Reading fluency in Spanish patients with Parkinson's disease: a reading prosody examination

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Abstract

Background. The expressiveness during reading is essential for a fluent reading. Reading prosody has been scarcely studied in an experimental manner, due to the difficulties in taking objective and direct measures of this reading skill. However, new technologies development has made it possible to analyze reading prosody in an experimental way. Prosodic patterns may vary, not being the same at the beginning of the reading learning process as in adulthood. They may also be altered in disorders such as dyslexia, but little is known about the prosodic characteristics and reading fluency of people with neurodegenerative diseases that cause language impairment, such as Parkinson's disease (PD). **Aims.** The aim of this work was to study reading fluency in PD considering the prosodic characteristics of its reading. **Methods & Procedures.** The participants were 31 Spanish adults with PD and 31 healthy controls, aged 59-88 years. Two experimental texts were designed that included declarative, interrogative, and exclamatory sentences and experimental verbs and nouns. The manipulability level of the nouns and the motor content of the verbs were considered. The reading of the participants was recorded and analyzed with the Praat software. **Outcomes & Results.** A longer reading duration and a greater number of pauses, especially in verbs, were found in the PD group, which also showed less pitch variation than the control group in the experimental sentences. The control group showed a big initial rise in declarative and interrogative sentences, as well as a stronger final declination in declarative and exclamatory ones, when compared to the PD group. **Conclusions & Implications.** The use of experimental methodologies for the analysis of reading fluency, allows learning more about the prosodic characteristics of people with different pathologies, such as PD. Scarce pitch variability found in the analysis, together with the great number of pauses and the longer reading duration, leads to a poorly expressive reading, which compromises fluency in PD. The exhaustive evaluation of the reading fluency of PD patients will make it possible to design more complete assessment methods that will favor the diagnosis and early detection of this pathology.

Keywords: reading fluency, Parkinson's disease, reading prosody, fundamental frequency, verb processing.

What is already known on this subject. (max 100 words):

- The speech of people with Parkinson's disease is often impaired by the appearance of hypokinetic dysarthria.
- The language of people with Parkinson's disease is usually affected with the progression of the disease, with lexico-semantic impairment which mainly affects verbs.
- Previous literature on reading fluency in Parkinson's disease usually considers reading speed and accuracy, neglecting prosody.
- Other neurodegenerative diseases with language impairment, such as Alzheimer's disease, commonly cause reading fluency problems.

What this study adds. (max 100 words):

- This study provides direct and objective measures of the reading fluency (speed, accuracy, and prosody) in patients with Parkinson's disease, by the design of experimental texts.
- Reading fluency characteristics were found to be altered in these patients, especially in pitch variations and reading duration. Parkinson's patients showed a reading with a more flattened pitch.
- In addition, a greater number of pauses and longer reading durations were also found in the reading of verbs compared to the control group.

Clinical implications of this study. (max 100 words):

- The use of experimentally texts makes it possible to analyze the influence of different psycholinguistic variables (frequency, length, motor content, manipulability) on reading fluency, and how the processing of these stimuli could be affected in Parkinson's disease.
- The objective analysis of the reading fluency characteristics in Parkinson's disease allows the design of more specific assessment and diagnostic tasks.
- More complete assessment methods may allow the early detection of the disease. In the same way, it may favor a differential diagnosis with other neurodegenerative diseases.

Introduction

Parkinson's disease (PD) is a neurodegenerative disorder, which affects the central nervous system and is caused by a dopaminergic deficit in the nigrostriatal pathway of the brain, which plays an important role in motor control. The motor symptomatology, which is typically found in patients with PD, is characterized by tremor, rigidity and bradykinesia (Rodríguez-Oroz et al., 2009). In addition, the deterioration of the dopaminergic pathways usually causes cognitive deficits from the onset of the disease, which are mainly associated with an alteration of executive functions, although memory and language are also affected (Rodríguez-Ferreiro et al., 2010; Smith & Caplan, 2018; Sollinger et al., 2010).

The main language impairments in PD include lexical-semantic difficulties, which affects the processing of action-related words from the early stages of the disease. Some studies have shown how semantic lexical impairment is more prevalent for verbs, compared to objects, in both lexical decision and naming tasks. (Boulenger et al., 2008; Rodríguez-Ferreiro et al., 2009). These results are in line with current theories concerning the organization of the semantic system in the brain. Specifically, embodied cognitive theories assume a distribution of concepts in neural assemblies through networks in distant regions of the cortex, also involving subcortical areas. According to this theory, concepts are distributed throughout the brain cortex according to their perceptual and motor characteristics (Pulvermüller et al., 1999; Pulvermüller, 2012).

As well as the grammatical category of the words, the amount of motor content of the verbs also affects their processing. Previous research found that naming is shown to be negatively affected in verbs with high motor content in PD patients (Bocanegra et al., 2017; Herrera et al., 2012). These mentioned difficulties on the processing of verbs with high motor content would be influenced by the pharmacological treatment with dopamine precursors, which is typically used in PD patients. Herrera and Cuetos (2012, 2013) examined action naming in PD Spanish patients on/off dopamine medication, by using picture-naming and word-association tasks. The results of both studies revealed a worse performance in verb naming when PD patients were off medication compared to controls, but these differences disappeared when PD group were tested on medication with dopaminergic treatment.

In addition to the impairment in verb processing, difficulties in the processing of some nouns have also been described with disease progression (Bocanegra et al., 2015; Cotelli et al., 2007). Bocanegra et al. (2017) analyzed verb and object processing in a naming task, and they considered the level of motor content (low/high) and manipulability (low/high) of the stimuli displayed. Manipulability refers to the affordability of an object to be handled manually. The participants of this study were divided into three groups: control, PD with Mild Cognitive Impairment (MCI) and PD without MCI. Their results showed a widespread lexical-semantic impairment in MCI-PD patients, which involved both verb and noun naming, regardless of their motor content or manipulability. In contrast, the non-MCI PD group showed a similar performance to controls, except for high motor verb naming, where they showed significant difficulties. The manipulability level has been shown to be a moderating variable in the dissociation between grammatical classes, and it involves the activation of fronto-parietal pathways (Saccuman et al., 2006). How this variable affects linguistic processing in PD is currently under discussion.

Besides the problems in lexical-semantic processing described above, between 70% and 90% of people with PD show abnormal speech production known as hypokinetic dysarthria (Logemann et al., 1978), which is related to the motor impairments inherent to this disease. According to recent reports, 89% of Parkinson's patients suffer from disorders affecting speech. Hypokinetic dysarthria is one of the most common disorders in these patients and can affect voice, articulation, and prosody. Although there are effective therapies for its treatment, recent studies suggest that more research is needed to determine which is the most effective approach for this speech impairment (Muñoz-Vigueras et al., 2021). The hypokinetic dysarthria causes a reduction in the overall rate of speech, accompanied by long silences between sentences (Ash et al., 2012). In addition to the problems that can be observed in the speech of these patients, which are produced by motor control impairment, together with the lexical-semantic impairments described above, the reading fluency of patients with PD may also be affected, especially in terms of reading speed and intonation or prosody. The motor control deficits, together with difficulties found in the lexicon access, could result in slower reading accompanied by a greater number of pauses.

But what do we mean by reading fluency? The most widely currently accepted definition is that fluent readers can read with speed, accuracy and proper expressiveness or intonation. (National Institute of Child Health and Human Development [NICHD], 2000). Reading speed and accuracy are achieved by the automation of grapheme-phoneme conversion rules and the creation of orthographic representations of the words. According to the self-teaching hypothesis (Share, 1995), the formation of orthographic representations is a lifelong process that involves every single word. As for the correct intonation or expressiveness of reading, it is characterized by the absence of inappropriate pauses and hesitations between syntactic structures or within a word, keeping punctuation marks, the syntactic and phonological agreement within a sentence, a lengthening at the end of sentences with an increase in the duration of the final vowel, a correct word stress, and the appropriate variation of pitch or fundamental frequency (F0). (Dowhower, 1991; Schwanenflugel & Benjamin, 2012). The combination of all these elements makes it possible to perceive a fluent reading, with correct expressiveness, speed, and accuracy.

Reading prosody has been commonly examined through observational scales (Allington, 1983; Klauda & Guthrie, 2008; Pinell et al., 1995; Rasinski et al., 2009), which have been mainly used in the educational field. These scales allow a quick and easy assessment of reading prosody but provide subjective results. The new technologies development allowed the implementation of computer software such as Praat, (Boersma & Weenink, 2019), which enabled an objective and direct analysis of this aspect of reading fluency based on the spectrogram analysis. This software enables the analysis of acoustic waveforms, by the manipulation of voice recordings in digital format. The Praat software can be used to take experimental measurements of pitch, intensity, and duration of the reading and it allows the analysis and synthesis of voice recorders as well as statistical processing of the data. It also provides the function for splitting the recordings into layers that can be separated by label using TextGrids, which is necessary for automating analysis. The use of software such as Praat requires more training for the evaluator and therefore it is a more complicated approach for the reading fluency analysis, but it provides objective information about the reading prosody.

Several studies which relate prosody and reading fluency using spectrogram analysis have shown that, as decoding ability (accuracy and speed) improves and reading becomes increasingly fluent, prosodic reading patterns begin to resemble those achieved by healthy adults (Álvarez-Cañizo, et al., 2018; Benjamin & Schwanenflugel, 2010; Miller & Schwanenflugel, 2008; Schwanenflugel, et al., 2004; Schwanenflugel, et al., 2015). Álvarez-Cañizo et al. (2018) analyzed the reading fluency of Spanish children who were learning to read. They found that children with a better reading fluency showed an initial F0 rise in the interrogative sentences and a final F0 decline in the declarative ones. These results were similar to the adult prosodic pattern. On the other hand, the group with poor reading fluency did not show significant variations in the F0 when reading declarative and interrogative sentences, and they also had a greater number of pauses, which were also longer. These differences are explained by a poor decoding ability and a difficulty in the anticipation of sentence structure in the group of children who have not achieved a fluent reading yet.

Prosodic patterns are not only impaired in children who are learning to read, as they may also be affected in adults with poor reading skills (Binder et al., 2013) or in people with reading difficulties, such as dyslexia (Suárez-Coalla, Álvarez-Cañizo, Martínez, García, & Cuetos, 2016). Therefore, reading expressiveness varies depending on reading ability, regardless of age. However, few studies have been conducted to analyze the characteristics of reading fluency during aging. Considering the reading fluency impairments among the different populations described, it could be expected that the reading fluency would also be impaired in aging and in the onset of diseases that cause communication problems. It is worth considering, what happens to reading fluency in the elderly? And can reading fluency be affected by neurodegenerative diseases that cause language impairment? Pérez-Sánchez et al. (2021) analyzed the reading fluency in a group of Spanish patients with Alzheimer's disease (AD). Their results showed significantly longer reading durations at the syllable, word, and sentence level in the AD group. The group of patients also showed a greater number of pauses within words, which were also longer, and a greater number of reading errors in words with different stress. Differences with the control group were also found in the syllabic F0 variation of exclamatory and interrogative sentences. These results suggest that reading fluency is affected in patients with AD, with impairment of speed and accuracy, but also of reading prosody. Considering all these factors, it could be expected that other neurodegenerative diseases which are associated with language impairment, and more specifically with speech impairment, as is the case of PD, may also show an impairment in reading fluency.

In the study by Darkins et al. (1988), they used spectrogram analysis and described some disturbances in the reading prosody in a group of 30 American PD patients. These disturbances were characterized by a reduced pitch variation and a longer duration of pauses. They used a task of reading compound words paired with noun phrases (adjective followed by noun). Their results showed that these abnormalities in the reading prosody of PD patients were also independent of gender, age, disease progression, or patient medication dosage.

