participants the overall ANOVA showed a main effect of condition $\left(F_{1}(2,22)=79.16\right.$, MSE $=.332, p<.0001 ; F_{2}(2,34)=135$, MSE $\left.=.5, p<.0001\right)$. AD participants, on average, were less accurate in repeating words in the Two-Clause condition (Mean $=.64$ ) than in the One-Clause condition $(\mathrm{M}=.94)\left(F_{1}(1,11)=111, \mathrm{MSE}=1.1, p<.0001 ; F_{2}(1,17)=183, \mathrm{MSE}=1.6\right.$, $p<.0001$ ) and than in the One-Clause-Auxiliary condition ( $\mathrm{M}=.91 ; F_{1}(1,11)=72.4$, MSE $=.90$, $\left.p<.0001 ; F_{2}(1,17)=149, \mathrm{MSE}=1.3, p<.0001\right)$. For the control participants the overall ANOVA showed a significant main effect of condition $\left(F_{1}(2,22)=4.4, \mathrm{MSE}=.004, p=.02 ; F_{2}(2,34)=22\right.$, MSE $=.02$, $p<.0001$ ). Control participants, on average, were less accurate in repeating words in the Two-Clause condition ( $\mathrm{M}=.93$ ) than in the One-Clause condition (Mean $=.99$ ) (approached significance for participants participants: $\left.F_{1}(1,11)=4.3, \mathrm{MSE}=.01, p=.06 ; F_{2}(1,17)=24.3, \mathrm{MSE}=.06, p<.0001\right)$ and than in the One-Clause-Auxiliary condition $\left(\mathrm{M}=.99 ; F_{1}(1,11)=4.7, \mathrm{MSE}=.01, p=.05 ; F_{2}(1,17)=21\right.$, MSE $=.06, p<.0001$ ). The planned single degree of freedom comparison between the mean percent correct words repeated in the Two-Clause condition by AD participants ( $\mathrm{M}=.64$ ) vs. control participants (Mean $=.93$ ) was significant $\left(t_{1}(22)=5.9, p<.0001, t_{2}(17)=14.7, p<.0001\right.$ ).

In summary, both AD participants and controls were less accurate in their overall ability to repeat words from the target sentence in complex, two-clause sentences, but the AD participants were more affected by sentence complexity than the controls.

### 2.2.2. Percent null subjects

We considered all instances in which a participant produced a null subject, irrespective of where the null subject occurred (i.e., whether it occurred in the main clause (Null-Main), or in the subordinate clause (Null-Subordinate), in the Two-Clause condition). Note that in the One-Clause conditions there is only one subject position and thus only one chance per sentence to produce a null subject, whereas in the Two-Clause condition there are two potential null-subject positions. To equalize the chances of producing a null subject across conditions, we excluded cases in which participants produced null subjects both in the main clause and in the subordinate clause (Null-Both). In fact, participants rarely produced null subjects in both positions: there were only 2 instances of repetitions scored as Null-Both, and they were produced by two AD participants. We thus analyzed null subjects produced somewhere in the sentence. For both One Clause (One-Clause and One-Clause-Auxiliary) sentences this was the main (only) subject position. For Two-Clause sentences, null subjects could occur either in the main clause, or in the subordinate clause. Table 3 shows the mean proportions of null subjects produced by Italian AD participants and controls in the One-Clause, One-Clause-Auxiliary, and Two-Clause conditions.

A 3 (condition) $\times 2$ (population) mixed effects ANOVA showed significant main effects of condition $\left(F_{1}(2,44)=40, \mathrm{MSE}=.11, p<.0001, F_{2}(2,34)=41, \mathrm{MSE}=.16, p<.0001\right)$, population $\left(F_{1}(1,22)=31\right.$, MSE $\left.=.032 ; p<.0001 ; F_{2}(1,17)=34, \mathrm{MSE}=.14, p<.0001\right)$ and a significant condition $\times$ population interaction $\left(F_{1}(2,44)=31, \mathrm{MSE}=.085, p<.0001 ; F_{2}(2,34)=29.7, \mathrm{MSE}=.13, p<.0001\right)$. Because of the significant condition $\times$ population interaction, we followed up with separate one-way ANOVAs for AD

