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Software-assisted identification of non-native pitch elements for Russian-speaking learners of Spanish

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ABSTRACT: In this paper we present the results of an automatic comparative-contrastive analysis of functional elements of intonational contour (anacrusis, first peak, body, nucleus and final inflection) produced by non-native speakers of Spanish, whose first language is Russian. This analysis was carried out with the Plugin for phonetic-phonological analysis in Spanish (PAFe), a software tool for an instant comparative analysis of a non-native speakers' pronunciation which takes audio recordings as input and implements multiple intonation comparison algorithms between native and non-native speakers of Spanish to calculate the percentage of similarity in intonation production. We used the intersyllabic analysis function of PAFe in order to identify which functional pitch elements of Russian speaking learners of Spanish –male and female– present more tonal deviations. Our results show that most tonal differences occurred in the body of the f_0 contour for female speakers whereas for male speakers the greatest tonal contrast was in the first peak. The obtained data indicate that these pitch elements are potentially challenging for Russian speaking learners of Spanish in their pursuit of acquiring phonetic-phonological competence. In addition, this study allowed us to identify which parameters of PAFe analysis per syllables require further refinement, such as processing of limited intonational spectrum values.

Keywords: prosody, pitch, software, Spanish L2, Russian speakers

RESUMEN: *Identificación de elementos del contorno entonativo en habla no nativa asistida por software para estudiantes rusófonos de español.* Presentamos en este artículo los resultados del análisis automático comparativo-contrastivo de elementos funcionales del contorno entonativo (anacrusis, primer pico, cuerpo, núcleo e inflexión final) producidos por hablantes no nativos de español, cuya primera lengua es ruso. Dicho análisis fue realizado con el Plugin para el análisis fonético-fonológico en español (PAFe), una herramienta de software para el análisis comparativo instantáneo de la pronunciación de hablantes no nativos que toma grabaciones de audio como entrada e implementa múltiples algoritmos de comparación de entonación entre hablantes nativos y no nativos de español para calcular el porcentaje de similitud en la producción de su entonación. Empleamos el algoritmo de análisis intersilábico de PAFe para identificar qué elementos entonativos de los aprendientes rusos del español –masculinos y femeninos– presentan más desviaciones tonales. Nuestros resultados estadísticamente probados muestran que la mayoría de diferencias tonales, en el caso de las hablantes femeninas, ocurre en el cuerpo del contorno entonativo y, para los hablantes masculinos, un mayor contraste tonal presenta el primer pico. Los datos obtenidos indican que estos son los elementos potencialmente desafiantes para los estudiantes rusos a la hora de adquirir la competencia fonético-fonológica en español. Además, el presente estudio nos permitió detectar ciertos parámetros del análisis intersilábico de PAFe para su perfeccionamiento, como procesamiento de valores limitados del espectro entonativo.

Palabras clave: prosodia, tono, software, español como L2, aprendientes rusófonos

1. INTRODUCTION

Improvement of the phonetic-phonological competence of second language learners constitutes a multifaceted challenge for educators and learners alike. As posited by Patil and Rao (2012), the fluency of second language speakers is commonly evaluated by comparing their articulation and prosody with those of native speakers. To facilitate the acquisition of acoustic and prosodic features and to identify potential errors in the pronunciation of second language learners, various tools have been developed. Noteworthy examples include the tool introduced by Elvira-García, Farrús, and Garrido-Almiñana (2023), which enables the automatic computation of speech rate; the tools by Patil and Rao (2012) and Oplustil and Toledo (2019), designed for displaying phonetic-phonological similarity; and the tool by Strik, Truong, De Wet, and Cucchiarini (2009), tailored for error detection in pronunciation. Despite these valuable contributions, there is currently an absence of a unified tool that encompasses the dual functionality of identifying tonal deviations and providing insights into differences and similarities in L2 learners' prosody. Moreover, these existing tools fall short in documenting and tracking the progress of second language learners' phonetic-phonological competence acquisition.

In light of this, Couto-Fernández, Sarymsakova, Condori-Fernández, and Martín-Rodilla (2022) have developed a software tool titled PAFe (in Spanish: *Plugin para el análisis fonético-fonológico en español*; in English: *Plugin for phonetic-phonological analysis in Spanish*) in order to amend phonetic-phonological competence of second language learners and streamline the efforts of L2 educators. This tool is versatile, serving both didactic and autodidactic purposes. As the latest studies by Couto-Fernández (2021), Sarymsakova (2022) and Couto-Fernández et al. (2022) show, the current version of PAFe provides comparative-contrastive melodic analysis in terms of suprasegmental speech characteristics for native and non-native speakers, their intonational features in concrete. The tool calculates the similarity of intonation production and detects tonal deviations between native and non-native speakers of Spanish. PAFe provides feedback to learners via both percentage similarity and graphs of pitch contrast, and stores data recorded by reference speakers and learners.

