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RESEARCH ARTICLE

Reading Fluency in Spanish Patients with Alzheimer's Disease

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Abstract: ***Background*:** Reading fluency is essential for our functioning in the literate society in which we live. Reading expressiveness or prosody, along with speed and accuracy, are considered key aspects of fluent reading. Prosodic patterns may vary, not being the same in children learning to read as in adulthood. But little is known about the prosodic characteristics and reading fluency of people with neurodegenerative diseases that causes language impairment and reading difficulties, such as Alzheimer's disease (AD).

***Objective*:** The aim of this work was to study reading fluency in AD, considering reading speed, accuracy and reading prosody.

***Method*:** The participants were 20 healthy elderly Spanish adults, and 20 AD patients, aged 64-88 years. An experimental text was designed, that included declarative, exclamatory, and interrogative sentences, words with different stresses and low-frequency words. The reading of the participants was recorded and analyzed using Praat software.

***Results*:** The AD group showed significantly longer reading duration, both at the syllable level and at the word and sentence level. These patients also committed more pauses between words, which were also longer, and more reading errors. The control group showed a variation of the syllabic F0 in the three types of sentences, while these variations only appeared in declarative ones in the AD group.

***Conclusion*:** The pauses, along with the slight pitch variations and the longer reading times and errors committed, compromise the reading fluency of people with AD. Assessment of this reading feature could be interesting as a possible diagnostic marker for the disease.

Keywords: Reading fluency, Alzheimer's disease, reading prosody, fundamental frequency, reading duration, reading accuracy.

1. INTRODUCTION

When we read, it is important to do it accurately and at an appropriate speed, but there are other aspects such as intonation or the time we take to breathe, which are also important to read fluently. These aspects, which contribute to reading expressiveness, are known as prosodic reading markers [1, 2].

Although reading fluency has been traditionally studied in terms of the number of words produced per minute (speed) and their accuracy, in more recent studies, research has suggested the importance of reading prosody for fluent reading [3-5]. For this reason, the most widely used definition of reading fluency today is that reading is fluent when it is accurate, with a correct speed, and has a correct intonation or expressiveness [6].

Correct intonation or expressiveness refers to different linguistic keys of speech, which are considered suprasegmental aspects of language that include pitch variations, stress, or pauses. When these suprasegmental aspects are presented in fluent reading, we talk about prosodic reading [7]. There are some prosodic features associated with pauses, fundamental frequency (F0), duration and syllabic intensity, which are present in all languages [8]. The F0 refers to the changes in pitch of the reader's voice, and the more the pitch varies, the more expressive the reading is perceived [2].

Some of the studies on reading fluency including analysis of prosody, have shown that, as children who are learning to read improve decoding ability (speed and accuracy), reading becomes more fluent and prosodic patterns begin to resemble those of adults [5, 9-13]. It has been shown that English children with more years of reading experience, who had a quick and accurate reading, also tend to present a more pronounced rise in pitch at the beginning of interrogative sentences and a greater declination at the end of declara-

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tive sentences. In addition, they had shorter and more adult-like pause structures [11, 12]. In contrast, in the early years of reading experience, when fluent reading has not yet been achieved, Spanish and English children make more inappropriate pauses and show a flattened melodic contour, which is associated with a poor ability to anticipate the structure of the sentence [9, 13]. Binder *et al*. [14] found similar results in adults with poor reading abilities, who made many pauses, which were also longer, and showed no change in pitch when reading interrogative sentences.

Reading expressiveness can also be altered in people with language disorders which causes reading difficulties, such as dyslexia or specific language impairment (SLI). Suárez-Coalla, Álvarez-Cañizo, Martínez-García, García and Cuetos [15] analyzed reading prosody in Spanish adults and children with dyslexia and their results showed that people with dyslexia made more and longer pauses, even when they were adults. In addition, people with dyslexia showed longer reading times and flattened pitch changes at the end of sentences. Similar results were found in Spanish children with SLI [16], who showed longer reading duration and made many inappropriate pauses. Children with SLI also showed less F0 variation in interrogative sentences, especially marked at the end of the sentence.

Studies have been conducted with children of different ages with the aim of assessing how learning to read improves reading prosody and therefore reading fluency but, what happens in the opposite process when reading begins to be impaired as a result of neurodegenerative diseases? Reading fluency has been scarcely studied in the elderly population, and little is known about its characteristics. However, many of the pathologies related to age are associated with language and reading problems, which could cause alterations in reading fluency, such as Alzheimer's disease (AD).

Language disorders in AD are often unnoticed in the early stages of the disease, as these disorders are less conspicuous than the memory loss of these patients. However, when a specific assessment of language is made, difficulties in production and comprehension can be found in the early stages of the disease, both at the oral and written levels [17].

Regarding reading in AD, it was assumed that this ability was preserved in these patients. Cummings, Houlihan and Hill [18] measured the speed and accuracy of reading letters and regular and irregular words in a group of English people with AD. Their results showed poor reading in severe AD patients, but no impairment was found in mild patients. In contrast, reading comprehension showed a decline from the early stages of the disease that indicates a deficit in semantic access. Cuetos *et al*. [17] found similar results in Spanish AD patients, who showed significantly worse performance on those tasks requiring semantic processing (oral and written naming, semantic verbal fluency, semantic association, image sorting), and on non-word reading, but no difference was found in word reading. More recent researches suggest that reading can be impaired at speed and accuracy level, especially when reading certain types of stimuli [19].

In this line, several studies have described the difficulty to read irregular and low frequency words [20-23] and pseudo-words [24] in English-speaking patients with AD. Patterson, Graham and Hodges [22] measured the speed and accuracy when reading non-words and regular and irregular words with different lexical frequency. Their results revealed a significantly higher number of errors in low-frequency words, which correlated with the impairment in the semantic memory of the patients. Non-words reading was impaired in both moderate and severe patients, but no differences were found between groups when reading regular words. Similar results are described in the longitudinal study by Fromm, Holland, Nebes and Oakley [20] which showed how the reading performance of irregular words gets worse as the disease progresses, supporting semantic impairment in AD. In addition, over time, patients no longer applied grapheme-phoneme conversion rules when reading irregular words, and they tried to guess them based on their similarity to other words. The most common reading errors made by patients with AD were phonological (addiction, omission, or substitution of phonemes) and lexical errors (changing the word for a similar one). In contrast, Raymer and Berndt [25] analyzed the reading of words and pseudo-words in an AD group and their results showed little difficulty in reading these stimuli. Most of the reading errors made by the patients were phonological, regularization and stress errors.

