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Auditory skills of figure-ground and closure in air traffic controllers

Habilidades auditivas de figura-fundo e fechamento em controladores de tráfego aéreo

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Keywords

Hearing
Auditory Perception
Hearing Tests
Burnout Professional
Air Traffic Controllers

ABSTRACT

Purpose: To investigate the auditory skills of closure and figure-ground and factors associated with health, communication, and attention in air traffic controllers, and compare these variables with those of other civil and military servants. **Methods:** Study participants were sixty adults with normal audiometric thresholds divided into two groups matched for age and gender: study group (SG), comprising 30 air traffic controllers and control group (CG), composed of 30 other military and civil servants. All participants were asked a number of questions regarding their health, communication, and attention, and underwent the Speech-in-Noise Test (SIN) to assess their closure skills and the Synthetic Sentence Identification Test - Ipsilateral Competitive Message (SSI-ICM) in monotic listening to evaluate their figure-ground abilities. Data were compared using nonparametric statistical tests and logistic regression analysis. **Results:** More individuals in the SG reported fatigue and/or burnout and work-related stress and showed better performance than that of individuals in the CG for the figure-ground ability. Both groups performed similarly and satisfactorily in the other hearing tests. The odds ratio for participants belonging in the SG was 5.59 and 1.24 times regarding work-related stress and SSI-ICM (right ear), respectively. **Conclusion:** Results for the variables auditory closure, self-reported health, attention, and communication were similar in both groups. The SG presented significantly better performance in auditory figure-ground compared with that of the CG. Self-reported stress and right-ear SSI-ICM were significant predictors of individuals belonging to the SG.

Descritores

Audição
Percepção Auditiva
Testes Auditivos
Esgotamento Profissional
Controladores de Tráfego Aéreo

RESUMO

Objetivo: Investigar o perfil das habilidades auditivas de fechamento e figura-fundo e fatores relacionados à atenção, comunicação e saúde de controladores de tráfego aéreo de aproximação de aeronaves e comparar com os de outros profissionais civis e militares. **Método:** Participaram 60 adultos com limiares audiométricos normais reunidos em dois grupos, pareados por idade e gênero: o grupo estudo formado por 30 profissionais do Controle de Aproximação de aeronaves e o controle, por 30 outros servidores civis e militares. Todos foram submetidos a perguntas relacionadas à atenção, comunicação e saúde e ao Teste de Fala com Ruído e de Identificação de Sentenças Sintéticas em escuta monótica (SSI) para avaliar fechamento e figura-fundo, respectivamente. Foram usados testes estatísticos não paramétricos e análise de regressão logística. **Resultados:** O CTA autorreferiu maior cansaço/esgotamento e estresse e obteve melhor desempenho do que o grupo controle em figura-fundo e semelhante em fechamento. Foi observado que ocorreu uma probabilidade de ser CTA para o estresse em 5,59 vezes e para identificação de sentenças em escuta monótica à orelha direita de 1,24. **Conclusão:** Fechamento e autorrelato de dificuldades de saúde, comunicação e atenção na maioria das questões foram similares em ambos os grupos. Figura-fundo foi significativamente melhor em CTA. Autorreferência de estresse e desempenho à orelha direita no SSI foram preditores significantes do indivíduo ser do CTA.

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INTRODUCTION

Aircrafts have their trajectory controlled by Air Traffic Controllers (ATC) from flight departure to arrival. These professionals work in groups at different air traffic control units: Tower (TWR), Approach Control (APP), and Area Control Center (ACC). ATCs who work in the TWR are responsible for the aircraft until they lose visual contact with it; those who work in the APP are in charge of directing the airplane in its intermediate trajectory, regarding takeoff and landing; and those who work in the ACC are responsible for the direction of the aircraft for most of the flight(1).

