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Bilingualism and auditory processing abilities: performance of adults in dichotic listening tests

Bilinguismo e habilidades de processamento auditivo: desempenho de adultos em tarefas dicóticas

ABSTRACT

Purpose: To evaluate and compare the dichotic listening abilities in non-hearing-impaired adults monolingual speakers of the Brazilian Portuguese language (CG) and simultaneous Brazilian Portuguese-German (GG) bilingual speakers or successive Brazilian Portuguese-Italian bilingual speakers (IG). **Methods:** This is about an observational, descriptive, transverse and quantitative research. The sample consisted of 87 subjects aged between 18 and 55 years, divided into: Control Group (CG), of 30 monolingual speakers of Brazilian Portuguese; Study Group A (SGA), of 31 simultaneous Brazilian Portuguese-German bilingual speakers; and Study Group I (SGI), of 26 successive Brazilian Portuguese-Italian speakers. The individuals were submitted to the Dichotic digits test (DDT) and to Staggered Spondaic Words (SSW). **Results:** The DDT results showed difference in right ear and total scores when comparing SGA to CG. Comparing the CG and the SGI, it was observed difference in right and left ears and total scores. Comparing the SGA and the SGI, no difference was observed between the groups. Results of SSW showed that both bilingual groups were significantly better in the right and left ears scores and even in total one when compared to CG. Comparing the SGA and the SGI, the SGI showed better significant scores in the right ear and total. **Conclusion:** Bilingual experiences seem to influence positively the ability of high predictability dichotic listening, evaluated by DDT, and the low predictability dichotic listening, evaluated by SSW test. The SSW results also showed statistically significantly better results for successive Brazilian Portuguese-Italian bilingual speakers when compared to simultaneous Brazilian Portuguese-German speakers.

RESUMO

Objetivo: Avaliar e comparar o desempenho de sujeitos adultos normo-ouvintes monolíngues do Português, bilíngues simultâneos do Português-Alemão e sucessivos do Português-Italiano em tarefas de escuta dicótica de dissílabos. **Métodos:** Trata-se de um estudo quantitativo, de caráter observacional descritivo e de corte transversal. A amostra foi composta por 87 sujeitos com idade entre 18 e 55 anos, distribuídos em: Grupo Controle (GC), composto por 30 monolíngues falantes do Português Brasileiro; Grupo Estudo A (GEA), composto por 31 bilíngues simultâneos do Português-Alemão; e Grupo Estudo I (GEI), composto por 26 bilíngues sucessivos do Português-Italiano. Os indivíduos foram submetidos ao Teste Dicótico de Dígitos (TDD) e ao Teste de Escuta Dicótica de Dissílabos (SSW). **Resultados:** No TDD, observou-se diferença no escore da orelha direita e total ao comparar-se o GC e o GEA. Entre o GC e o GEI, observou-se diferença no escore das orelhas direita e esquerda e no total. Comparando-se GEA e GEI, não houve diferença de desempenho entre os grupos. No SSW, ambos os grupos bilíngues apresentaram diferença de desempenho comparados aos monolíngues na análise das orelhas separadamente e no total. Comparando-se GEA e GEI, observou-se vantagem significativa do GEI no escore da orelha direita e total. **Conclusão:** Observou-se influência positiva do bilinguismo na escuta dicótica de dissílabos de alta previsibilidade, avaliada pelo TDD, e de baixa previsibilidade, analisada através do SSW. No SSW, houve vantagem significativa no desempenho dos bilíngues sucessivos do GEI quando comparados aos bilíngues simultâneos.

Study carried out at the Universidade Federal de Santa Maria – UFSM – Santa Maria (RS), Brasil.

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INTRODUCTION

For many years, the bilingualism was seen as harmful to the cognitive, linguistic and educational development of its speakers⁽¹⁾. A new perspective on the learning of two languages, however, was presented as results start being found, which evidence advantages bilingual individuals have over monolingual ones. These benefits relate to verbal and non-verbal abilities, to metalinguistic tasks, cognitive abilities⁽²⁾, inhibitory control^(2,3), memory and attention^(4,5), as well as possible structural, functional, and lateralization brain alterations⁽⁶⁻⁸⁾.