Conclusions from reading studies in AD are very disparate and provide different explanations for the difficulties described. Some researchers considered that reading is impaired by a decline in the semantic system in AD, which affects reading comprehension, but hardly reading aloud and causes a non-semantic lexical reading [25]. Other studies also described impairment of the phonological route of reading [20, 22, 24], and there are also a few studies which explained the semantic damage of reading in AD by non-linguistic cognitive problems due to memory impairment, such as visual or attentional processes [21].

Reading studies in AD consider speed and accuracy when reading single words, but what about reading prosody? This feature of reading fluency has been scarcely studied in AD. In fact, most oral language studies analyze speech in spontaneous language tasks, while reading prosody has been hardly studied. According to the review by Pulido *et al*. [26], the research on speech in AD has increased in recent years, but only 3% of the scientific production in this area examine reading aloud tasks, compared to 73% of studies that analyze spontaneous speech.

Regarding studies that analyze speech in AD using spontaneous speaking tasks, similar results have been reported in different languages. Gayraud, Barkat-Defradas and Lee [27] analyzed the spontaneous language of French people with AD, using questions about their biography. Their results showed that AD patients made more silent pauses, but no differences in filled pauses and elongations were found. Speech rate was slower in the AD group, but articulation speed did not differ between the groups. Beltrami *et al*. [28] analyzed spontaneous language in Italian AD patients, considering the

syntactic and lexical complexity of the speech. Language rhythm and grammar seemed to be preserved in these patients, however, the linguistic production was semantically weak and showed more simple syntactic structures. Forbes-McKay, Shanks and Venneri [29], used a picture description task to evaluate English patients with AD. Results showed semantic lexical impairment, with an increase in speech pauses and undefined sentences, as well as less complex sentences with flatter pitch contours than controls. In addition, the prevalence of phonological errors increased with the course of the disease. Fraser Meltzer and Rudzicz [30] used spontaneous speech data in picture description in patients with AD and they were able to classify 81% of the cases correctly. The key aspects that discriminated between AD and control participants were semantic impairment, acoustic abnormalities and weaker syntactic complexity.

Considering the markers of the reading prosody in AD, the few studies carried out in Spanish described the reading of these patients as not very expressive. In the studies by Martínez-Sánchez, Meilán, Pérez, Carro and Arana [31] and Martínez-Sánchez *et al*. [32], they analyzed the reading of Spanish people with AD, using a semi-automatic prosody transcription program. The participants read the first paragraph of the book *Don Quixote de la Mancha*. The main differences between AD and controls were found in the overall reading time, as well as in vowel length and pauses. They also found little pitch variations in these patients, who did not show the final pitch decline in the declarative sentences. In addition, people with AD also showed a longer average syllable length, as well as a more irregular rhythm than healthy elderly people. Long reading times, along with a large number of pauses and pitch alterations, make reading for AD patients poorly prosodic.

Bearing in mind the alterations described in the reading of these patients, some research has been conducted to study the characteristics of reading prosody in AD as a diagnostic marker for the disease. Meilán *et al*. [33] analyzed temporal and acoustic spectrograms of the reading aloud of familial declarative sentences. They also found a slow reading with plenty of pauses in AD patients, and their model was able to discriminate 84% of the cases. In a similar study, Martínez-Sánchez, Meilán, García-Sevilla, Carro and Arana [34], using a semiautomatic temporal analysis of reading in AD, proposed the analysis of reading fluency as a method to discriminate around 80% of cases with AD.

It has been shown that patients with AD suffer from some reading difficulties, especially characterized by a slow and inaccurate reading of irregular and infrequent words. Reading prosody also seems to be affected in these patients when analyzing the reading aloud of a text. However, reading studies have yielded disparate results over the years, and very few studies have considered reading prosody in AD. The divergences between research findings may be due to the fact that, in previous research, the reading of isolated words or non-experimental texts with different characteristics was analyzed. Nevertheless, the use of experimental texts is necessary in order to control all the variables that have been shown to influence linguistics tasks in AD, such as lexical frequency or word regularity. In addition, these texts should include different types of sentences since the reading prosody varies from a declarative sentence to an interrogative or exclamatory one. Furthermore, the use of new analysis tools allows a detailed and experimental analysis of the prosodic features of reading.

Therefore, the aim of this paper was to study the reading fluency of AD, by analyzing reading speed and accuracy of AD patients, as well as their reading prosody. In contrast to the studies described above, an experimental text was designed for this research, which included some experimental stimuli. Psycholinguistic variables such as lexical frequency or word length, which have been demonstrated to be relevant in the study of Spanish reading [35], were considered in the stimuli selection. Measurements of pauses, stress, duration, and pitch, as well as reading errors in some experimental stimuli, were analyzed. The spectrogram analysis methodology was implemented using the Praat software [36]. Considering the results reported in the literature, we anticipate that some impairment in the reading fluency components of AD patients could exist. In particular, we expect to find some reading prosody disturbances in patients with AD that differ from the control group.

2. MATERIALS AND METHOD

2.1. Participants

Participants were 40 Spanish adults, aged between 64 and 88 years, with a mean age of 79.25 years (SD = 6.77). The participants were all native Spanish speakers and had no history of alcohol abuse or any other neurological or psychiatric disorder other than AD.

