Revista CEFAC

eISSN 1982-0216

DOI: 10.1590/1982-0216/20242648423 | Rev. CEFAC. 2024;26(4):e8423

Original articles

Central auditory processing and phonological processing in Brazilian Portuguese–English bilingual subjects

Érica Aparecida Picoli Quatrini[1]
Carolini Marchetti Rodrigues[1]
Patrícia Aparecida Zuanetti[2]
Sthella Zanchetta[3]
Marisa Tomoe Hebihara Fukuda[3]

[1] Universidade de São Paulo - USP, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Ribeirão Preto, São Paulo, Brasil.

[2] Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo (HCFMRP-USP) - Ribeirão Preto, São Paulo, Brasil.

[3] Universidade de São Paulo, Faculdade de Medicina de Ribeirão Preto (FMRP-USP), Ribeirão Preto, São Paulo, Brasil.

A study conducted at the Speech-Language-Hearing Research Laboratory at the Ribeirão Preto Medical School of the Universidade de São Paulo - FMRP USP, Ribeirão Preto, São Paulo, Brazil.

Financial support: Nothing to declare

Conflict of interests: Nonexistent

Corresponding author:
Érica Aparecida Picoli Quatrini
Avenida Bandeirantes, 3900
CEP: 14048-900 - Ribeirão Preto, São Paulo, Brazil
E-mail: ericamap@yahoo.com.br

Received on September 12, 2023
Received in a reviewed form on November 21, 2023
Accepted on April 10, 2024

ABSTRACT

Purpose: to compare temporal auditory processing (temporal ordering) and phonological processing skills in bilingual and monolingual subjects.

Methods: 100 undergraduate and postgraduate university students divided into a bilingual group (BG; n = 50) and a monolingual group (MG; n = 50). The study assessed the two groups' phonological processing skills (phonological awareness, working memory – phonological loop, and rapid lexicon access) and temporal auditory processing skills (Frequency Pattern and Duration Pattern Tests). The Mann-Whitney test (p = 0.05) was used for statistical analysis.

Results: BG performed better than MG in phonological awareness and phonological working memory tasks – nonword repetition and rapid naming tasks, except for color naming, and the two auditory processing tests.

Conclusion: Bilinguals performed better on phonological and auditory tests. These skills help them identify and discriminate variations in the phonology of both languages, influencing their performance.

Keywords: Memory; Auditory Perception; Multilingualism

INTRODUCTION

Bilingualism may have many advantages because those who can speak various languages benefit from the ability to communicate with more people, expand their social circles, grant greater employment, commerce, and travel opportunities, appreciate other cultures, access medical and other services, and have careers that involve the use of multiple languages[1].

The main initial stage in language learning involves converting acoustic into linguistic information for subsequent phonological, lexical, and morphosyntactic encoding[2]. Hence, there is an unquestionable relationship between hearing skills and bilingualism.

Understanding a second language (L2) requires the development of specific skills that begin with the information heard. There is a broad relationship between individual differences in central auditory processing skills and the ultimate language acquisition throughout life, including L2 learning[3].

Recent evidence suggests that mastery of central auditory processing (sensitivity to the spectral-temporal characteristics of sounds) helps determine individual differences in L2 speech acquisition outcomes[3,4].

Temporal ordering or sequencing skills are widely studied, as they relate to the person's ability to sequence and order the processed auditory stimuli within a certain time interval[5,6], assigning them an important role in speech perception. These skills are approached as a bottleneck for spoken language acquisition (spectral and temporal details convey phonemic, phonological, and prosodic categories)[7].

In addition to central auditory processing, another aptitude is suggested for the subject's performance in L2 acquisition. Studies have shown that the working memory–phonological loop (WMP) plays a key role in the initial phase of learning new sounds. As bilinguals gain more L2 experience, other cognitive skills, such as phonemic coding, appear to play a key role in determining the acquisition of more advanced L2 proficiency, evidenced in the activation of speech motor control and auditory perception[8].

Based on theoretical conceptualizations that converge on the intrinsic relationship between bilingualism and the performance in central auditory processing tasks[3] and working memory tasks[8], this study aimed to compare temporal auditory processing (temporal ordering) and phonological processing (PF) skills in monolingual native Portuguese (L1) speakers and bilingual ones whose L2 was English.

METHODS

This is an observational, cross-sectional study, with a convenience sample. It was approved by the Research Ethics Committee of the College of Philosophy, Sciences, and Languages of Ribeirão Preto – University of São Paulo, São Paulo, Brazil, under number CAEE 47435315.0.0000.5407. Data collection began only after approval from the Research Ethics Committee and consent from the volunteers.

The study comprised 100 undergraduate and postgraduate university, aged 18 to 40 years, divided into two groups: bilingual group (BG) (n = 50), with native Portuguese-speaking students (L1) proficient in English (L2); and monolingual group (MG) (n = 50), with native Portuguese-speaking students (L1) not proficient in any other language. The criteria to identify the participant's proficiency and define the groups were based on the Common European Framework of Reference for Languages. The exclusion criteria were any type of hearing loss and abnormal results in tympanometry or acoustic reflex tests. Also, music students were dismissed, due to their exceptional sound recognition skills.

