VoxSenes Acoustic Database

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Abstract

Motivated by the need to increase knowledge about the effect of age on speech production, and by the lack of speech data on European Portuguese (EP), this work focuses on the development of a speech database, with acoustic data of healthy adults using standardized recording procedures. The objective of this database is to support a comprehensive analysis of age and gender effects in EP speech at segmental and suprasegmental levels.

In this vein, the present work provides the description of one acoustic speech database containing all EP vowels produced in similar context (reading speech), and also semi-spontaneous speech (image description) collected from a large sample of 144 adults from the central region of Portugal, between the ages 35 and 97. This paper summarizes the research design of the acoustic database and includes details about the study region, participants, participants' tasks, corpus, data acquisition, and segmentation/annotation of the data.

This database has been used in different studies, where various aspects of the aging speech were explored through different methods, such as static acoustic features and dynamic vowel formants. However, the collected data could be used on other acoustic studies of speech over the lifespan.

Key Words: aging; vowels; suprasegmental features; European Portuguese; speech acoustic database.

Résumé

Vu la nécessité d'accroître les connaissances sur l'effet de l'âge, sur la production de la parole et vu le manque de données concernant la parole en portugais européen (PE), ce travail analyse le développement d'une base de données sur la parole, avec des données acoustiques d'adultes en bonne santé à l'aide d'un enregistrement et des procédures standardisés. Cette base de données permet une analyse complète des effets de l'âge et du sexe dans le discours PE aux niveaux phonématique et suprasegmental.

Dans cette perspective, le présent travail décrit une base de données de parole acoustique contenant toutes les voyelles du PE produites dans un contexte similaire (discours de lecture), ainsi qu'en parole semi-spontanée (description d'image) collectée, à partir d'un large échantillon de 144 adultes de la région centrale du Portugal, âgés de 35 à 97 ans. Cet article présente le design de la recherche de la base de données acoustique ainsi que les données sur la région d'étude, les participants, les tâches des participants, le corpus, l'acquisition de données et la segmentation/annotation des données.

Cette base de données a été utilisée dans différentes études, où divers aspects de la parole vieillissante ont été explorés au moyen de différentes méthodes, comme les caractéristiques acoustiques statiques et les formants dynamiques des voyelles. Les données recueillies pourraient cependant être également utilisées dans d'autres études acoustiques sur le développement de la parole tout au long de la vie.

Mots clés : vieillissement ; voyelles ; traits suprasegmentaux ; portugais européen ; base de données acoustiques de parole.

Resumen

Habida cuenta de la necesidad de aumentar el conocimiento sobre los efectos de la edad en la producción del habla y la falta de datos fonéticos sobre el portugués europeo (PE), este trabajo se centra en el desarrollo de una base de datos de habla, con datos acústicos de adultos sanos utilizando grabaciones y procedimientos estandarizados. El objetivo de esta base de datos es respaldar un análisis integral de los efectos de la edad y del género en el PE hablado a nivel segmental y suprasegmental.

En este sentido, el presente trabajo proporciona la descripción de una base de datos acústicos de habla que contiene todas las vocales del PE, producidas en un contexto similar (lectura), y también en habla semiespontánea (descripción de una imagen) recolectada de una muestra grande de 144 adultos de la región central de

Portugal, con edades entre 35 y 97 años. Este documento resume el diseño de la base de datos acústica e incluye detalles sobre la región de estudio, los participantes, las tareas de los participantes, el corpus, la adquisición de datos y la segmentación/ anotación de los datos.

Esta base de datos se ha utilizado en diferentes estudios, donde se exploraron varios aspectos del envejecimiento del habla a través de diferentes métodos, como las características acústicas estáticas y la dinámica de los formantes de las vocales. Sin embargo, los datos recopilados podrían usarse en otros estudios acústicos sobre el desarrollo del habla a lo largo de la vida.

Palabras clave: envejecimiento; vocales; elementos suprasegmentales; portugués europeo; base de datos acústicos de habla

Resum

Atesa la necessitat d'augmentar el coneixement sobre l'efecte de l'edat en la producció de la parla i la manca de dades fonètiques sobre el portuguès europeu (PE), aquest treball se centra en el desenvolupament d'una base de dades de parla, amb dades acústiques d'adults sans utilitzant procediments estandarditzats d'enregistrament. L'objectiu d'aquesta base de dades és donar suport a una anàlisi exhaustiva dels efectes de l'edat i del gènere en el PE oral en els nivells segmental i suprasegmental.

En aquest sentit, el present treball proporciona la descripció d'una base de dades acústica de parla que conté totes les vocals del PE produïdes en un context similar (lectura), i també parla semi-espontània (descripció d'una imatge) recollida d'una gran mostra de 144 adults de la regió central de Portugal amb edats compreses entre els 35 i els 97 anys. Aquest article resumeix el disseny de la base de dades acústica i inclou detalls sobre la regió d'estudi, els participants, les tasques dels participants, el corpus, l'adquisició de dades i la segmentació/anotació de les dades.