Half of the participants, 19 women and 1 man were AD patients diagnosed by the Neurology Department in a hospital of Asturias. AD diagnosis was made following NINCDS-ADRDA criteria [37]. The other participants (19 women and 1 man) were healthy elderly people who were evaluated in a social center in Asturias and comprised the control group. No significant differences were found between the groups in age [$t_{(38)} = 0.25$, $p = .8$] or educational level [$t_{(38)} = 0.18$, $p = .85$]. Most of the participants in the study had received secondary education. Having at least a basic educational level and being able to read and write were considered a requirement to participate in the study. The characteristics of the participants are shown in Table **1**.

All participants were evaluated with the Spanish adaptation of the Mini-Mental State Examination (MMSE) [38]. The mean score in this test was 19.7 (*SD*=3.71) in the AD group, and 28.15 (*SD* = 0.98) in the control group. Significant differences between the scores of both groups were found [$t_{(21.69)} = 9.866$, $p < .001$].

2.2. Materials

A narrative text of 200 words was designed to conduct this study (see Appendix A). This experimental text

Table 1. Demographic profile of participants (*M*, mean; *SD*, standard deviation)..

-	Control *M (SD)*	EA *(SD)*
Age	79.55 (6.71)	79 (7.01)
Years of schooling	16.1 (2.61)	15.95 (2.58)
MMSE	28.15 (0.98)	19.7 (3.7)

included declarative sentences (*i.e.*, "*Antonio se puso muy contento* [Antonio got very happy]", exclamatory sentences (*i.e.*, "*¡Creo que la primavera ha llegado por fin!* [I think spring has come at last!]"), and interrogative sentences (*i.e.*, *"¿Por qué tarda tanto en llegar la primavera?* [Why does it take so long for spring to come?]").

In order to analyze the stress in the reading, words with different stresses were also selected: eight words with stressed on the antepenultimate syllable (*i.e.*, *bóveda*, *ánfora* [vault, amphora]), and eight words stressed on the penultimate syllable (*i.e.*, *almendros*, *acacias* [almond tree, acacia]). These words were paired according to their lexical frequency ($t_{(14)}$ = 0.15, p = .886) and length ($t_{(14)}$ = 1.84, p = .087) (see Appendix B) and were included in the experimental text. Words stressed on the penultimate syllable are the most common in both Spanish [39] and English [40]. In Spanish, the studies by Gutierrez [41] showed that the stress mark is processed with a stress value, and this stress mark plays an important role in the lexical search.

Finally, eight very low frequency words were also included in the text ($M_{\ lexical\ \ frequency}$= 0.55, *SD* = 1.24; *i.e.*, *subyugado*, *alfeizar* [subjugated, windowsill]) (see Appendix C). Although word regularity is a variable that appears to be influencing the reading of people with AD in English [19], only word frequency was considered in this study. This is due to the fact that in Spanish, all words can be read correctly by applying the rules of grapheme-phoneme conversion, as the correspondences are always consistent [35]. Two of the low frequency words (*secuoya*, *magnolia* [sequoia, magnolia]) were repeated in the text, once in the first part of the text and once in the final part, in order to explore whether their repetition might influence their reading times. The lexical frequencies of the chosen words were obtained from the LEXESP database [42].

The experimental text was presented to the participants on a sheet of DIN-A4 paper, which was printed in black ink. The text was in Times New Roman 12-point font, with 1.15 point spacing. The reading of the participants was recorded with an H4n voice recorder, connected to an Ht2-P Audix headset condenser microphone.

2.3. Procedure

The AD patients were assessed in a hospital room, while the control group was examined in an office of the social center they attended. In both places, the assessment room was isolated from noise and other disturbances.

When the participants arrived, the examiner explained to them that they were going to perform some memory and reading tasks. An informed consent was then signed, guaranteeing the confidentiality of their personal data. In the case of AD patients, their families were also informed. First, the researcher asked the participants some personal data (name, age, years of schooling, native language). The participants were then evaluated with the MMSE test [38]. Finally, participants were given a microphone connected to a voice recorder. The researcher then presented the experimental text, printed on a sheet of paper, to the participants. Thay were asked to read the text aloud, trying not to make mistakes. Each session of assessment lasted between 15 and 20 minutes.

The audio recordings were analyzed with the Praat software [36], which allows the analysis, synthesis, and manipulation of voice data in digital format, and the measurement of pitch, intensity, and duration of the recordings. In order to automate the analyses, some published scripts for extracting pitch in two passes [43], for the creation of pictures [44] and specially written scripts for Praat were used. Three sentences were extracted from the text: one declarative, one exclamatory and one interrogative. The sentences extracted from the text were analyzed using the measures explained below. These measures have been found to be of interest to the study of reading fluency in relation to reading prosody [1, 2, 8].

- Pauses (s):
  - Number and duration of inappropriate pauses committed during the reading of sentences, that is, pauses between words in the absence of a grammatical mark, and pauses made within a word.
- Duration (s):
  - Sentence duration: Time between the first and last syllable of the sentence.
  - Syllable duration: Duration of the first and last syllable of the sentences and mean duration of the intermediate syllables.
- Intensity (dB):
  - Syllable intensity: Intensity of the first and last syllables of the sentences and mean intensity of the intermediate syllables.
- Pitch measures or fundamental frequency (F0):
  - Initial rise (St): distance between the lowest value of F0 at the beginning of the sentence and the first peak of F0 in declarative and interrogative sentences.
  - Final rise (St): the difference in pitch between the last trough of F0 and the end of an interrogative sentence.
  - Slope (St/s): declination of F0 from the first peak to the end of the sentence, expressed in

units of time in declarative and exclamatory sentences.
    - Syllables (St): the mean pitch of the first syllable, the intermediate syllables, and the final syllable.

In addition, the words with different stresses were extracted from the voice recordings (8 stressed on the penultimate syllable and 8 on the antepenultimate syllable). The analysis of these words included:

- Duration (s): Reading duration of the words.
- Stress errors: Number and type of stress errors committed.