An overview regarding bilingualism in Brazil can be imagined when we become aware of the existence of nearly 200 languages in the country⁽⁹⁾. More specifically in Rio Grande do Sul, in 1940, more than 700 thousand inhabitants would speak German or Italian in their households, instead of the official language of the country, the Portuguese⁽¹⁰⁾. Even today, what we see in the region is that the learning of the language of the immigrants and the Portuguese occur simultaneously, i.e., being exposed to two languages precociously and in different environments. This kind of bilingualism is called simultaneous⁽¹¹⁾.

The learning of a second language cannot be associated solely to family relationships, since in a world each time more globalized and competitive, the knowledge of a second language can be a synonym for economic and social advantages. This way, many are the individuals who choose to learn a second language later in life, after the acquisition of the mother language is fully consolidated. This bilingualism is called successive⁽¹¹⁾.

Once the hearing is shown as the main entrance gateway to stimuli that lead to the acquisition of a language, the relation between this human sense and bilingualism is undeniable, though still not fully understood.

The Auditory Process is conceptualized as the effectiveness and efficiency with which the central nervous system uses the audio information⁽¹²⁾. A series of structures between the cochlea and the auditory cortex compose the complex connections which communicate among each other so the information can be processed and executed correctly, in order to promote the localization and lateralization of the sound, the auditory discrimination, auditory pattern recognition, temporal aspects of hearing, including integration, discrimination, ordering and temporal mask, and the auditory performance in the presence of competitive signals⁽¹²⁾.

The big question raised by the authors is regarding the positive and negative effects that the conflict of information, caused by the exposure to two different language concepts, causes to the development of auditory abilities in bilingual individuals⁽¹³⁾.

Considering the global tendency to multiculturalism, this study justify itself by the need of investigating the processes by which bilingual individuals are exposed to different linguistic systems. The objective was to evaluate and compare the performance of normal-hearing monolingual adult individuals who speak Portuguese, simultaneous bilinguals of Portuguese–German and successive bilinguals of Portuguese–Italian in disyllabic dichotic tasks (Dichotic Digits Test [DDT] and Alternate Disyllable Dichotic Test [SSW]).

Please check and confirm whether the abbreviation SSW ‘Staggered Spontaneous Words’ should be defined here.

MÉTODOS

This research is the result of a subproject within a bigger project entitled “Hearing Disorders: assessment and intervention,” registered in the Chamber of Projects under No. 032630, and previously approved by the Ethics in Research Committee, Universidade Federal de Santa Maria, certificate No. 05765712.3.0000.5346. All individuals involved in the study have signed the Informed Consent form.

It is a quantitative research, of descriptive observational cross-sectional character, carried out at the Clinic of Audiology, Speech and Hearing Pathology Service of the institution. Data collection was conducted from April to June 2012.

For this study, three groups were created, following the inclusion criteria: being between 18 and 59 years age, presenting normal hearing and having concluded High School.

As differential inclusion criteria to be part of the Control Group (CG), the subjects should be monolingual speakers of Brazilian Portuguese, with no fluency in speech and comprehension of any other language whatsoever. The subjects in Study Group A (SGA) should be bilingual, speakers of Portuguese as mother language and German as a second language, acquired before 6 years of age, and the Study Group I (SGI) should be bilingual, speakers of Brazilian Portuguese as mother language and of Italian as a second language, acquired after 6 years of age.

The concept of age as a determining factor for the learning of a second language is controversial. In the current literature on the subject, references to the various critical periods may be found, each based on a specific component of language; thus, our focusing on the age of 6 years for the acquisition of a second language was related to phonology, which establishes the age of 6 years as the approximate critical period for phonological development⁽¹⁴⁾, decisive factor do decide the age criteria of this study.

Also, the choice of German and Italian speakers and of the established ages to compose the group was determined based on the reality of the region and on the participants interested in taking part on the research. There was no demand for bilingual participants, speakers of Portuguese and German, who would have acquired both languages successively. It was the same for Portuguese-Italian speakers, of simultaneous acquisition of the languages, which would allow sample composition with only one kind of bilingual acquisition. Due to this fact and for further enrichment of the study, we chose to classify them into simultaneous bilinguals or successive ones, according to the exposed criteria.

The adopted exclusion criteria was: presence of evident neurological alterations, alterations observed during visual inspection of the external auditory canal or in audiological tests and being bilingual or multilingual, in the case of CG, or not being proficient in the second language, for the participants of SGA and SGI.