Considering the high prevalence of speech disturbances in PD, some studies have compared different speech tasks in the assessment of dysarthria in patients with PD. The results of some of them show how the naturalness or intelligibility of speech is more impaired in spontaneous speech tasks compared to other types of tasks, such as reading aloud (Kempler & Van Lancker, 2002; Weir-Mayta et al., 2017). However, some studies did not find significant differences between the two tasks. Tjaden and Wilding (2011) compared recordings of speech during a paragraph reading task with the production of a monologue in patients with PD. Their results suggest that the measures obtained from the reading analysis could predict the intelligibility of spontaneous speech, hence the two tasks were comparable.

Therefore, reading tasks seem to be useful in the assessment of PD, but they also tend to underestimate the impairment of patients (Kempler & Van Lancker, 2002; Weir-Mayta et al., 2017. New measures, such as prosody examination, could improve the assessment protocols for this disease. According to this approach, several research has been focused on the potential usefulness of these speech characteristics in the early diagnosis of the disease. Bocklet et al. (2011) assessed different prosodic features in German people with PD using seven tasks: sustained phonation, syllabic repetition, reading a text, monologue, reading 10 sentences with different emotional content, reading an experimental text with 8 different sentences and 10 words with different stress, and rhythmic reading of a text. Their results showed that F0 and pause features during reading tasks were the prosodic elements that best predicted the presence of PD. They also concluded that reading a standardized text was the best task to discriminate PD. Further studies, such as the one by Galaz el al. (2016), described a decreased F0 variation along with an increased variability of intensity in a group of 98 Czech PD patients. They used three reading tasks: reading stress-modified words, reading a paragraph with a neutral intonation, and poem recitation. The decrease in F0 variation in Czech PD patients was also described in a study by Rektorova et al. (2016), where the reading of 135 were analyzed using the Praat software. Regarding the medication effects on reading fluency, and specifically on its expressiveness, the literature supports that prosodic reading parameters are not influenced by the presence or absence of dopamine precursor medication in PD Czech and German patients (Elfmarková et al., 2016; Skodda et al., 2009; Skodda et al., 2010).

In summary, the literature is consistent about the evidence of language impairment in PD patients, especially at the lexical-semantic level, and about the presence of disturbances of reading and speech processes in these patients. However, how language impairment in PD affects language processing at its different levels are still unknown. Regarding reading, this is the first study in Spanish to our knowledge that examines reading fluency, considering reading prosody, through the analysis of objective measures, and which also consider the linguistic variables that have been shown to influence language processing in PD. Therefore, the aim of this work was to analyze, directly and objectively, the measurable features of reading fluency, focusing on reading prosody, in a PD group and a healthy elderly group. For this purpose, two experimental texts were designed considering several psycholinguistic variables that seem to influence the language processing in PD (Bocanegra et al., 2017; Cotelli et al., 2007 Herrera et al., 2012). Based on previous research about language in PD, both at lexical-semantic and speech level, reading fluency is expected to be affected at all three levels, with marked alterations in speed and expressiveness.

Method

Participants

Sixty-two Spanish adults, 29 women and 33 men, with an age range of 59 to 88 years and a total average of 71.27 years (*SD* = 9.71) were involved in this study. All the participants were native Spanish speakers and were able to read and write. Participants had no history of alcoholism, psychiatric illness, or any neurological disease other than PD.

Half of the participants (10 women and 21 men) had a medical diagnosis of PD under neurological supervision, with a disease duration of 0.5 to 22 years. They were users of an association where they received physical rehabilitation exercises and cognitive psycho-stimulation twice a week. Moreover, all of them were taking the medication prescribed by their physician (dopamine precursors) by the time of the assessment. The control group consisted of 31 healthy adults, 19 female and 12 males, most of which were users of a day center where they also attended cognitive psycho-stimulation sessions. No significant differences were found between the groups in age or educational level. As the experimental groups were not gender balanced, the pitch measurements were converted from Hertz to semitones, in order to avoid the influence of this variable in the analyses.

Each participant was assessed using a multi-scale protocol to examine their cognitive, executive and emotional state. The Montreal Cognitive Assessment Test (MoCA) (Nasreddine et al., 2005) was used to rule out those participants with moderate or severe cognitive impairment. Statistically significant differences were found between both groups scores [$t(60)=3.507$, $p=.001$], although there were no differences in the tasks with memory, orientation, language, or visuospatial content. The characteristics of the groups are shown in Table 1.

Table 1.

Characteristics of the participants.

	PD *M (SD)*	Control *M (SD)*
Disease duration	6.75 (5.12)	
Age	69.16 (7.43)	73.32 (11.37)
Years of schooling	9.19 (4.21)	10.74 (4.74)
MoCA*	25.52 (2.81)	27.81 (2.3)

(*M*, mean; *SD*, standard deviation; * significant differences between the groups)

Materials

Two experimental narrative texts entitled "*El bailarín* [The Dancer]" (see Appendix 1) and "*La excursión* [The Trip]" (see Appendix 2) were designed for this study. Two texts were used with the purpose of including a greater number of stimuli without heavily increasing the length of the text, in order to avoid the fatigue of the participants during their reading. This method also made it possible to separate the experimental stimuli within the texts, preventing any influence of some stimuli over the others in the reading processing. Each text contained a declaratory sentence (*"Felipe se pone un sombrero* [Felipe puts on a hat]" / "*Teresa se come su almuerzo* [Teresa eats her lunch]"), an exclamatory sentence ("*¡Qué frío tengo aquí afuera!* [How cold I am out here!]" / *"¡Qué feliz estoy aquí arriba*! [How happy I am up here!]") and an interrogative one *("¿Cuándo será la hora del baile?* [When will it be dance time?]" / "*¿Dónde está el claro del bosque?* [Where is the forest glade?]". The couples of sentences matched in syntactic structure, number of syllables and final vowel. Studies on reading prosody have shown that there is a characteristic pitch pattern for each type of sentence. Declarative sentences show an increase in pitch at the beginning of the sentence, which then decreases. Exclamatory sentences begin with a high pitch, which decreases throughout the sentence. As for interrogative sentences, they show two F0 peaks, one at the beginning of the sentence and the other at the end (Álvarez-Cañizo, et al., 2018; Benjamin & Schwanenflugel, 2010; Miller & Schwanenflugel, 2008; Schwanenflugel, et al., 2004; Schwanenflugel, et al., 2015).

Several types of stimuli were included in the texts, and they were matched in length and lexical frequency within each class. The *Student t-test* for independent samples was used to test the equivalence of these variables within each group of stimuli. The lexical frequency of all experimental stimuli was obtained from the LEXESP database (Sebastián et al., 2000).

In order to study the effect of stress in reading, 8 proparoxytone words (stressed in the antepenultimate syllable, i.e., *plástico*, *círculos* [plastic, circles]) paired in lexical frequency and length with 8 paroxytone words (stressed in the penultimate syllable, i.e., *bebidas, paisaje* [drinks, landscape]), were also selected and included in the texts (see Appendix 3). It has been shown that the stress mark (which is used in proparoxytone words in Spanish) is processed as stress and it plays an important role in the lexical search (Gutierrez, 2003). The reading of these words with stress mark was compared with the reading of paroxytone words, which are the most common in both English (Black & Byng, 1986) and Spanish (Harris, 1995).

Sixteen verbs were also selected according to their motor content, 8 of them with high (i.e., *saltar, correr* [jump, run]) and 8 with low motor content (i.e., *cantar, sufrir* [sing, suffer]) [$t(9.58) = 10.48$, $p<.001$]. All of them were paired in length and lexical frequency (see Appendix 4) and half of them (4 high and 4 low motor content) were included in each text. The motor content rate of the verbs was obtained from the database of San Miguel and Gonzalez-Nosti (2019).

Finally, 16 nouns, matched in length and lexical frequency, were chosen according to their manipulability. Each text included 4 nouns high-manipulability (i.e., *trompeta, guitarra* [trumpet, guitar]) and 4 low-manipulability nouns (i.e., *terraza, montaña* [terrace, mountain]) [$t(9.01) = 12.704$, $p<.001$] (see Appendix 5). The manipulability rate of the experimental nouns was obtained from a survey of 25 participants, with a Likert-type scale (1 = non-manipulable and 7 = highly manipulable) (See Appendix 6).

Each text was printed in black ink, in 14-point Calibri (body) font and 1.5 spacing, on a white DIN-A4 sheet of paper. The reading aloud was recorded with an H4n voice recorder, connected to an Ht2-P Audix headset condenser microphone. This type of microphone is placed over the ears around the head and stays about five centimeters away from the mouth of the participant.

Procedure

The participants were assessed in a room isolated from noise and distractions, in the Parkinson association, in the case of the PD group, and in the day center where they attended, in the case of the control group.

Before starting the assessment, the participants were informed about the purpose of the study, the tests to be conducted during the session and about the requirement to record their reading. They also signed an informed consent form that guaranteed the confidentiality of their personal data, in accordance with the ethical and privacy regulations established by the deontological code. Afterwards, they were given the microphone of the recorder and they were also asked to put their reading glasses on in case of need. Then they were introduced to one of the experimental texts and asked to read it aloud, trying not to make mistakes. After that, the microphone was removed and the participants were assessed with several neuropsychological tests, to determine their cognitive profile. First, the MoCA test (Nasreddine et al., 2005) was used, followed by the YESAVAGE geriatric depression scale (Aguado et al., 2000). This scale was used to assess emotional status, in order to exclude participants with probable depression. After that, the text memory task of the Barcelona test (Text B) (Peña-Casanova, 1990) was applied, which assesses immediate recall with and without clues. Next, the Stroop test (Golden, 2001) was administered. Sheet 1 of the Stroop test consists of reading words aloud, while in Sheet 2 the patient must name the colors that are shown. These sheets are sensitive to disturbances in the name function of language and in speed of processing, which can be affected in PD. Sheet 3 measures the capacity of inhibition of an automatic response (reading) against visual color identification. The second part of the text memory task were presented, which assesses delayed memory evocation with and without clues. Finally, two additional tasks were used to assess attention and working memory. They consisted in 12 series of numbers and letters, initially formed by 3 items, which increased their length until reaching 9 elements. In the attention task participants were asked to listen the series and to report how many letters there were in each set, while in the working memory task they had to repeat the numbers in ascending sequence and then the letters in alphabetical order.

To conclude the examination tasks, the participants were given the microphone again and they were introduced to the other experimental text. Same instructions as for the first text were given. In order to avoid the effects of fatigue on reading aloud, half of the participants read the text entitled "The Dancer" at the beginning of the assessment, while the other half read the text "The Excursion" first. The whole session lasted between 40 to 50 minutes. This research protocol was reviewed and approved by the Ethics Committee of the Principality of Asturias, project no. 266/19.

All the recordings obtained from the reading of the participants were analyzed using the Praat software (Boersma & Weenink, 2019). The experimental stimuli were annotated manually on the TextgGrids, following the audio of the reading recordings and the visual representation of the spectrogram. This was done to avoid unwanted errors in the automatic selection of stimuli (for example, to avoid counting as pauses the pronunciation of plosive consonants). No manual corrections were made for pitch or other variables. The analyses were automated using scripts published for Praat for two-step pitch extraction (Atria, 2014; Elvira & Roseano, 2014) and some scripts specifically written for this software. The measures of the stimuli analyzed are described below. Both the reading errors and the pauses committed were marked during the recordings analysis and subsequently hand-counted.