Finally, the 8 very low frequency words were extracted, two of which (sequoia, magnolia) were repeated at the end of the last paragraph. The following measures were considered in the analysis of these stimuli:

- Duration (s): Reading duration of low frequency words.
- Pauses (s):
    - Number and duration of inappropriate pauses made in the low frequency stimuli: pauses committed before low frequency words and pauses within these words.
- Reading errors: The number and type of errors committed during the reading of these words were analyzed. Reading errors were identified during the reading analysis with the Praat software and they were classified manually according to their type: Phonological errors (changing phonemes for others by substitution, omission, or addition), lexical errors (changing the word for a similar word) and repetitions (repetition of the word) were considered.

This research procedure was approved by the Research Ethics Committee of the Principality of Asturias. It was included in a research project for the study of reading and writing fluency in neurodegenerative diseases, Project No. 266/19. The privacy of the information obtained was always guaranteed, in accordance with the ethical and privacy regulations required by the code of ethics.

2.4. Data Analyses

The data collected using the Praat software [36] were analyzed using the SPSS software (IBM Corp. Released 2012). IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IMB Corp.

3. RESULTS

3.1. Sentences Analyses

In order to analyze the number and duration of pauses made by both groups, the overall reading duration of the sentence and the variations in pitch in each of the sentences, the *Student t-test* for independent samples were used. On the other hand, syllables measurements were analyzed with a mixed effect analysis of variance (ANOVA). Measures of F0, intensity and duration of the syllables were included as intra-subject factors. The group was used as an inter-subject factor. The normality of the three variables in the three types of sentence was confirmed using the Kolmogorov-Smirnov test. The measures of the variables analyzed in the sentences are shown in Table **2**.

First, the pauses in the sentences were analyzed. AD patients showed a significantly higher number of inappropriate pauses between words in the exclamatory and interrogative sentences [Exclamatory ($t_{(19)}$= 3.81, p=.001); Interrogative ($t_{(19)}$= 4.39, p<.001)], which were also significantly longer in the interrogative sentences [($t_{(19)}$= 2.88, p=.01)]. No significant differences were found between the groups in pauses within words.

Concerning overall sentence duration, patients with AD showed significantly longer reading times than the control group in all three sentence types [Declarative ($t_{(19)}$= 3.27, p=.004); Exclamatory ($t_{(19)}$= 2.76, p=.012); Interrogative ($t_{(19)}$= 3.89, p=.001)]. At the syllable level, the AD group showed a longer mean duration of the syllable than the control group. A significant effect of the inter-subject variable (group) on declarative [($F_{(1,38)}$=13.56, p=.001, partial η^2=.26)] and interrogative [($F_{(1,38)}$=12.39, p=.001, partial η^2=.25)] sentences was found. The comparison of Bonferroni was used. It was found that the syllabic duration was significantly higher in the AD group in the intermediate syllables (p=.001) and the last syllable (p<.001) in the declarative sentences. The same was found for all syllables in the interrogative sentences [First syllable (p=.003); Intermediate syllable (p=.004); Last syllable (p=.04)].

On the other hand, the analysis of syllabic intensity showed a higher syllable intensity in the AD group in all sentences [Declarative ($F_{(1,38)}$=10.89, p=.002, partial η^2=.22); Exclamatory ($F_{(1,38)}$=11.79, p=.001, partial η^2=.237); Interrogative ($F_{(1,38)}$=7.47, p=.009, partial η^2=.16)].

As for the pitch analysis, no significant differences were found between the groups at the first F0 rise in the declarative and interrogative sentences. No differences were either found in the F0 final rise of interrogative sentences. No significant differences were found between the groups in the F0 slope of any of the sentences either.

The results of the syllabic pitch showed significant differences between the AD group and the control group. The interaction between F0 and group was statistically significant in all three types of sentence. In declarative sentences [Declarative F0 Syllable*Group ($F_{(2, 58)}$=3.86, p=.026, partial η^2=.12)], both groups showed a significant decrease in pitch from the intermediate syllables to the final one [AD Intermediate-last syllabic F0 (p<.001); Control Intermediate-last syllabic F0 (p<.001)]. However, the pitch of the patients with AD was significantly higher than the controls in the last syllable (p=.033) (see Fig. **1**).

Table 2. Mean and SD of the parameters analyzed in the experimental sentences (*M*, mean; *SD*, standard deviation; s, seconds; dB, decibels; St, semitones; *, statistically significant differences).