Considering the criteria adopted, groups were divided as follows:

- CG: 30 participants of both gender, monolingual speakers of Brazilian Portuguese (mother language).
- SGA: 31 participants of both the genders, bilingual speakers of Brazilian Portuguese (mother language) and German (second language), acquired before 6 years of age.
- SGI: 26 participants of both gender, bilingual speakers of Brazilian Portuguese (mother language) and Italian (second language), acquired after 6 years of age.

It is emphasized that the criteria for determining bilingual and monolingual individuals was based on the answers to the bilingualism protocol, which explored the knowledge of other languages other than Portuguese.

First, the participants were submitted to the anamnesis, seeking for information about personal data, education level, otological background and hearing complaints, and after that, answered the bilingualism protocol, containing information related to the acquisition of their first and second languages. Afterwards, the participants went through a visual inspection of the external auditory canal and the obtaining of their hearing thresholds from 500 to 8,000 Hz, the speech recognition threshold and the percentage index of the speech recognition.

Procedures were conducted in soundproof cabin with the two-channel digital audiometer, *FonixHearingEvaluator* brand, model FA 12 type I and TDH-39P earphones, from *Telephonics*.

Those who presented tritone average (500, 1,000 and 2,000 Hz) lower or equal to 25 dBHL (decibel hearing level) were considered normal-hearing individuals⁽¹⁵⁾.

Hearing processing tests, Alternate Disyllabic Dichotic Test and Dichotic Digits Test

Next, the hearing processing tests were applied: DDT and SSW. The tests were performed using a digital Toshiba-4149 *Compact Disc Player* connected to the audiometer with the CD version of the *Central Hearing Processing* evaluation manual⁽¹⁶⁾. The DDT objective is to evaluate the ability to group components of the acoustic signal in figure-ground and identify them, i.e., name them.

During implementation, the listener should report the information presented to both ears and at the same time, covering the process of binaural integration.

The test was presented at 50 dBHL, having as reference the average of pure tone thresholds at 0.5, 1, and 2 kHz. The list of digits used in the test⁽¹⁶⁾ was formed by the digits 4, 5, 7, 8, and 9 selected among digits from 1 to 9, which form disyllable words in Portuguese. These numbers were combined two by two, eliminating the equal ones. The order of the pairs was random and formed List 1, with 20 pairs of digits. This list was presented to one of the ears. List 2, which was presented to the other ear, simultaneously to List 1, i.e., was elaborated from the combination of the same pairs of digits, but so that each pair was combined with a different pair of List 1. This way, two pairs of digits were presented at a time, one for each ear. The number of mistakes was recorded separately for each ear.

The dichotic hearing test SSW was adapted to the Brazilian Portuguese⁽¹⁷⁾ and it assesses the memory hearing abilities to sounds in sequence and figure-ground to non-verbal sounds.

The test consists of 40 items and each of them formed by four disyllable paroxytone, in a total of 160 words. In each item, there is a presentation of two words in each ear, with a partial overlap, i.e., the second syllable of the second Word and the first syllable of the third are sent simultaneously to both — opposite — ears. Previously, the participants received the following instruction: “You will hear two words in each ear. Wait until all of them are said and then repeat them in the same order you heard them”. The presenting of each item was preceded by the introductory sentence “pay attention”, providing this way a clue on which ear would start the test. Before the beginning of the test, there was a training phase with the presentation of the first three items so that individuals understand the task which should be performed.

The 160 words were analyzed separately and together. Each one of the words is individually considered as right or wrong. Are considered mistakes: omission, substitution or distortion of the words.

The assessing of the results was performed in a quantitative way, related to the hearing condition and hearing abilities of figure-ground to non-verbal sounds, this being performed through the analysis of total and by ear.

Data analysis

Finally, a descriptive and statistical analysis of the data was made, through the software Statistica 9.0. A 95% confidence level was adopted ($p < 0.05$).

Considering the abnormal distribution of the analyzed variables, the statistical test U of Mann–Whitney was used to compare the results obtained in each different group.

RESULTS

In Table 1, the descriptive measures and the comparative tests of CG, SGA, and SGI in DDT are presented.

In Table 2, the descriptive measures and the comparative tests of CG, SGA, and SGI in SSW test are presented.