Aquesta base de dades s'ha utilitzat en diferents estudis, en els quals es van explorar els efectes de l'envelliment en la parla mitjançant diferents mètodes, com ara característiques acústiques estàtiques i la dinàmica dels formants de les vocals. Tanmateix, les dades recollides es podrien utilitzar en altres estudis acústics sobre el desenvolupament de la parla al llarg de la vida.

Paraules clau: envelliment; vocals; elements suprasegmentals; portuguès europeu; base de dades acústiques de parla

1. Introduction

The older population is quickly increasing worldwide. Demographic aging, while due primarily to lower fertility, also reflects a human success story of increased longevity (He, Goodkind, Kowal, 2016). Portugal is one of the developed countries with the highest rate of older population (between 1970 and 2021, the percentage of people aged 65 and over increased from 9.7% to 23.4%) (Statistics Portugal, 2015, 2021), and it is classified as one of the fastest aging countries by the Organization for Economic Co-operation and Development (OECD) (Rudnicka, Napierała, Podfigurna *et al.*, 2020). Moreover, the old-age dependency rate may increase between 2018 and 2080, from 33.9 to 67.8 older people per 100 potentially active people (Statistics Portugal, 2019; United Nations Department of Economic and Social Affairs Population Division, 2019).

The natural and inexorable process of aging involves changes at different levels (e.g., physiological, cognitive, psychological, social) (Makiyama, Hirano, 2017) and the human speech production mechanism is no exception (Linville, 2001; Mautner, 2011; Schötz, 2006). The anatomical and physiological changes in the speech organs (e.g., decreased lung capacity; ossification and calcification of the laryngeal cartilages; vocal fold atrophy and motor function decrease of resonant organs) (Linville, Rens, 2001; Makiyama, Hirano, 2017; Schötz, 2006), are reflected in the variation of several acoustic parameters (Eichhorn, Kent, Austin, *et al.*, 2018; Linville, Rens, 2001; Schötz, 2006). Nonetheless, the magnitude of the speech changes depends upon the individual (Fuchs, Koenig, Gerstenberg, 2021), as the voice is intricately linked to the dynamics of the speech organs (Makiyama, Hirano, 2017), as well as the pattern and extent of those changes vary by gender (Linville, 2001; Makiyama, Hirano, 2017).

Unlike other languages, in which speech variations related to age have been widely studied since the 1960s (Schötz, 2006), for the European Portuguese (EP) there are only a few studies about segmental and suprasegmental changes motivated by aging (Albuquerque, Oliveira, Teixeira *et al.*, 2014; Guimarães, Abberton, 2005; Pellegrini, Hämäläinen, de Mareüil *et al.*, 2013; Rato, Rodrigues, Varanda, 2017). Additionally, the few available studies are mainly focused on the acoustic characteristics of the oral vowels produced by young adults (Costa, 2004; Escudero, Boersma, Rauber *et al.*, 2009; M. R. D. Martins, 1973) and children, or in articulatory data of nasal vowels (Cunha, Silva, Teixeira *et al.*, 2019; Oliveira, Martins, Teixeira, 2009; Oliveira, Martins, Silva, et al., 2012).

Therefore, the main goal of our work was to perform a comprehensive analysis of age and gender effects in EP speech at segmental and suprasegmental level using acoustic data.

A deeper knowledge of how speech changes with age is crucial for clinical assessment and treatment of different speech disorders, which are often age-related (Caruso, Mueller, Shadden, 1995; Johns III, Arviso, Ramadan, 2011), and to provide information for other fields of knowledge (e.g., phonetics, speech science, forensic linguistics and biometric recognition) (Lanitis, 2010; Morrison, 2013). Additionally, directly or indirectly, knowledge of how speech changes with age in a given language is essential to develop speech technologies more adequate to the end user. In this sense, to build automatic speech recognition (ASR) systems capable of successfully recognizing elderly speech, a sufficient amount of elderly speech data is needed for training the acoustic models. Microsoft Language Development Center (MLDC) collected a wideband speech read out by elderly Portuguese speakers (Hämäläinen, Avelar, Rodrigues *et al.*, 2014), that was used in different projects to support applications to help the elderly stay healthy, active, independent and socially connected (Hämäläinen, Meinedo, Tjalve *et al.*, 2014; Hämäläinen, Pinto, Dias *et al.*, 2012).

The purpose of this paper is to describe the research design of the VoxSenes database, containing all EP vowels produced in similar context (reading speech), and also semi-spontaneous speech (image description) collected from a large sample of adults in good health using standardized recording procedures. Details about the study region, participants, participants' tasks, corpus, data acquisition, and segmentation of the data set are presented.