The Common European Framework of Reference for Languages (CEFRL)[9] was used to assess the participants' proficiency in L2 (English) and define groups. The instrument establishes six proficiency levels: basic level (A1- beginner and A2- basic); regular level (B1- intermediate and B2- independent); and advanced level (C1- effective and C2- full mastery). Among the instrument's various aspects, the research used self-assessed understanding, speaking, and writing. After recording the responses, the groups were defined. Participants who declared themselves as A1 or A2 were included in MG and those who declared themselves as B1, B2, C1, or C2, according to the CEFRL, were included in BG. To minimize the risk of self-assessment bias and better define BG, the participant had to have lived for at least 2 years in an English-speaking country with prior knowledge and experience with the language or have a certificate in a formal English course, following the schools' criteria in their curricular guidelines, which direct the student's learning and evolution at standardized levels.

All MG and BG participants underwent an assessment of phonological awareness (PA), WMP, and rapid naming test (lexical access) in both English and Portuguese to assess phonological processing skills.

The Sequential Assessment Instrument (CONFIAS)[10] was used to assess phonological awareness in Portuguese. It assesses PA syllabic (nine tasks) and phonemic (seven tasks) skills, scoring 40 points in syllabic awareness tasks and 30 in phonemic awareness tasks, totaling 70 points – one point for each correct answer. The tasks were applied and answered orally, providing two examples for training. In case of error, no points were scored. Each test item was repeated only once; when the participant asked to have an item repeated more than once, their answer was disregarded.

The Brazilian Children's Test of Pseudoword Repetition (BCPR)[11] was used to assess WMP with pseudowords in Portuguese. The test has 40 pseudowords divided into four groups, with 10 words in each group, ranging from two to five syllables. Participants were instructed to repeat all pseudowords presented orally, one at a time. Correct repetitions scored 2 points on the first attempt and 1 point on the second attempt; if there was no correct repetition, no points were recorded.

The Nonword Repetition Test[12] was also used to evaluate WMP in Portuguese. It has 60 nonwords (from two to five syllables), with no sound similarity to words of the language and with different orders, such as six plosive phonemes (/p/, /t/, /k/, /b/, /d/, /g/), three nasal phonemes (/m/, /n/, /ñ/), six fricative phonemes (/f/, /v/, /S/, /Z/, /s/, /z/), three liquid phonemes (/l/, /R/, /λ/), and five closed vowels (/a/, /e/, /i/, /o/, /u/). The syllabic patterns were consonant + vowel (CV); vowel + consonant (VC); consonant + vowel + consonant (CVC); and consonant + consonant + vowel (CCV). The test was presented orally, and an immediate repetition was requested, with 2 points being awarded for a correct answer in the first attempt, 1 point in the second attempt, and 0 points in case of an error in both attempts.

The Rapid Automatized Naming Test (RAN)[13], adapted to Brazilian Portuguese[14], was applied to assess the lexical access speed through the rapid naming of visual stimuli. Each subtest has 50 visual stimuli, distributed across 10 lines (each line has five pictures). The stimuli were presented in the form of letters, digits, objects, and colors. The letter test consists of "p", "d", "o", "a", and "s"; the digit test is made up of the numbers 6, 2, 4, 9, and 7; The object test consists of the images of a comb, an umbrella, a watch, scissors, and a key; and the color test consists of red, blue, black, yellow, and green. Each test's naming time was recorded.

PA skills in English were assessed with the Phonological Awareness Test in a Foreign Language – English[15]. The test assesses PA syllabic (seven tasks) and phonemic (seven tasks) skills in English, with four items per task. The 56 items score as follows: 28 points in syllabic tasks and 28 in phonemic tasks, totaling 56 points. One point was awarded for each correct answer; in case of error or omission, no points were awarded.

The Repetition Priming of Word, Pseudoword, and Nonword[16] was used to assess WMP with words, pseudowords, and nonwords in English. This study used 15 words and 15 pseudowords, presented orally one by one, asking for immediate oral repetition. Two points were awarded for a correct answer on the first attempt, one point for the second attempt, and no points for an error on both attempts. It also used the Nonword Decoding Test[17], which has 39 invented words that are in line with English phonology. The nonwords were presented orally, one at a time, asking them to repeat them orally in the sequence. Two points were recorded if the repetition was correct in the first attempt, one point in the second attempt, and no point was scored for an error in both repetitions.

RAN was also used to assess rapid naming in English[13]. They were asked to rapidly name the stimuli in English (letters, digits, objects, and colors), timing their answers in each test. Letter names in English were requested according to English phonetics, as were all other tasks. The digit test used "six, two, four, nine, seven"; the object test used "comb, umbrella, watch, scissors, key"; and the color test used "red, blue, black, yellow, and green".

The temporal auditory skills were assessed with the Duration Pattern Test (DPT) and the Frequency Pattern Test (FPT), Mudiek version[18]. Altogether, 60 sequences were presented binaurally at 50 dB (sensation level) through headphones in a sound booth. Before applying the tests, 10 stimuli per test were presented for familiarization training. The total number of correct answers was counted to analyze the results.