Table 3
Italian null-subject results: mean percentage (and raw number) of null subjects produced in each condition, by population.

| Population | One Clause | One-Clause-Auxiliary | Two Clauses |
| :--- | :--- | :--- | :--- |
| AD | $.005(1)$ | $.005(1)$ | $.23(50)$ |
| Control | $.000(0)$ | $.000(0)$ | $.014(3)$ |

participants and controls. For the AD participants the overall ANOVA showed a main effect of condition $\left(F_{1}(2,22)=36.7, \mathrm{MSE}=.2, p<.0001 ; F_{2}(2,34)=36.4, \mathrm{MSE}=.29, p<.0001\right)$. AD participants, on average, produced significantly more null subjects in the Two-Clause condition ( $\mathrm{M}=.23$ ) than in the One-Clause condition ( $\mathrm{M}=.005 ; F_{1}(1,11)=36.7$, $\mathrm{MSE}=.58, p<.0001 ; F_{2}(1,17)=39$, MSE $=.87$, $p<.0001$ ) and than in the One-Clause-Auxiliary condition ( $\mathrm{M}=.005 ; F_{1}=36.7$, $\mathrm{MSE}=.58, p<.0001 ; F_{2}$ $(1,17)=35.2, \mathrm{MSE}=.87, p<.0001)$. For the control participants the overall ANOVA showed a significant main effect of condition ( $\left.F_{1}(2,22)=3.7, \mathrm{MSE}=.001, p=.04 ; F(2,34)=3.4, \mathrm{MSE}=.001, p=.05\right)$, but the single degree of freedom contrasts between the mean proportion null subjects produced in the Two-Clause condition ( $\mathrm{M}=.014$ ) and both One-Clause conditions ( M One-Clause $=.00$; M One-ClauseAuxiliary $=.00$ ) were not significant $\left(F_{1}(1,11)=3.67\right.$, MSE $=.002, p=.08$ for both contrasts; $F_{2}(1,17)=3.4, \mathrm{MSE}=.003, p=.08$, for both contrasts). The planned single degree of freedom comparison between the mean proportion of null subjects produced in the Two-Clause condition by AD participants $(\mathrm{M}=.23)$ vs. control participants $(\mathrm{M}=.014)$ was significant $\left(t_{1}(22)=5.64, p<.0001\right.$, $t_{2}(17)=5.6, p<.0001$ ).

In summary, as predicted, Italian AD participants produced null subjects when repeating longer sentences: they produced significantly more null subjects in the Two-Clause condition than in the OneClause and the One-Clause-Auxiliary conditions. Italian control participants produced fewer null subjects overall and showed no differences across sentence conditions. In the Two-Clause condition, AD participants produced significantly higher rates of null subjects than did the control participants. It is important to note that subject omission was independent of the lexical frequency of the word in subject position: first, the same subjects were used in the subordinate clause of the Two-Clause sentences and in the only clause of the One-Clause sentences, yet subject omission was overwhelmingly found in Two-Clause sentences. Second, there was no correlation between the encoding of a nominal as a null subject (e.g., the proportion of times that "grandmother" as the subject of the subordinate clause was encoded as a null subject) and the log frequency of the word (e.g., log frequency of "grandmother") ( $r=.047, p=.85$ ).

### 2.2.3. Position of null subjects in the Two-Clause condition

For the null subject analyses reported above, null subjects in Two-Clause conditions could occur either in the main clause (Null-Main) or in the subordinate clause (Null-Subordinate), given that instances where they occurred in both were excluded from the analyses. The overwhelming proportion of null subjects in the Two-Clause condition, however, was produced in the subordinate clause: in this condition there was only one null subject produced in the main clause, by one AD participant.

### 2.3. Discussion

We hypothesized that for speakers with AD, grammar and sentence length interact, such that AD speakers should be less accurate in repeating longer/more complex sentences overall. In addition, if the language is a null-subject language, AD speakers should omit subjects when they are asked to repeat longer sentences containing two clauses. Both predictions were confirmed. AD participants and controls were less accurate in their overall ability to repeat words from the target sentence in longer sentences, but AD participants were more affected by sentence length than the controls. Italian participants with AD produced null subjects, overwhelmingly in subordinate clauses. Control participants hardly ever produced null subjects.