According to Villar et al.(1), ATCs at the APP ensure that a minimum distance is maintained between aircrafts when they are close to the airports under their command; to this end, they indicate by radiofrequency the coordinates (headings), speed, and altitude that the pilot should adopt to fly with maximum safety in order to avoid collisions. This is a very delicate task, and it requires special attention from these controllers because, in addition to providing the final orientation for landing, they must separate the aircrafts that are landing from those that are taking off. Thus, their actions determine the success and safety of flight displacements(1).

The work environment of ATCs is surrounded by noise, both from communication with the pilots (radio frequency chirping and/or unauthorized radio interference) and with their colleagues, considering that the work sectors are arranged side by side. Therefore, these workers need to make use of compensatory strategies(2), by means of auditory skills such as figure-ground and closure, so that the crew can conduct the flight safely.

These auditory skills are part of a physiological mechanism of auditory processing called Selective Attention. In 1997, Pereira(3) defined Auditory Processing as a series of processes that succeed each other over time, allowing individuals to perform a metacognitive analysis of sound events, such as detection, discrimination and localization of sounds, sequential memory of sounds, and selective attention.

The specific scientific literature presents several studies(2,4-7) on the influence of stress on ATCs. It is known that stress results from the environment-individual interaction, and that there is an association between auditory processing disorders and stress(8).

The air traffic control activity is considered to be complex; it reflects a particularized perception built on a daily basis and requires intellectual agility, reasoning speed, and resistance to stress(7), considering that mistakes can lead to catastrophic consequences. Therefore, knowing the auditory skills of these professionals and comparing them with those of other civil and military servants can reveal a differentiated performance, in addition to assisting with the training of these abilities in individuals with auditory processing disorders.

The present study aims to investigate the auditory skills of closure and figure-ground and factors associated with health, communication, and attention in air traffic controllers, and compare these variables with those of other civil and military servants.

METHODS

This study was approved by the “Destacamento de Controle do Espaço Aéreo de São Paulo – DTCEA-SP” and the Research Ethics Committee of the aforementioned Institution (no. 1.031.282; April 22, 2015). All study participants signed in Informed Consent Form (ICF) prior to study commencement. The samples were collected between May and July, 2015.

Study participants were 60 adult volunteers aged 21-44 years. The groups were paired according to gender - each group comprised 16 male individuals (53.3%), and age - mean age of 26.87 years.

These participants were divided into groups of 30 individuals. The study group (SG) was composed of military professional servants allocated to the Approach Control (APP-SP), responsible for directing aircrafts in their intermediate trajectory, regarding takeoff and landing, in the function of Air Traffic Controllers - hereinafter referred to as ATCs.

The control group (CG), whose participants were paired according to age and gender to those of the SG, was composed of other civil or military servants. This group comprised professionals from other areas, namely, two business administrators, two lawyers, three speech-language pathologists, three aircraft mechanics, 10 management technicians, five electronic technicians, and three communication technicians.

Exclusion criteria for both groups were as follows: present hearing thresholds outside the normal range, i.e., above 25 dB HL(9); be on vacation or on leave due to health problems. It is worth mentioning that the use of medications and the presence of auditory inabilities in the behavioral assessment of auditory processing were not exclusion criteria.

Participants in both groups had at least 12 years of schooling, that is, complete High School. Seventeen individuals (28.33%) in the sample had College degrees or graduate studies. Regarding the socioeconomic level of the sample, according to the classification of the Brazilian Association of Research Companies – ABEP(10), 10 individuals (16.66%) were C1 or higher, which represents an estimated mean household income of R$ 2.705,00 and 11 individuals (18.33%) were B1 or lower, equivalent to a monthly income of R$ 9,254.00.

All participants were submitted to meatoscopy, pure-tone audiometry, and measurement of the Speech Recognition Percentage Index (SRPI) with recording of stimuli(3,11), which are clinical procedures routinely used to discard hearing loss.