The empirical approach for evaluating the usability of PAFe was employed by Couto-Fernández (2021) in order to test this tool targeting both Spanish L2 students and educators. The assessment included various metrics, namely efficiency (percentage of task completion relative to allocated time), effectiveness (degree of task completion during tool testing), user satisfaction, and usefulness (alignment with user expectations). The outcomes of this evaluation, as reported in the cited work, were derived from survey responses, revealing a notable level of efficiency, effectiveness, and user satisfaction. Notwithstanding, the usefulness metrics underscored the imperative for enhancing the tool's usability, emphasizing the need for further testing across diverse domains, extending beyond didactics.

The later studies by Couto-Fernández et al. (2022) and Sarymsakova (2022) have found that, among other results, PAFe provides the most accurate intonational production feedback through its approach of intersyllabic analysis. Based on the outcomes and with the objective of extending contributions to the field of contrastive-comparative prosody studies between Russian and Spanish through the PAFe tool, we address the problem of phonetic-phonological competence acquisition among Russian speaking learners of Spanish We formulate our hypothesis in the present investigation as follows: The application of the PAFe tool automates the discernment of pitch functional elements in both male and female Russian speaking learners of Spanish and serves to furnish valuable insights into potential challenges encountered by these learners in their pursuit of acquiring phonetic-phonological competence of Spanish.

To test this hypothesis, this study aims to achieve the following objectives:

a. By comparing the empirical data obtained via intersyllabic intonation analysis of native and Russian speaking learners of Spanish performed by PAFe tool, to define the f_0 functional elements where the most pitch deviations occurred.
b. To identify which parameters of intersyllabic analysis offered by PAFe require further refinement and implementation in future versions.

The subsequent sections of this manuscript are organized as follows. Section 2 provides a brief overview of the intonational systems of Russian and Spanish, alongside an operation of the PAFe tool and its application in second language didactic studies. Section 3 presents the terminology used throughout our study, poses the research questions, and describes the methodology employed to address the given questions. Section 4 presents the experiment description and the main findings collected within the PAFe tool intersyllabic analysis. Finally, we conclude in Section 5.

2. BACKGROUND

2.1. Russian and Spanish prosodic systems

In the context of prior contrastive-comparative investigations into the phonetic-phonological systems of Russian or Spanish, noteworthy contributions have been made by García-Riverón (1980, 1987), Mazina (1984), Dmítrieva (2017), and Sarymsakova (2022). The elucidations provided by these authors distinct dissimilarities in the functioning of melodic patterns within the respective linguistic frameworks of Russian or Spanish. As explained in subsection 4.1, we have selected four speech acts representing pragmatic categories identified as challenging by Sarymsakova (2022). These acts –namely, threat, politeness, irony, and request– have been deemed

challenging due to the pivotal role of pitch in activating implicit meaning. Accordingly, we focus on delineating distinctions in the melodic patterns characterizing these utterances within contributions made by García Riverón, Mazina, Dmitrieva, and Sarymsakova, dedicated to the undertaking of contrastive-comparative analyses within the domain of phonetic-phonological systems in Russian and Spanish.

Henceforth, these authors concur in the observed distinctions in melodic patterns within the Russian and Spanish intonational systems. Regarding the melodic characteristics of speech acts such as threat and request, the Russian intonational system manifests an ascending pitch movement at the centre of its intonational construction. As defined by Bryzgunova (1977), the centre of its intonational construction signifies a pitch functional element denoting semantic-pragmatic alterations within an utterance, wherein a declarative statement transitions into an interrogative through the modulation of the centre of intonational construction. Nevertheless, the authors mentioned above underline the incompleteness in the characterization of melodic patterns pertaining to irony and politeness within the Russian intonational system.

Moreover, Hidalgo-Navarro (2019) and Cantero-Serena and Mateo-Ruiz (2013) emphasize the employment of circumflex (ascending-descending) tonal movements in the tonemes associated with politeness and irony (which are not entirely delineated within the Spanish system). Additionally, they identify the utilization of plain tonemes in threat expressions and ascending tonemes in politeness utterances.

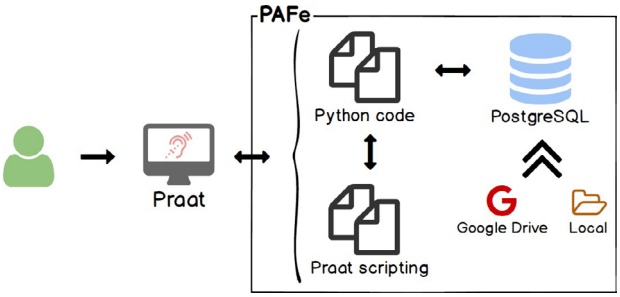
In summary, the aforementioned authors delineate fundamental challenges encountered by Russian speakers in the acquisition of Spanish melodic patterns. Certain pitch features associated with speech acts, such as irony and politeness, lack a clear definition within the Russian intonational system. While the Russian intonational system exhibits modulation of the pitch functional element known as the center of intonational construction, Spanish pitch features are distinctly specified for particular speech acts.