It was observed a significant difference in the right ear score and in the total score between monolingual and bilingual speakers of Portuguese and German in the DDT hearing tasks, and bilinguals showed better results.

Between Portuguese-Italian speakers, as to monolingual and bilingual performance in DDT hearing tasks, a significant difference was observed between the right and the left ears scores, both separately and total. In this case too bilinguals presented better results.

No significant difference was observed when comparing the performance of SGA and SGI individuals as to their right ear ($p = 0.118827$), left ear ($p = 0.274771$), and total score ($p = 0.118827$) in DDT.

It was observed a significant difference in the score of the right and left ears separately, and in total, between monolingual

and bilingual Portuguese-German speakers in the hearing tasks of the SSW test. The bilingual group presented better results.

Between the performance of the monolingual and bilingual Portuguese-Italian speakers in hearing tasks of the SSW test, it was observed a significant difference in the scores of right and left ears separately and in total. The bilingual group presented better results.

Table 1. Distribution of individuals in the monolingual Control Group, Portuguese-German bilingual Study Group, Portuguese-Italian bilingual Study Group regarding each ear's and total performance in the listening skills

		Minimum	Maximum	Mean	p-value
Right ear	CG	60	100	90.33	0.034942*
	SGA	85	100	94.52	
Left ear	CG	70	100	92.17	0.068762
	SGA	85	100	96.13	
Total	CG	70	100	91.25	0.017718*
	SGA	87,5	100	95.32	
Right ear	CG	60	100	90.33	0.002845*
	SGL	85	100	96.35	
Left ear	CG	70	100	92.17	0.006544*
	SGL	90	100	97.69	
Total	CG	70	100	91.25	0.000403*
	SGL	90	100	97.02	
Right ear	SGA	85	100	94.52	0.118827
	SGL	85	100	96.35	
Left ear	SGA	85	100	96.13	0.274771
	SGL	90	100	97.69	
Total	SGA	87,5	100	95.32	0.118827
	SGL	90	100	97.02	

U test of Mann-Whitney; *Statistically significant value.

Caption: CG = Monolingual Control Group; SGA, Bilingual Portuguese-German Study Group; SGL, Bilingual Portuguese-Italian Study Group.

Table 2. Distribution of individuals in the monolingual Control Group, Portuguese-German bilingual Study Group and Portuguese-Italian bilingual Study Group regarding the total and each ear'

		Minimum	Maximum	Mean	p-value
Right ear	CG	52.5	100	92.38	0.017006*
	SGA	92.5	100	97.06	
Left ear	CG	65	100	92.79	0.016894*
	SGA	91.25	100	96.33	
Total	CG	58.75	100	92.59	0.013686*
	SGA	93.12	100	96.69	
Right ear	CG	52.5	100	92.38	0.000204*
	SGL	91.25	100	98.22	
Left ear	CG	65	100	92.79	0.001066*
	SGL	90	100	97.16	
Total	CG	58.75	100	92.59	0.000400*
	SGL	90.62	100	97.69	
Right ear	SGA	92.5	100	97.06	0.008134*
	SGL	91.25	100	98.22	
Left ear	SGA	91.25	100	96.33	0.051245
	SGL	90	100	97.16	
Total	SGA	93.12	100	96.69	0.006918*
	SGL	90.62	100	97.69	

U test of Mann-Whitney; *Statistically significant value.

Caption: CG = Monolingual Control Group; SGA, Bilingual Portuguese-German Study Group; SGL, Bilingual Portuguese-Italian Study Group.

When comparing Portuguese-German bilinguals to Portuguese-Italian ones in the hearing tasks of the SSW test, a significant difference was observed in the score of the right ears and in total score. Individuals from SGI presented better results.

DISCUSSION

Since listening and language skills share brain structures and underlying cognitive resources, the association between the central processing of hearing information and the acquisition and development of a language, whether native or not, is implied.

Studies have shown that, even achieving a high proficiency level in the second language, the bilingual individuals present greater difficulty when subjected to tests in their second language^(18,19). Therefore, in this study, the assessment was conducted in Portuguese, native language of all participants.