A questionnaire prepared by the study researchers was applied to the participants of both groups. It included questions about life history, difficulty in hearing and/or understanding speech, use of medication, and 10 other issues related to attention, communication, and health (Chart 1). These questions addressed fatigue and/or burnout (question 1), difficulty sleeping (2), restlessness (3), difficulty concentrating (4), presence of work-related stress (5), dizziness (6), visual (7) and respiratory problems (8), caffeine consumption (9), and use of earphones (10). Participants in the SG also responded to questions about their working hours, presence of difficulty in

Chart 1. Questionnaire prepared for this study

Q1	Do you feel tired and/or exhausted?
Q2	Do you have trouble sleeping?
Q3	Do you tend to be restless?
Q4	Do you find it hard to focus on something or get distracted easily?
Q5	Do you find your job stressful?
Q6	Do you feel dizzy?
Q7	Do you have eye problems?
Q8	Do you have any respiratory problems (rhinitis, sinusitis, bronchitis, etc.)?
Q9	Do you ingest caffeine (coffee, coca cola derivatives, etc.)?
Q10	Do you use earphones?

learning their professional activity, and presence of a concurrent professional activity.

Auditory processing was assessed through the application of the following behavioral tests[3,11]: Speech-in-noise Test (SIN), for the physiological mechanisms of low redundancy speech recognition; Synthetic Sentence Identification Test - Ipsilateral Competitive Message (SSI-ICM), for speech recognition in monotic listening. These tests present reference normality values available along with the recordings of the stimuli[11].

As a means of standardization, application of the SIN and SSI-ICM tests began on the right ear.

The Speech-in-noise Test (SIN)[3,11,12] consisted of presenting a list of 25 words in the presence of ipsilateral competitive background noise, in a relation of [+5] between the sound levels in decibel sound pressure level (dB SPL). Volunteers were asked to verbally repeat the word heard. Percentages of correct responses per ear were analyzed. The skill assessed is called auditory closure.

The Synthetic Sentence Identification Test - Ipsilateral Competitive Message (SSI-ICM)[3,11,13] consisted in the presentation of 10 sentences inserted in ipsilateral competitive message in a relation of [0] between the sound levels to provide instruction by demonstration and of [-15] for assessment. Volunteers were asked to identify the sentence heard from a table of written sentences and ignore the story in the competitive message. Percentages of correct responses per ear were analyzed. The skill assessed is called auditory figure-ground in monotic listening.

The procedures were conducted at the beginning of the ATCs' work activity, or at the latest within two hours from the start, in order to avoid assessment at the end of the work shift because of the greater presence of stress on these professionals, as demonstrated by Lima et al.[5].

Meatoscopy was performed using a Heine - Mini 3000 otoscope. Pure-tone audiometry and measurement of the Speech Recognition Percentage Index (SRPI) were conducted using a single-channel, portable AS-70 audiometer (Auditec). The auditory processing assessment tests were performed using a dual-channel, portable PAC-200 audiometer (Auditec), with recording of the stimuli[11], which were presented using a TDH39 headset.

Data collection was conducted in a quiet room at the "Serviço Regional de Proteção ao Voo de São Paulo (SRPV-SP)", a unit of the Brazilian Air Force where the Approach Control - APP-SP is located; this is the Air Traffic Control unit with the largest aircraft flow in Brazil[14], and the workplace of the ATCs and other military servants who participated in this study.

Statistical analysis was performed with the application of nonparametric tests. The Mann-Whitney test was used to compare performance in the auditory tests considering the Group variable, whereas the Wilcoxon signed-rank test was applied to compare performance according to the Ear variable. For comparison between the groups, considering the responses given to the 10 questions in the questionnaire, the Mann-Whitney test was once again used. The Spearman correlation test was applied to verify the existence of correlation between length of service as ATC and performance in the auditory processing tests. The Cronbach's alpha test was used in the analysis of the internal consistency and reliability of the questionnaire[15]. All statistical analyses were processed using the IBM SPSS Statistics 22.0 software.