Drawing upon the abovementioned dissimilarities of melodic patterns of Russian or Spanish and possible challenge for phonetic-phonological competence acquisition among Russian speaking learners of Spanish, we aim to contribute to the field of comparative-contrastive studies of intonational systems of Russian or Spanish by employing the PAFe tool, which is expounded upon below.

2.2. PAFe operation and usage

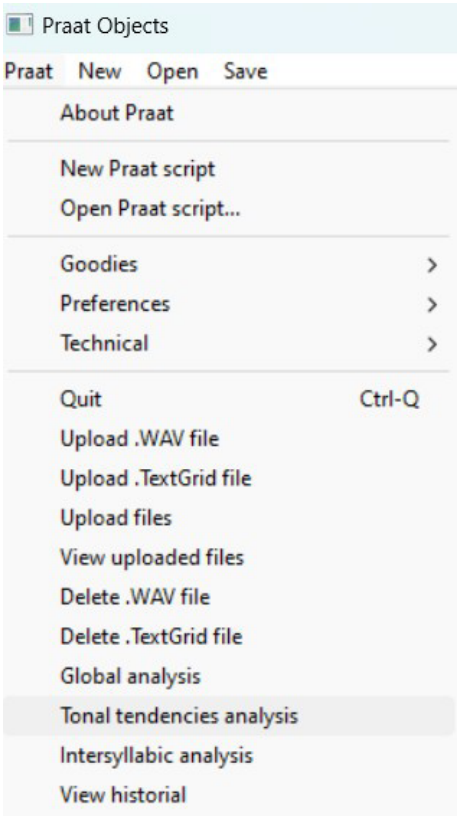
The PAFe tool has been created as an extension to an existing desktop application for acoustic speech analysis, Praat, developed by Boersma and Weenink (2019). PAFe consists of a series of scripts in the Python programming language and implements three intonation comparison algorithms of an ELE learner (in Spanish: *Español como Lengua Extranjera*; in English: *Spanish as Foreign Language*) and a native Spanish speaker. This software tool is based on the Praat architecture (Boersma & Weenink, 2019), to which a new module (PAFe, as an extension of Praat) is coupled (see Figure 1) made up of Praat scripts, Python code and a PostgreSQL database. Praat, through its scripting, allows command line calls to other systems, as described by Pop and Altar (2014), making it possible to extend the application through the use of other languages and technologies external to Praat.

Figure 1: PAFe global architecture. Image credit: Couto-Fernández et al. (2022)



This new module (PAFe) communicates with the original system by means of new Praat scripts associated with the application's menu items (see Figure 2), from which these files are executed. Sometimes, the new module dispenses with calls to Praat and generates information windows directly from Python code files.

Figure 2: User Interface visualising the new functionalities added to Praat.



Natural language processing and audio processing techniques are used in the PAFe tool, taking as the main source the human voice recordings of native speakers and students. This tool allows three different types of analysis: global, tonal tendency, and intersyllabic, as Couto-Fernández et al. (2022) describe. In addition, PAFe provides its users with (a) a database containing their user profile, pronunciation exercises and WAV. audios, and (b) a graphical interface including reports on their progress, such as improvement of their pronunciation in Praat.

Concerning its application, the PAFe tool has predominantly undergone testing within the domain of second language didactics. As previously anticipated in Section 1, subsequent evaluations of the PAFe tool underscore its merits as a computer-assisted instrument for enhancing phonetic-phonological competence among both second language educators and learners (Couto-Fernández, 2021; Sarymsakova, 2022). A notable outcome from prior PAFe evaluations, in addition to presenting feedback similarity percentages in intonational production, is the participants' recognition of its capacity for graphical visualization of native and non-native melodic curves that indicate each syllable tonal movement (Couto-Fernández, 2021). This feature was deemed a valuable resource for aiding in the improvement and acquisition of melodic patterns in the target language.

Following a brief overview of relevant background related to our study and connected to comparative-contrastive studies on Russian and Spanish intonation, as well as aligned with the PAFe operation and testing, the ensuing section will focus on delineating the methodologies and techniques employed in the processing and interpretation of our data.

3. METHODOLOGY

Due to its widespread use in the design of experiments and empirical studies in information systems and software engineering (Martin-Rodilla, Panach, Gonzalez-Perez, & Pastor, 2018; Panach, España, Dieste, Pastor, & Juristo, 2015), we chose Wohlin's framework (Wohlin et al., 2012) for the design of an experiment to test our hypothesis as formulated in the Section 1. Specifically, Wohlin's framework includes diverse phases inherent to experimental design, such as scoping, hypothesis formulation, experimental design, operation, analysis and interpretation, hypothesis testing, and conclusion. This framework, in addition to being used for software validation and methodological proposals in various domains, has been used for the initial validation of tools and methodologies in areas such as Digital Humanities and/or Natural Language Processing as in Martin-Rodilla and Gonzalez-Perez (2023). Therefore, we consider it appropriate as a reference for our experimentation.