This database has allowed the characterization of vowel production in the normative aging process, being a reference for clinical assessment and intervention of different speech disorders. Furthermore, the age effects at the suprasegmental level in EP spontaneous speech has been explored in an effort to establish the normal patterns of rhythm and intonation in spontaneous speech across age among adult Portuguese native speakers.

2. Method

2.1 Participant selection

A convenience sampling strategy was used to recruit healthy adults over 35 years old. To ensure an equitable distribution of participants, the following age groups were covered: [35-49], [50-64], [65-79] and ≥ 80, with at least ten females and ten males in each group. The main assumptions for this age division rely on the chronological definition of older people, and also on the reported patterns of physiological changes along the aging continuum (He, Goodkind, Kowal, 2016; Mautner, 2011; World Health Organization, 2007). The youngest group [35-49] represents adults prior to the onset of physical aging that involve changes of the vocal fold tissue (Mautner, 2011). The age groups [50-64] and [65-79] were defined based on the World Health Organization definition of older persons (He, Goodkind, Kowal, 2016). The oldest group ≥ 80 represents healthy adults who are at an age where changes to the vocal fold tissues tend to be more prevalent according to literature (Mautner, 2011).

In addition to the age grouping, gender was also considered due to the substantial gender differences in the extent and timing of the aging process (Linville, 2001; Makiyama Hirano, 2017; Mautner, 2011; Pontes, Brasolotto, Behlau, 2005; Schötz, 2006).

This study[1] was carried out in the center of Portugal (namely the regions of Aveiro and Coimbra), due to the easy access to informants. Participants were recruited through personal contacts and through snowball technique in the community, and in Senior Universities, day centers and nursing homes from the central region of Portugal, and also in the University of Aveiro.

Taking into account the well-known Cintra (1971) classification of Portuguese dialects (*Nova proposta de classificação dos dialectos galego-portugueses*), the selected region is part of the central-southern Portuguese dialect (*português centro-meridional*), more specifically the centro-litoral dialect (*estremenho-beirões*), which covers *Estremadura* and part of *Beira Litoral* (see Figure 1) (Blayer, 2002; Segura, 2013). Some authors point that the central region of Portugal (including *Beiras*) is a transitional area between the north (i.e., a conservative area) and south (Blayer, 2002; Boléo, Silva, 1961; Brissos, 2020; Cuesta, Luz, 1980). Additionally, most studies focus on these extremes (Brissos, 2020), as they consider *Beira Litoral* as a dialectal region without distinctive dialect/phonetic features (Boléo, Silva, 1961; Salema, 2007).

[1] This study was approved by the Ethics Committee Centro Hospitalar São João/ Faculty of Medicine, University of Porto, Portugal (approval number N38/18).

Regarding the inclusion criteria, participants were included if they: were native Portuguese speakers (who lived in a non-Portuguese-speaking country for no more than 5 years); lived in Aveiro or Coimbra region; had no history of speech-language impairment; had no severe hearing problems; and no history of neurological disorders or head/ neck cancer. Also, the participant inclusion criteria consisted of non-hospitalized and free of upper respiratory tract infection for 3 weeks prior to the experiment. Participants were excluded if they: were current smokers or had smoked within the previous 5 years; self-reported poor general health; wore hearing aids, had received speech and language therapy, and reported that their voice was different than usual on the day of testing (e.g., having a cold or allergy symptoms).