In order to understand the individual differences and Odds Ratio, that is, the probability of an individual belonging to a particular group, logistic regression analysis was conducted with Group as a dependent variable, and the questions with statistical significance (step 1) and the measures of the auditory tests that evaluated auditory processing (step 2) as control variables. The IBM SPSS Statistics 20 software was used to process this measurement.

A level of significance of 5% ($p \leq 0.05$) was adopted for all statistical analyses. Statistically significant values were marked with an asterisk.

RESULTS

With respect to the use of medication, 13.33% of the individuals in the study group (SG) make use of controlled drugs, whereas the same percentage of individuals in the control group (CG) use continuous medication for hypertension, hypothyroidism, and diabetes. In the SG, 3.33% of the sample reported difficulty in hearing, whereas 6.66% of the participants in the CG reported the same complaint. Difficulty in understanding speech in noise was reported by 20% of the individuals in both groups. As for difficulty in understanding speech during group conversations, 20 and 23.33% of the participants in the SG and CG reported this complaint, respectively.

The Cronbach's alpha test showed an internal consistency index of 0.722 in the questionnaire created for the present study, which is considered satisfactory[16]. It is worth highlighting two questions that differentiated the groups (Table 1). One question concerns the presence of fatigue and/or burnout (question 1 - Q1). A total of 86.7% of positive responses were verified in the SG, whereas 60% of positive responses were observed in the CG, with statistically significant difference (p=0.004). The other question that drew attention is the positive opinion regarding presence of work-related stress (Q5). In the SG, 93.4% of positive responses were observed, whereas occurrence of 53.3% was found in the CG, with statistically significant difference (p<0.001). The questions that sought to verify the occurrence of difficulties in sleeping, restlessness, difficulty concentrating, occurrence of dizziness, visual and respiratory problems, caffeine consumption, and use of earphones did not present significant differences between the groups in the present study.

Logistic regression analysis indicated that the questionnaire was a good predictor of individuals belonging to a group ($\chi^2_{(6)}$ = 3.391; p=0.758; R^2=0.446), but only question 5 (positive opinion regarding the presence of work-related stress) was considered a significant predictor (Odds Ratio= 5.59; CI= 2.26-13.86; p<0.001) (step 1).

Comparative analysis in the same group for the same test between the ears showed statistically significant difference in the measurement of the SRPI for both groups (p-values of 0.023 and 0.001 in the SG and CG, respectively) (Table 2). Thus, analysis between groups was performed separately per ear (Table 3).

Comparison of performance by test separately per ear between the groups (Table 3; Figure 1) showed statistically significant difference in the SSI-ICM test for both the right (p<0.001) and left (p=0.001) ears. No statistically significant differences in performance were observed in the SRPI and SIN tests (Table 3). This table shows minimum values below reference normality for the SSI-ICM test. This occurred because three individuals (10%) in the CG presented poor performance in this test: one individual presented alteration at the left ear and two individuals showed changes at right ear.

The combination of questions 1 and 5 with performance in auditory processing tasks were even better predictors of individuals belonging to a group ($\chi^2_{(8)}$=4.818; p=0.777; R^2=0.647). Question 5 continued to be a significant group predictor (Odds Ratio=13.54; CI=1.75-104.43) and performance at the right ear was the only significant auditory processing measure to predict the groups (Odds Ratio=1.24; CI=1.01-1.5; p<0.001) (step 2).

In order to verify the results of the sample without the three individuals who presented auditory inabilities, statistical calculations were performed based on a sample of 57 individuals divided into two groups: Reduced CG, with 27 individuals, and SG, with 30 individuals (Table 4; Figure 2).