FPT[18] consists of the presentation of three-tone sequences with low (L) (880 Hz) and high (H) (1,122 Hz) tones, each one lasting 150 milliseconds (ms), with a 200-ms interval between tones, and a 7-second interval between sequences. The tones have different positions in each sequence, allowing for six possible configurations: HHL, HLH, HLL, LLH, LHL, and LHH.

The volunteer should name the perceived pattern in the order of the stimuli.

DPT it is a temporal ordering test regarding the duration of three pure tones at the same frequency (1,000 Hz), two of them always with the same duration and the other with a different one. The short tone lasts 250 ms, and the long tone lasts 500 ms, with 300-ms intervals between stimuli, and 6-second intervals between sequences – which were presented simultaneously in both ears. The short (S) and long (L) stimulus sequences were presented in different orders: 500 ms – 250 ms – 500 ms (long – short – long), 250 ms – 250 ms – 500 ms (short – short – long), and so forth. Possible combinations were SSL, SLL, SLS, LLS, LSS, and LSL. The participant was instructed to name the patterns heard using the term "short" for shorter sounds and "long" for longer ones.

The entire test battery was applied in one session, lasting 2 hours on average.

The Mann-Whitney nonparametric test compared the two groups' performance in phonological processing skills in both Portuguese and English, setting the significance level at 0.05, as the data did not have a normal distribution. The same test was used to compare the groups' performances regarding PA temporal ordering skills.

A logistic regression analysis was performed to determine the factors associated with bilingualism, including all independent variables tested.

RESULTS

The profile data on the sample's mean age, sex, and field of study are shown in Table 1. It included 100 university undergraduate and postgraduate students, with a mean of 22.91 years, divided into two groups: BG (n = 50) and MG (n = 50).

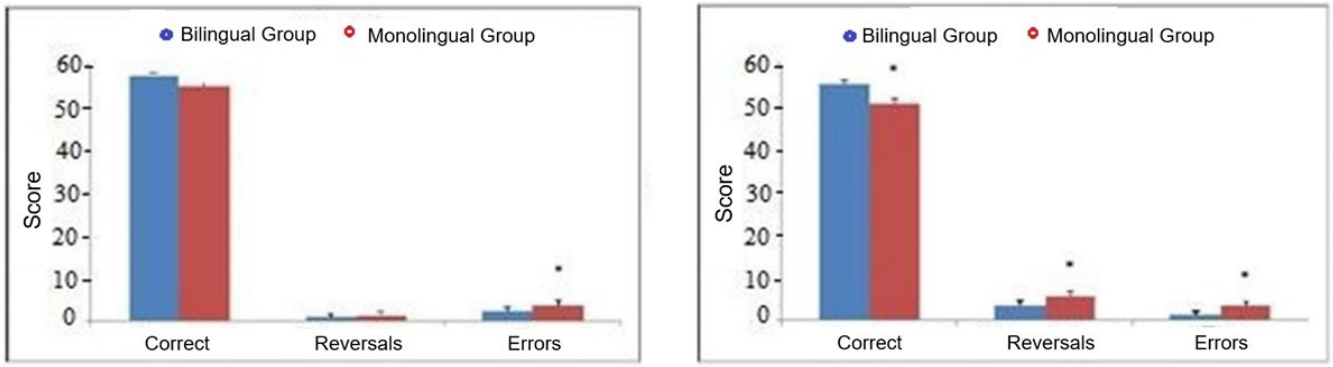
Table 1. Characteristics of the sample

Variable	Monolingual Group		Bilingual Group	
	Absolute number	%	Absolute number	%
Sex				
Females	36	48	39	52
Males	14	56	11	44
Education level				
Undergraduates	47	66.19	24	33.80
Postgraduates	3	10.34	26	89.65
Field of Study				
Human Sciences	6	85.71	1	14.28
Biological Sciences	39	45.34	47	54.65
Exact Sciences	5	71.42	2	28.57

Central Auditory Processing

Significant statistical differences were found in the number of correct answers ($p = 0.001$) and errors ($p < 0.001$) in DPT, though not for reversals ($p = 0.156$) – BG had higher correct scores and fewer errors than MG. The results suggest that BG had greater efficiency in discriminating sound duration.

FPT results showed significant differences, according to statistical analysis, for correct answers ($p = 0.005$), errors ($p = 0.008$), and reversals ($p = 0.011$). The data suggest that BG performed better in sound frequency discrimination than MG. These results are presented in Figure 1.