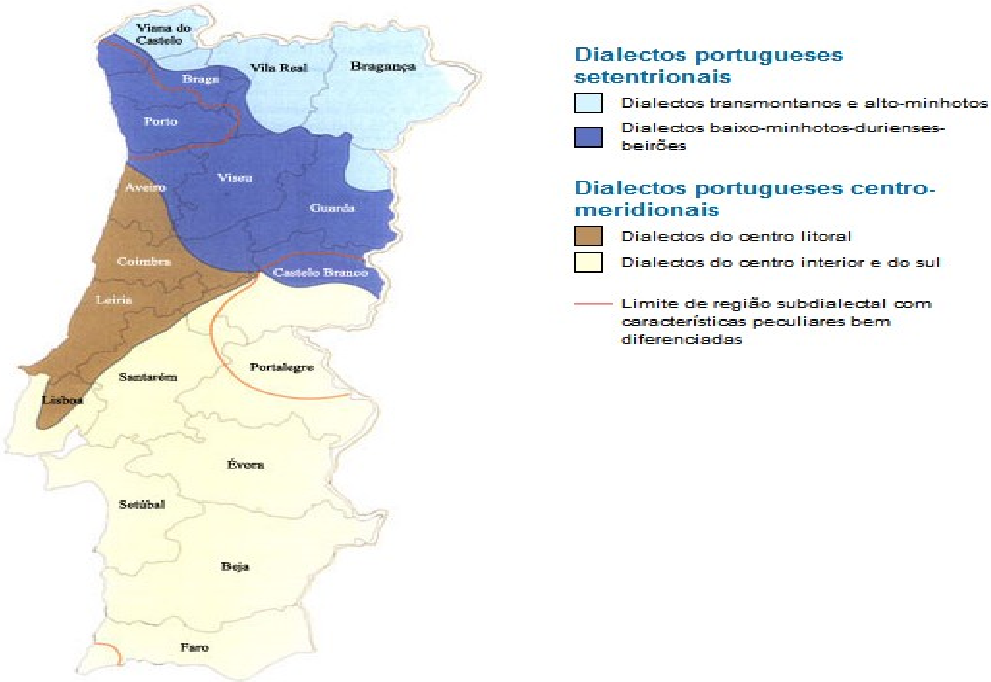

Figure 1: Classification of Galician-Portuguese dialects, by Cintra (1971) (adapted from Segura, Saramago (2011)).

Participants who exhibited any observable sign of speech, voice, or severe hearing problems as assessed by a speech pathologist at the moment of recording and those who were unable to follow directions were excluded.

The exclusion criteria were defined considering factors that affect vocal quality (Guimarães, 2007; Sataloff, Kost, Linville, 2017), as well as the criteria considered in studies of a similar nature (Dehqan, Scherer, Dashti *et* *al.*, 2013; Goy, Fernandes, Pichora-Fuller *et al.*, 2013; Guimarães, Abberton, 2005; Mautner, 2011; Sebastian, Babu, Oommen *et al.*, 2012; Selent, 2014).

A background questionnaire was designed considering the inclusion and exclusion criteria previously defined. A pre-test was carried out with 10 participants (5 females and 5 males aged between 28 and 86). The participants answered the questionnaire and then its duration, ambiguous or difficult questions were analyzed, as well as if the questions allowed to obtain the intended information. Considering the pre-test results, some questions were reformulated in the final version of the questionnaire.

The background questionnaire contained socio-demographic items (gender, academic qualifications, professional status, place of birth and city where he/she resides), medical and voice related history (self-evaluation of health status, reproductive phase, previous diagnoses of clinical conditions that may affect vocal quality, professional use of voice), support device needs (hearing aids, glasses or contact lenses, dental prostheses or orthodontic appliances) and surrounding/ environmental conditions and habits (exposure to adverse conditions, smoking habits, alcohol, water and caffeine consumption).

A total of 144 participants were included in this database. Figure 2 shows the distribution of the participants by age group and gender.

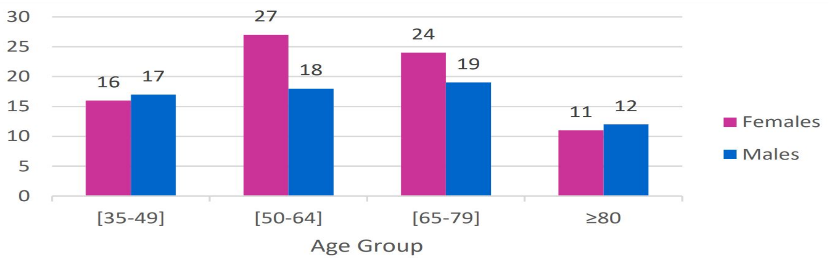

Figure 2: Number of participants recorded by gender and age group.

2.2 Corpus

The corpus consists of two types of data: the first refers to segmental and the second includes suprasegmental data.

2.2.1 Segmental corpus

The speech corpus consisted of 36 words, with the EP oral vowels [i], [e], [ɛ], [a], [o], [ɔ], [u] in stressed position and the vowels [ɨ] and [ɐ] in unstressed position. Each vowel was produced in a disyllabic sequence, mostly C**V**.CV (C-consonant, V-vowel)(e.g. "pato", *duck*), where C was a voiced/ voiceless stop consonant ([p], [t], [k], [b], [d], [g]) or a voiced/ voiceless fricative consonant ([f], [s], [ʃ], [v], [z], [ʒ]). To facilitate vowel segmentation, words with voiceless consonants are preferred (Escudero, Boersma, Rauber *et al.*, 2009). However, due to the difficulty to find real words, it was also necessary to include words with voiced consonants.

Additionally, the speech corpus also contained 20 words, with a similar structure to the one described above, with the EP nasal vowels [ɐ̃], [ẽ], [ĩ], [õ] and [ũ] in stressed position. The list of 56 words used in this study is presented in Table 1, and contains four words per vowel.

The speech stimuli were carefully chosen to allow easy and accurate formant measures since the vowel context is restricted to stop and fricative consonants. The corpus was also designed to collect data over the lifespan. Thus, the words were therefore chosen to be familiar to all ages, and also, easily represented by images (to avoid the interference of reading abilities in the production of words) (Eichhorn, Kent, Austin *et al.*, 2018).