Table 1. Descriptive analysis of the questions with their variables separated by group and *p*-value for comparison

Variable (Question)	Group	% of "Never" responses	% of "Seldom" responses	% of "Sometimes" responses	% of "Usually" responses	% of "Always" responses	*p*-value** SG x CG
Q1	SG	0	13.3	53.4	23.3	10.0	0.004*
	CG	13.3	26.7	50.0	6.7	3.3	
Q2	SG	26.7	23.3	20.0	13.3	16.7	0.236
	CG	26.7	43.3	16.7	6.7	6.6	
Q3	SG	3.3	26.7	46.7	13.3	10.0	0.425
	CG	10.0	30.0	40.0	10.0	10.0	
Q4	SG	10.0	36.7	36.7	10.0	6.6	0.527
	CG	3.3	33.3	50.0	6.7	6.7	
Q5	SG	0	6.6	16.7	30.0	46.7	< 0.001*
	CG	16.7	30.0	43.3	10.0	0	
Q6	SG	60.0	30.0	3.3	3.3	3.4	0.782
	CG	56.7	30.0	10.0	3.3	0	
Q7	SG	53.3	20.0	10.0	6.7	10.0	0.873
	CG	46.7	30.0	13.3	3.3	6.7	
Q8	SG	33.4	20.0	23.3	20.0	3.3	0.951
	CG	40.0	13.3	16.7	20.0	10.0	
Q9	SG	0	10.0	16.7	40.0	33.3	0.951
	CG	0	23.3	23.3	30.0	23.4	
Q10	SG	3.3	33.4	20.0	30.0	13.3	0.830
	CG	10.0	33.4	13.3	23.3	20.0	

*Statistically significant at 5% probability; **Mann-Whitney test
Caption: Q = question; SG = study group; CG = control group

Table 2. Results of the comparison between ears tested for the study and control groups

Variable compared		*p*-value** RE X LE
SRPI	SG	0.023*
	CG	0.001*
SIN	SG	0.267
	CG	0.057
SSI-ICM	SG	0.412
	CG	0.129

*Statistically significant at 5% probability; **Mann-Whitney test
Caption: SG = study group; CG = control group; RE = Right Ear; LE = Left Ear; SRPI = Speech Recognition Percentage Index; SIN = Speech-in-noise Test; SSI-ICM = Synthetic Sentence Identification Test - Ipsilateral Competitive Message

Statistically significant differences were found between the groups in the SSI-ICM test at the right and left ears.

In the SG, 40% of the volunteers reported difficulty in learning their professional activity because of distortion in the speech of pilots caused by radiofrequency chirping and difficulty concentrating amid the noises of the work environment. Among these professionals, 10% have a concurrent professional activity - they all teach to supplement the family income. The length of service as ATC varied from six months to 23 years, with mean time of six years. No statistically significant correlation was observed between length of service as CTA and performance in any of the auditory tests.

Table 3. Descriptive statistical analysis of the hearing tests according to performance per ear and *p*-value of comparison between the study and control groups (n = 60)

Variable	Group	Median	Moda	Minimum	Maximum	CI (95%)	*p*-value** SG X CG
SRPI at RE	SG	92.00	92.00	88.00	100.00	91.47-93.60	0.554
	CG	92.00	92.00	84.00	100.00	90.53-93.20	
SRPI at LE	SG	96.00	96.00	88.00	100.00	93.07-95.07	0.693
	CG	96.00	96.00	88.00	100.00	93.60-95.47	
SIN at RE	SG	90.00	92.00	80.00	96.00	86.53-90.40	0.988
	CG	88.00	88.00	80.00	100.00	86.93-90.40	
SIN at LE	SG	90.00	92.00	80.00	100.00	88.00-91.07	0.281
	CG	92.00	96.00	76.00	100.00	88.53-92.40	
SSI-ICM at RE	SG	90.00	90.00	70.00	100.00	84.33-89.00	< 0.001*
	CG	80.00	80.00	50.00	90.00	70.67-78.67	
SSI-ICM at LE	SG	90.00	90.00	70.00	100.00	86.00-90.00	0.001*
	CG	80.00	90.00	50.00	100.00	73.33-82.33	