I. Measurements of experimental sentences:

In order to analyze the experimental sentences, the following measures were considered, which have shown to be relevant in the study of reading fluency and prosody (Dowhower 1991; Schwanenflugel & Benjamin, 2012; Vaissière, 1983).

- Pauses:
  - Number and duration (s) of pauses committed between words during the reading of sentences in the absence of a grammatical mark (comma, period, full stop…).
  - Number and duration (s) of pauses committed within a word, during the reading of sentences.

- Duration (s):
  - Sentences global duration: Time from the first syllable to the end of the sentence.
  - Vowel duration: Mean duration of the final vowel of the sentences. Also mean duration of a middle atonic vowel, same as the final one (i.e., "*¿Cuándo será la hora del baile?* [When will it be dance time?]").

- Intensity (dB):
  - Vowel intensity: Mean intensity of the final vowel of sentences and also of an unstressed middle vowel same as the final one (i.e., "*¡Qué feliz estoy aquí arriba!* [How happy I am up here!]").

- Fundamental frequency or pitch (F0):
  - Initial rise (St): The difference in pitch between the first F0 valley and its first peak on the pitch contour, in declarative and interrogative sentences.
  - Final rise (St): Difference between the last drop of F0 and the end of interrogative sentences.
  - Slope (St/s): F0 decline from the first peak to the end of the declarative and exclamatory sentences. It is expressed by unit of time.
  - Vowels (St): Mean F0 of the final vowel and mean F0 of the same middle atonic vowel, in all experimental sentences. (i.e., "*¿Dónde está el claro del bosque?* [Where is the forest glade?]"

II. Measurements of proparoxytone and paroxytone words:

The experimental proparoxytone and paroxytone words were also extracted from the reading recordings. The following parameters were analyzed:

- Duration (s): Reading duration of the experimental words with different stresses.

- Number of stress errors committed during the reading of these words.

III. Measurements of the experimental verbs and nouns:

Finally, the experimental verbs and nouns were analyzed (8 verbs with high and 8 with low motor content: 8 nouns with high and 8 with low manipulability). The following measures were considered:

- Duration (s): Reading duration of experimental nouns and verbs.

- Pauses:
  - Number and duration(s) of pauses committed before reading the experimental verbs and nouns.
  - Number and duration (s) of reading pauses made within the experimental verbs and nouns.

- Reading errors: Number and type of reading errors made when reading experimental verbs and nouns. Phonological errors (changes of phonemes by substitution, omission, or addition), lexical errors (change a word for a similar one) and repetition errors (the repetition of a word) were considered.

Data analyses

Data obtained from the Praat software (Boersma & Weenink, 2019) were analyzed statistically using the SPSS software (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0 Armonk, NY: IBM Corp.).

Regarding the sentences analysis, three repeated measures analysis of variance (ANOVA) were used for the analysis of vowels, one for each analyzed variable (F0, intensity and duration). The measurements of duration, intensity and F0 were included as intra-subject factors in each case, and the group was the inter-subject factor. The normality hypothesis was accepted using the *Kolmogorov-Smirnov test* and the Bonferroni adjustment was used to compare the simple effects within significant interactions. Mean comparisons were also conducted between the experimental groups for the number and duration of pauses, the overall duration of each type of sentence and the F0 measures (first rise in declarative and interrogative sentences; final rise in the interrogative sentences; slope in declarative and exclamatory sentences). The *Student t-test* for independent samples was used to make these comparisons when the variables to be analyzed met the assumption of normality. If the variables did not meet the normality criterion, the *Mann-Whitney U test* was used instead. The hypothesis of normality of all the variables analyzed was assessed using the *Kolmogorov-Smirnov test.*

As for the analysis of the experimental proparoxytone and paroxytone words, an ANOVA was used to compare the mean reading durations of each group of words according to their stress. Reading duration was included as a dependent variable, while group and stimulus type were included as inter-subject factors. The assumption of normality was accepted using *Kolmogorov-Smirnov test* and the Tuckey adjustment were also used in post hoc analysis for multiple comparisons.

Finally, statistical analyses of the experimental verbs and nouns included an ANOVA for the analysis of verbs duration and another for noun duration. Group and stimulus type were included as inter-subject factors and duration as the dependent variable. The normality of the data was tested using the *Kolmogorov-Smirnov test.* The reading durations, the number and the duration of pauses made of the experimental groups for each type of stimulus were compared using the *Student t-test* when the assumption of normality was accepted and with the *Mann-Whitney U test* when normality was rejected.

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Results

Sample analysis

The results obtained in the neuropsychological tests conducted in both experimental groups are reported below. No significant differences were found between the groups in the geriatric depression scale (YESAVAGE test; Aguado et al., 2000) in the 5-item version, nor in the 15-item version. As for the text memory task of the Barcelona test (Peña-Casanova, 1990), significant differences were found between the scores of the control group and the PD group in all task conditions [Immediate recall $t(60) = 2.57$, p=.012; Immediate recall with keys $t(60)$=2.03, p =.047; Delayed recall $t(60)$= 2.32, p=.023; Delayed recall with keys $t(60)$= 2.59, p=.012]. Significant differences were also found between the groups in the Stroop test (Golden, 2001) [Sheet 1 scores, Words x$t(60)$= 2.21, p=.031], with a higher score in the control group. The performance of the groups did not differ in the other sheets of the test. Finally, Significant differences were found between groups in the attention and working memory tasks [Attention $t(60)$=2.45, p=.017; Working memory $t(60)$= 2.62, p=.011], however, the scores of both groups were within normal limits. Table 2 shows the mean scores obtained in both groups in each test.

Table 2.

Scores of the participants in the assessment tests.

		PD *M (SD)*	**Control *M (SD)***
YESAVAGE Test	5 items version	0.52 (0.51)	0.55 (0.62)
	15 items version	2.39 (1.33)	1.84 (1.37)
Text memory task	Direct recall*	6.51 (2.34)	7.96 (2.08)
	Direct recall with key*	9.27 (1.79)	10.26 (2.01)
	Delayed evocation*	7.4 (2.57)	8.85 (2.33)
	Delayed evocation with key*	9.27 (2.08)	10.61 (1.98)
Stroop test	Sheet 1*	77.61 (18.73)	88.65 (20.53)
	Sheet 2	54.45 (14.75)	60.23 (13.46)
	Sheet 3	31.29 (10.59)	32.87 (11.45)
Attention task *		9.84 (2.34)	11.06 (1.5)
Working memory task *		8.06 (2.11)	9.45 (2.04)

(*M*, mean; *SD*, standard deviation; * significant differences between the groups)

Sentences analyses

First, no differences were found between the groups in the number of pauses committed during the reading of the sentences. In terms of pauses duration, the PD group committed pauses within words which were longer than the control group when reading declarative sentences [Z=-2.55, p=.011]. Sentence duration analyses showed no significant differences between the groups in their overall reading duration [Declaratives Z=-1.78, p=.075; Exclamatory Z=-0.55, p=.58; Interrogatives Z=-1.84, p=.065].

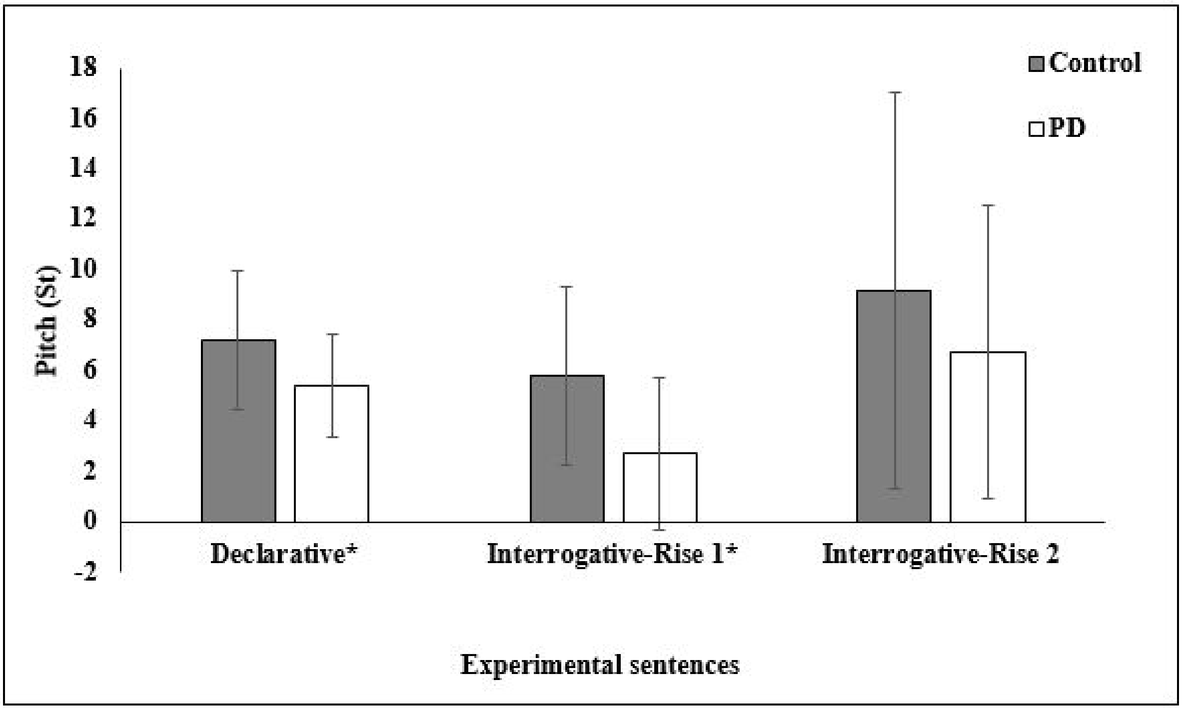
Regarding vowel analysis, normality assumption was checked using the *Kolmogorov-Smirnov test*, and the hypothesis of normality of the three variables in the three types of sentences were accepted. Table 3 shows the mean results of the parameters analyzed. In terms of vowel duration, a significantly longer duration of the mean-vowel was found in the PD group in declarative [$t(60)$= 3.025, p=.004], exclamatory [$t(60)$= 3.338, p=.001] and interrogative sentences [$t(60)$= 4.457, p<.001]. The duration effect of the final vowel on the three types of sentences was also significant [declarative ($F(1,60)$= 78.53, p<.001, *partial* η^2=.567); exclamatory ($F(1,60)$=136.46, p<.001, *partial* η^2=.695); interrogative ($F(1,60)$= 537.59, p<.001, *partial* η^2=.9)], which showed a lengthening of the final vowel in both groups in all the sentences.

As for sentence intensity analysis, a significant effect of vowel intensity was found in all three types of sentences [declaratives ($F(1,60)$= 92.077, p<.001, *partial* η^2= .605); exclamatory ($F(1,60)$= 239.58, p<.001, *partial* η^2= .8); interrogatives ($F(1,60)$= 114.43, p<.001, *partial* η^2= .656)], which showed a decline from the unstressed middle vowel to the final one in both groups in all sentences. In all cases the decline was more pronounced in the control group.

Finally, the sentence pitch analysis showed significant differences between the groups in the initial rise of declarative sentences [$t(60)$=2.918, p=.005] and in interrogative ones [$t(60)$=3.678, p=.001]. The pitch was significantly lower in the PD group in both sentences. No significant differences were found in the final F0 rise in the interrogative sentences, although the control group showed a higher mean F0 in this parameter. Statistically significant differences between the groups in the F0 slope of the declarative sentences were found [$t(60)=2.19$, $p=.032$], but no differences were found in the F0 slope of the exclamatory ones. Figures 1 and 2 show the differences found in pitch between the groups in the three types of sentences. Examples of the reading pitch contour of different PD patients and control participants in the experimental sentences are shown in Figure 3, Figure 4 and Figure 5.