A pilot naming study was conducted for the selection of these images. 101 pictures were selected from color pictograms of ARASAC (Palao, 2017) and presented to a group of 10 participants (5 males and 5 females), ranging from ages 28 to 86. The results indicated that adult participants were able to properly name most of the pictures (percentage of accuracy equal or higher than 70%, except for 11 images) (see Table 1). However, these stimuli remained in the study due to the difficulty in finding alternative words that met the previously defined criteria. The stimuli were embedded in a carrier sentence "Diga ... por favor" ("Say ... please").

Vowels		**Words**			
Stressed oral vowels	**[i]**	[ˈfitɐ] *(ribbon)*	[ˈbiku] *(beak)*	[ˈfigu] *(fig)*	[ˈpizɐ]* *(pizza)*
	[e]	[ˈseʃtɐ] *(basket)*	[ˈdedu] *(finger)*	[ˈpezu] *(weight)*	[ˈzebɾɐ] *(zebra)*
	[ɛ]	[ˈsɛtɨ] *(seven)*	[ˈtɛtu] *(ceiling)*	[ˈsɛtɐ] *(arrow)*	[ˈʃɛkɨ] *(check)*
	[a]	[ˈʃavɨ] *(key)*	[ˈfakɐ] *(knife)*	[ˈgatu] *(cat)*	[ˈpatu] *(duck)*
	[ɔ]	[ˈkɔpu] *(glass)*	[ˈbɔtɐ] *(boot)*	[ˈfɔkɐ] *(seal)*	[ˈtɔʃɐ]* *(torch)*
	[o]	[ˈbokɐ] *(mouth)*	[ˈkoku] *(coconut)*	[ˈposu] (well)	[ˈgotɐʃ] *(drops)*
	[u]	[ˈʃuvɐ] *(rain)*	[ˈʃupɐ]* *(lollipop)*	[ˈkubu]* *(cube)*	[ˈʒubɐ]* *(mane)*
Unstressed oral vowels	**[ɨ]**	[bɨˈbeɾ] *(to drink)*	[dɨˈdaɫ] *(thimble)*	[pɨˈdaɫ] *(pedal)*	[pɨʃˈkaɾ]* *(to fish)*
	[ɐ]	[kɐˈfɛ] *(coffee)*	[ʃɐˈpɛw] *(hat)*	[pɐˈtĩʃ] *(rollerblades)*	[pɐˈpɛɫ] *(paper)*
Nasal vowels	**[ɐ̃]**	[ˈbɐ̃ku] *(bench)*	[ˈsɐ̃gɨ] *(blood)*	[ˈkɐ̃pu]* *(field)*	[ˈpɐ̃dɐ]* *(panda)*
	[ẽ]	[ˈpẽtɨ] *(comb)*	[ˈpẽsu] *(bandage)*	[ˈtẽdɐ] *(tent)*	[ˈdẽtɨ] *(tooth)*
	[ĩ]	[ˈsĩku] *(five)*	[ˈpĩsɐ] *(tweezers)*	[ˈtĩtɐ] *(ink)*	[ˈsĩtu] *(belt)*
	[õ]	[ˈpõtɨ] *(bridge)*	[ˈpõbɐ] *(dove)*	[ˈbõbɐʃ] *(petrol pumps)*	[ˈkõʃɐ] *(shell)*
	[ũ]	[ˈfũdu] *(bottom)*	[ˈʃũbu]* *(lead)*	[ˈʒũtu]* *(together)*	[ˈfũgu]* *(fungus)*

*Table 1: List of words per vowel (International Phonetic Alphabet). The symbol * indicates that the pictogram of this word presented a naming percentage of accuracy lower than 70%.*

2.2.2 Suprasegmental corpus

In order to analyze spontaneous speech, semi-spontaneous speech samples were collected from the participants using a standard Boston Diagnostic Aphasia Examination (Goodglass, Kaplan, 1983) picture description task, with the standardized picture "Cookie Theft" stimulus shown in Figure 3. The participants were instructed to describe the picture (Morgan, Rastatter, 1986; Pakhomov, Kaiser, Boley *et al.*, 2011).

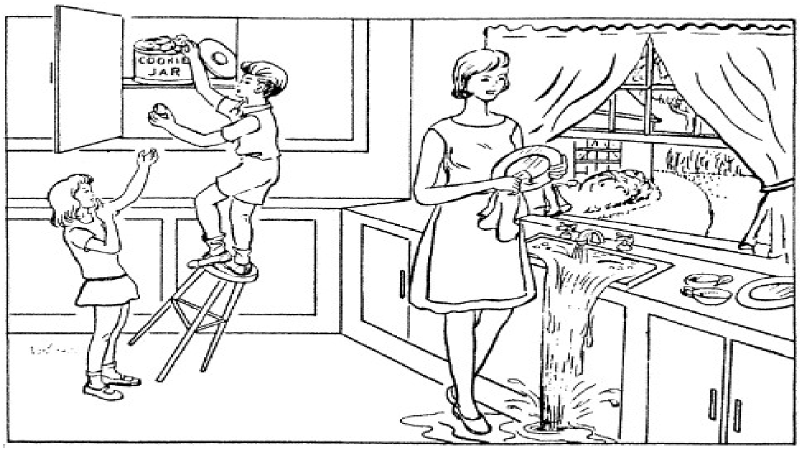

Figure 3: The "Cookie Theft" picture from the Boston Diagnostic Aphasia Examination, in Goodglass, Kaplan (1983).