## 3. Experiment 2: English

In Experiment 1, we examined the performance of Italian AD participants and controls using an elicited repetition task with sentences of varying lengths. We found that Italian AD participants produced null subjects in Two-Clause sentences, an effect that we attribute to the grammatical option allowing null subjects in Italian. The goal of Experiment 2 was to replicate Experiment 1 in English, a language where null subjects are not grammatical. The predictions for English were that, with longer sentences, AD speakers 1 ) would be less accurate in correctly repeating words from the target sentence, and 2 ) would not produce repetitions containing null subjects.

### 3.1. Method

### 3.1.1. Participants

Ten participants (four males) diagnosed with AD and 10 healthy age- and education-matched controls (two males) participated in the study. AD participants were recruited through the Clinical Neuroscience Centre and Department of Psychology, University of Hull, UK, as part of a larger study on the "Assessment of age and disease-related cognitive impairment." AD participants met the NINCDSADRDA criteria for probable Alzheimer's Disease (McKhann et al., 1984) and were mild to moderate in severity, as assessed by the Mini-Mental State Examination (Folstein et al., 1975). AD participants and controls did not differ significantly in age or years of education. All participants gave their informed consent. Human subjects research approval was obtained from the joint East Riding and University of Hull Local Research Ethics Committee (UK) and the Internal Review Board of Hunter College, CUNY. See Table 4 for participant information.

### 3.1.2. Stimuli

English stimuli were created to match the Italian materials as closely as possible, and nominal referents were in most cases translation equivalents. One-Clause sentences were 5-7 words long and contained a subject, a main verb in the past tense, and a direct object preceded by an adjectival modifier (e.g., " the broken wires") or genitive phrase modifier (e.g., "this evening's program"). One-Clause-Auxiliary sentences were $7-8$ words long and contained the same syntactic constituents as the One-Clause sentences, except that the verb was in the future, which in English is a periphrastic form consisting of the auxiliary will and the bare form of the main verb. Two-Clause sentences were 10-12 words long and contained a main clause with a subject and a verb followed by a subordinate clause introduced by the complementizer that. The subordinate clause was identical to the clause in the OneClause sentences, except for the tense of the subordinate verb, which was either in the present perfect (e.g., "had extracted") or conditional (e.g., "would win"). Thus, One-Clause and One-Clause-Auxiliary sentences contained one subject, a verb, and a direct object. In the Two-Clause sentences there were two subjects (one main, one subordinate), two verbs (main and subordinate), and one direct object (subordinate). Below is an example of each condition, while a list of all experimental materials is given in Appendix 2.

## One-Clause Condition:

The electrician mended the broken wires

## One-Clause-Auxiliary Condition:

The electrician will mend the broken wires

## Two-Clause Condition:

The builder stated that the electrician would mend the broken wires

### 3.1.3. Procedure

Similar procedures were used for the English participants to those used for the Italian participants in Experiment 1. Because the reading data were not used in Experiment 1, English participants were not asked to read the sentences upon completion of the repetition task.

### 3.1.4. Scoring

Scoring criteria were identical to those used in Experiment 1 for Italian (see Section 2.1.4).

Table 4
Demographics for English participants: means (and ranges) for age, Mini Mental Score, and education.

| Population | Age | MMSE | Education |
| :--- | :--- | :--- | :--- |
| AD | $70(55-94)$ | $19(15-25)$ | $13(10-18)$ |
| Control | $67(53-79)$ | $30(28-30)$ | $14(10-17)$ |

### 3.2. Results

The predictions for English were that, with longer sentences, AD speakers 1) would be less accurate in correctly repeating words from the target sentence, and 2) would not produce repetitions containing null subjects. We thus report patients' and controls' mean percent words correctly repeated (percent correct words) and their mean percent repetitions containing null subjects (percent null subjects). We then compared Italian and English AD participants' repetition ability directly. For the percent correct measure separate analyses were performed treating participants ( $F_{1}$ ) and items $\left(F_{2}\right)$ as random effects. Statistical analyses were also performed on the arcsine-transformed proportions of responses, which produced the same pattern of results as analyses of raw proportions. We present statistics on raw proportions because they are easier to interpret than arcsines (Studebaker, 1985). All proportions are computed with unweighted means. For the null-subject measure, no statistical analyses were performed because participants hardly produced any null subjects.