Considering the Wohlin's framework, we chose to test our hypothesis as formulated in Section 1 following the summary of our scoping, i.e. we analyse the pitch deviation of Russian speaking learners' of Spanish for the purpose of identification of potential challenges in phonetic-phonological competence acquisition with respect to the background on previous comparative-contrastive studies from the point of view of PAFe users in the context of the linguistic studies. This study also aims to identify areas for improvement in the tool's operability.

In order to provide accurate contrastive-comparative intonation analysis data of native and non-native speakers through PAFe tool, we base our study on the Melodic Speech Analysis methodology of Cantero-Serena (2002, 2019) and employ the following essential principles from speech processing:

a. We annotate the syllables of each speech act in a Praat textgrid (Boersma & Weenink, 2019); we identify pitch values of all vowels in the syllables (voiced or voiced consonants are also measured), using the Praat Script developed by Mateo (2010a, 2010b), which extracts the absolute values in Hz, relativises them and draws the graph of the standardised melody;
b. We select relevant frequency values between tonal segments from irrelevant values; according to Cantero-Serena (2002, 2019), Font-Rotchés and Cantero-Serena (2008, 2009), less than 10 percent difference between segments is considered imperceptible.

As for the classification of the functional elements of pitch contour, we refer to Cantero-Serena (2002, 2019), Font-Rotchés and Cantero-Serena (2008, 2009) studies. We assume body to be the part of the melody that goes from the first peak (the first tonic vowel) to the last tonic vowel of the contour, which we call the core (or toneme). In our study we also distinguish the final inflection, which refers to the syllables after the last tonic syllable or core. Finally, the anacrusis, represents the unstressed syllables preceding the first peak.

In order to reach the objectives of the study as formulated in Section 1 and apply the aforementioned methods and approaches, the following research questions were specified:

1. Which pitch functional elements, identified by the PAFe tool, pose particular challenges for male and female Russian speaking learners of Spanish as a second language (L2) striving to enhance their phonetic-phonological competence?
2. Does the tool provide sufficient data for intonational analysis of native and Russian speaking learners' of Spanish melodic curve?

4. EXPERIMENTAL DESIGN AND DATA PROCESSING RESULTS

4.1. Data collection

In accordance to the Wohlin's stage of experimental design, the preliminary data on assessment of pitch functional elements via PAFe feedback has been obtained through multiple recording sessions with Russian speaking learners of Spanish. In order to carry out these record-

ings, we have chosen four indirect speech acts that have been identified as "challenging" by Sarymsakova (2022) due to the main role of intonation in activation of implicit meaning. These speech acts (SA) are presented in Table 1 and Table 2 include the following lexical-syntactic structures and pragmatic functions (PF):

- SA 1: "Y, claro, luego usted será responsable"; PF: indirect threat.[1]
- SA 2: "No tengo ninguna duda de que sois buenas guías, eso ya lo sé"; PF: negative politeness.
- SA 3: "Con eso entiendo que es usted muy listo para dar las explicaciones"; PF: irony.
- SA 4: "Pero, eso no puede volver a repetirse"; PF: indirect request.

In English: SA 1: "And, of course, then you will be responsible"; SA 2: "I have no doubt that you are good guides, I know that"; SA 3: "Saying that I understand that you are very smart to give explanations"; SA 4: "But, that can't happen again".

The recording procedure design consists of the following steps:

a. Preparation: the students are required to complete certain exercises in order to train and test their phonetical-phonological competence in Spanish as L2.[2]
b. Beginning: listening to the audios we have previously recorded with two native speakers of Spanish (young female and male primary and secondary school teachers from urban area of Galicia). This stage is repeated at least 5-10 times or until the students memorise and freely reproduce the utterance and intonation of the reference audio. It is worth mentioning that we have not provided the written text of the utterances in order for the participants to show their level of listening comprehension and, in this way, confirm their command of intermediate-advanced level of spoken Spanish.
c. Recording of the utterances: the obtained result represents four audios of four reproduced utterances (maximum duration 2-4 seconds) for each of our students.
d. Data collection: in total, 5 female learners (24-34 years old) and 4 male learners (18-35 years old) whose L1 is also Russian have participated in this empirical study. All our students are B1-B2 level and do not currently reside in a Spanish-speaking country. We have recorded 36 audios, thus, throughout this step, we have produced 36 files in the .TextGrid format containing the syllable-by-syllable of each of the utterances respectively. For the TextGrid annotations, we used the Schiel (1999); Kisler, Reichel, and Schiel (2017) software tools to automatize TextGrid generation. In order to perform the intersyllabic type of intonational analysis offered by PAFe, we stored both the audios and the .TextGrids of our learners and native speakers in PAFe memory using the "Upload .WAV file" and "Upload.TEXTGRID file" options.