*Statistically significant at 5% probability; **Mann-Whitney test
Caption: SG = study group; CG = control group; RE = Right Ear; LE = Left Ear; SRPI = Speech Recognition Percentage Index; SIN = Speech-in-noise Test; SSI-ICM = Synthetic Sentence Identification Test - Ipsilateral Competitive Message

Table 4. Descriptive statistical analysis of the hearing tests according to performance per ear and *p*-value of comparison between the study and reduced control groups (n = 57)

Test	Group	Mean	SD	Median	Minimum	Maximum	*p*-value**	Effect size (r)
SRPI at RE	CG	92.00 (90.52-93.48)	4.00 (2.94-4.83)	92.00 (92.00-96.00)	84.00	100	0.704	-
	SG	92.53 (91.47-93.60)	3.10 (2.33-3.75)	92.00 (92.00-92.00)	88.00	100		
SRPI at LE	CG	94.81 (93.63-96.00)	2.90 (1.86-3.65)	96.00 (96.00-96.00)	88.00	100	0.437	-
	SG	94.13 (92.93-95.33)	3.28 (2.39-3.95)	96.00 (92.00-96.00)	88.00	100		
SIN at RE	CG	89.04 (86.81-91.26)	5.93 (4.65-6.85)	88.00 (84.00-92.00)	80.00	100	0.786	-
	SG	88.53 (86.53-90.53)	5.82 (4.72-6.51)	90.00 (84.00-92.00)	80.00	96		
SIN at LE	CG	91.85 (90.07-93.48)	4.64 (3.39-5.75)	92.00 (88.00-96.00)	80.00	100	0.058#	0.251
	SG	89.60 (88.00-91.20)	4.53 (3.40-5.49)	90.00 (88.00-92.00)	80.00	100		
SSI-ICM at RE	CG	76.30 (72.22-80.00)	10.80 (8.59-12.28)	80.00 (70.00-80.00)	60.00	90.00	< 0.001*	0.475
	SG	86.67 (84.00-89.33)	7.11 (5.31-8.61)	90.00 (80.00-90.00)	70.00	100		
SSI-ICM at LE	CG	80.00 (75.19-84.07)	11.77 (8.92-13.60)	80.00 (70.00-90.00)	60.00	100	0.005*	0.369
	SG	88.00 (85.67-90.00)	6.10 (4.03-7.94)	90.00 (80.00-90.00)	70.00	100		

*Statistically significant at 5% probability; **Mann-Whitney test
Caption: SG = study group; CG = control group; RE = Right Ear; LE = Left Ear; SRPI= Speech Recognition Percentage Index; SIN = Speech-in-noise Test; SSI-ICM = Synthetic Sentence Identification Test - Ipsilateral Competitive Message

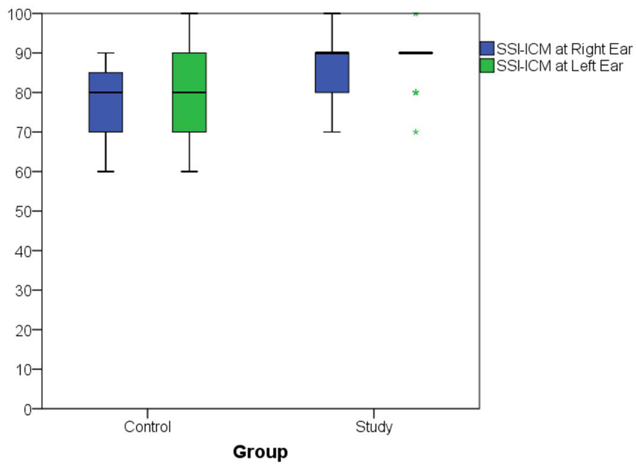

Figure 1. Box-plot diagram of correct responses (%) in the SSI-ICM test for the control and study groups (n = 60)