2.3 Data acquisition

The data acquisition was conducted between February 28, 2018, and January 30, 2019. The same researcher was present in all data acquisition sessions. The participants filled in the background questionnaire, which took approximately 10 minutes to complete. In exceptional cases, due to low literacy or visual difficulties, the questions were presented orally by the researcher.

Regarding the corpus acquisition, all recordings took place in quiet rooms using an AKG C535 EB cardioid condenser microphone connected to a USB external 16-bit sound system (PreSonus AudioBox™ USB), with a sampling rate of 44100 Hz. The participants were seated at a table and the microphone was adjusted to each participant and positioned at an approximately 15-20 cm distance from the mouth.

The sentences were randomized and presented individually on the computer screen using the software system SpeechRecorder (Draxler, Jänsch, 2017, 2004), where picture and orthographic words could be viewed simultaneously (Figure 4).

Figure 4: Visualization of target word picture (pictogram of ARASAC (Palao, 2017)) and the carrier sentence in the SpeechRecorder program (Draxler, Jansch, 2017).

Three practice words in the same carrier sentence were used at the beginning to adjust recording levels. Thus, participants were asked to read the sentences at comfortable pitch and loudness level, after familiarizing themselves with the structure of the sentences. During recording, stimuli that were mispronounced or occurred with intense background noise were repeated. Additionally, participants could take a break at any time they wished, and each speaker attended a single recording session.

Each carrier sentence was repeated three times. Thus, each participant produced 12 repetitions of each vowel, in a total of 168 productions by speaker, and needed approximately 20 minutes to complete this task.

The participants were also instructed to describe the "Cookie Theft" picture (Goodglass, Kaplan, 1983) at comfortable pitch and loudness level, after familiarizing themselves with the image, in order to obtain induced spontaneous speech (Morgan, Rastatter, 1986; Pakhomov, Kaiser, Boley *et al.*, 2011). The image was also presented on the computer screen with software system SpeechRecorder (Draxler, Jänsch, 2017, 2004). The instruction given to participants was as follows: "Tell me everything you see in this picture.". This task took approximately 30 seconds to complete.

2.4 Segmentation

This section includes information about the segmentation of the segmental and suprasegmental data. The basic steps before segmentation were the following: speech recordings were uploaded to a computer and saved into separate files (by word and image description) by the software system SpeechRecorder (Draxler, Jänsch, 2017, 2004). The files of each participant were saved in a folder identified with its numerical code.

For a long time, the processing of data from sizeable speech corpora was limited by technical shortcomings, which made the data segmentation difficult and time-consuming, but automated systems nowadays allow to perform these tasks easier and in a less amount of time (Elvira-García, 2014; Van der Harst, Van de Velde, 2014; Watson, Evans, 2016). Despite the availability and use of programmable tools, it was only possible to annotate part of the 144 valid participants in the database, as manually correction of the segmentation is still a time-consuming task (Watson, Evans, 2016).

The selection of the participants for manual correction of the segmentation was based on the sound quality of the recordings and tried to ensure an equitable distribution of participants by the age groups previously defined (i.e., [35-49], [50-64], [65-79], and ≥ 80).

2.4.1 Segmental annotation

The recorded data was first automatically segmented at word and phoneme level using WebMAUS General for Portuguese language (PT) (Kisler, Reichel, Schiel, 2017; Schiel, 1999) and then imported into Praat speech analysis software (Version 6.1.08) (Boersma, Weenink, 2012), so that four trained analyzers could manually check and correct, when necessary, the accuracy of the vowel boundaries.

Thus, the segmentation and labeling of each carrier word, vowel target and flanking consonants were manually verified, over the digitized sound wave (see Figure 5). The start and end points of the vowel were determined by finding the first and last periods that had considerable amplitude and whose shape resembled that of more central periods, with both points of the selection chosen to be at a positive zero crossing of the waveform.

The analyzers revised 18 984 recordings of 113 speakers, as each participant produced 12 repetitions of each vowel, in a total of 168 productions by speaker (113 participants x 56 words x 3 repetitions = 18 984 recordings). Note that, the 168 productions per speaker are the result of 56 words repeated 3 times.