Type of Sentence	Parameter	-	AD	Control
-	-	-	*M (SD)*	*M (SD)*
Declarative	Nº pauses between words	-	0.45 (0.76)	0.15 (0.36)
-	Duration of pauses between words (s)	-	0.05 (0.09)	0.12 (0.46)
-	Nº pauses within words	-	0.05 (0.22)	0 (0)
-	Duration of pauses within words (s)	-	0.11 (0.05)	0 (0)
-	Reading sentence duration (s) *	-	2.23 (0.51)	1.8 (0.22)
-	Duration of the syllable (s)	First	0.19 (0.05)	0.18 (0.03)
-	-	Intermediate *	0.22 (0.04)	0.18 (0.02)
-	-	Last *	0.21 (0.05)	0.15 (0.02)
-	Intensity of the syllable (dB) *	First	68.52 (9.62)	61.68 (6.56)
-	-	Intermediate	68.57 (7.04)	62.11 (4.76)
-	-	Last	57.8 (8.85)	49.67 (6.49)
-	F0 Rise (St)	-	7.33 (2.94)	8.07 (1.93)
-	F0 Solpe (St/s)	-	48.12 (16.35)	45.77 (12.94)
-	F0 of the Syllable (St)	First	89.82 (2.04)	88.88 (2.71)
-	-	Intermediate	91.74 (1.59)	91.72 (2.81)
-	-	Last *	87.19 (1.61)	85.22 (3.02)
Exclamatory	Nº pauses between words *	-	1.55 (1.27)	0.4 (0.59)
-	Duration of pauses between words (s)	-	0.31 (0.33)	0.12 (0.21)
-	Nº pauses within words	-	0.05 (0.22)	0.05 (0.22)
-	Duration of pauses within words (s)	-	0.02 (0.08)	0.02 (0.08)
-	Reading sentence duration (s) *	-	3.65 (1.66)	2.57 (0.56)
-	Duration of the syllable (s)	First	0.25 (0.06)	0.24 (0.04)
-	-	Intermediate	0.17 (0.04)	0.14 (0.02)
-	-	Last	0.38 (0.08)	0.34 (0.05)
-	Intensity of the syllable (dB) *	First	73.39 (9.2)	65.32 (5.11)
-	-	Intermediate	71.89 (8.32)	66.98 (5.57)
-	-	Last	67.91 (6.51)	59.86 (5.64)
-	F0 Solpe (St/s)	-	39.14 (14.36)	36.07 (10.16)
-	F0 of the syllable (St)	First	91.94 (3.41)	94.03 (2.94)
-	-	Intermediate *	89.41 (3.73)	92.34 (2.61)
-	-	Last *	88. 56 (3.28)	89.35 (2.78)
Interrogative	Nº pauses between words *	-	2.55 (2.3)	0.4 (0.75)
-	Duration of pauses between words (s) *	-	0.56 (0.76)	0.07 (0.14)
-	Nº pauses within words	-	0.30 (0.66)	0.05 (0.22)
-	Duration of pauses within words (s)	-	0.09 (0.21)	0.02 (0.09)
-	Reading sentence duration (s) *	-	5.93 (3.62)	2.69 (0.55)
-	Duration of the syllable (s)	First *	0.26 (0.06)	0.23 (0.04)
-	-	Intermediate *	0.22 (0.06)	0.18 (0.03)
-	-	Last *	0.23 (0.06)	0.19 (0.05)
-	Intensity of the syllable (dB) *	First	68.85 (8.61)	61.39 (6.63)
-	-	Intermediate	71.19 (7.74)	65.45 (5.85)
-	-	Last	68.16 (9.81)	63.41 (7.31)
-	F0 Rise 1 (St)	-	5.82 (7)	7.37 (2.74)
-	F0 Rise 2 (St)	-	1.93 (8.48)	4.84 (5.42)
-	F0 of the syllable (St)	First *	89.84 (2.12)	92.09 (3.25)
-	-	Intermediate *	90.73 (2.17)	91.28 (2.21)
-	-	Last *	90.12 (3.58)	89.39 (3.01)

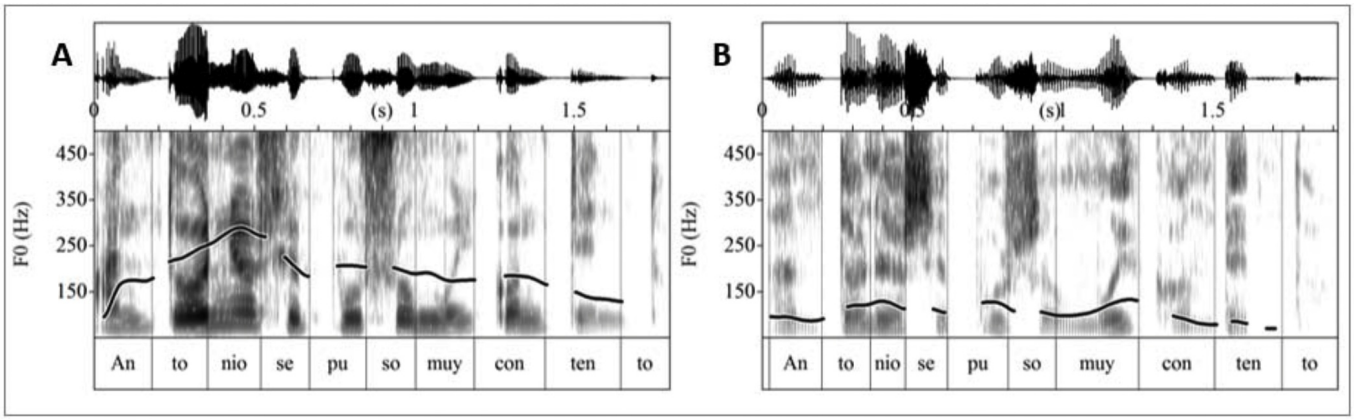

Fig. (1). Example of the pitch contour of declarative sentence in control group (**A**) and AD group (**B**). *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

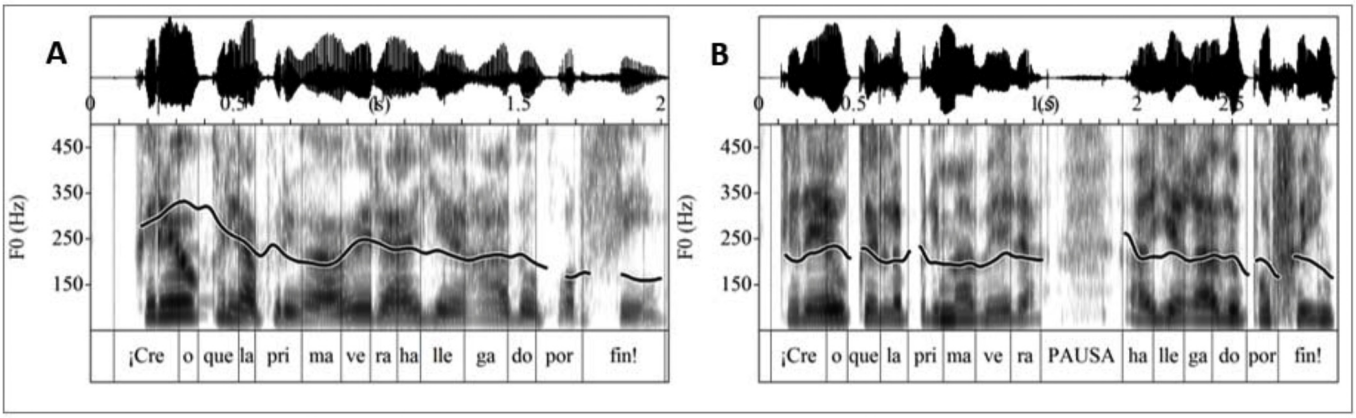

Fig. (2). Example of the pitch contour of exclamatory sentence in control group (**A**) and AD group (**B**). *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

On the other hand, in the exclamatory sentences [Exclamatory F0*Group ($F_{(1.51, 55.82)}$=4.24, p=.029, partial η^2=.11)], significant differences in syllabic pitch were found in all three syllables in the control group [First-intermediate syllabic F0 (p<.001); First-final syllabic F0 (p<.001); Intermediate-last syllabic F0 (p<.001)]. However, no significant difference between the pitch of the intermediate syllable and the last syllable was found in the AD group (see Fig. **2**).