Figure 1.

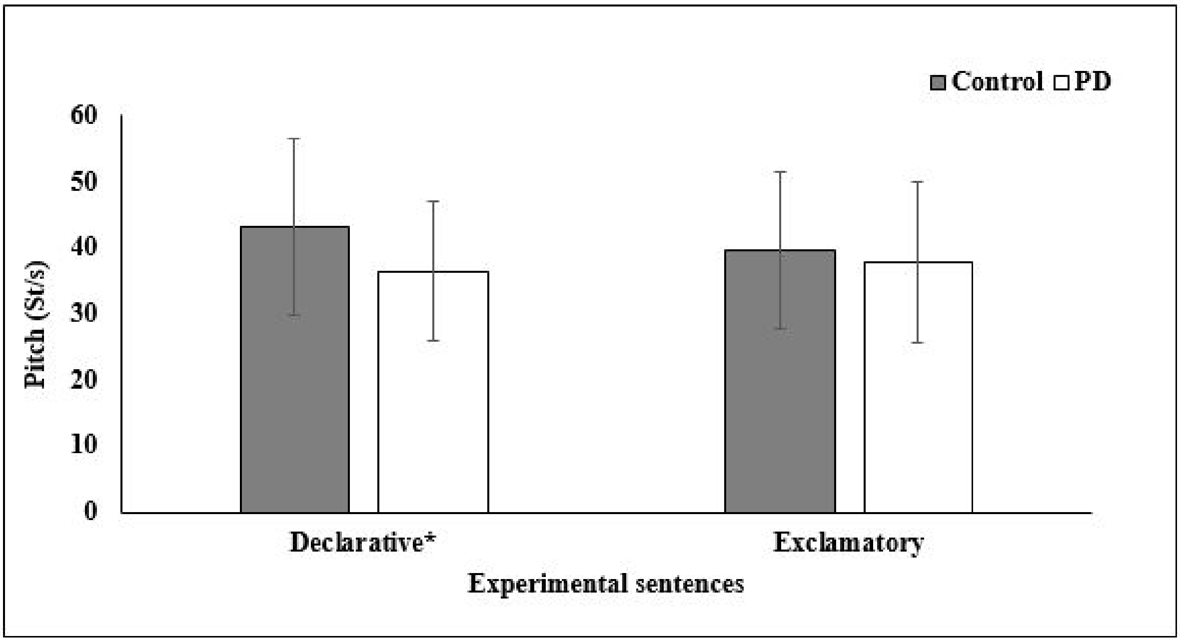
Pitch rise in declarative and interrogative sentences in the control group and the PD group.



(St, semitones; *, statistically significant differences between groups).

Figure 2.

Pitch slope in declarative and exclamatory sentences in the control group and the PD group.

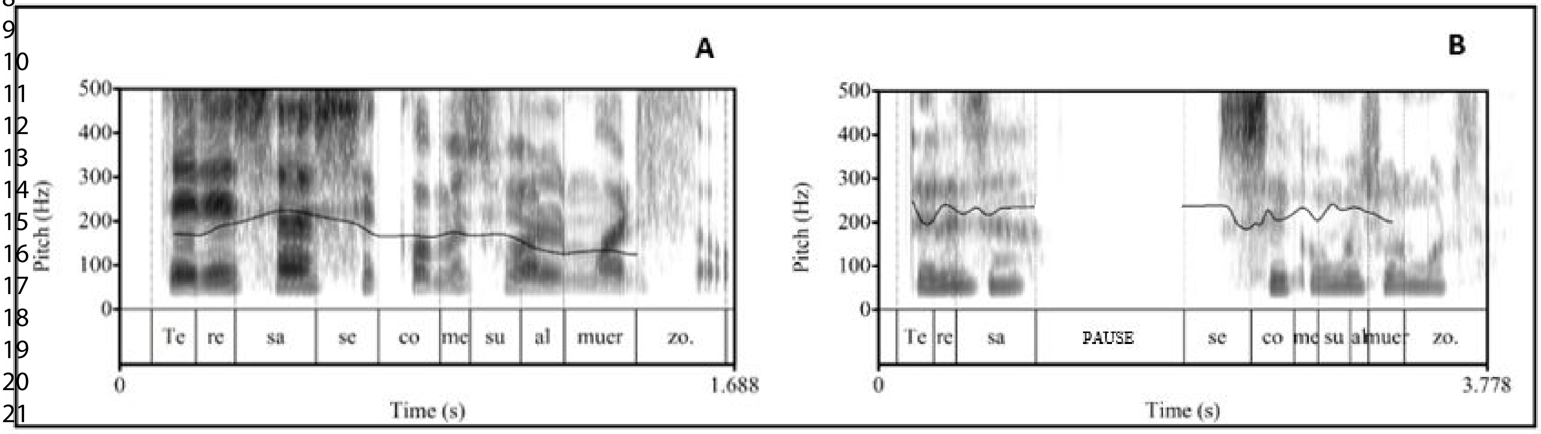


(St/s, semitones per second; *, statistically significant differences between groups).

Vowel F0 analyses showed a significant effect of the interaction between the vowel F0 and the group on declarative sentences [F(1,51)= 4.293, p=.043, *partial* η^2= .078]. The analysis of the interaction showed a decline from the F0 of the middle atonic vowel to the F0 final vowel in both groups [Control middle-vowel F0 – final-vowel F0 (p<.001); PD middle-vowel F0 – final-vowel F0 (p=.028)]. Significant differences were also found between the groups in the F0 of the middle atonic vowel in the declarative sentences [middle-vowel F0 Control – PD (p=.035)], which was higher in the control group. A significant effect of the F0 vowel was also found in the exclamatory sentences, [F(1,49)= 13.977, p<.001, *partial* η^2 = .222], which showed a decline from the unstressed middle vowel to the final one in both groups.

Figure 3.

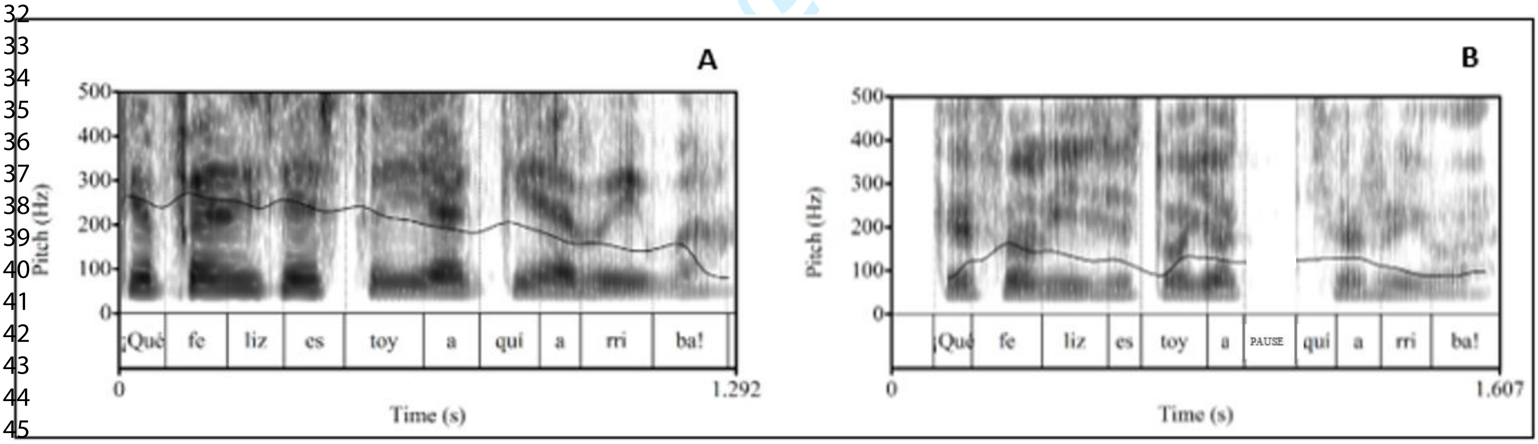
Pitch contour of the declarative sentence of Text 2 in the control group (A) and the PD group (B) (pitch in hertz; time in seconds).



("*Teresa se come su almuerzo* [Teresa eats her lunch]").

Figure 4.

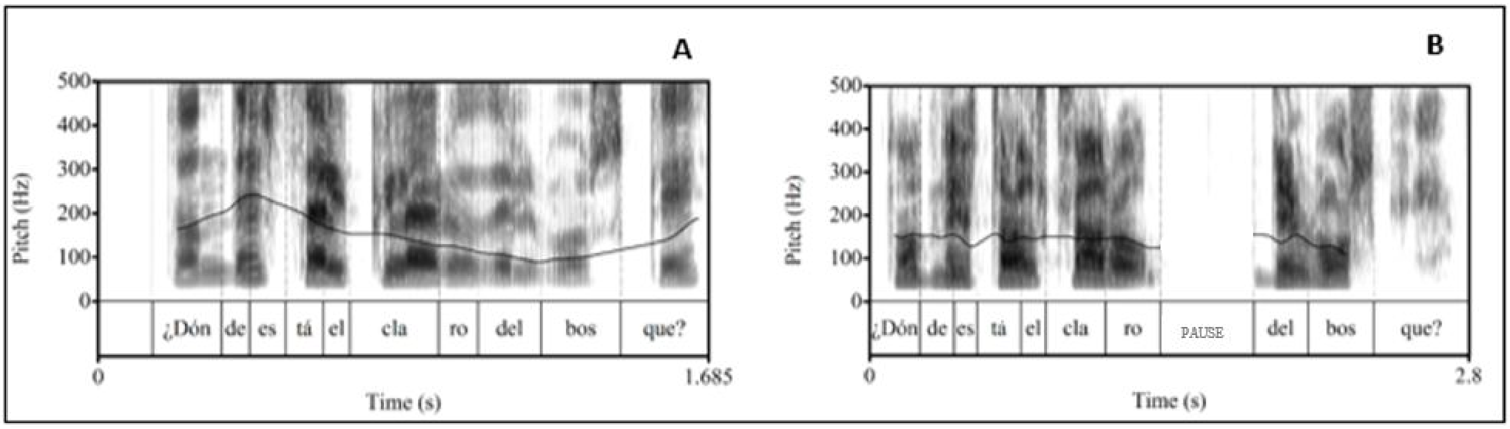
Pitch contour of the exclamatory sentence of Text 2 in the control group (A) and the PD group (B) (pitch in hertz; time in seconds).



(*"¡Qué feliz estoy aquí arriba!* [How happy I am up here!]").

Figure 5.

Pitch contour of the interrogative sentence of Text 2 in the control group (A) and the PD group (B) (pitch in hertz; time in seconds).



(“*¿Dónde está el claro del bosque?* [Where is the forest glade?]”).

Table 3.

Mean and SD of the parameters analyzed in the experimental sentences.