Regarding the age of acquisition of the second language, studies indicate simultaneous learning as the ideal situation, since this would not cause any disadvantages in the skills of speech perception⁽¹⁹⁾. These theories are based on the so called critical or sensitive periods for the acquisition of a second language, since the greater elasticity children's brains would make them more efficient apprentices⁽¹⁴⁾. Several references to critical periods can be found depending on the language aspect to be considered. In this study, we chose to focus on phonology⁽¹⁴⁾, determining the age of 6 years as the differential age between simultaneous and successive speakers.

In order to evaluate the monolingual, the Portuguese-German simultaneous bilingual and the Portuguese-Italian successive speakers, the so called dichotic tests were selected, once they evaluate the ability of the individual to listen to signals, speech signals in this case, in situations of degraded or competitive stimuli⁽²⁰⁾.

The presentation of speech in dichotic form tends to suppress the ipsilateral pathways inside the central hearing nervous system, being the stimuli conducted by contralateral pathways to reach the areas of the cortex responsible for hearing⁽²¹⁾.

The DDT, first to be conducted aiming at evaluating the listening skill of figure-ground to non-verbal sounds through the binaural integration task.

In dichotic test, when using linguistic stimuli, the right ear may have an advantage, especially children, but this tends to decrease until it reaches adult score⁽²²⁾.

The highest number of correct answers of SGA for the right ear exposed the advantage previously referred by the author, even in adult life, which can be explained by the fact that the second language was acquired before 6 years of age. These results reflect the asymmetry in the function of brain hemispheres, and the left temporal lobe being dominant. Although the findings emphasize the participation of the most important cortical area for the perception of verbal stimuli when assessed the hearing ability of dichotic digits^(7,8), they discredit the authors who affirm early bilinguals would show bilateral hemispheric involvement^(7,8).

The results of the presented study also disagree from the research which analyzed the listening behavior in Standard Frequency and Duration tests and on DDT and SSW, in Japanese descendants speakers of both Portuguese and Japanese; Japanese descendants speakers of Portuguese but not speakers of Japanese) and non-descendants of Orientals and speakers of Portuguese⁽¹³⁾. The study mentioned did not find differences on the mean of correct answers of DDT among the groups, and there was no advantage of the right ear.

In SGI, it was observed a significant advantage by the bilingual individuals over the monolingual ones, both in the performance of the right and left ears separately as in the general evaluation of the required abilities for the DDT, not demonstrating dominance by either hemisphere. These data disagree from the international literature, which has been studying the relation of learning a non-native language, with its anatomical and functional differences in bilingual individuals' brain cortex⁽⁶⁾, since it was pin pointed that the bilateral hemisphere usage would occur in early bilinguals, and late monolingual and bilingual individuals on the other hand would have the predominance of one of the hemispheres^(7,8).

On the other hand, a research which examined both early and late bilinguals with syntactic and semantic tasks, found increased activation of the Broca's area, inferior frontal gyrus, and the right hemisphere of the individual of late acquisition of a second language when assessed in syntax tasks⁽²³⁾. This data meets the results of the study at hand, which verified, besides the usage of the left hemisphere, also the participation of the right one in the proposed task.

Also, from the neurobiological point of view, there is no evidence on the impact of the age of acquisition of a second language in the neutral substrate of bilingual individuals⁽²⁴⁾.

In literature, some aspects are discussed when indicated as possible benefits and disadvantages of the bilingualism, such as the level of proficiency⁽¹⁹⁾ and the age of acquisition of the second language, related to the critical period of learning⁽¹⁴⁾. As was observed, there was no difference when comparing the performance of the SGA and the SGI in DDT, exposing the benefits of bilingualism in the development listening skills, regardless the time of the acquisition of the second language.

The present study agrees both with the pioneer study⁽²⁵⁾ seen as a "watershed" in research area, which evidenced that the bilingual individuals outperform monolinguals on verbal measures, as well as more recent researches which indicates, as a bilingualism advantage, the better control and maintenance of attention when in a situation with conflicting information⁽²⁶⁾, since DDT assesses the ability of figure-ground for verbal sounds.

The SSW is considered a test to evaluate the listening process which requires great demand of linguistic competence and allows evaluating, beyond the ability to figure-ground, the attention and the participant's memory.

In Table 2, we observe that in the skills assessed by the SSW test, bilingual individuals presented better results when

compared to monolingual individuals. This fact was also observed in the previously cited study, with Japanese descendants, in which the group of Japanese descendants, speakers of Brazilian Portuguese and Japanese presented a higher number of correct answers when compared to the remaining groups⁽¹³⁾.