Finally, in the interrogative sentences [Interrogative F0*-Grupo ($F_{(1.71, 60.01)}$=5.09, p=.012, partial η^2=.12)] significant differences were found in the pitch of the syllables in the control group [First-last syllabic F0 (p=.003); Intermediate-last syllabic F0 (p=.019)]. In contrast, no differences were found in the AD group in this parameter (see Fig. **3**).

3.2. Analyses of Words with Different Stresses

To analyze the words with different stresses, an ANOVA was carried out. A significant effect of the type of stress was found [($F_{(3,76)}$) = 6.33, p = .001, partial η^2 =.2] (Table **3**). The results of the post-hoc HSD Tukey test showed a significantly longer reading duration in the AD group for both stimuli [Penultimate syllable stress words (p = .05); Antepenultimate syllable stress words (p = .005)]. No effect of stress on reading duration was found within each group. Concerning reading errors, the percentage of stress errors was higher in the AD group (29%) than in the control group (11%) [$t_{(29.89)}$=2.53, p=.017].

3.3. Analyses of Low Frequency Words

The duration of low-frequency words was significantly longer in the AD group than in the control group ($t_{(19)}$= 2.67, p =.015) (Table **4**). To analyze the repeated words in the text (sequoia, magnolia), a mixed effect ANOVA was carried out. It was found that the repetition had no effect on their reading duration.

The analysis of pauses in low-frequency words showed that the AD group committed more inappropriate pauses before these words. These pauses were significantly longer

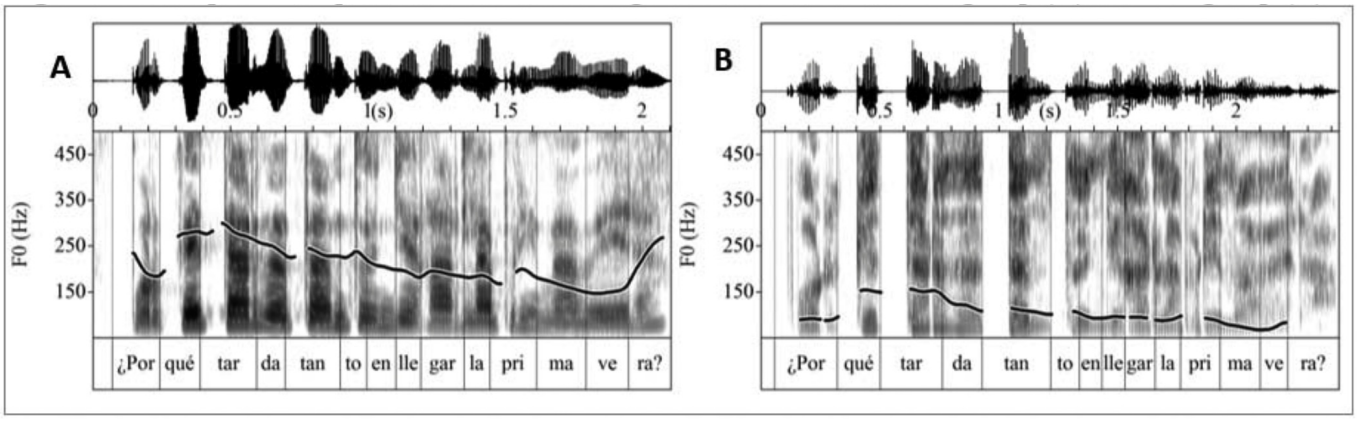

Fig. (3). Example of the pitch contour of interrogative sentence in control group (**A**) and AD group (**B**). *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

Table 3. Mean and standard deviation of reading duration for words with different stresses (*M*, mean; *SD*, standard deviation; s, seconds).

Parameter	-	AD	Control
-	-	*M (SD)*	*M (SD)*
Reading duration (s)	Stress on the penultimate syllable	1.4 (0.96)	0.81 (0.17)
-	Stress on the antepenultimate syllable	1.56 (1.01)	0.78 (0.25)

Table 4. Mean and standard deviation of the parameters analyzed in the very low frequency words (*M*, mean; *SD*, standard deviation; s, seconds).

Parameter	EA	Control
-	***M (SD)***	***M (SD)***
Nº pauses between words	3.92 (2.31)	3.25 (2.55)
Duration of pauses between words (s)	0.63 (0.42)	0.34 (0.22)
Nº pauses within words	3.40 (3.73)	2.5 (3.17)
Duration of pauses within words (s)	0.37 (0.32)	0.43 (0.52)
Reading word duration (s)	2.16 (1.53)	1.2 (0.55)
Reading duration 1 (sequoia, magnolia)	2.72 (2.57)	1.58 (1.29)
Reading duration 2 (sequoia, magnolia)	2.35 (2.04)	1.26 (1.05)

Table 5. Percentage of reading errors committed by the control group and the AD group in the low frequency words.

Type of Error	EA	Control
Phonological errors	35%	26%
Lexical errors	2%	3%
Repetition errors	18.3%	15%

than in the control group ($t_{(19)}$= 2.23, p=.038). Concerning reading error analysis, phonological errors (*i.e.*, substitutions, additions, omissions, etc.) and repetitions were the most frequent in both groups (Table **5**). No differences between groups were found regarding the number of errors committed during the reading of these words ($t_{(38)}$= 1.09, p=.28).

4. DISCUSSION

The aim of this work was to study reading fluency in Spanish patients with AD, by considering the speed and accuracy of their reading, but focusing on the analysis of their reading prosody. For this purpose, an experimental text was designed, which included selected words according to their

length and lexical frequency and different types of sentences.