Type of sentence	Parameter		PD	Control
			M (SD)	***M (SD)***
Declarative	Nº pauses between words		1 (1.34)	0.45 (0.96)
	Duration of pauses between words (s)		0.246 (0.434)	0.16 (0.539)
	Nº pauses within words		0.193 (0.401)	0 (0)
	Duration of pauses within words (s) *		0.612 (0.142)	0 (0)
	Sentence total duration (s)		2.188 (0.914)	1.781 (0.483)
	Duration of the vowels (s)	Mean vowel *	0.991 (0.024)	0.082 (0.018)
		Final vowel	0.127 (0.029)	0.124 (0.028)
	Intensity of the vowels (dB)	Mean vowel	70.621 (4.55)	70.74 (5.35)
		Final vowel	65.177 (7.11)	63.979 (7.271)
	F0 Rise (St) *		5.428 (2.034)	7.224 (2.757)
	F0 Slope (St/s)*		36.414 (10.54)	43.109 (13.36)
	F0 of the vowels (St)	Mean vowel *	25.509 (1.171)	26.268 (1.185)
		Final vowel	25.092 (1.77)	25.108 (1.66)
Exclamatory	Nº pauses between words		0.548 (0.994)	0.322 (0.652)
	Duration of pauses between words (s)		0.128 (0.231)	0.063 (0.15)
	Nº pauses within words		0.645 (0.249)	0 (0)
	Duration of pauses within words (s)		0.011 (0.041)	0 (0)
	Sentence total duration (s)		1.771 (0.537)	1.625 (0.303)
	Duration of the vowels (s)	Mean vowel *	0.108 (0.023)	0.09 (0.019)
		Final vowel	0.14 (0.031)	0.153 (0.026)
	Intensity of the vowels (dB)	Mean vowel	71.699 (7.399)	70.002 (6.271)
		Final vowel	63.984 (7.36)	63.128 (6.357)
	F0 Slope (St/s)		37.843 (12.272)	39.631 (11.925)
	F0 of the vowels (St)	Mean vowel	25.267 (1.23)	25.742 (1.002)
		Final vowel	24.532 (1.323)	25.201 (2.112)

Interrogative	Nº pauses between words		0.32 (0.871)	0.645 (0.249)
	Duration of pauses between words (s)		0.075 (0.201)	0.022 (0.086)
	Nº pauses within words		0.032 (0.179)	0.032 (.0179)
	Duration of pauses within words (s)		0.009 (0.051)	0.004 (0.024)
	Sentence total duration (s)		1.953 (0.712)	1.644 (0.326)
	Duration of the vowels (s)	Mean vowel *	0.084 (0.028)	0.059 (0.012)
		Final vowel	0.159 (0.023)	0.152 (0.029)
	Intensity of the vowels (dB)	Mean vowel	76.37 (5.305)	74.641 (4.81)
		Final vowel	68.566 (8.483)	67.198 (6.107)
	F0 Rise 1 (St) *		2.693 (3.033)	5.778 (3.55)
	F0 Rise 2 (St)		6.727 (5.83)	9.197 (7.87)
	F0 of the vowels (St)	Mean vowel	26.526 (1.529)	27.118 (1.312)
		Final vowel	26.311 (1.789)	27.068 (1.497)

(*M*, mean; *SD*, standard deviation; s, seconds; dB, decibels; St, semitones; *, statistically significant differences between groups).

Words and stress analysis

The assumption of normality was accepted using *Kolmogorov-Smirnov* test [Z=1.27, p=.078] for the ANOVA, which was used to compare the mean reading durations of each group of words according to their stress. No statistically significant differences were found between the groups in the reading duration of these stimuli [Paroxytone words Control-PD (p=.076); Proparoxytone words Control-PD (p=.139)] when multiple comparisons were conducted using the Tuckey adjustment. Also no effect of stress on reading duration was found within each group [Control Paroxytone-Proparoxytone words (p=.357); EP Paroxytone-Proparoxytone words (p=.139)]. No stress errors were recorded in the reading of these words in any of the groups. The mean reading times are shown in Table 4.

Table 4.

Mean and standard deviation of reading duration for words with different stresses.

Parameter		PD *M (SD)*	Control *M (SD)*
Reading duration (s)	Stress on paroxytone words	0.68 (0.17)	0.59 (0.081)
	Stress on proparoxytone words	0.61 (0.15)	0.54 (0.08)

(*M*, mean; *SD*, standard deviation; s, seconds).

Analysis of experimental verbs and nouns

First, an analysis by subjects was made to analyze the reading duration of verbs and nouns. The assumption of normality was confirmed using the *Kolmogorov-Smirnov* test. Regarding verbs, the assumption of normality was accepted in low (Z=1.204, p=.11) and high motor content verbs (Z=1.139, p=.15). As for the nouns, the assumption of normality was rejected, both in the low (Z=1,34, p=.045), and high manipulability nouns (Z=1.788, p=.003). No significant effect of manipulability or motor content on reading duration of the experimental groups was found.

The *Student t-test* for independent samples and the *Mann-Whitney U-test* were used to compare the reading duration of these stimuli in both groups. In table 4 the mean values of the parameters analyzed in these stimuli are shown. A significantly longer reading duration was found in the PD group for low motor content verbs [t(43.59)=2.326, p=.025] and for nouns with high manipulability [Z=-1.95, p=.05].

The analysis of pauses in these stimuli showed that the PD group made a significantly higher number of inappropriate pauses both within low-motor content verbs [t(30)=2.794, p=.009] and before these verbs [t(46,92)=2.705, p=.01]. These reading pauses were also significantly longer in the PD group [Pauses within low-motor content verbs (Z=-2.78, p=.005); Pauses before low-motor content verbs (Z=-2.845, p=.004)]. The PD group also showed significantly longer duration of reading pauses made before high motor content verbs [Z=-2.054, p=.04].

Regarding noun analysis, the PD group made a significantly higher number of inappropriate pauses before low manipulability nouns [t(31,09)=3.219, p=.003]. In addition, these pauses were longer than those found in the control group [Z=-3.215, p=.001]. The PD group also committed a significantly higher number of inappropriate pauses within high-manipulability nouns [t(32,09)=2,941, p=.006] and before these same nouns [t(33,36)=3,042, p=.005]. In both instances, these reading pauses were significantly longer than those in the control group [Pauses within high-manipulability nouns (Z=-3,034, p=.002); Pauses before high-manipulability nouns (Z=-2,73, p=.006)]. Results are shown in table 5. The number and type of errors made in the reading of experimental verbs and nouns were also analyzed (see Table 6). Reading errors of these stimuli were identified during the analysis of the reading recordings with the Praat software, and they were classified manually by the researcher according to their nature (phonological, lexical, repetition).

Table 5.

Mean and standard deviation of the parameters analyzed in the experimental verbs and nouns.

Stimuli		**Parameter**	**PD** *M (SD)*	**Control** *M (SD)*
Verbs	High motor content	Nº pauses before verbs	2.29 (1.346)	1.61 (1.453)
		Duration of pauses before verbs (s) *	0.36 (0.237)	0.24 (0.168)
		Nº pauses within verbs	0.23 (0.56)	0.03 (0.18)
		Duration of pauses within verbs (s)	0.076 (0.261)	0.014 (0.081)
		Reading duration (s)	0.427 (0.136)	0.379 (0.064)
	Low motor content	Nº pauses before verbs *	1.55 (1.567)	0.68 (0.871)
		Duration of pauses before verbs (s) *	0.353 (0.401)	0.11 (0.157)
		Nº pauses within verbs *	0.26 (0.514)	0 (0)
		Duration of pauses within verbs (s) *	0.77 (0.188)	0 (0)
		Reading duration (s) *	0.421 (0.131)	0.359 (0.064)
Nouns	High manipulability	Nº pauses before nouns *	0.94 (1.436)	0.13 (0.341)
		Duration of pauses before nouns (s) *	0.19 (0.245)	0.09 (0.271)
		Nº pauses within nouns *	0.55 (0.961)	0.03 (0.18)
		Duration of pauses within nouns (s) *	0.117 (0.215)	0.003 (0.017)
		Reading duration (s) *	0.639 (0.212)	0.539 (0.074)
	Low manipulability	Nº pauses before nouns *	0.81 (1.327)	0.03 (0.18)
		Duration of pauses before nouns (s) *	0.148 (0.245)	0.008 (0.49)
		Nº pauses within nouns	0 (0)	0.03 (0.18)
		Duration of pauses within nouns (s)	0 (0)	0.02 (0.11)
		Reading duration (s)	0.601 (0.132)	0.549 (0.091)

(*M*, mean; *SD*, standard deviation; s, seconds; *, statistically significant differences).

Table 6.

Percentage of reading errors committed by the control group and the PD group in the experimental verbs and nouns.

Stimuli		Type of error	EP	Control
Verb	High motor content	Phonological errors	0	0
		Lexical errors	1.21%	0.4%
		Repetition errors	0	0
	Low motor content	Phonological errors	0	0
		Lexical errors	0.4%	0.4%
		Repetition errors	0.81%	0%
Nouns	High manipulability	Phonological errors	0.4%	0
		Lexical errors	0	0.4%
		Repetition errors	0.4%	0
	Low manipulability	Phonological errors	0	0.4%
		Lexical errors	0	0.4%
		Repetition errors	0.81%	0

Discussion

The aim of this study was to analyze the reading fluency of people with PD, focusing on the main prosodic reading features. For this purpose, two experimental texts were designed including different types of sentences and stimuli with different psycholinguistic characteristics. The main prosodic features of reading were analyzed using Praat software (Boersma & Weenink, 2019).

First, the reading of the experimental sentences was analyzed. According to sentence type (declarative, exclamatory, and interrogative), the results showed statistically significant differences between groups in the initial rise of declarative and interrogative sentences, where the control group showed a higher initial pitch rise. Differences were also found in the slope of declarative sentences, showing a marked decrease in pitch per second in the control group. These findings demonstrate a poor pitch variation observed in PD patients, as previous studies have already described

(Bocklet et al., 2011; Darkins et al., 1988; Galaz el al., 2016; Rektororva et al., 2016). Nevertheless, only two of these studies analyzed the reading of a text, and none of them included an experimental selection of the sentences that comprised the text. The experimental selection of stimuli conducted in this study clarifies the results of previous studies by establishing specific differences between the groups according to the stimuli read (declarative, exclamatory, and interrogative sentences).

Secondly, a pitch analysis of the syllables was also conducted according to their position in the sentence (initial, middle, and final). A lower F0 of the final vowel, compared to the mid atonic vowel, was found in both groups in declarative and exclamatory sentences. This result seems to indicate a pitch decrease at the end of the sentence. The F0 decline over time, which was already described by Vaissière (1983), is considered as a characteristic of a proper reading prosody. Although people with PD show less variation in F0 than the control group, and even if their reading is less expressive, they display the expected pitch pattern, with a decrease in F0 from the beginning of the sentence to the end in declarative and exclamatory sentences. However, previous researchers describe a longer reading duration in people with PD, with a greater number of pauses (Ash et al., 2012; Bocklet et al., 2011; Darkins et al., 1988). The present study did not find significant differences between the PD group and the control group in the overall sentence reading duration. Further analysis at the vowel level showed a lengthening of the final vowel in both groups in the three types of sentences, which was described as a characteristic of fluent speech (Dowhower, 1991). Nonetheless, the mid-vowel duration was significantly longer in the PD group in all three types of sentences. This result would indicate a slower reading at the segmental level, which appears at the vowel level, but no differences were found in the duration at the suprasegmental level (sentence). Regarding pauses during sentence reading, no significant differences were found between the groups in the number of pauses made, although the PD group showed longer intrasentential pauses than the control group in the reading of declarative sentences.

Finally, intensity measurements were also taken at vowel level in all experimental sentences, but no differences were found between the vowel intensity of the PD group and the control group. Both groups showed an intensity decline from mid vowel to the final one in all three types of sentences. This result is consistent with the expected speech patterns reported by Vaissière (1983), who describes a pitch decrease over time, along with an intensity decline. The findings in this study regarding reading intensity would be in disagreement with those presented by Galaz et al. (2016), who described a reduction in F0 variance along with a higher intensity variability in PD patients. These authors explained the contradictory nature of their results as a problem in the control of speech intensity caused by the hypokinetic dysarthria described in PD, which can affect voice, articulation, and prosody (Muñoz-Vigueras et al., 2021). The speech problems due to poor motor control can be expected to affect the reading of these patients, making it slower and more paused, and could explain differences in intensity. Nevertheless, results found in the present study suggest that reading intensity in the PD group is equivalent to that of the controls in all the sentences analyzed.