### 3.2.1. Percent correct

Table 5 shows the mean percent words correctly repeated by English AD participants and controls in the One-Clause, One-Clause-Auxiliary, and Two-Clause conditions.

A 3 (condition) $\times 2$ (population) mixed effects ANOVA showed significant main effects of condition $\left(F_{1}(2,36)=23.4, \mathrm{MSE}=.12, p<.0001, F_{2}(2,17)=96.4, \mathrm{MSE}=.21, p<.0001\right)$, population $\left(F_{1}(1,18)=11\right.$, MSE $\left.=.35 ; p=.004 ; F_{2}(1,17)=166.7, \mathrm{MSE}=.63, p<.0001\right)$ and a significant condition $\times$ population interaction $\left(F_{1}(2,36)=14.3, \mathrm{MSE}=.07, p<.0001 ; F_{2}(2,34)=87.8, \mathrm{MSE}=.13, p<.0001\right)$. Because of the significant condition $\times$ population interaction, we followed up with separate one-way ANOVAs for AD participants and controls. For the AD participants the overall ANOVA showed a main effect of condition $\left(F_{1}(2,18)=21, \mathrm{MSE}=.19, p<.0001 ; F_{2}(2,34)=112, \mathrm{MSE}=.35, p<.0001\right)$. AD participants, on average, were less accurate in repeating words in the Two-Clause condition (Mean $=.67$ ) than in the One-Clause condition $(\mathrm{M}=.91)\left(F_{1}(1,9)=21.7\right.$, $\left.\mathrm{MSE}=.58, p=.001 ; F_{2}(1,17)=149.3, \mathrm{MSE}=1, p<.0001\right)$ and than in the One-Clause-Auxiliary condition $\left(\mathrm{M}=.91 ; F_{1}(1,9)=20.6\right.$, $\mathrm{MSE}=.54, p=.001 ; F_{2}(1,17)=107$, $\mathrm{MSE}=1, p<.0001$ ). For the control participants the overall ANOVA was not significant by participants $\left(F_{1}(2,18)=2.6, \mathrm{MSE}=.003, p=.1\right)$ but it was significant by items $\left(F_{2}(2,34)=7.6\right.$, $\left.\mathrm{MSE}=.005, p=.002\right)$. The single degree of freedom contrasts were not significant by participants (M Two-Clause $=.97 \mathrm{vs}$. M One-Clause $=.99, F_{1}(1,9)=2.5$, MSE $=.008, p=.14$; M Two-Clause $=.97$ vs. M One-ClauseAuxiliary $\left.=.99, F_{1}(1,9)=2.7, \mathrm{MSE}=.009, p=.13\right)$. In the analyses by items, the contrast between the Two-Clause condition and the One-Clause condition was significant ( $F_{2}(1,17)=7.3$, $\mathrm{MSE}=.015, p=.01$ ), as was the contrast between the Two-Clause condition and the One-Clause-Auxiliary condition $\left(F_{2}(1,17)=9.3, \mathrm{MSE}=.02, p=.007\right)$. The planned single degree of freedom comparison between the mean percent correct words repeated in the Two-Clause condition by AD participants ( $\mathrm{M}=.67$ ) vs. control participants ( $\mathrm{M}=.97$ ) was significant $\left(t_{1}(18)=3.7, p=.005, t_{2}(17)=14.6, p<.0001\right)$.

In summary, both English AD participants and controls were less accurate in their overall ability to repeat words from the target sentence in longer sentences, but the AD participants were more affected by sentence length than the controls.

### 3.2.2. Null subjects

The results are shown in Table 6. The prediction that English speakers would not produce null subjects was confirmed: as can be seen from Table 6, English participants hardly ever produced null subjects. There was only one instance of a null subject description, and it was produced by one control participant. Statistical analyses were thus not performed on these data.