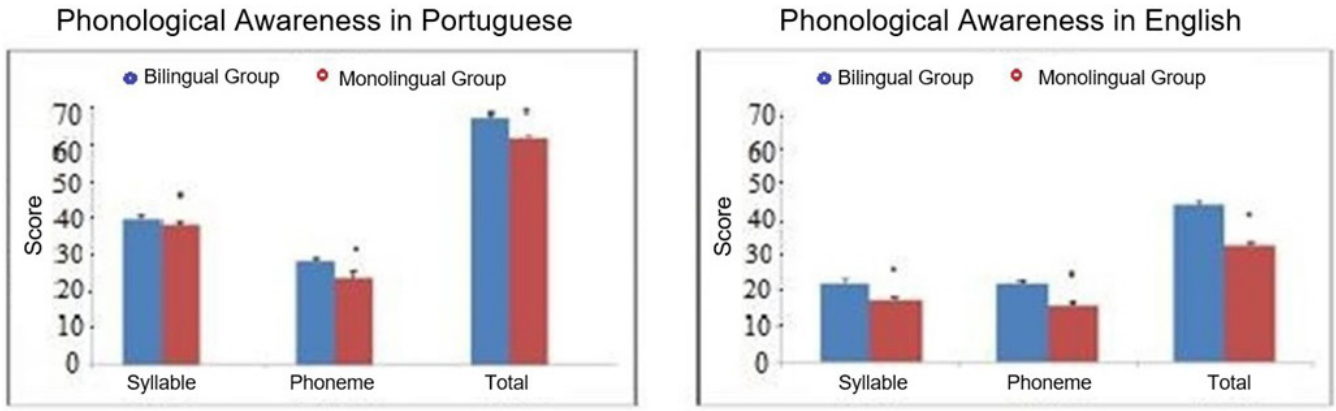


An * indicates a statistical difference between the groups ($p < 0.05$), according to the Mann-Whitney test.

Figure 1. Performance of the Bilingual Group and Monolingual Group on the Duration Pattern Test and Frequency Pattern Test, respectively

Phonological Processing

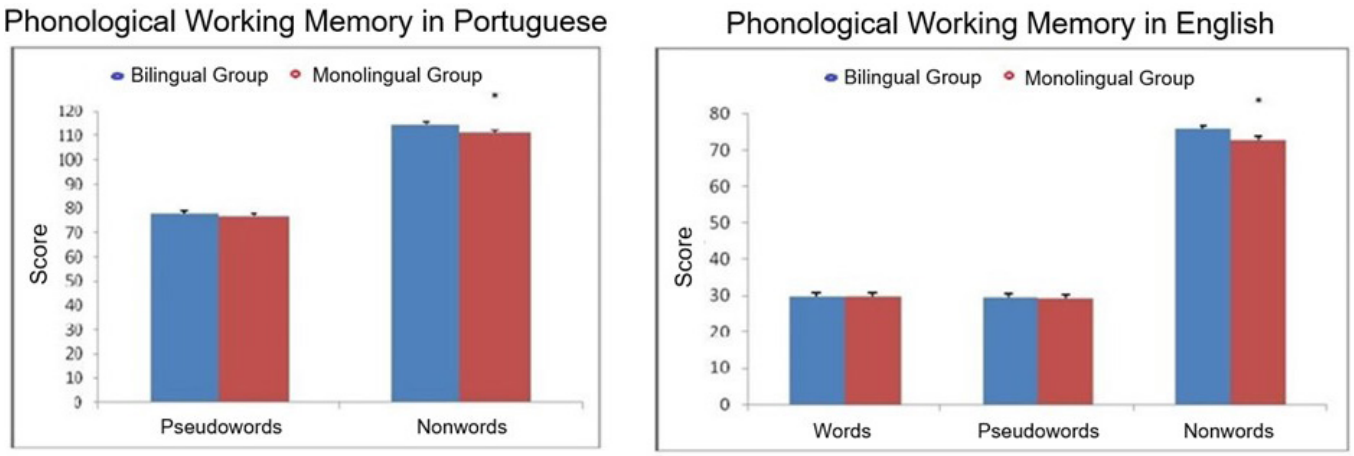
Regarding PA (in Portuguese), the Mann-Whitney test showed that BG had significantly higher scores at all test levels (Syllabic, Phonemic, and Total) ($p < 0.001$), suggesting that bilinguals perform better in this task. Statistically significant differences between the groups were also found in the English PA tests ($p < 0.001$) – BG had higher scores at all test levels (Syllabic, Phonemic, and Total), suggesting that BG performs better in this task. Figure 2 shows the difference in performance between the groups.



An * indicates a statistical difference between the groups ($p < 0.05$), according to the Mann-Whitney test.

Figure 2. Performance of the Bilingual Group and Monolingual Group in the Portuguese and English phonological awareness tasks regarding syllables, phonemes, and total awareness