First, we analyzed the speed and accuracy of the reading by taking measurements of the duration and errors made in the reading of words with different stresses and low frequency words. The reading time of declarative, exclamatory, and interrogative sentences was also measured. The AD group showed significantly longer reading duration for words with different stresses, regardless of stress type, as well as for words with low frequency. These results can be expected according to studies that describe a lower speed in AD people for reading single words, especially when these words have low frequency [22]. In addition to a slower reading on these stimuli, some reading errors were also found. Patients with AD made more stress errors than control group when reading the stimuli with different stresses. In both groups, the stress errors were to read the antepenultimate syllable stress words as if they were stressed on the penultimate syllable, which is the most common type of stress in Spanish [39]. According to Gutierrez [41], in Spanish the stress mark is processed as stress value and has an important role in lexical access. Reading words with incorrect stress could suggest reading by the sublexical route, which would mean a deterioration of the lexical-semantic route of reading. These findings are in line with studies that showed a significant impairment of the semantic system in AD, which has been described in different tasks, such as naming [45. 46], verbal fluency [17, 47], spontaneous speech [28-30], and also in reading, especially when reading low-frequency and irregular words in English [19].

Regarding low-frequency words, patients with AD made more pauses before these words, which were significantly longer, and made a greater number of reading errors. The lexical frequency is the variable that most influences in Spanish reading for the lexical access [35], therefore, the difficulties to read this type of words also support a deterioration in the lexical-semantic route. In addition, most of the reading errors were phonological errors, produced by changing or omitting phonemes. This type of reading error is made when the phonological reading route is used and previous studies had described them in the reading of AD patients [20, 25, 29]. Nevertheless, although the number of reading errors was higher in the AD group in this study, the differences were not significant, so the result should be taken with reservation.

In terms of sentences, the AD group showed significantly more reading time than the controls in all three types of sentence (declarative, exclamatory and interrogative). This slow pace of the reading of AD Spanish patients had already been described at the sentence level. The studies by Martínez-Sánchez, Meilán, García-Sevilla, Carro and Arana [34] and Meilán *et al*. [33] analyzed the reading of the first paragraph of a novel, formed by declarative complex sentences, and found a significantly longer total reading duration in the AD group. For our study, an experimental text was developed, that allowed us to include several types of stimuli, such as declarative, exclamatory, and interrogative sentences. We found significantly longer reading durations in AD group in all three types of sentences. This result suggests that the slowdown at sentence reading level does not depend on the type of phrase read, since reading showed a general slowness.

In order to consider all the elements of reading fluency, the reading prosody of the participants was also analyzed. To this end, measures of the pauses made during the reading of the experimental sentences (declarative, exclamatory, interrogative) were taken, as well as measures of duration, intensity and syllabic pitch. The analysis of sentence pauses showed a significantly higher number of inappropriate pauses between words in exclamatory and interrogative sentences, which also were longer than those made by the controls. However, no differences were found between the groups in the pauses of the declarative sentences. In contrast, some previous research [31, 34], described a greater number of pauses in the reading of people with AD in declarative sentences. These previous studies analyzed the reading of the first paragraph of the novel *Don Quixote de la Mancha*, which is comprised of long and complex declarative sentences, with some infrequent or unknown words. This fact could make it difficult to read the sentences, even if they were declarative. In our work, we tried to study the influence of the type of sentence on reading, so the sentences analyzed were composed of medium-frequency words so they would not interfere in prosody. Concerning exclamatory and interrogative sentences, we do not know of any other research that analyzed this kind of stimuli in Spanish AD patients. Nevertheless, our results suggest that these patients may have more difficulties when reading exclamatory and interrogative sentences compared to declarative ones. This could be due to the fact that declarative sentences are the most common structure when we read a text.

Within the analysis of prosody, a longer syllable duration was found in the AD group in all sentences, which helps to slow-down reading. The study by Martínez-Sánchez *et al*. [32] also described a significantly longer mean syllable length in people with AD, but the fragment read was composed of declarative sentences only. In our case, the differences between the groups were significant in all the syllables (initial, intermediate, final) of the interrogative sentence. This would indicate that the group with AD required a significantly longer amount of time to read interrogative sentences, even if they generally had longer syllabic duration than the controls. As described in previous studies, long reading times and a large number of pauses in the reading of sentences contribute to the slowness of the reading of AD patients [31, 32, 34].

Further syllable analysis, measurements of the syllabic intensity of the sentences were taken. It is known that there is a tendency for F0 to decline over time, except for interrogative sentences, and this decline in F0 is usually accompanied by a decline in intensity [8]. In this work, both the control and the AD groups showed a decrease in the intensity from the intermediate syllable to the end of declarative and exclamatory sentences, which is consistent with a cor-

rect prosodic pattern. However, the AD group showed a higher mean syllabic intensity than the control group in all the sentences. These results are not in line with expectations according to previous studies, which describe the reading of patients with AD as tremulous and less intense than controls. In the study by Meilan *et al*. [33], reading intensity was measured by voice intensity, voiceless signals and phonatory stability during the reading of a non-experimental text that was comprised of declarative sentences. In the present study, we analyzed declarative, exclamatory and interrogative sentences in an experimental text, finding higher syllabic intensity reading in all of them. Galaz *et al*. [48] describe similar results to those found in our work in a group of people with Parkinson's disease and explain these results by an impairment in the control of reading intensity. A similar pattern could be observed in AD, where high levels of intensity could be trying to balance out the small pitch changes that showed these patients. Nevertheless, research on syllabic intensity in AD is very scarce, so more studies are needed to reach a conclusion.