4.2. Data analysis outcomes

Hereafter, we present the results obtained after synthesis of collected data. Table 1 shows the outcomes we got after the recordings with our five female non-native speakers (Sp 1F, 2F, 3F, 4F, 5F) and intersyllabic analysis performed by PAFe tool. Table 1 illustrates five Russian female learners took part in the aforementioned recordings, which were used for PAFe intersyllabic tests; the task was to reproduce four indirect speech acts pronounced by a native speaker of Spanish as accurately as possible, conveying the pragmatic feature indicated before (first paragraph of the present section). By comparing the results obtained from PAFe's automatic calculations when running the intersyllabic analysis algorithm, we observe that the results range for these speakers is from 80.93% to 93.41% of intonation accuracy, which we consider closely similar to the intonation of the native speaker.

Table 1: Results of the intersyllabic analysis by PAFe tool for female Russian speaking learners. Intonation similarity percentage. SA = speech act. Sp = speaker. F = female.

SA	Sp 1F	Sp 2F	Sp 3F	Sp 4F	Sp 5F
1	88.23	88.69	86.38	88.69	88.23
2	86.05	87.05	90.60	91.10	91.65
3	88.55	88.77	87.86	93.41	89.68
4	80.93	90.71	90.57	88.71	89.79

Table 2: Results of the intersyllabic analysis by PAFe tool for male Russian speaking learners. Intonation similarity percentage. SA = speech act. Sp = speaker. M = male.

SA	Sp 1M	Sp 2M	Sp 3M	Sp 4M
1	80.20	79.90	78.70	83.30
2	90.70	80.10	74.00	74.20
3	87.18	77.50	74.77	78.14
4	87.67	81.92	83.25	76.00

Regarding the intersyllabic analysis results of our male non-native speakers (Sp 1M, 2M, etc.), see Table 2. Taking the same considerations about the stages of the recording performance as described above, the similarity percentages for our male Russian speaking learners of Spanish range from 74% to 90.70%. These results show slightly lower similarity in reproducing the intonation of the native speaker compared to the percentage of female learn-

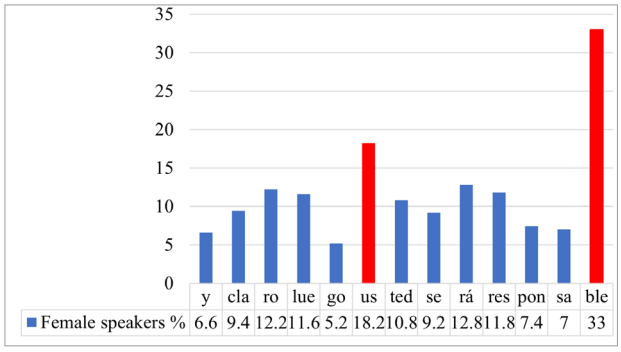
[1] In case of male non-native speakers, the text of the reproduced SA 1 and SA 4 is slightly different due to native speakers' recordings which represent semi-spontaneous communicative interaction: "Luego usted será responsable" and "Eso no puede volver a repetirse". The lexical-syntactic structure of these SA does not affect the results of intonational similarity because SA have the same functional elements of the pitch contour.

[2] The didactical sequence for the mentioned exercises has been proposed by Sarymsakova (2022).

ers. However, we still consider them quite satisfactory because none of our participants showed less than 70% similarity. Regarding the pitch difference per syllable of each reproduced speech act, see Figures 3-8.

Figure 3 indicates the major difference (from here onwards marked in red for female speakers) for SA 1 produced by female non-native speakers appears in the final inflection (last unstressed syllable) *ble* (33%). Likewise, in the body of SA 1, the unstressed syllable *us* in the body of the pitch contour indicates a percentage of differentiation of 18.2%.

Figure 3: Average difference of pitch deviation by syllables for SA 1 reproduced by female non-native students. Red is used to highlight the syllables with the largest difference.



Regarding the SA 1 by male non-native speakers, Figure 4 shows the largest difference (from here onwards marked in green for male speakers) in the body, the unstressed syllable *se* (36%) and the stressed syllable *rá* (29.5%) of the nucleus of the verbal syntagm.

Figure 4: Average difference of pitch deviation by syllables for SA 1 reproduced by male non-native students. Green is used to highlight the syllables with the largest difference.

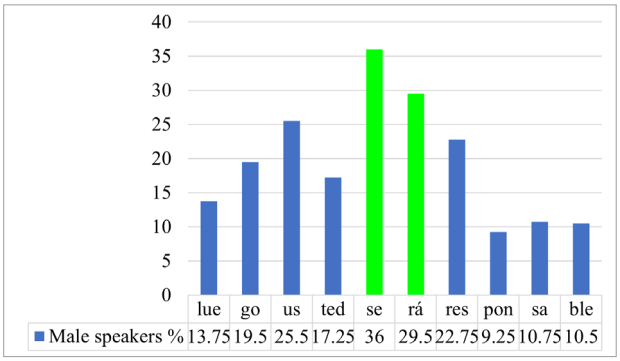


Figure 5: Average difference percentage of pitch deviation by syllables for SA 2 reproduced by both female and male non-native students. Red is used to highlight the syllables with the largest difference in female speakers. Green is used to highlight the syllables with the largest difference in male speakers.