In general terms, results found after sentence analysis are similar to those described in people showing reading difficulties, such as dyslexia (Suárez-Coalla et al., 2016), and in children who are learning to read (Álvarez-Cañizo et al., 2018). Suárez-Coalla et al. (2016), reported that Spanish children and adults with dyslexia had longer reading durations than their normal-reading peers, and they also had more and longer pauses. These authors also described significant differences in the F0 of people with dyslexia, who showed lower final declination in declarative sentences and lower final rise in interrogative sentences. They explain these differences by a difficulty in decoding skills and in the recognition of unusual sentence structures such as interrogative sentences. According to our results, people with PD showed marked differences in pitch, but also in duration when analyzed at the vowel level, which suggests a slower reading with scarce pitch variation. Although in this work the main differences are found in declarative sentences, it could be hypothesized that the F0 of more complex syntactic structures may be affected with age in normal aging. It would be the simplest structures, such as declarative sentences, where differences that are suggestive of neurodegenerative disease could be found. Therefore, PD could be considered to produce a regression to the early stages of learning to read. More studies are needed to address this question, focusing on a larger number of stimuli, in order to analyze expressiveness in non-pathological aging.

Regarding the stress influence on reading prosody, no significant differences were found between the groups in the reading duration of these words. No stress effect was found in the reading duration of these stimuli, nor differences in stress errors were found between the groups. As a result, the reading speed and accuracy of the PD group were similar to that of the control group when reading these stimuli, where word stress did not affect the reading fluency of PD patients. This result indicates in turn a preservation of lexical reading in the PD group for different stressed stimuli. A similar study where stress influence was analyzed in a group of Spanish patients with Alzheimer's disease (AD) (Pérez-Sanchez et al., 2021), reported longer reading duration in both paroxytone and proparoxytone words in the patient group, as well as a higher number of stress errors, when compared to the control group. Consequently, this study suggests an impairment of lexical reading for these stimuli in Spanish AD patients. In sum, these results seem to support a differentiation between the two pathologies when reading different stressed stimuli. Future lines of research could be aimed to analyze these differences, as they could be considered key stimuli in the identification of these diseases.

The influence of motor content on verb processing in people with PD was also analyzed. This variable has been widely studied, showing a greater impairment when processing high motor content verbs (Bocanegra et al., 2017; Herrera et al., 2012). The results of the present study showed significantly longer reading duration on verbs with low motor content in PD patients. On his part, the analysis of pauses showed a significantly higher number of pauses before and within verbs with low motor content, which were significantly longer than those of the control group. Significant differences were also found in the duration of pauses before high motor content verbs, which were longer in the PD group. These results point to a verb processing impairment in people with PD, which is particularly characterized by the large number of pauses.

Previous studies have described an impairment in lexical-semantic processing of verbs in lexical decision and naming tasks in people with PD, when reaction times and accuracy are analyzed (Boulenger et al., 2008; Rodríguez-Ferreiro et al., 2009). However, in this study we did not find a motor content effect on verb processing in PD, in contrast the descriptions by Bocanegra et al. (2017) and Herrera et al., (2012) in action naming tasks. The discrepancies when compared to previous studies could be due to the small number of stimuli used. Previous research that described lexical-semantic impairment for action naming in PD patients, such as the work of Herrera et al. (2012), analyzed 50 verbs in a naming task, whereas in this case only 8 stimuli of each category were compared. The scarce number of stimuli was due to the fact that it is difficult to find stimuli that can be matched in many variables such as length, frequency and motor content, and that in turn can be used to form a coherent text together. Consequently, future research could be focused on a broader study of these stimuli in text reading. In the same way, medication could also be affecting verb processing in this study. Some research in the field reported how verb naming worsens in PD patients when they are not on medication with dopamine precursors. In contrast, the differences when compared to the control group disappeared when PD patients were assessed while they were taking the dopaminergic medication (Herrera & Cuetos, 2012; 2013). In the present study, all participants with PD were on dopamine precursor medication during the reading assessment, which may mask the effect on the motor content processing.

In addition, the reading of different nouns was analyzed, which were selected according to their manipulability, a variable that has shown to influence their reading processing. (Saccuman et al., 2006). The results showed significantly longer reading durations for highly manipulable nouns in the PD group, along with significantly more pauses before and within these stimuli, which in both cases were longer than those of the control group. A greater number of pauses before low manipulability nouns, which were also longer, were also found in the PD group. As in the case of the motor content of the verbs, this result makes it difficult to understand if there is a real influence of the manipulability variable on reading, or if it is just the typical speech patterns of people with PD, who would show more pauses and longer durations in their reading (Ash et al., 2012; Darkins et al., 1988; Bocklet et al., 2011). It should be noted that the type of pauses found within high-manipulability nouns are more intrusive than pauses before found in low-manipulability nouns, since the within pauses are produced in the middle of the word and indicate further difficulty in the reading of these stimuli. The influence of noun manipulability on the expressiveness of text reading would require further study, using a larger number of stimuli, in order to draw conclusions about their reading processing in Spanish PD patients. As in the case of verbs, the potential influence of dopaminergic medication which could be masking the effect of manipulability, should also be assessed. However, other studies have found that levodopa treatment improves the processing of verbs, but not of nouns, in PD patients (Herrera & Cuetos, 2012).

The results found so far are not conclusive enough to determine whether the difficulties detected in PD for certain verbs and nouns are due to a lexical-semantic impairment, where variables such as motor content and manipulability affect their processing, as some authors point out (Herrera et al., 2012; Herrera & Cuetos, 2012;

Herrera & Cuetos, 2013), or in any case, whether they are due to an impairment of the grammatical category. This perspective suggests a marked difficulty of verbs as compared to nouns, which could also be impaired with disease progression, regardless of other variables. This hypothesis would be supported by those studies in which impairment is observed in the processing of verbs, but not in objects (Boulenger et al., 2007), or in which difficulties with object processing are found when the disease is advanced, regardless of their manipulability (Bocanegra et al., 2015). However, previous studies were based on isolated word tasks in both instances, which makes it difficult to fit the results obtained regarding motor content of verbs and manipulability of nouns in the previous literature due to the nature of the tasks used. Further studies in which all elements of reading fluency can be assessed with different reading tasks will be necessary, since the influence of different stimuli and their variables on reading processing in PD can provide very useful tools for both assessment and treatment.

Following this line of research, several studies have highlighted the importance of using spontaneous speech tasks in the assessment of dysarthria in PD, and the results found suggest that the naturalness and intelligibility of language is more preserved in reading tasks compared to spontaneous language tasks (Kempler & Van Lancker, 2002; Weir-Mayta et al., 2017). Weir-Mayta et al. (2017) compared sentences extracted from a recording of spontaneous speech with the same read aloud sentences in a group of 10 American PD patients. Their results show how language understandability and naturalness increased significantly in reading tasks. Therefore, the authors conclude that spontaneous speech tasks should be included in the assessment process for these patients. Conversely, Tjaden and Wilding (2011) compared speaking tasks (monologue vs paragraph reading) and found that both tasks were comparable, as the reading measures were able to predict the severity of spontaneous language impairment. In the present study, no spontaneous speech measures could be made for comparison with the reading samples, and it would have been interesting to have more information about the speech characteristics of patients. Despite this limitation, the results suggest that the experimental assessment of reading fluency is a useful tool when assessing language in PD, since several differences with the control group are found. Therefore, it should be considered for use in the diagnostic process of PD.

Moreover, the analysis of the reading fluency using a reading text task, considering the specific features of reading expressiveness, has been studied as a possible diagnostic marker of PD (Bocklet et al., 2011). Although many aspects about the reading prosody in PD must be clarified for this procedure to be used as a diagnostic test, this work allows us to learn more about these reading features. The results found in his work in terms of F0 variations in different types of sentences are complementary to the results described in this line in previous research. In addition, this study showed a new approach in terms of methodology, since the texts used were designed considering the psycholinguistic characteristics of the stimuli and its effects on reading fluency. However, this procedure severely restricted the number of stimuli. Most studies that analyze reading fluency focus on reading speed and accuracy, which makes it possible to conduct single words experiments, which allows the inclusion of a large number of stimuli. However, the analysis of reading prosody requires the use of texts. Building a coherent text with stimuli that meet all the psycholinguistic variables that have been considered (frequency, length, motor content, manipulability) is very complicated. There are studies of isolated word reading where these characteristics are considered in patients with PD (Bocanegra et al., 2015; Bocanegra et al., 2017; Cotelli et al., 2007; Herrera et al., 2012), but we are not aware of any study that has analyzed them in a Spanish text. Therefore, further research should be aimed to increase the number of stimuli analyzed, especially for nouns, where we found discrepancies which are difficult to explain in the results regarding manipulability. This could clarify how the lexical-semantic impairment described in PD affects reading fluency also at reading prosody level.

The impossibility to control the dopamine precursor medication is another important limitation of this study. Although previous literature is consistent in that this medication has no influence on reading prosody (Elfmarková et al., 2016; Skodda et al., 2009; Skodda et al., 2010), which is still impaired in the presence of dopaminergic medication in PD, an influence of medication on lexical-semantic processing of verbs has been found (Herrera & Cuetos, 2012; 2013). This fact has not allowed us to study the influence of the motor content of verbs on reading fluency in PD as it was intended. In the future, these findings could be broadened by assessing PD patients with and without dopaminergic and mediation.

Despite the limitations described above, the experimental analyses of prosody conducted in this work allowed to describe some reading fluency characteristics of PD, where the most affected features are speed and expressiveness. Within reading prosody, main impairments were related to the low pitch variability during reading and in the number of pauses committed. These aforementioned affectations cause PD reading to be slower and less expressive than that of their control group, thereby reading fluency of these patients is compromised.

Conclusions and clinical applications

The results achieved in this study provide new information on the characteristics of reading fluency in Spanish speakers with PD, using experimental analysis techniques and by taking objective measures. The use of experimentally designed texts makes it possible to analyze the influence of different psycholinguistic variables (frequency, length, motor content, manipulability) on reading, and how the processing of certain stimuli could be affected by the disease. In addition, the implementation of the Praat software in the analysis of the reading fluency of these patients allowed to take measurements of the main prosodic parameters, where the most striking findings were found in the reading pitch, as well as in the number of pauses committed, although differences were also found in the reading speed. Therefore, the use of computer-based instruments such as Praat offered the possibility to analyze reading fluency in an objective way, as well as to identify some features that could indicate a PD reading pattern. Further studies should be aimed to improve the results obtained in this study. It would be desirable to include a higher number of stimuli to be analyzed, for example a higher number of verbs, different types of sentences, words with different stress, etc. These new reports could allow to determine what kind of stimuli are the most difficult for patients with PD when reading. Likewise, it would be interesting to compare the characteristics of reading fluency in PD with other neurodegenerative diseases that also cause language impairment, such as AD. Further knowledge of the linguistic features (especially reading fluency) and how they are impaired in PD may contribute to the design of assessment and diagnostic tasks for an early detection of the pathology, as well as to a differential diagnosis with other neurodegenerative diseases.

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Supplementary Material

Appendix 1

EL BAILARÍN

Felipe es un gran bailarín. Todos los sábados por la tarde coge su cartera y su mejor abrigo. Antes de salir de casa se mira al espejo y ve que le falta algo. Felipe se pone un sombrero. Después sale de casa y sigue las señales hasta llegar a la entrada de un edificio. El portero le saluda y Felipe compra una entrada.