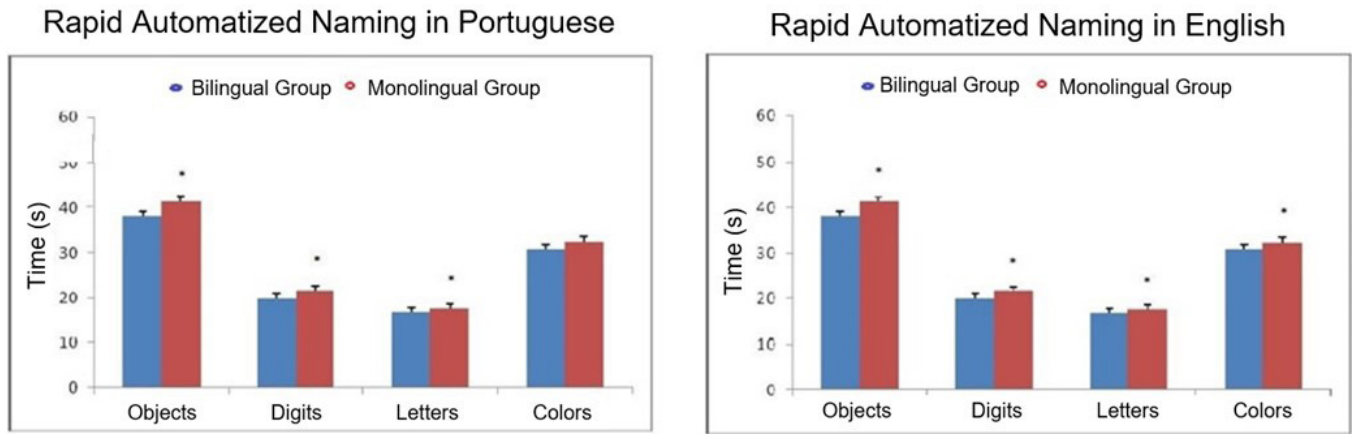
Regarding WMP, no statistically significant differences were observed between the groups ($p = 0.119$) for pseudoword repetition scores in Portuguese. BG and MG performed similarly, with scores close to the maximum allowed by the test. Regarding nonword repetition in Portuguese, the Mann-Whitney test found statistically significant differences ($p = 0.009$). BG had a higher score, suggesting that bilinguals performed better in the WMP assessment in Portuguese. The same result was found in the WMP assessments in English – no statistically significant differences were found between BG and MG in the word and pseudoword repetition test, whereas statistically significant differences were found in English nonword repetition ($p < 0.001$). BG had higher scores on the tests, which suggests that they performed better than MG. These aspects are shown in the charts in Figure 3.



An * indicates a statistical difference between the groups ($p < 0.05$), according to the Mann-Whitney test.

Figure 3. Performance of the Bilingual Group and Monolingual Group in phonological working memory assessment tasks involving pseudowords and nonwords in Portuguese and English, respectively

The statistical analysis highlighted significant differences in RAN in Portuguese between the time spent by MG and BG to name objects ($p = 0.009$), digits ($p = 0.026$), and letters ($p = 0.044$) – BG named them more rapidly, suggesting a better performance. However, no statistically significant differences were found in the color naming test, suggesting similar performances between the groups. The RAN task in English was performed by both groups, and BG performed better than MG. The statistical analysis with the Mann-Whitney test showed significant differences between the time spent by BG and MG to name objects ($p < 0.001$), digits ($p < 0.001$), letters ($p < 0.001$), and colors ($p < 0.001$). These aspects are presented in Figure 4.



An * indicates a statistical difference between the groups ($p < 0.05$), according to the Mann-Whitney test.

Figure 4. Performance of the Bilingual Group and Monolingual Group in the Rapid Automatized Naming Test tasks in Portuguese and English, respectively

This study also conducted a logistic regression test to verify which factors could predict a person's ability to learn a new language – i.e., their ability to master two languages. The most associated variables were their ability to correctly recognize the phonemes in the other language (performance in English PA tasks) and rapidly name in another language (performance in English RAN tasks).

DISCUSSION

This study aimed to bring scientific contributions to clarifying peculiarities of phonological processing and temporal ordering skills of bilingual (L1 Brazilian Portuguese and L2 English) and monolingual individuals by assessing and comparing the performance of the two study groups.

The study results showed that bilinguals have a more refined auditory ability to recognize sound duration and frequency, demonstrated by their better performance in FPT and DPT, with more correct answers. Accordingly, studies show that central auditory processing skills are superior in multilinguals and bilinguals than in monolinguals, with multilinguals having the best results[4].

One study investigated the effects of bilingualism and multilingualism on central auditory processing skills in children, with 90 participants divided into three groups – monolingual, bilingual, and multilingual. It assessed amplitude modulation detection thresholds, gap detection thresholds, pitch discrimination, and spectral ripple discrimination thresholds. Bilingual and multilingual children performed better than monolingual ones in temporal tests, with multilingual children achieving the best results[4].

A study investigated the hypothesis that individual differences in central auditory processing may be responsible for some variability in L2 learning[19], examining psychoacoustic thresholds, motor-auditory temporal integration, and auditory neural coding in 40 adult native Polish speakers living in the United Kingdom, with a mean age of 25 years, who had English as their L2. They found that accurate English vowel perception and grammatical judgment were related to lower psychoacoustic thresholds, better auditory-motor integration, and more consistent responses to sound frequency tracking. Psychoacoustic thresholds and sound coding explained independent variance in vowel perception. These results suggest that individual differences in the success of L2 acquisition arise, at least in part, from mastering auditory perception.