Table 5
English percent correct results: mean percentage of correct words produced in each condition, by population.

| Population | One Clause | One-Clause-Auxiliary | Two Clauses |
| :--- | :--- | :--- | :--- |
| AD | .91 | .91 | .67 |
| Control | .99 | .99 | .97 |

Table 6
English null-subject results: mean percentage (and raw number) of null subjects produced in each condition, by population.

| Population | One Clause | One-Clause-Auxiliary | Two Clauses |
| :--- | :--- | :--- | :--- |
| AD | $.00(0)$ | $.00(0)$ | $.00(0)$ |
| Control | $.00(0)$ | $.00(0)$ | $.006(1)$ |

It is important to rule out the possibility that the different pattern seen in English and Italian AD patients with respect to subject omission is due to the lexical frequency of the word in subject position. Frequencies for English were taken from the British National Corpus, which is a 100 -million word corpus of samples of written (90\%) and spoken (10\%) English from a wide range of sources. Frequencies for Italian were taken from CORIS, which is a 120 -million word corpus of samples of written Italian. A paired samples $t$-test was conducted to compare the logarithm of the frequency (log frequency) of subject words in English and Italian. The difference between the log frequency of the Italian subject words $(\mathrm{M}=3.2, \mathrm{SD}=.57)$ and their English translation equivalent subject words ( $\mathrm{M}=3.3, \mathrm{SD}=.69$ ) was not significant ( $t=-.97, p=.34$ ). Hence, the difference in subject omission rates between the Italian and the English participants cannot be imputed to a difference in the frequencies of the lexical words in the stimuli used.

### 3.3. Discussion

We hypothesized that English speakers with AD would be less accurate in repeating longer/more complex sentences overall, but would not produce null subjects. Both predictions were confirmed. AD participants and controls were less accurate in their overall ability to repeat words from the target sentence in longer sentences. English speaking patients with AD produced no null subjects.

## 4. Comparisons between Italian and English

### 4.1. Comparison of percent correct between Italian and English participants

In Experiment 1, we found that Italian AD participants produced null subjects in repeating TwoClause sentences, while Experiment 2 showed that English AD participants with comparable MMSE scores produced no null subjects when assessed with matched materials. It was important, however, to rule out that the absence of null subjects in the English data could not be accounted for by any differences in the global ability to repeat sentences between English and Italian AD participants' overall ability to repeat sentences, but instead reflected the influence of a grammatical difference between the two languages on participants' performance. In addition, although Italian and English AD participants were comparable in their degree of cognitive impairment, as confirmed by their MMSE scores, they differed on years of formal education, with Italian AD participants on average having completed fewer years of schooling (Mean Years Education for Italian AD participants $=6$; Mean Years Education for English AD participants $=13$, see Tables 1 and 4, respectively). To rule out general repetition ability, we directly compared the average percent correct words repeated by English and Italian AD participants. The data on the mean percent correct words repeated were reported separately for Italian and English participants (see Table 2, Experiment 1 and Table 5, Experiment 2), but are summarized again for AD participants only in Table 7 for ease of consultation.

A 3 (condition) $\times 2$ (language) mixed effects ANOVA on the mean percent correct words produced by Italian and English $A D$ participants, with education as a covariate in the subject analysis, revealed a significant main effect of condition $\left(F_{1}(2,38)=4.9\right.$, $\mathrm{MSE}=.033, p=.01 ; F_{2}(2,34)=224$, $\mathrm{MSE}=.82$, $p<.0001$ ). Language was not significant $\left(F_{1}(1,19)=1\right.$, MSE $\left.=.014, p=.33, F_{2}<1\right)$ nor was education $\left(F_{1}(1,19)=1.7\right.$, MSE $=.024, p=.21, F_{2}<1$ ). None of the interactions was significant (all $F_{1} s<1$, $\left.F_{2}(2,34)=2.7, \mathrm{MSE}=.008, p=.08\right)$.

In summary, Italian and English AD participants showed no difference in their global repetition abilities, as measured by the percentage of words correctly repeated from the target.