En el interior, Felipe observa una sala grande con muchas columnas, decoradas con símbolos musicales. Pero la sala está vacía. Al fondo, el camarero llena copas de vino y prepara otras bebidas en vasos de plástico. Felipe se acerca y le pregunta:

- ¿Cuándo será la hora del baile?

De repente los músicos comienzan a tocar. Felipe pide una copa de vino y salta a la pista de baile. Las trompetas suenan y el cantante toca el teclado. La gente empieza a entrar desde la calle y ríen, beben y hablan.

Felipe baila durante horas y pierde la noción del tiempo. Este es su momento favorito de la semana. Cuando la banda canta la última canción, Felipe llama al ascensor y sube hasta el tejado del edificio. Allí hay una gran terraza para tomar el aire. Felipe contempla desde lo alto la gran ciudad en la que vive, que está toda cubierta de nieve. Después de unos minutos en silencio exclama:

- ¡Qué frío tengo aquí afuera!

Entonces decide volver a la sala de baile, pero la gente ya se ha marchado. Recoge su abrigo y su sombrero, bebe una última copa, y regresa a su casa a esperar que vuelva a ser sábado por la tarde.

Appendix 2

LA EXCURSIÓN

Los días que hace buen tiempo Teresa sale de excursión. Hoy va a buscar un claro en el bosque, que está en lo alto de la montaña. Prepara su mochila con comida y también coge su guitarra. Sale de casa y sube por una colina cercana. Por el camino corre hacia un granero, donde se detiene para atarse un zapato. Cuando entra en el bosque juega con las hojas del suelo y huele el aire fresco del otoño. En su paseo se cruza con las ruinas de un castillo.

Dentro del bosque escucha pájaros cantando, especialmente palomas. También encuentra muchos insectos. Después de un rato caminando vuelve a encontrarse junto al castillo. Teresa sufre por haber caminado en círculos. Pensativa se pregunta:

- ¿Dónde está el claro del bosque?

Teresa continúa su camino y encuentra un prado con caballos. El paisaje es diferente en esa zona del bosque. Ha encontrado el camino correcto. Descubre un claro donde apenas hay árboles. Coloca unas toallas en el prado y con unos fósforos enciende una pequeña hoguera para calentar su comida. Teresa se come su almuerzo. Cuando termina de comer, limpia sus cubiertos y duerme la siesta.

De repente, Teresa nota una brisa que la despierta. Un molino cercano se mueve con el viento. Teresa se encuentra en paz, adora la naturaleza. Coge su guitarra y piensa:

- ¡Qué feliz estoy aquí arriba!

Después de cantar unas cuantas canciones, recoge su mochila y su guitarra, se despide de los caballos y emprende el camino de vuelta a casa.

Appendix 3

Table 7.

Length and lexical frequency of experimental paroxytone and proparoxytone words.

PAROXYTONE WORDS	Length	Lexical Frequency	PROPAROXYTONE WORDS	Length	Lexical Frequency
Text 1					
Portero [doorman]	7	9,87	Músicos [musicians]	7	7,5
Cantante [singer]	8	15	Plástico [plastic]	8	20,24
Ascensor [elevator]	8	20,12	Símbolos [symbols]	8	8,45
Bebidas [drinks]	7	14,11	Sábados [Saturdays]	7	5,72
Mean	7,5	14,77		7,5	10,47
Text 2					
Paisaje [landscape]	7	5,79	Árboles [tres]	7	30,14
Insectos [insects[]	8	10,88	Fósforos [matches]	8	4,54
Caballos [horses]	8	32,25	Círculos [circles]	8	7,33
Palomas [pigeons]	7	5,04	Pájaros [birds]	7	17,06
Mean	7,5	13,49		7,5	14,77
Global mean	7,5	14,13		7,5	12,62

Appendix 4

Table 8.

Psycholinguistic characteristics of experimental verbs (simple present).

LOW MOTOR CONTENT	Length	Lexical Frequency	Motor content level	HIGH MOTOR CONTENT	Length	Lexical Frequency	Motor content level
Text 1							
Canta [sings]	5	17,02	2,59	Salta [jumps]	5	16,51	5,65
Llena [fills]	5	52,83	2,33	Baila [dances]	5	15,33	6,34
Pierde [loses]	6	26,71	1,95	Compra [buys]	6	29,66	4,19
Pide [asks]	4	36,68	2	Sale [goes out]	4	95	4,5
Mean	5	33,31	2,22		5	39,12	5,17
Text 2							
Sufre [suffers]	5	21,51	1,73	Juega [plays]	5	31,87	5,76
Huele [smells]	5	45,19	1,65	Corre [runs]	5	76,2	6,14
Duerme [sleeps]	6	29,41	1,61	Limpia [cleans]	6	35,34	4,81
Nota [feels]	4	71,73	1,65	Sube [climbs]	4	51,89	4,63
Mean	5	41,97	1,66		5	48,82	5,34
Global mean	5	37,64	1,94		5	43,97	5,25

Appendix 5

Table 9.

Psycholinguistic characteristics of experimental nouns.

LOW MANIPULA-BILITY	Length	Lexical Frequency	Manipu-lability level	HIGH MANIPULA-BILITY	Length	Lexical frequency	Manipu-lability level
Text 1							
Terraza [terrace]	7	5,07	1,27	Cartera [wallet]	7	18,14	6,52
Señales [signs]	7	27,18	2,05	Teclado [keyboard]	7	3,03	5,6
Tejado [roof]	6	6,34	2,28	Abrigo [coat]	6	25,33	6,65
Columnas [columns]	8	3,89	1,57	Trompeta [trumpet]	8	2,54	4,96
Mean	7	10,62	1,79		7	12,26	5,93
Text 2							
Montaña [mountain]	7	33,34	1,18	Mochila [backpack]	7	12,62	5,36
Granero [barn]	7	7,09	1,41	Zapato [shoe]	6	17,11	5,92
Molino [mil]	6	3,17	1,88	Toallas [towels]	7	11,03	5,68
Castillo [castle]	8	21,29	1,38	Guitarra [guitar]	8	17,59	5,76
Mean	7	16,22	1,46		7	14,59	5,68
Global mean	7	13,42	1,63		7	13,42	5,81

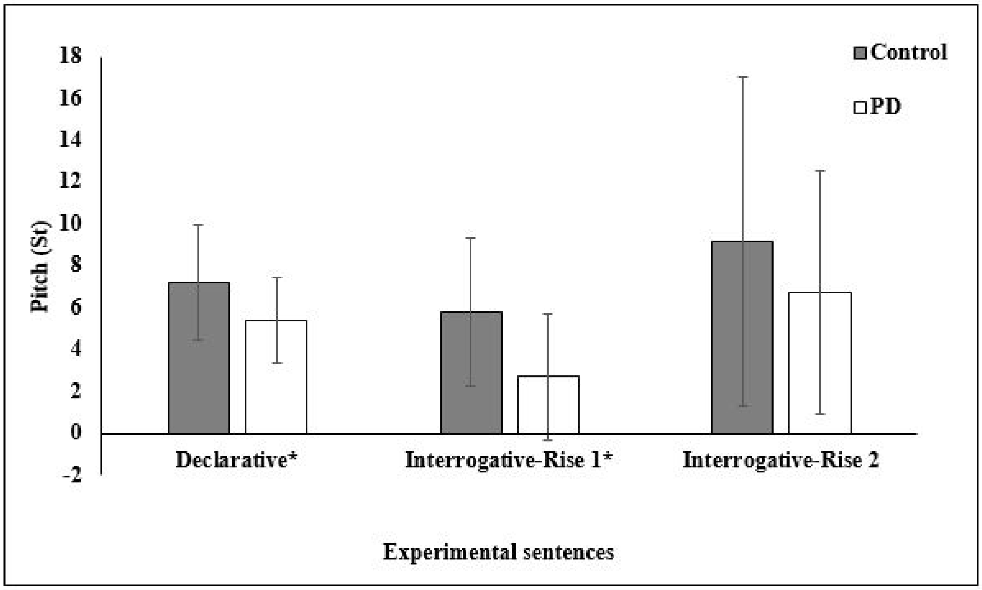
Appendix 6

Concerning the survey about the degree of manipulability of experiential nouns

With the purpose of obtaining a manipulability database, we removed from a database of 1000 black and white drawings (not published) all items involving animals (e.g. squirrel), fantasy creatures (e.g. ghost), people (e.g. referee, painter...) and body parts (e.g. hand). The final list consisted of 724 items in total. After that, seven questionnaires were created, which were formed by a list of words referring to objects that included all the selected items. Four of them were composed by 104 items, while the other three questionnaires were formed by 103 items. This was done in order to avoid participant weariness when completing overly long questionnaires. Participants were asked to rate the ability to handle or use the objects with their hands, feet, or any other part of the body, using a Likert scale from 1 to 7 (1 not manipulable at all and 7 highly manipulable). Questionnaires were completed online by university students. For the development of the final database, incongruent values were removed (e.g., if in one item all subjects answered 1 except for two scores, 6 and 7, they were discarded). Descriptive statistics of mean, mode and standard deviation were then obtained for each item of the database.

Figure 1.

Pitch rise in declarative and interrogative sentences in the control group and the PD group.



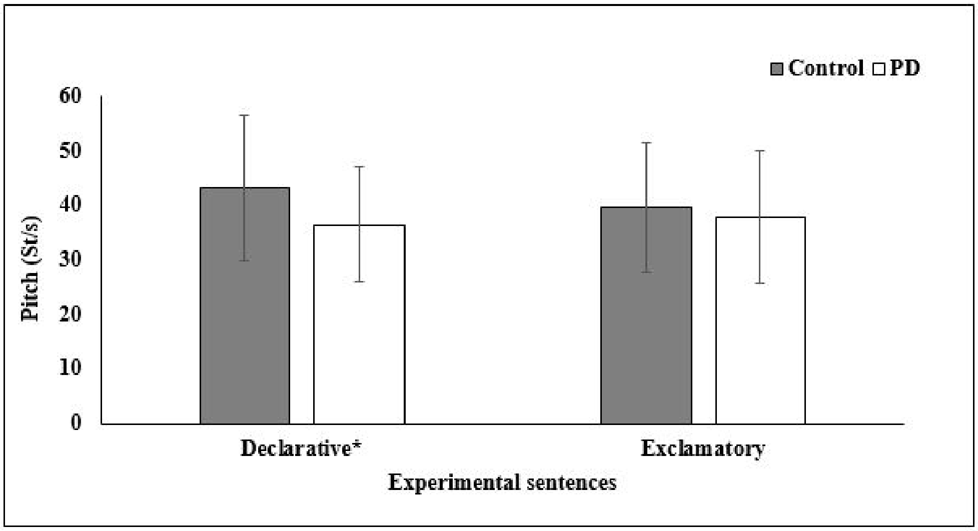
(St, semitones; *, statistically significant differences between groups).

Figure 1.
Pitch rise in declarative and interrogative sentences in the control group and the PD group.

161x116mm (96 x 96 DPI)

Figure 2.

Pitch slope in declarative and exclamatory sentences in the control group and the PD group.