Nonverbal sound ordering skills involve behaviors of acoustic stimulus recognition, discrimination, and phonological evocation. Nonverbal sounds, present in DPT and FPT, are similar to the sound stimuli of the language (phonemes), regardless of the language spoken, and good performance in such tasks suggests a good capacity to recognize and discriminate linguistic sounds, especially speech, essential to learning L1 and L2. Thus, using sound frequencies is of great value to speech comprehension and assessment[20].

The literature has studies addressing the ability to reflect on the phonological aspects of the language, investigating PA in bilingual samples[21]. Even though many studies focus on PA skills in bilingual groups, most of them have child samples (in general, learning or having learned to read and write), using varied assessment instruments. It is understood that many PA assessment studies are carried out with children (especially preschoolers) because at this stage they are learning to read and write and gradually developing their reading skills, which helps them develop skills to do PA tasks[22]. PA skills are known to be poorly developed while learning to read and write, being consolidated and improved through the literacy process[23]. Studies evaluating PA in adults mostly have illiterate samples, since such skills are supposedly developed in educated adults without reading/writing deficits[23].

Although the phonological processing assessment instruments (PA in Portuguese) were initially developed for children and adolescents, the present study used them in educated adults. Hence, it expected a satisfactory performance in this task, as this population's PA in their native language is supposedly established. However, it was not known whether the ability to reflect on the phonology of the language would be consolidated for another language. Therefore, this study used a PA assessment instrument for English (Phonological Awareness Test in a Foreign Language – English[15]) that follows the same evaluative standard as the test applied in this study (CONFIAS[10]). MG was expected to perform worse than BG in this PA assessment in English, due to BG's experience and knowledge of English.

Both groups performed quite well in the PA assessment in Portuguese, whose test scores were close to the maximum allowed by the instrument. Even so, there were differences between the MG and BG scores, as MG performed worse. The results of this study suggest that greater auditory stimulation, through contact with different languages, can favor the

emergence and permanence of an auditory representation of the language, as they know and understand its phonological structure.

Many studies have investigated the assessment of WMP in bilingual children[24,25] and bilingual adults[26,27].

A study compared cortical and behavioral outcomes of 99 monolingual and bilingual older adults who reported no cognitive or memory problems in three types of memory that typically decline in old age, namely: working memory (measured by n-back), item, and associative recognition[28]. The results showed that bilinguals were faster on the working memory task than monolinguals[26].

A meta-analysis on the association between bilingualism and WMP ability[29] extracted data from 116 studies (involving 177 pairs of participants and 444 effect sizes), examining age, characteristics of WM tasks – i.e., complexity (simple span vs. transformation vs. complex span tasks) and domain (verbal vs. nonverbal) –, age at first exposure to L2, and L2 proficiency as potential moderating variables. Results indicated a small WMP advantage in bilinguals, which was stronger when the WM task compared L2 with L1. The authors concluded that bilingual experience is associated with slightly higher WM capacity.

The results of the present study showed that BG performed better than MG in repeating nonwords in both English and Portuguese and like MG in repeating words and pseudowords in both languages. In other words, the greater the complexity of the task and the greater the required WMP performance, the better the BG's performance compared to MG.

Tests that use word and pseudoword repetition are less effective than WMP assessment instruments, as lexical interference may assist the repetition of the stimuli. While pseudowords have some sound similarity to words of the language, nonwords do not have any similarity. This lack of similarity requires the individual to use their WMP for repetitions[30].

The results of this study corroborate other ones in the literature[26,31], in which bilinguals performed better than monolinguals, considering the different complexity levels of the WMP task (words, pseudowords, and nonwords).

The next component of phonological processing to be discussed is the mental lexicon access speed, assessed through the ability to efficiently retrieve phonological information or rapidly and automatedly name things – i.e., RAN. Rapid naming activities for visual stimuli assess the information processing speed[32]. The mental lexicon is part of the semantic memory that assimilates and understands different – graphic, phonological, morphological, syntactic, or semantic – aspects of the word, using them in speech reception and emission in a conversation or linguistic text production[33].

Not many studies have assessed RAN and its relationship with bilingualism in adults, whereas various studies have investigated RAN in bilingual children. Many studies with adults, especially with reading/writing impairments, have approached naming speed, though not associating it with bilingualism. The present study demonstrated better bilinguals' performance in rapid naming tasks (phonological access to the mental lexicon) compared to monolinguals in both English (which was expected) and Portuguese.

The results of this study suggest that knowing a second language and its concepts favors greater naming speed – due to faster lexical retrieval, with less time spent on rapid naming assessment tasks – compared to the performance of the monolingual group. This result remains the same when comparing the performance of MG and BG in L1 tests. BG's better RAN performance in English was expected, as MG would take longer to complete the task for not knowing the English lexicon and not having a lexical representation of the visual stimuli used in the tests. This result is corroborated by another study, which suggests that the acquisition of a second language can influence the development of this skill[32].

The logistic regression results showed that PA ability, especially linked to the phonemic aspects of English, can be considered a predictor of L2. The results suggest that the better ability to recognize and accurately discriminate the different English phonemes may influence this language learning or have been influenced by it. The subtle differences in language phonology form its unique linguistic system. Thus, greater skills in recognizing these phonemic differences (variations/oscillations) help understand the new linguistic code.