Table 7
Italian/English comparison: mean percent correct repetitions produced by AD participants in each condition once null subjects are excluded.

| Population | One Clause |  | One-Clause-Auxiliary |  | Two-Clause |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | English | Italian | English | Italian | English | Italian |
| AD | . 91 | . 94 | . 91 | . 91 | . 67 | . 64 |

### 4.2. Comparison of subject words between Italian and English participants: lexical content analysis

We examined how Italian and English patients repeated the lexical content of the main-clause subject (Subject 1) and the subordinate-clause subject (Subject 2) in the Two-Clause sentences, irrespective of its grammatical role in the repetition. Coding was aimed at examining whether the lexical content of the subject was correctly repeated, omitted, or substituted with another noun phrase or pronoun. We excluded sentences for which we could not determine whether the subject of either the main or the subordinate clause was present (fragments such as "The policeman") and sentences that were repeated correctly (verbatim). Note that this analysis is very different from the Null-Subject analysis. The Null-Subject analysis looks at subjects from a grammatical role point of view, while the lexical content analysis does not. All the sentences with a null subject in the Null-Subject analysis also count as having an omitted subject in the lexical content analysis, however the converse is not true. An omitted subject in the lexical content analysis may be due to another repetition pattern other than a null subject (see below, Section 4.1.3). For example, for the target sentence "The builder stated that the electrician would mend the broken wires", a repetition such as "The technician will mend the broken wires", Subject 1 would be coded as omitted and Subject 2 would be coded as substituted. This repetition was coded as Subordinate Only (see Section 4.1.3, below for coding of other error patterns) and was excluded in the Null-Subject analysis. The data are presented in Table 8. While we do not perform statistical analyses on these data, a qualitative analysis showed differences between the two languages. The lexical content of the main-clause subject was omitted to some extent in both languages, but proportionally more in Italian than in English. The other types of errors for the mainclause subject did not differ across the two languages. When looking at the subordinate-clause subjects, some interesting differences emerged. While the lexical content of the subordinate clause was mostly omitted in the Italian AD participant data, for the English participant data there was a more even distribution across omissions, substitutions with full NPs and substitutions with pronouns.

### 4.3. Error patterns for Two-Clause sentences, other than null subjects

The primary goal of this study was to determine whether AD participants would produce null subjects as a function of whether their grammar allowed null subjects or not. In this section we report a qualitative analysis of other error patterns. The fact that Italian participants produced Null Subjects and English participants did not, but they did not differ in their overall repetition ability, as measured by percent correct words repeated, suggests that English participants produced errors other than Null Subjects. A description of these error patterns is provided below, and a summary by language is given in Table 9.

Subordinate only: were mono-clausal sentences with overt subject Verb and Object from the target subordinate clause only (e.g., "The reporter predicted that the cyclist would lose the regional race" repeated as "The reporter predicted that The cyclist would lose the regional race").

Table 8
Encoding of subjects in repetitions with errors, for Two-Clause sentences, by Italian and English AD participants.

| Language | Subject 1 <br> Correct | Subject 1 Omission | Subject 1 <br> Substitution | Subject 1 <br> Pronoun | Subject 2 <br> Correct | Subject 2 <br> Omission | Subject 2 Substitution | Subject 2 Pronoun |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Italian | . 62 (115) | . 16 (29) | . 13 (25) | 0 (0) | . 45 (73) | . 49 (91) | . 06 (11) | . 0 (0) |
| English | . 72 (96) | . 10 (14) | . 12 (16) | 0 (0) | . 50 (39) | . 31 (42) | . 12 (16) | . 08 (11) |

Table 9
Other repetition errors for Two-Clause sentences produced by Italian and English AD participants, percentage and raw counts.

| Language | Subordinate Clause Only | Blend | Structure Change | Fragment | Other |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Italian | $.09(19)$ | $.07(16)$ | $.03(7)$ | $.06(14)$ | $.13(33)$ |
| English | $.03(6)$ | $.02(3)$ | $.02(3)$ | $.26(46)$ | $.09(19)$ |

Blends: were mono-clausal sentences with an overt Subject Verb and Object where the Subject came from the main clause, the Object from the subordinate clause and Verb either from the main or the subordinate clause (e.g., "The reporter predicted that the cyclist would lose the regional race" repeated as "The reporter predicted that the cyclist would lose the regional race" or "The reporter predicted the eyclist would lose the regional race).
Fragments: were sentences without a predicate (e.g., "The reporter predicted that the cyclist would lose the regional race" is repeated as "The cyclist... the race").
Change: this category contained sentences that altered the structure of the clause, but did not fall into either the Blend or Subordinate (e.g., "The reporter predicted that the cyclist would lose the regional race" repeated as: "The reporter told the cyclist about the race").
Other: this miscellaneous category consisted of sentences with a predicate and sentences that did not alter the structure of the clause, but contained a variety of substitutions from the target that did not allow classification in any of the above categories, including sentences with perseverations, false starts, and interruptions after the verb (e.g., "The reporter predicted that the cyclist would lose the regional race" repeated as "The reporter predicted that the race...").