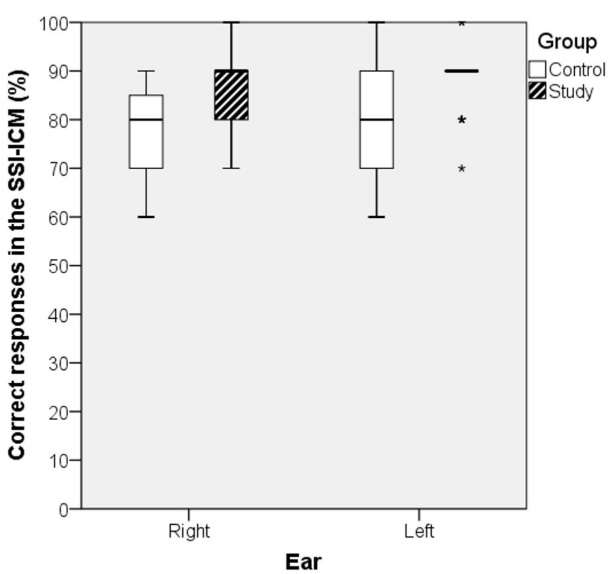

Figure 2. Box-plot diagram of correct responses (%) in the SSI-ICM test per ear for the control and reduced study groups (n = 57)

DISCUSSION

It is worth mentioning that care was taken when forming the control group (CG) to match the sample for gender and age to that of the study group (SG). In this study, auditory inabilities could occur in the constitution of the sample investigated considering that we sought to identify individual differences in the performance of the selected procedures.

The occupation of ATC is not regulated in Brazil(17), and this fact can generate governmental inattention with this professional class, which is essential for aviation. Studies assessing the auditory processing of ATCs who work at Approach Control (APP) are scarce in the literature.

A fact that motivated the realization of this study was that 40% of the individuals in the SG reported difficulty in understanding the speech of pilots because of noises in the transmission by radiofrequency and in directing attention to only one speaker. These difficulties were reported at the beginning of their careers, but decreased after some time of professional exercise. Thus, a hypothesis was raised regarding adjustment in auditory-verbal communication, suggesting improvement in the auditory skills of these professionals. In their work environment, ATCs make constant use of their listening skills for verbal communication with aircraft pilots through radio frequency as well as with their colleagues in their workplace, sometimes simultaneously.

Participants in the SG are 26.87 years old on average, and they represent a new population of ATCs, which is becoming increasingly young[18].

One out of 10 individuals in the SG has a concurrent professional activity. Other studies[2,4] have also reported presence of double working shifts with the aim to circumvent the low wages received by this professional class; however, this can have harmful consequences, such as increased fatigue and/or burnout[2]. Still in search of other activities, 83.33% of the ATCs who participated in this study are either attending tertiary courses or have college degrees, a fact also observed by Motter et al.[7]. Fatigue, burnout, and stress can negatively influence the individual's attention span[5].

The combination of factors such as work overload, difficult work schedules, low pay, and lack of valorization, recognition, and career plan, contributes to the high level of avoidance[18]. One year after data collection of the present study, 10% of the ATCs included in the SG no longer exercised this professional activity.

The groups differed significantly with respect to self-report of fatigue and/or burnout (Q1) and stress (Q5) caused by work, with a larger number of participants in the SG more affected by these factors (p=0.004 and p<0.001, for Q1 and Q5, respectively) (Chart 1; Table 1).

Logistic regression analysis applied to these two questions verified that both were predictors of an individual belonging to the SG, but only Q5 was statistically significant. Thus, self-report of the presence of work-related stress increases by 5.59 times the chance of an individual belonging to the SG.

A few studies have also correlated these professionals with high levels of stress[2,4-7]. Martinussen and Richardsen[19] did not observe this fact. Nevertheless, it is worth noting that this variation of results can be explained by differences in population, because the workload can vary significantly among ATCs and is directly dependent on the level of control performed (TWR, APP, or ACC) and on the aircraft flow at the workplace.