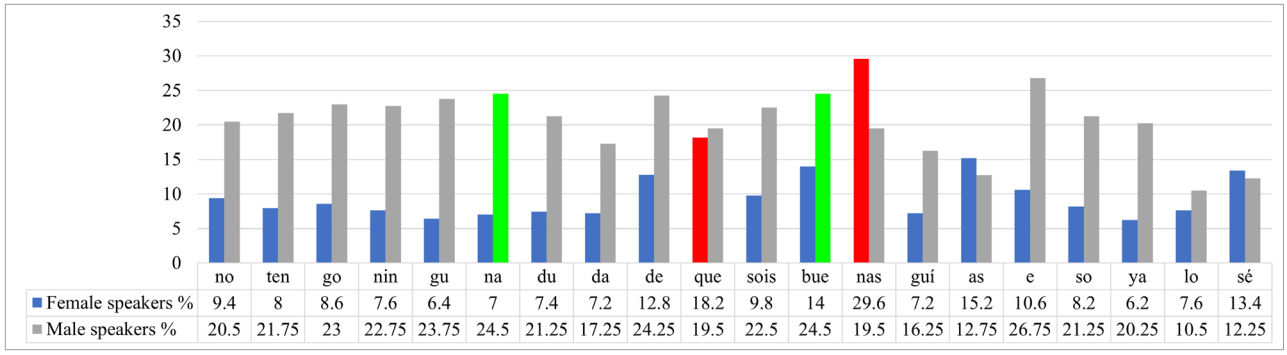


Figure 6: Average difference percentage of pitch deviation by syllables for SA 3 reproduced by both female and male non-native students. Red is used to highlight the syllables with the largest difference in female speakers. Green is used to highlight the syllables with the largest difference in male speakers.

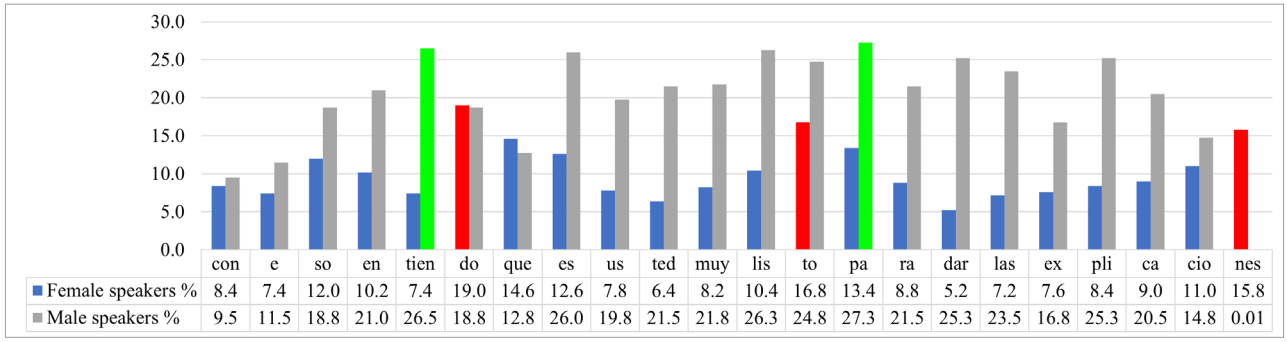


Figure 7: Average difference of pitch deviation by syllables for SA 4 reproduced by female non-native students. Red is used to highlight the syllables with the largest difference in female speakers.

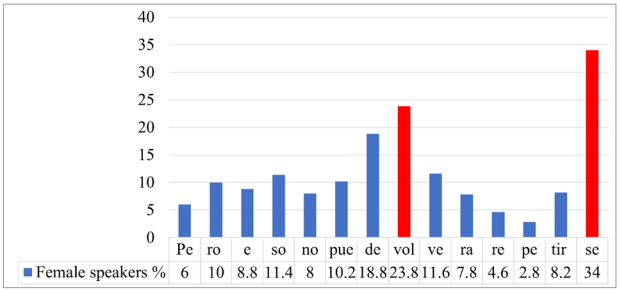


Figure 8: Average difference of pitch deviation by syllables for SA 4 reproduced by male non-native students. Green is used to highlight the syllables with the largest difference in male speakers.