Another factor strongly associated with bilingualism among the variables studied was the rapid naming of visual stimuli in English. This association of rapid vocabulary recall skills (lexicon) and bilingualism was expected since language cannot be constructed without a lexicon. The acquisition of new L2 words (expansion of the lexicon) enables one to learn the second language – and semantic aspects are embedded in this lexicon, favoring an entire network of meaning around the new

language. Therefore, L2 lexical acquisition brings with it semantic components that facilitate communication, an important aspect of language.

It is important to highlight that the study sample comprised young adults immersed in undergraduate and postgraduate programs – i.e., they had been previously and routinely exposed to both Portuguese and English. Even though those in MG declared themselves as not having enough speaking, reading, and comprehension skills to fit into BG, they had been exposed to English before, which could be a limitation of this study. Future research should assess bilingualism objectively along with the self-assessment questionnaire, which could reduce the risk of bias in determining study groups. Moreover, further studies are needed in different sociodemographic populations.

CONCLUSION

This study found that bilingual subjects perform better in phonological processing skills than those at a similar academic level without L2 fluency.

Bilinguals also discriminated and temporally ordered sound patterns more efficiently than monolinguals regarding duration and frequency, performing better in temporal auditory processing tasks.

REFERENCES

1. Antoniou M. The advantages of bilingualism debate. An Rev of Linguist. 2019;5:395-415. https://doi.org/10.1146/annurev-linguistics-011718-011820
2. Saito K, Kachlicka M, Sun H, Tierney A. Domain-general auditory processing as an anchor of post-pubertal second language pronunciation learning: Behavioural and neurophysiological investigations of perceptual acuity, age, experience, development, and attainment. J of Mem and Languag. 2020;115(2). https://doi.org/10.1016/j.jml.2020.104168
3. Saito K, Kachlicka M, Suzukida Y, Petrova K, Lee BJ, Tierney A. Auditory precision hypothesis-L2: Dimension-specific relationships between auditory processing and second language segmental learning. Cognition. 2022;229:105236. https://doi.org/10.1016/j.cognition.2022.105236 PMID: 36027789.
4. Kumar K, Sreeshma R, Kalaiah MK. A comparison of temporal processing and spectral processing abilities of monolingual, bilingual and multilingual children. Int J Audiol. 2020 Jul;59(7):501-505. https://doi.org/10.1080/14992027.2020.1720921 PMID: 32022604.
5. Terto SSM, Lemos SMA. Aspectos temporais auditivos: produção de conhecimento em quatro periódicos nacionais. Rev. CEFAC. 2011;13(5):926-36. https://doi.org/10.1590/S1516-18462011005000050
6. Gois M, Biaggio E, Bruckmann M, Pelissari I, Bruno RS, Garcia MV. Habilidade de ordenação temporal e nível de especificidade nos diferentes testes tonais. Audiol., Commun. Res. 2015;20(4):293-9. https://doi.org/10.1590/2317-6431-2015-1593
7. Werker JF. Perceptual beginnings to language acquisition. Applied Psycholinguistics. 2018;39(4):703-28. https://doi.org/10.1017/S0142716418000152
8. Reiterer SM, Hu X, Erb M, Rota G, Nardo D, Grodd W et al. Individual differences in audio-vocal speech imitation aptitude in late bilinguals: Functional neuroimaging and brain morphology. Front. Psychol. 2011;2:271. https://doi.org/10.3389/fpsyg.2011.00271 PMID: 22059077. PMCID: PMC3203549.
9. Conselho da Europa. Quadro Europeu Comum de Referência para as Línguas: aprendizagem, ensino, avaliação. Col: Perspec Act/Educ Porto, 2001; Portugal: Edições Asa.
10. Moojen S. CONFIAS - Consciência Fonológica: instrumento de avaliação sequencial. 2003; São Paulo: Casa do Psicólogo.
11. Santos FH, Bueno OFA. Validation of the Brazilian children's test of pseudoword repetition in Portuguese speakers aged 4 to 10 years. Braz J Med Biol Res. 2003;36(11):1533-47. https://doi.org/10.1590/S0100-879X2003001100012
12. Hage SRV, Grivol MA. Desempenho de crianças normais falantes do português em prova de memória de trabalho fonológica. Cadernos de Comunicação e Linguagem. 2009;1(1):61-72.
13. Denckla MB, Rudel R. Rapid "automatized" naming of pictured objects, colors, letters and numbers by normal children. Cort. 1974;10(2):186-202. https://doi.org/10.1016/s0010-9452(74)80009-2 PMID: 4844470.
14. Ferreira TL, Capellini SA, Ciasca SM, Tonelotto JMF. Desempenho de escolares leitores proficientes no teste de nomeação. Temas desenvolv. 2003;12(69):26-32 tab, graf | LILACS | ID: lil-365113.
15. Aquino C. Uma discussão acerca da consciência fonológica em LE: o caminho percorrido por aprendizes brasileiros de inglês na aquisição da estrutura silábica. [Dissertation] Porto Alegre (RS): Instituto Federal de Educação, Ciência e Tecnologia Sul-Grandense (IFSUL); 2010. https://doi.org/10.13140/RG.2.2.15255.83368
16. Stark CEL, McClelland JL. Repetition priming of words, pseudowords and, nonwords. J of Exper Psyc: Learn, Mem and Cog. 2000;26(4):945-72. https://doi.org/10.1037//0278-7393.26.4.945 PMID: 10946373.
17. Turner M. The non-word decoding test. Dysl rev [Journal on the internet]. 1994;6(2):23-4. [accessed 2023 ago]. Available at: https://training.dyslexiaaction.org.uk
18. Musiek FE. Frequency (Pitch) and Duration Pattern Tests. J Am Acad Aud. 1994;5(4):265-8. PMID: 7949300.
19. Kachlicka M, Saito K, Tierney A. Successful second language learning is tied to robust domain-general auditory processing and stable neural representation of sound. Brain Lang. 2019;192:15-24. https://doi.org/10.1016/j.bandl.2019.02.004 PMID: 30831377.
20. Sanayi R, Ghassem M, Akram P, Leila J, Shohreh J, Soudabeh S. Auditory temporal processing abilities in early azari-persian bilinguals. Iran J Otorhinolaryngol. 2013;25(73):227-32. PMCID: PMC3846248. PMID: 24303445.
21. Hickmann G, Guimarães S, Hickmann A. Aprendizado bilíngue e linguagem escrita: desenvolvimento de habilidades metalinguísticas. Cad. Pes. 2017;24(2):156-69. https://doi.org/10.18764/2178-2229.v24n2p156-169
22. Mota HB, Romero MV, Kaminski TI, Vidor-Souza D, Berticelli A. Desempenho de adultos não-letrados em avaliação das habilidades em consciência fonológica. Rev. CEFAC. 2012;14(2):249-53. https://doi.org/10.1590/S1516-18462011005000102