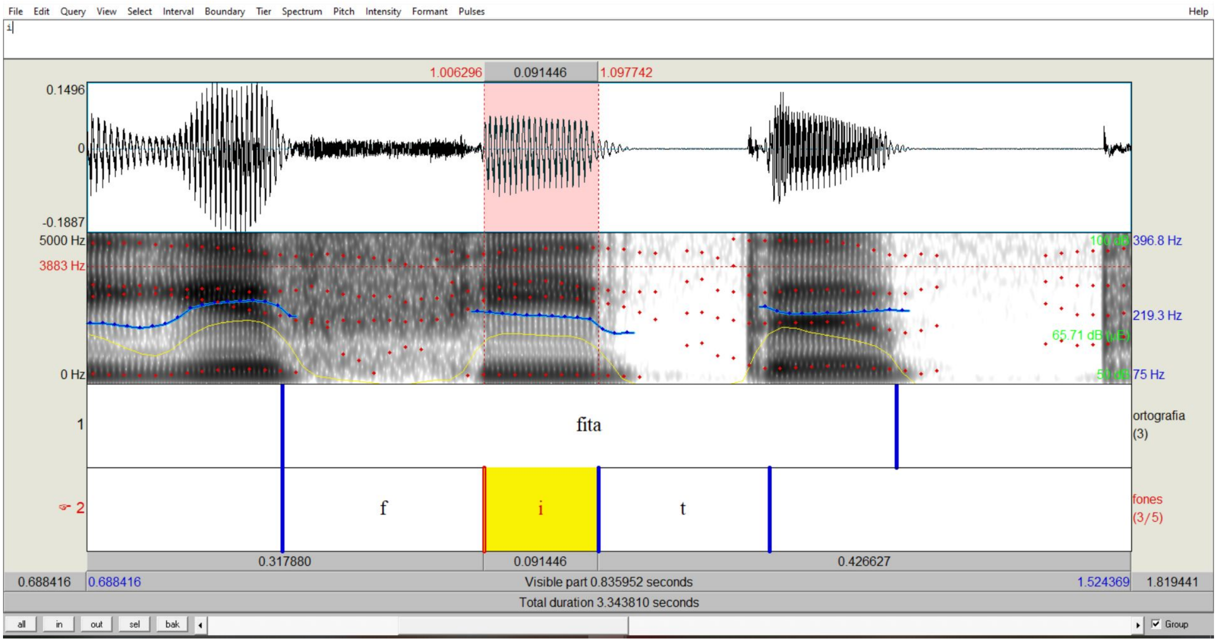

Figure 5: Annotation of vowel target, flanking consonants and carrier word in Praat software. An example of the word "fita" - ['fitɐ].

The work carried out so far has focused on the acoustic analysis of oral vowels, with the main goal of extracting acoustic parameters, such as fundamental frequency (F0) and vowel formants (e.g., F1, F2 and F3), according to age and gender. The analysis of nasal vowels is a work in progress, so annotation/segmentation of these words was not described here, since these vowels have not been yet analyzed.

For oral vowels, a total of 736 recordings were discarded (approximately 6% of trials) due to problems with the recordings (e.g., clipping, noise, misread, hoarseness or vocal fry) or vowel reduction (vowel [ɨ] was the most deleted vowel, mostly in the context of "pescar" ([pɨʃ"kaɾ] - to fish)). In the present study the vowel [ɨ] deletion was observed in 26.7% (359 deletions) of the vowel occurrences. Previous studies of EP spontaneous speech have reported higher occurrences of [ɨ] deletion, around 40% to 70% (Rodrigues, 2016). Studies on other languages have also indicated higher levels of vowel deletion in spontaneous speech comparing with reading context (Adda-Decker, Boula De Mareüil, Lamel, 1999; Munson, 2007).

2.4.1.1 Reliability in oral vowel segmentation

A set of acoustic measurements were extracted from the recording data, namely duration, F0, F1, F2 and F3 of the annotated oral vowels, using Praat scripts adapted from Escudero, Boersma, Rauber *et al.* (2009).

To determine inter- and intra-rater reliability of the measures, 36 TextGrids of each analyzer (1 TextGrid randomly selected from each word) were relabelled by all analyzers. Thus, 144 (1.2%) of a total of 12 204 TextGrids (113 participants * 36 stimulus * 3 repetitions) were manually relabelled for reliability by the four judges. The scripts to obtain vowel duration and formant frequencies were then readministered.

Inter and intra-rater reliability was assessed using the intraclass correlation coefficient (ICC) and the two-way mixed model (the raters were considered fixed) with an absolute agreement definition.

Reliability among the raters was considered excellent, with ICC values >0.952 for all vowels/ acoustic parameters (duration, F0, F1, F2, F3), except F1 of [1] where ICC was 0.846, but still considered good reliability (Shrout, Fleiss, 1979).

To assess intra-rater reliability, a random sample of 36 textgrids (one of each stimuli) was manually rechecked by the same rater. Again, reliability was excellent with ICC values >0.909 for all vowels/ acoustic parameters (Shrout, Fleiss, 1979).

2.4.2 Suprasegmental annotation

Concerning semi-spontaneous speech, the speech and pauses were labeled, and in the speech intervals, the vowel onsets were also detected, through automatic Praat scripts.