In terms of syllabic pitch, the analysis showed that people with AD performed the usual final F0 decline on the final syllable of declarative sentences, although their pitch was significantly higher than that of controls. These results are not congruent with those described in the study by Martínez-Sánchez, Meilán, Pérez, Carro and Arana [31], which showed an inappropriate reading of declarative texts of AD patients, which did not present the final declination of F0. Our results showed a final pitch decline in the reading of declarative sentences in patients with AD when the pitch was analyzed at syllable level, although the declination was less pronounced than in the control group. It is possible that the intonation in these sentences is starting to be impaired, but it is not yet lost. The differences could also be due to the profile of the participants and their impairment degree. However, in the study by Martinez-Sanchez Martínez-Sánchez, Meilán, Pérez, Carro and Arana [31], participants with AD were in stadium 4 of the GDS [49], which implies a slight language impairment. In our work, the mean score of the AD group in the MMSE test [38] was 19.7, which would suppose a similar impairment. On the other hand, syllabic F0 analysis of the exclamatory sentences, showed a significant decrease from the intermediate syllables to the final one in the control group, but this difference did not appear in the AD group. During the interrogative sentences, the control group showed syllabic F0 changes from the intermediate to the final syllables, which were not found in the AD group. The scarce pitch variation in exclamatory and interrogative sentences may be due to the fact that these kinds of sentences have a more complex structure than declarative ones. Therefore, the impairment of these patients could be affecting the correct reading of these sentences. However, we do not know of any other work in which the reading of exclamatory and interrogative sentences in Spanish AD patients is analyzed, in order to compare our results. Although further study of syllabic F0 in AD reading would be needed, these results seem to indicate that the type of stimuli (declarative, exclamatory, interrogative sentence), as well as the analysis of F0 at syllable level, are relevant features in the study of the pitch in AD.

Some previous studies that analyzed reading fluency in Spanish children and adults with dyslexia [15] showed akin results to those found in this research. People with dyslexia made many pauses and had longer reading times and little pitch changes at the end of sentences, especially in interrogative ones. Similar results have also been described in Spanish children with SLI [16], who showed inappropriate reading of interrogative sentences without changes in pitch and made many intrusive pauses. In both studies, findings are explained by difficulty in anticipating the sentence structure. Therefore, the differences found in this study between the control group and the AD patients in terms of syllabic pitch, syllabic duration, and pauses in the exclamatory and interrogative sentences, could be due to the fact that the deterioration of these patients causes difficulties in anticipating the sentence structure, since this type of sentence is less common than the declarative ones in Spanish.

The great number of pauses, along with longer reading times, reading errors made, and little pitch changes in AD people, is causing a slower and less expressive reading. The disturbances of prosody, along with alterations in reading speed and accuracy would be affecting the reading fluency of AD patients. Lack of reading fluency has been related in recent years to decoding difficulties [5, 9-12]. In some of the studies conducted in the early years of reading learning in English, patterns of reading fluency comparable to those reported in this paper are described. Children who had not achieved fluent reading made more and longer pauses than children with better reading fluency. They also showed important differences in pitch sentences, with less final decline in declarative sentences, as well as less rise at the beginning of interrogative ones [11]. Similar results have been found in Spanish children. The work of Alvarez-Cañizo, Suarez-Coalla and Cuetos [9], describes how children in the third year of primary school have not yet developed the adult prosodic pattern, showing a greater number of pauses and a flattened pitch contour, with difficulties in anticipating the sentence structure. The results found in children who are learning to read and have not achieved reading fluency are very similar to those described in this study with AD patients. Bearing this in mind, it could be inferred that decoding ability is being impaired, and this would be affecting reading fluency in all its elements: speed, accuracy and expressiveness. AD patients could be suffering from a decline process, which could be inverse to that of learning reading fluency. The first affectations would be at the reading prosody level, and later accuracy and speed would be compromised. Further researches which consider the impairment degree of AD participants are necessary to examine this hypothesis.

In general, reading studies in AD are carried out using single word reading tasks, where only the speed and accuracy of reading are assessed, and they found disparate results. Some investigations explain the difficulties found in reading words in AD by damage in the semantic system [18, 25]. Others describe impairment in the phonological route [20,

22, 24]. These differences could be due to patient profiles, as the most impaired patients may be suffering greater deterioration and show more reading impairments than early stage patients. Other explanations could be related to the type of task used. Although some studies showed preserved reading in AD when reading irregular and low-frequency words in English [18], it could be possible that analysis of texts or sentences could show differences on more levels than reading single words, since reading text tasks allow the analysis of the reading prosody.

In sum, the use of texts whose stimuli have been selected experimentally allows knowing which types of stimuli are key when designing reading assessment tasks in different populations. The findings of this paper support those that propose reading fluency tasks as an assessment instrument in AD. Some studies have suggested the utility of assessing reading fluency in the diagnosis of neurodegenerative diseases with language impairment, such as AD [33, 34]. This method is time efficient, non-invasive, and does not require many resources. Although there are still many aspects to know about reading fluency in AD, especially regarding reading prosody, this work is the first, to our knowledge, that asses all the components of reading fluency in Spanish patients with AD using an experimental text. According to the results found in this work, it seems that linguistic variables such as the lexical frequency or the type of stress can affect the speed and accuracy of reading in AD. Moreover, the reading of exclamatory and interrogative sentences seems to be key when distinguishing the severity of these patients.

CONCLUSION

The control in the stimuli selection allowed the analysis of the speed and reading accuracy and it also made possible the measurement of a great number of prosodic variables in an experimental manner in AD. This research method allowed the description of some characteristics of the reading prosody of these patients, which is often overlooked in the reading fluency study. While the present study mainly considered the temporal parameters of reading fluency, other acoustic variables that have been shown to influence reading in patients with AD, such as variations of the melodic curve or shimmer disturbances [33], could be taken into account in further research. The scarce number of participants in this study was also an important limitation since it did not allow the analysis of reading prosody through the different AD stages, which would also be useful for diagnosis. Furthermore, similar studies could be carried out on other neurodegenerative pathologies which cause language impairment. In this way, assessment instruments to discriminate reading fluency characteristics of these diseases could be developed.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals were used in this study. All human procedures were followed in accordance with the guidelines of the Declaration of Helsinki.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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SUPPLEMENTARY MATERIAL

Supplementary material is available on the publisher's website along with the published article.

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