23. Lopes APN, Minervino CASM. Phonological awareness in illiterate adults. Rev. CEFAC. 2015;17(5):1466-74. https://doi.org/10.1590/1982-0216201517519214

24. Girbau D, Schwartz RG. Phonological working memory in Spanish-English bilingual children with and without specific language impairment. J Commun Disord. 2008;4(2):124-45. https://doi.org/10.1016/j.jcomdis.2007.07.001 PMID: 17765916. PMCID: PMC2267769 NIHMSID: NIHMS39774.

25. Asadollahpour F, Baghban K, Mirbalockzehi P, Naderifar E, Tahmasebi B. The performance of bilingual and monolingual children on working memory tasks. Iranian Rehabilitation Journal. 2015;13(2):53-7. ID: 147348204.

26. Kaushanskaya M, Blumenfeld HK, Marian V. The relationship between vocabulary and short-term memory measures in monolingual and bilingual speakers. Intern J Biling. 2011;15(4):408-25. https://doi.org/10.1177/1367006911403201 PMID: 2218091.

27. Yoo J, Kaushanskaya M. Phonological memory in bilinguals and monolinguals. Mem Cognit. 2012;40(8):1314-30. https://doi.org/10.3758/s13421-012-0237-x PMID: 22907206.

28. Anderson JAE, Grundy JG, Grady CL, Craik FIM, Bialystok E. Bilingualism contributes to reserve and working memory efficiency: Evidence from structural and functional neuroimaging. Neuropsychologia. 2021 Dec 10;163:108071. https://doi.org/10.1016/j.neuropsychologia.2021.108071 PMID: 34715120.

29. Monnier C, Boiché J, Armandon P, Baudoin S, Bellocchi S. Is bilingualism associated with better working memory capacity? A meta-analysis. Intern J Bil Educ and Biling. 2022;25(6):2229-55. https://doi.org/10.1080/13670050.2021.1908220

30. Grivol NA, Hage SR. Memória de trabalho fonológica: estudo comparativo entre diferentes faixas etárias. J Soc Bras Fonoaudiol. 2010;23(3):245-51. https://doi.org/10.1590/S2179- 64912011000300010

31. Warmington MA, Kandru-Pothineni S, Hitch G. Novel-word learning, executive control and working memory: A bilingual advantage. Biling: Lang and Cog. 2019;22(4):763-82. https://doi.org/10.1017/S136672891800041X

32. Silva C, Cunha VLO, Pinheiro FH, Capellini SA. Nomeação rápida, leitura e compreensão em escolares com dificuldades de aprendizagem. J Soc Bras Fonoaudiol. 2012;24(4):355-60. https://doi.org/10.1590/S2179-64912012000400011

33. Bernardo AM. O léxico mental no ensino e aprendizagem da L2 (Alemão). Linguística. Revista de Linguística da Universidade do Porto. 2010;5(1):27-40.

Authors' contributions:

EAPQ: Writing – original draft; Writing – review & editing.

CMR: Conceptualization; Investigation; Data curation; Data analysis.

PAZ: Data analysis; Writing – review & editing.

SZ, MTHF: Conceptualization; Methodology; Supervision.