As can be seen in Table 9, numerical differences in error patterns emerge between English and Italian AD speakers. English speakers had a larger proportion of errors in the Fragment category, whereas Italian speakers produced numerically more Blends and Subordinates, and errors in the Other category. It is hard to conclude anything definitive about what these differences mean, especially because the Fragment and Other categories are extremely heterogeneous. A fragment may consist of the repetition of just one word (e.g., "The cyclist") or an incomplete sentence (e.g., "The reporter predicted that the cyclist...").

The important finding in our results is the presence of a clear error pattern that can be predicted based on the grammatical properties of the language spoken by the participants. The different distribution of error patterns is of interest to the extent that they give an explanation as to why English and Italian AD participants were comparable in their global repetition abilities (as measured by percent correct words), but only Italian AD speakers produced Null-Subject repetitions.

## 5. General discussion

The goal of the present study was to examine the effect of language-specific properties (i.e., grammaticality of null subjects) on the sentence repetition performance of patients with Alzheimer's disease. Our study was aimed at teasing apart those aspects of performance that are controlled by general repetition abilities from those that reflect linguistic specific constraints. For this purpose, we chose two languages, English and Italian, which differ with respect to whether they require nominal referents in certain grammatical positions (i.e., grammatical subject position) to be overtly expressed (English) or not (Italian). The two experiments reported here used identical tasks and translation equivalent materials across the two languages, and tested participants that were matched in terms of their overall disease severity, as measured by their scores on the Mini-Mental State Examination. The participants were also comparable with respect to their global repetition ability (expressed in terms of percentage words correctly repeated). In line with our hypothesis that sentence repetition ability and language particular grammatical properties interact, we found that Italian AD speakers omitted sentence subjects in repeating Two-Clause sentences while English AD speakers did not. Because the two groups of $A D$ participants otherwise performed comparably on the same task as measured by the percentage of words correctly repeated, the differences between Italian AD and English AD can be safely imputed to genuine language-specific differences, and not to extra-linguistic differences between the two groups of $A D$ participants. In summary, this study is the first to uncover cross-
linguistic differences in how AD patients encode nominal referents in a production task. The results have implications for the cross-linguistic study of sentence production in that they reveal an interaction between the language production system and the grammatical properties of the language of the speaker. Understanding what aspects of the language processing systems (production and comprehension) are universal and what aspects are language-specific requires systematic studies in languages that contrast grammatically, both with normal speakers (Costa, Alario, \& Sebastián-Gallés, 2007), and, like in the current study, speakers with impairments. Future studies examining comprehension as well as production are needed to examine the impact of language-specific properties on the language breakdown of speakers with AD , and to determine potentially different clinical guidelines on how to talk to speakers with AD with different language backgrounds. Our research shows that nature carves language at its joints. Alzheimer's disease does not randomly compromise syntactic function, nor is it guided by purely semantic considerations. Rather, speakers' knowledge of the fundamental syntactic properties of their language remains intact, even when much else is lost.

## Appendix 1. Italian stimuli

Il pompiere spegnerà il fuoco pericoloso
Il pompiere avrà spento il fuoco pericoloso
La guardia assicura che il pompiere spegnerà il fuoco pericoloso

La nonna porterà i regali natalizi
La nonna avrà portato i regali natalizi
Il padre pensa che la nonna porterà i regali natalizi
Il dentista estrarrà il dente cariato
Il dentista avrà estratto il dente cariato
Il paziente teme che il dentista estrarrà il dente cariato
Il ciclista perderà la corsa regionale
Il ciclista avrà perduto la corsa regionale
Il reporter prevede che il ciclista perderà la corsa regionale