Despite the lack of researches using the SSW test to evaluate bilingual individuals, considering the abilities assessed by them some remarks may be made on the results found.

The use of two languages makes the individual face throughout life occasions with conflicting information and linguistic concepts, resulting in perturbation which allows the improving of the listening abilities involved in the process. One of these abilities is the figure-ground, especially to verbal sounds.

Since the figure-ground task demands the ability to listen to sound, in this case speaking language, among competitive signals, it requires the individual's attention to some sounds and the inhibition of others. About that, researchers claim that cognitive abilities of inhibitory control and attention are much more evident in bilingual individuals⁽²⁷⁾, since they frequently have to select a language to be used in different contexts, leading the brain into paying attention to the chosen system. Besides that, the selection of relevant data requires the activation of the memory to execute the rescue of pre-stored information and, in cases that a task must be performed, as the repetition of words in the case of the DDT, the attention is required once more⁽²⁷⁾. In this process, the three abilities assessed by the SSW are involved.

In accordance to what was previously exposed, a study carried out with monolingual speakers of English and bilingual ones of English and Korean got to the conclusion that bilingual individuals are better able to direct their attention toward the relevant information and to ignore the irrelevant ones, knowing that this fact caused a positive impact in the work memory of the individuals⁽²⁶⁾. Another research taken place in the South of Brazil⁽²⁾ also found difference in the test used to assess attention, inhibitory control and work memory in favor of the bilingual sample. In addition to this one, there are other studies which meet the results found in this research, as they point to a better performance of bilingual individuals in tasks of attention and work memory^(4,5).

When comparing the two bilingual groups, it is possible to identify that the SGI, that learned the second language after 6 years of age, presented better results, statistically significant (right ear and total) and with significant tendency (left ear) than the SGA, which went through simultaneous learning process. This data disagrees with the authors who defend the existence of critical periods of learning⁽¹⁴⁾ and who claim that the earlier a second language is acquired the lesser are the disadvantages in speech perception⁽¹⁹⁾. This idea is based on the statement of neuroscientist on children being more efficient learners than adults⁽¹⁴⁾.

In the same direction of the findings in the SSW test in this study, there are, already, contradictions regarding the critical periods of learning a second language due to the elevated

number of successive bilingual individuals reach similar performance level of a native speaker in the second language⁽²⁸⁾. This performance can be the result of cognitive experience, imitation capacity, adult expressions and motivation, which many times lacks in children⁽¹¹⁾. Added to that, studies point to successive bilingual advantages when compared to simultaneous bilinguals in inhibitory control tasks^(2,3) and minutiae of speech perception⁽²⁹⁾.

In short, the findings of this study demonstrate that bilingual individuals presented superior results in speech recognition tests in relation to the monolingual group, regardless the acquisition of the language being simultaneous or successive. The abilities of the hearing process were statistically better, as observed in the presented results.

The difference in results found among the tests can be explained by the fact that both stimulate the same results, but present different demand levels. The DDT, classified as a high predictability test, has a smaller linguistic burden, it is considered easier and it does not demand so much from the listening memory. As the presented numbers repeat themselves, there is a higher number of ways to the evaluated individual. On the other hand, the SSW, of low predictability, has a greater linguistic burden, demands much from memory, the attention level must be higher and the sorting is more required, being considered more difficult test.

It is noteworthy that there is the need of other studies focused in this area, making use of the same tests and also analyzing the other abilities, so that more broadening discussions on the theme are possible, which will be able to contribute even more to the evident benefits of bilingualism.

CONCLUSION

The results obtained in this study indicate that the bisyllable dichotic hearing of high predictability, evaluated by the DDT, is influenced by bilingualism, since there is a difference in the scores of both bilingual groups, with better results in simultaneous and successive groups, when compared to monolingual ones.

The same way, the results of the SSW test point differences in the scores of bilingual groups when compared to monolingual ones, making evident the positive effect of bilingualism on low predictability disyllable dichotic hearing. In this test, the results indicated yet a difference in performance by the successive bilingual individuals of the SGI when compared to the simultaneous bilingual individuals from the SGA. The SGI had better results.

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