The Praat Script Syllable Nuclei v2 (de Jong, Wempe, 2009)[2] was used to automatically detect silent pauses of over length 250 ms (Cannizzaro, Harel, Reilly *et al.*, 2004) and to create textgrid files. The automated alignments of silent pauses were manually checked by two trained analyzers, who verified the accuracy of pauses and speech intervals, and also labelled intervals with speaker or environmental noise. The intervals were labeled as: pause (breathing sound was considered as silent pause), speech, verbal non lexical (i.e., filled

[2] The Praat Script Syllable Nuclei v2 was modified by Hugo Quené, Ingrid Persoon, Nivja de Jong and is available in: https://sites.google.com/site/speechrate/Home/praat-script-syllable-nuclei-v2.

pauses), noise (i.e., noise that occurs during the speaker's pauses), vocal non lexical (i.e., laughter, coughing or other human noises), and speech with noise (i.e., speech intervals with environmental noise that could affect the acoustic measurements) (Pellegrino, 2019; Schuller, Steidl, Batliner *et al.*, 2013).

Vocal non lexical phenomena were considered as pause time, while verbal non lexical phenomena were not included in the present analysis (Pellegrino, 2019; Tuomainen, Hazan, Taschenberger, 2019). Speech intervals with noise were not counted for further analysis, and also the beginning and ending of all recordings were not pondered in the analysis due to sentence initial and final acoustic variability (a total of 7% of the speech intervals were excluded).

Regarding the syllables spoken, an adapted Praat script of the BeatExtractor (Barbosa, 2006, 2010) was used to detect vowel onset using a beat wave (a normalized and band-specific amplitude). The cut-off frequency was defined automatically. The thresholds were 0.1 and 0.06, the filter was defined as Butterworth and the technique was Amplitude. The total number of syllables were automatically obtained through the sum of all vowel onset detected within all valid speech intervals per speaker. A random check was done to verify the vowel onsets and confirm the script performance.

Based in the suprasegmental annotation of speech, pauses and syllables, several rhythm measures were computed, such as speech duration, pause duration, percent pause time, speech pause ratio, number of pauses, speech rate and articulatory rate.

3. First Results

The collected data were used, for example, on speech acoustic studies over the lifespan, and allowed to examine the age-related changes on speech production at segmental (Albuquerque, Oliveira, Teixeira *et al.*, 2023, 2019; Albuquerque, Teixeira, Oliveira *et al.*, 2022) and suprasegmental (Albuquerque, Valente, Teixeira, Figueiredo, et al., 2021; Albuquerque, Valente, Teixeira, Oliveira *et al.*, 2021a, 2021b) level, especially for EP. Globally, the first results show that, acoustically, the aging speech is characterized by: 1) longer vowels (in both genders); 2) a tendency for F0 to decrease in women and slightly increase in men; 3) lower vowel formant frequencies in females, especially F1 and F2; 4) a significant reduction of the vowel acoustic space in men; 5) vowels with higher trajectory slope of F1 (in both genders) (i.e., the dynamic features of vowels also seem to be affected by age); 6) shorter descriptions with higher pause time for males; 7) faster speech and articulation rate for females (in semi-spontaneous speech); and 8) a decrease of the voice quality for females (i.e., lower Harmonic to Noise Ratio (HNR) in semi-spontaneous speech). These results corroborated that acoustic characteristics of speech change with age and present different patterns between genders, and also suggest that speakers might develop specific articulatory adjustments during speech with aging. Beyond the positional vowel changes, the age-related changes observed on formant dynamics (i.e., in F1C1, which corresponds to the second discrete cosine transform (DCT) coefficient of F1 and can be interpreted as the magnitude and direction of change from the mean (i.e., the trajectory slope) (C1) (Albuquerque, Teixeira, Oliveira *et al.*, 2022)) also confirm this statement.

4. Conclusion

This database has contributed to knowledge on aging speech, and it provides new information on aging speech for a language other than English. Thus, this database is the starting point for a broader lifespan study, involving a large number of EP speakers, from infancy to old age, producing different types of speech corpora.

Despite the studies of the age-related effect on static and dynamic characteristics of vowel formants have added important new knowledge, this topic deserves continuation in several lines, mainly: 1) investigate the effects of age (by gender) on dynamic properties of vowel formant frequencies (F1, F2), applying generalized additive mixed models (GAMMs) to compare curvilinearly varying formant measurements along vowel segments; 2) identify which are the dynamic features with more impact on classification performance; 3) consider other features besides formants, such as cepstral coefficients; 4) extend the set of machine learning algorithms, including, as soon as dataset allows, deep learning methods; and 5) investigate the effects of age (by gender) on properties of nasal vowels.

In addition to the studies of the effects of age on segmental and suprasegmental speech characteristics, the described database can bear for other acoustic analysis of a different nature.

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