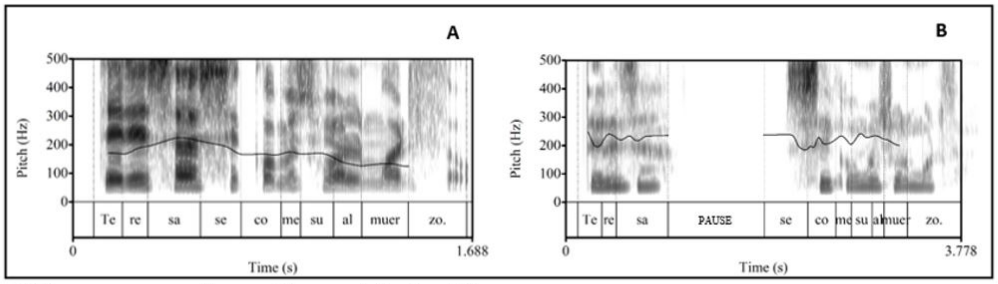
(St/s, semitones per second; *, statistically significant differences between groups).

Figure 2.
Pitch slope in declarative and exclamatory sentences in the control group and the PD group.

163x110mm (96 x 96 DPI)

Figure 3.

Pitch contour of the declarative sentence of Text 2 in the control group (A) and the PD group (B) (pitch in hertz; time in seconds).



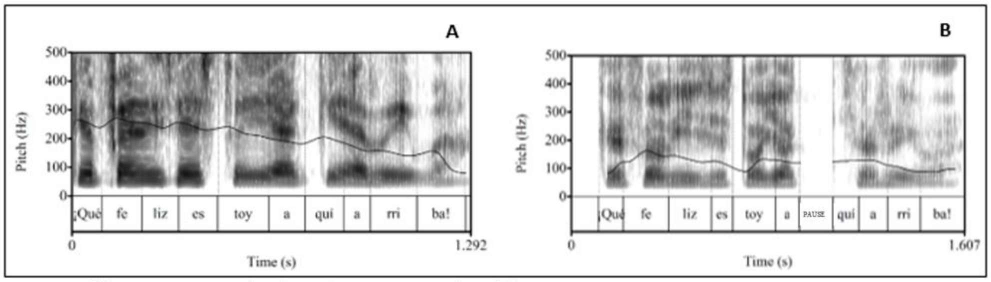
("*Teresa se come su almuerzo* [Teresa eats her lunch]").

Figure 3.
Pitch contour of the declarative sentence of Text 2 in the control group (A) and the PD group (B) (pitch in hertz; time in seconds).

265x113mm (96 x 96 DPI)

Figure 4.

Pitch contour of the exclamatory sentence of Text 2 in the control group (A) and the PD group (B) (pitch in hertz; time in seconds).



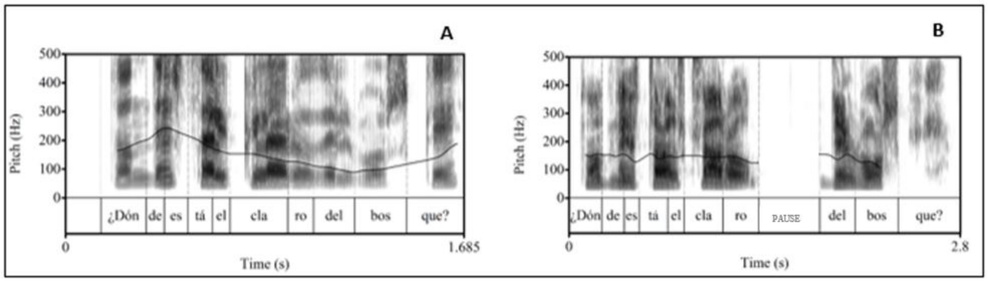
("*¡Qué feliz estoy aquí arriba!* [How happy I am up here!]").

Figure 4.
Pitch contour of the exclamatory sentence of Text 2 in the control group (A) and the PD group (B) (pitch in hertz; time in seconds).

266x109mm (96 x 96 DPI)

Figure 5.

Pitch contour of the interrogative sentence of Text 2 in the control group (A) and the PD group (B) (pitch in hertz; time in seconds).



("*¿Dónde está el claro del bosque?* [Where is the forest glade?]").

Figure 5.
Pitch contour of the interrogative sentence of Text 2 in the control group (A) and the PD group (B) (pitch in hertz; time in seconds).

263x113mm (96 x 96 DPI)

Table 1.

Characteristics of the participants.

	PD *M (SD)*	Control *M (SD)*
Disease duration	6.75 (5.12)	
Age	69.16 (7.43)	73.32 (11.37)
Years of schooling	9.19 (4.21)	10.74 (4.74)
MoCA*	25.52 (2.81)	27.81 (2.3)

(*M*, mean; *SD*, standard deviation; * significant differences between the groups)

Table 2.

Scores of the participants in the assessment tests.

		PD *M (SD)*	Control *M (SD)*
YESAVAGE Test	5 items version	0.52 (0.51)	0.55 (0.62)
	15 items version	2.39 (1.33)	1.84 (1.37)
Text memory task	Direct recall*	6.51 (2.34)	7.96 (2.08)
	Direct recall with key*	9.27 (1.79)	10.26 (2.01)
	Delayed evocation*	7.4 (2.57)	8.85 (2.33)
	Delayed evocation with key*	9.27 (2.08)	10.61 (1.98)
Stroop test	Sheet 1*	77.61 (18.73)	88.65 (20.53)
	Sheet 2	54.45 (14.75)	60.23 (13.46)
	Sheet 3	31.29 (10.59)	32.87 (11.45)
Attention task *		9.84 (2.34)	11.06 (1.5)
Working memory task *		8.06 (2.11)	9.45 (2.04)

(*M*, mean; *SD*, standard deviation; * significant differences between the groups)

Table 3.

Mean and SD of the parameters analyzed in the experimental sentences.

Type of sentence	Parameter		PD *M (SD)*	Control *M (SD)*
Declarative	Nº pauses between words		1 (1.34)	0.45 (0.96)
	Duration of pauses between words (s)		0.246 (0.434)	0.16 (0.539)
	Nº pauses within words		0.193 (0.401)	0 (0)
	Duration of pauses within words (s) *		0.612 (0.142)	0 (0)
	Sentence total duration (s)		2.188 (0.914)	1.781 (0.483)
	Duration of the vowels (s)	Mean vowel *	0.991 (0.024)	0.082 (0.018)
		Final vowel	0.127 (0.029)	0.124 (0.028)
	Intensity of the vowels (dB)	Mean vowel	70.621 (4.55)	70.74 (5.35)
		Final vowel	65.177 (7.11)	63.979 (7.271)
	F0 Rise (St) *		5.428 (2.034)	7.224 (2.757)
	F0 Slope (St/s)*		36.414 (10.54)	43.109 (13.36)
	F0 of the vowels (St)	Mean vowel *	25.509 (1.171)	26.268 (1.185)
		Final vowel	25.092 (1.77)	25.108 (1.66)
Exclamatory	Nº pauses between words		0.548 (0.994)	0.322 (0.652)
	Duration of pauses between words (s)		0.128 (0.231)	0.063 (0.15)
	Nº pauses within words		0.645 (0.249)	0 (0)
	Duration of pauses within words (s)		0.011 (0.041)	0 (0)
	Sentence total duration (s)		1.771 (0.537)	1.625 (0.303)
	Duration of the vowels (s)	Mean vowel *	0.108 (0.023)	0.09 (0.019)
		Final vowel	0.14 (0.031)	0.153 (0.026)
	Intensity of the vowels (dB)	Mean vowel	71.699 (7.399)	70.002 (6.271)
		Final vowel	63.984 (7.36)	63.128 (6.357)
	F0 Slope (St/s)		37.843 (12.272)	39.631 (11.925)
	F0 of the vowels (St)	Mean vowel	25.267 (1.23)	25.742 (1.002)
		Final vowel	24.532 (1.323)	25.201 (2.112)
Interrogative	Nº pauses between words		0.32 (0.871)	0.645 (0.249)
	Duration of pauses between words (s)		0.075 (0.201)	0.022 (0.086)
	Nº pauses within words		0.032 (0.179)	0.032 (.0179)
	Duration of pauses within words (s)		0.009 (0.051)	0.004 (0.024)
	Sentence total duration (s)		1.953 (0.712)	1.644 (0.326)
	Duration of the vowels (s)	Mean vowel *	0.084 (0.028)	0.059 (0.012)
		Final vowel	0.159 (0.023)	0.152 (0.029)
	Intensity of the vowels (dB)	Mean vowel	76.37 (5.305)	74.641 (4.81)
		Final vowel	68.566 (8.483)	67.198 (6.107)
	F0 Rise 1 (St) *		2.693 (3.033)	5.778 (3.55)
	F0 Rise 2 (St)		6.727 (5.83)	9.197 (7.87)
	F0 of the vowels (St)	Mean vowel	26.526 (1.529)	27.118 (1.312)
		Final vowel	26.311 (1.789)	27.068 (1.497)

(*M*, mean; *SD*, standard deviation; s, seconds; dB, decibels; St, semitones; *, statistically significant differences between groups).

Table 4.

Mean and standard deviation of reading duration for words with different stresses.

Parameter		PD *M (SD)*	Control *M (SD)*
Reading duration (s)	Stress on paroxytone words	0.68 (0.17)	0.59 (0.081)
	Stress on proparoxytone words	0.61 (0.15)	0.54 (0.08)

(*M*, mean; *SD*, standard deviation; s, seconds).

Table 5.

Mean and standard deviation of the parameters analyzed in the experimental verbs and nouns.

Stimuli		Parameter	PD *M (SD)*	Control *M (SD)*
Verbs	High motor content	Nº pauses before verbs	2.29 (1.346)	1.61 (1.453)
		Duration of pauses before verbs (s) *	0.36 (0.237)	0.24 (0.168)
		Nº pauses within verbs	0.23 (0.56)	0.03 (0.18)
		Duration of pauses within verbs (s)	0.076 (0.261)	0.014 (0.081)
		Reading duration (s)	0.427 (0.136)	0.379 (0.064)
	Low motor content	Nº pauses before verbs *	1.55 (1.567)	0.68 (0.871)
		Duration of pauses before verbs (s) *	0.353 (0.401)	0.11 (0.157)
		Nº pauses within verbs *	0.26 (0.514)	0 (0)
		Duration of pauses within verbs (s) *	0.77 (0.188)	0 (0)
		Reading duration (s) *	0.421 (0.131)	0.359 (0.064)
Nouns	High manipulability	Nº pauses before nouns *	0.94 (1.436)	0.13 (0.341)
		Duration of pauses before nouns (s) *	0.19 (0.245)	0.09 (0.271)
		Nº pauses within nouns *	0.55 (0.961)	0.03 (0.18)
		Duration of pauses within nouns (s) *	0.117 (0.215)	0.003 (0.017)
		Reading duration (s) *	0.639 (0.212)	0.539 (0.074)
	Low manipulability	Nº pauses before nouns *	0.81 (1.327)	0.03 (0.18)
		Duration of pauses before nouns (s) *	0.148 (0.245)	0.008 (0.49)
		Nº pauses within nouns	0 (0)	0.03 (0.18)
		Duration of pauses within nouns (s)	0 (0)	0.02 (0.11)
		Reading duration (s)	0.601 (0.132)	0.549 (0.091)

(*M*, mean; *SD*, standard deviation; s, seconds; *, statistically significant differences).

Table 6.

Percentage of reading errors committed by the control group and the PD group in the experimental verbs and nouns.

Stimuli		Type of error	EP	Control
Verb	High motor content	Phonological errors	0	0
		Lexical errors	1.21%	0.4%
		Repetition errors	0	0
	Low motor content	Phonological errors	0	0
		Lexical errors	0.4%	0.4%
		Repetition errors	0.81%	0%
Nouns	High manipulability	Phonological errors	0.4%	0
		Lexical errors	0	0.4%
		Repetition errors	0.4%	0
	Low manipulability	Phonological errors	0	0.4%
		Lexical errors	0	0.4%
		Repetition errors	0.81%	0