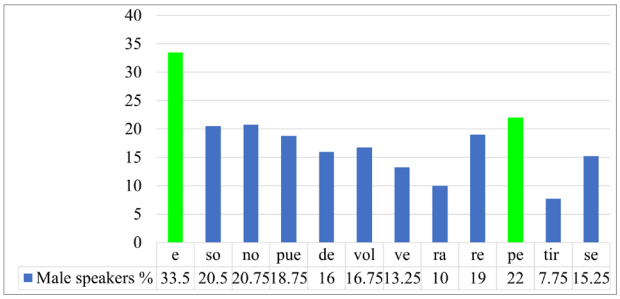
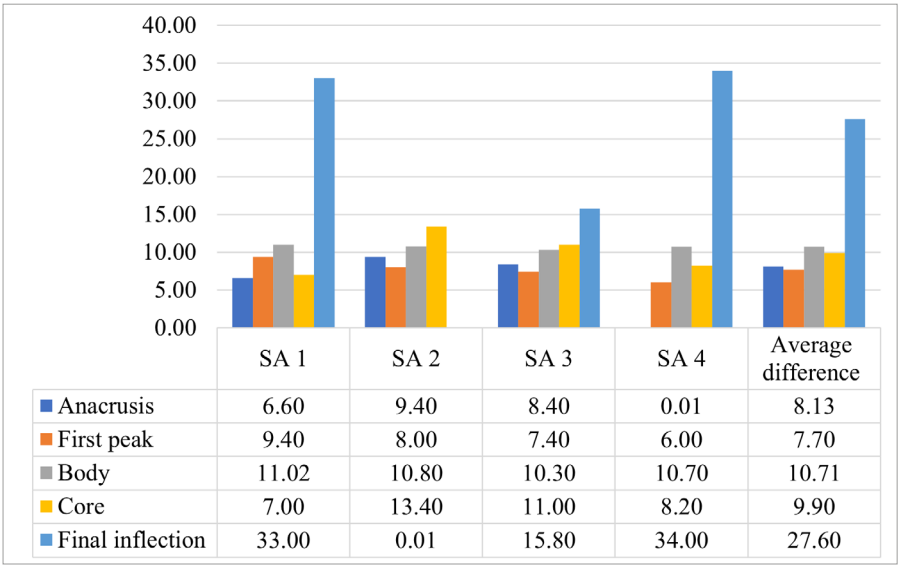
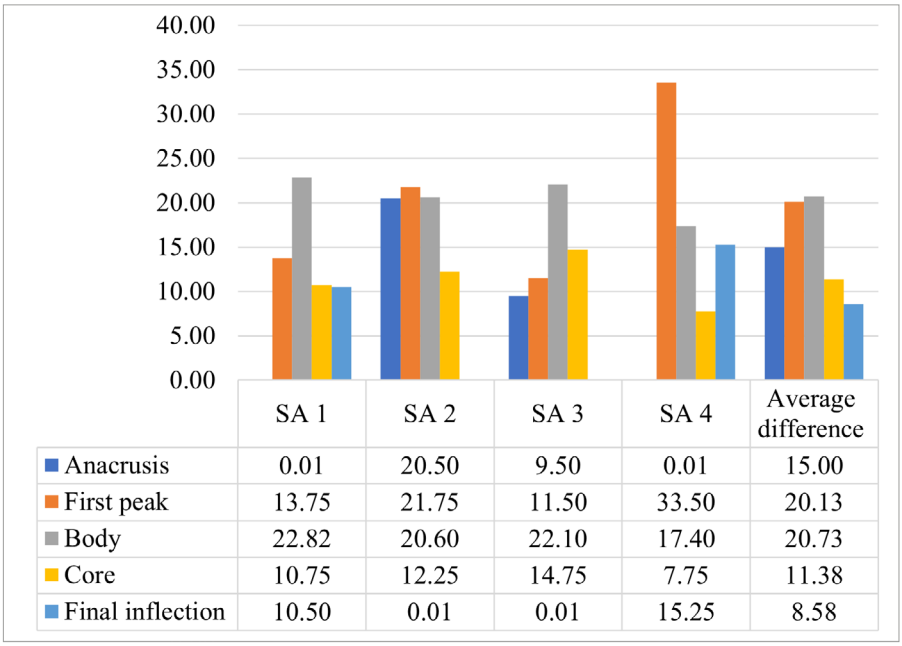


Figure 9: Pitch difference percentage detected by PAFe for functional elements in the Russian female pitch contour.



	SA 1	SA 2	SA 3	SA 4	Average difference
Anacrusis	6.60	9.40	8.40	0.01	8.13
First peak	9.40	8.00	7.40	6.00	7.70
Body	11.02	10.80	10.30	10.70	10.71
Core	7.00	13.40	11.00	8.20	9.90
Final inflection	33.00	0.01	15.80	34.00	27.60

Figure 10: Pitch difference percentage detected by PAFe for functional elements in the Russian male pitch contour.



	SA 1	SA 2	SA 3	SA 4	Average difference
Anacrusis	0.01	20.50	9.50	0.01	15.00
First peak	13.75	21.75	11.50	33.50	20.13
Body	22.82	20.60	22.10	17.40	20.73
Core	10.75	12.25	14.75	7.75	11.38
Final inflection	10.50	0.01	0.01	15.25	8.58

As for SA 2 with negative politeness pragmatic function, Figure 5 displays the largest syllabic difference for female speakers in the subordinate part, in the nexus *que* (18.2%) and the unstressed syllable *nas* (29.6%), both of them included to the body of the SA 2 utterance. Likewise, the male speakers showed 24.5% in the same pitch contour element (syllables *na* and *bue*).