Considering that the SRPI presented difference in performance between ears for both groups (Table 2), a comparative study between the groups was conducted separately per ear (Table 3). In the SG, performance in the SRPI was better at the left ear (LE) (median of 96% of correct responses) than at the right ear (RE) (median of 92% of correct answers), with variation from 88 to 100%. These values are considered within reference normality[11], indicating good ability to follow conversation in an ideal acoustic environment, that is, silent and non-reverberant. No statistically significant differences for the Ear variable in the SG were found in the other auditory tests (Table 2).

In the CG, statistically significant difference between ears was observed only in the SRPI measurement (Table 2), in which performance at the LE varied from 88 to 100% of correct responses whereas performance at the RE ranged between 84 and 100%. It is believed that the better performance observed at the LE occurred because of a possible inattention effect, considering that the audiometric thresholds for both ears were considered within normality[9].

In the comparison between groups, the SSI-ICM test stood out among the other selected tests (SRPI and SIN) (Tables 3 and 4). According to the specific scientific literature[20,21], the SNI-ICM test indicates task sensitivity for infratentorial functions. In addition, the correlation between the results of the SSI-ICM (monotic listening) and the functioning of the cerebellum is well known[22]. This functioning was altered in elderly individuals who reported good hearing skills[23], as well as in adults with auditory processing disorders[24].

It is worth noting that performance in the SSI-ICM test was worse than in the other tests, and with greater variability for both groups. The SG showed the best results - with approximately 10% more correct responses - and the smallest variability compared with that of the CG, which presented three individuals with auditory inabilities (Table 3). The vast majority of the findings in the sample are compatible with the baseline normality[11]. It is noteworthy that, even after exclusion of the individuals with values below reference normality in the SSI-ICM test, the SG and the Reduced CG differ statistically between the ears tested (Table 4).

In the behavioral tests, logistic regression analysis indicated performance at the RE in the SSI-ICM test as the only significant measure of auditory processing, because a one-unit increase in this test increases by 1.24 times the chance of an individual belonging to the SG. This type of statistical analysis assists with perceiving the probability of an event to occur as a function of other factors.

Further studies are needed to clarify these occurrences with respect to the auditory perception of speech in monotic listening in this population of ATCs.

Plasticity of the auditory cortex occurs through the functional reorganization of nerve cells from an environmental stimulus[25], in this case, the professional activity. The result of this indirect auditory training in ATCs is in agreement with those of recent studies[26,27].

It is known that variation in work shifts with consequent deregulation of work and sleep periods can interfere with the attention and alertness of ATCs, as reported in other studies[6,7]. However, the performance of these workers in the auditory processing assessment did not show attention disturbance (focus). This probably occurred because care was taken to perform auditory processing assessment at the beginning of the ATCs' work shift.

In addition to this irregularity of work schedule, the air traffic control activity is dynamic and requires high level of attention, and is considered stressful[2,4-7]. Although there is an association between auditory processing disorders and stress[8], this issue was not evidenced in the present study. It is believed that the performance of the ATCs in the applied tests was not affected by stress owing to a compensatory cognitive effort[28,29]. Thus, professional training makes ATCs less vulnerable to attention disturbances[29] thanks to the professional demands that make them more adept at coping with adversities in the acoustic environment trough cognitive effort[26-29].

In the specialized literature, this aspect was verified in a recent study[29] whose authors attributed this improvement to the professional need of ATCs to use cognitive strategies, such as planning rapid and accurate control strategies and adapting to deal with unexpected situations.

Further studies should be conducted on the Central Auditory Processing of ATCs comparing the results at the beginning and end of their work shift.

CONCLUSION

Results for the variables auditory closure, self-reported health, attention, and communication were similar in both groups. The study group (SG) presented significantly better performance in auditory figure-ground compared with that of the control group (CG). Self-reported stress and right-ear SSI-ICM were significant predictors of individuals belonging to the SG.

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Author contributions

ACNWBV was responsible for the study design, collection, analysis, and interpretation of data, and writing of the manuscript; LDP was the research adviser, and contributed in the study design, analysis and interpretation of data, and writing of the manuscript.