La scrittrice pubblicherà il romanzo nuovo
La scrittrice avrà pubblicato il romanzo nuovo
L'editore rivela che la scrittrice pubblicherà il romanzo nuovo
L'insegnante correggerà i compiti settimanali
L'insegnante avrà corretto i compiti settimanali
Lo studente dice che l'insegnante correggerà i compiti settimanali
La cantante cambierà il programma musicale
La cantante avrà cambiato il programma musicale
Il giornalista scrive che la cantante cambierà il programma musicale
L'elettricista accomoderà i fili della luce
L'elettricista avrà accomodato i fili della luce
Il costruttore promette che l'elettricista accomoderà i fili della luce
Il pescatore ormeggierà la barca danneggiata
Il pescatore avrà ormeggiato la barca danneggiata
Il maresciallo assicura che il pescatore ormeggierà la barca danneggiata
L'atleta affronterà la gara di salto
L'atleta avrà affrontato la gara di salto
L'allenatore ritiene che l'atleta affronterà la gara di salto

Il giornalista condurrà l'intervista televisiva
Il giornalista avrà condotto l'intervista televisiva
L'annunciatore dice che il giornalista condurrà l'intervista televisiva
La guida spiegherà la storia del luogo
La guida avrà spiegato la storia del luogo
Il conducente assicura che la guida spiegherà la storia del luogo
Il viaggiatore anticiperà la data della partenza
Il viaggiatore avrà anticipato la data della partenza
L'agenzia sospetta che il viaggiatore anticiperà la data della partenza
L'attrice sposerà il collega francese
L'attrice avrà sposato il collega francese
Il regista insinua che l'attrice sposerà il collega francese
Lo studente copierà gli appunti persi
Lo studente avrà copiato gli appunti persi
Il professore dice che lo studente copierà gli appunti persi
Il ladro abbandonerà la merce rubata
Il ladro avrà abbandonato la merce rubata
La polizia prevede che il ladro abbandonerà la merce rubata
La segretaria ribatterà la lettera del cliente
La segretaria avrà ribattuto la lettera del cliente
L'avvocato promette che la segretaria ribatterà la lettera del cliente
L'autista annuncerà la fermata richiesta
L'autista avrà annunciato la fermata richiesta
Il passeggero ritiene che l'autista annuncerà la fermata richiesta

## Appendix 2. English stimuli

The fireman put out the dangerous fire
The fireman will put out the dangerous fire
The policeman declared that the fireman had put out the dangerous fire
The grandmother brought the Christmas presents
The grandmother will bring the Christmas presents
The father thought that the grandmother had brought the Christmas presents
The dentist extracted the infected tooth
The dentist will extract the infected tooth
The patient indicated that the dentist had extracted the infected tooth
The cyclist lost the regional race
The cyclist will lose the regional race
The reporter mentioned that the cyclist had lost the regional race
The writer published a new book
The writer will publish a new book
The editor revealed that the writer had published a new book

The teacher marked everyone's homework
The teacher will mark everyone's homework
The student explained that the teacher had marked everyone's homework
The singer changed this evening's program
The singer will change this evening's program
The journalist wrote that the singer would change this evening's program
The electrician mended the broken wires
The electrician will mend the broken wires
The builder stated that the electrician would mend the broken wires

The fisherman docked the damaged boat
The fisherman will dock the damaged boat
The coastguard predicted that the fisherman would dock the damaged boat

The athlete performed the difficult jump
The athlete will perform the difficult jump
The coach believed that the athlete would perform the difficult jump

The journalist finished the lengthy interview
The journalist will finish the lengthy interview
The publicist said that the journalist had finished the lengthy interview

The guide explained the local history
The guide will explain the local history
The company promised that the guide would explain the local history
The traveler postponed the departure date
The traveler will postpone the departure date
The agency suspected that the traveler would postpone the departure date
The actress married a French colleague
The actress will marry a French colleague
The director mentioned that the actress had married a French colleague
The student copied all missed assignment
The student will copy all missed assignments
The professor guessed that the student would copy all missed assignments
The thief hid the stolen goods
The thief will hide the stolen goods
The police presumed that the thief would hide the stolen goods
The secretary typed the client's letter
The secretary will type the client's letter
The lawyer promised that the secretary would type the client's letter
The driver announced the next stop
The driver will announce the next stop
The passenger assumed that the driver would announce the next stop

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[^1]:    ${ }^{1}$ We will indicate omitted material by strikethroughs.