The data from Figure 6 presents pitch contour elements which has the major pith difference for SA 3. The ironical speech act by female speakers distinguishes three main tonal deviations: the body of the utterance formed by *do* (19%) and *to* (16%), and the final inflection *nes* (15.8%). On the other hand, the male Russian speaking learners' of Spanish utterance reveals only two main points of pitch contrast: *tien* (26.5%) and *pa* (27.3%) syllables, both from the body of ironical speech act. It should be noted that, in the case of the final inflection *nes*, the difference shown by PAFe is 0.01 due to imperceptible pith values of this segment (less than 75 Hz, due to PAFe default settings, as an extension of Praat).

Finally, Figure 7 shows the pitch difference in the body of indirect request speech act 4, namely in the unstressed syllable *vol* (23.8%), and in the final inflection represented by the syllable *se* (34%). Regarding the male speakers' tonal contrast found for SA 4, Figure 8 shows it in the first peak (first stressed vowel), specifically in the stressed syllable *e* of the demonstrative pronoun (33.5%), as well as in the beginning of the body of the same pitch contour, concretely in the unstressed syllable *pe* (22%).

In order to adequately interpret the provided empirical data obtained via intersyllabic intonation analysis of native and Russian speaking learners of Spanish performed by PAFe tool, we have obtained the pitch functional elements where the most of f_0 deviations occurred for female and male Russian speaking learners of Spanish. Figure 9 shows the most of the pitch deviations detected by PAFe, in the case of female Russian learners, occurs in the body (10.71%) and in the final inflection (27.60%) of the pitch contour, while our male non-native participants (Figure 10) showed a greater pitch contrast in the body (20.73%) and in the first peak (20.13%).

Nevertheless, Figure 9 and Figure 10 illustrate that there were instances where the comparison was deemed inapplicable, evident by tone values equivalent to 0.01. Given the emergence of such data, statistical testing became imperative. Consequently, we employed the software tool proposed by Rodríguez-Fernández, Canosa, Mucientes, and Bugarín (2015) to assess the statistical significance of the experimental data. We opted for the Friedman Aligned Ranks test due to the fact that the experimental data are not normally distributed and the property of homocedasticity is not satisfied. The resulting p-value, determined to be 0.03769 (with a significance level of 0.05), was observed for male first peak values, as well as female body tonal values. This implies that these pitch functional elements bear statistical significance within our study.

After all, the data obtained on Russian speaking learners of Spanish via intersyllabic analysis provided by PAFe tool and tested statistically have revealed the percentage of tonal deviations in functional elements of intonational contour (anacrusis, first peak, body, nucleus and final inflection) and have shown slight differences in those elements in speech acts produces by male and female speakers.

5. CONCLUSIONS

The study we have carried out showed that the PAFe tool facilitates identification of non-native pitch deviation patterns of the pitch contour and provides quantitative data on it automatically.

In summary, we highlight the following key aspects which we have set out in the Introduction section and which meet the initial objectives aroused within our hypothesis formulated in Section 1:

1. According to the empirical data obtained within the intersyllabic PAFe tests carried out with our Russian speaking learners of Spanish, we have identified that most of the tone deviation, in the case of female learners, occurs in the body of the four reproduced speech acts, while male Russian participants' pitch contour elements with greater melodic contrast was the first peak. The findings also imply that the pitch functional elements in question pose noteworthy challenges for Russian speaking learners of Spanish attempting to acquire phonetic-phonological proficiency in Spanish, as they manifest the most prominent tonal deviations. These outcomes substantiate the validity of our hypothesis, as the application of PAFe in the current research has effectively automated the discrimination of pitch functional elements and has yielded valuable data elucidating the potential impediments faced by Russian speaking learners of Spanish.
2. The intersyllabic functionality of PAFe tool enables automatization of melodic contrastive-comparative analysis for native and non-native speakers. However, there is a sequence of aspects that may limit melodic elements identification. The range of tonal values does not permit the analysis of pitch bellow 75 Hz. Also, as we indicated in Data collection subsection, audio and annotation files for native and non-native speakers (PAFe´s input files) are obtained separately. In to ease the intersyllabic analysis, the process of input files collection should be automatized and integrated to the PAFe interface, which we intend to develop in its future versions and include these variables in future experiments to be carried out.

Regarding future lines of research, we expect to deepen the study of gender differences in functional speech element and explain why female Russian speakers present more tonal deviance in final inflection, while male non-natives show the greatest contrast in first peak. Finally, our future purpose is to collect more data on functional speech element pitch contrast for Spanish native and non-native speakers by carrying out studies with Spanish

students with different L1 and, on the basis of synthesis of this data with the PAFe tool, generate a dataset for Spanish non-native speakers voice recognition software.

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