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Effect of aging on central auditory processing and cognitive abilities

Otorhinolaryngology

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ABSTRACT

Background: Aging has a significant effect on central auditory processing and cognitive abilities and this is associated with many difficulties in communication. Several tests can detect the effect of aging on central auditory processing abilities and on cognitive abilities.

Objective: To assess the effect of age on central auditory processing and cognitive abilities and to compare central auditory abilities between elderly & adults.

Methodology: A hospital based cross-sectional comparative study conducted on subjects attending at the hearing and speech institute clinics. The study consisted of 60 participants divided into 3 groups: Group (1): 20 participants ages ranged from 20-39 years old. Group (2): 20 participants ages ranged from 40-59 years old. Group (3) elderly group: 20 participants ages above 65 years old. The three groups underwent otological examinations, pure tone audiometry, acoustic impedance, speech in noise test (SPIN), synthetic sentences identification with ipsilateral competing message (SSI-ICM), duration pattern test (DPT), dichotic digits test (DDT), auditory memory tests and auditory continuous performance test (ACPT).

Results: There was statistically significant difference between the three groups in pure tone thresholds especially in high frequencies, SPIN, SSI-ICM, DPT, DDT, auditory memory tests and on ACPT.

Conclusion: There is marked decline in central auditory processing abilities and cognitive abilities with increased age.

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Keywords: Age related hearing loss, central auditory processing, central auditory processing disorders.

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INTRODUCTION

ARHL (age-related hearing loss) is a progressive, irreversible, and symmetrical bilateral neuro-sensory hearing loss resulting from degeneration of the cochlea or loss of auditory nerve fibers during cochlear aging, begins in the high-frequency region of the auditory spectrum and spreads towards the low-frequency regions [1]. Approximately 1.5 billion people, more than 42% of them aged 60 years and above experience hearing loss worldwide [2]. ARHL is linked to a reduction in the size of the right temporal lobe and the whole brain [3].

The six behavioral processes involved in central auditory processing are auditory discrimination, laterization and localization of sound, auditory pattern recognition, temporal aspects including integration, resolution, ordering, and masking, and auditory performance degradations with competing or/and degraded acoustic signals [4]. Poor speech understanding in noisy environments, or with competing speech, or any other alteration in terms of acoustics features of speech perception are the most specific characteristics of ARHL [5].

Different aspects of memory and attention underwent alterations. Reduced information processing speed with aging is one of the common results. The capacity of older people to perceive speech in noisy environments is significantly influenced by both auditory processing and cognitive. Leading medical organizations have recognized the link between ARHL and cognitive decline in recent years [6][7], and ARHL has been named as the biggest possibly reversible risk factor for dementia [8]. The goal of this research was to compare central auditory skills in old and adult participants as well as to determine the impact of age on central auditory processing and cognitive capacities.

PATIENTS AND METHODS

This hospital based cross-sectional comparative study was conducted on 60 participants. They were chosen from Egyptian clinic patients of the Hearing and Speech Institute. The research was carried out during a one-year period (from March 2020 to March 2021). After thorough discussion of the research, all participants signed a written informed consent.

Inclusion criteria

The study comprised of 60 patients, based on age they were divided into 3 groups:

- **Group 1**: included 20 participants with age ranging from 20-39 years old.
- **Group 2**: included 20 participants with age ranging from 40-59 years old.
- **Elderly group**: included 20 participants with age above 65 years old.

Exclusion criteria

Patients with history of neurological disease, acoustic or physical trauma, known vestibular disorder, conductive hearing loss, unilateral sensorineural hearing loss and left-handed individuals were excluded from the study.

Participants were subjected to the following: Full history taking, otological examination, pure tone audiometry, Speech audiometry Including Speech Recognition threshold **(SRT)**, Word discrimination score, Immittancemetry, Behavioral Central Auditory Processing Assessment, Auditory memory battery of Goldman–Fristoe–Woodcock **(GFW)** and Auditory continuous performance test **(ACPT)**

1) **Behavioral Central Auditory Processing Assessment:** The tests were chosen to evaluate central auditory processing abilities and cognitive communicative skills. Tests were performed in a sound treated room through earphones.

2) **Speech in Noise Test (SPIN):** A list of 25 monosyllabic Arabic words at 50 dB SL with ipsilateral speech noise (S\N ratio used is 0 dB). Scoring by percent correct.

3) **Synthetic Sentence Identification with Ipsilateral competing Message (SSI-ICM):** The evaluation material consisted of ten made-up lines that were played over a recording of natural speech in the background at two different message-to-competition ratios (MCR): 0 and -15 dB. The ten sentences were read silently at an intensity level of 50 dB SL. The subject was given a single statement to listen to, and then they were asked to repeat it. The scoring was determined by the percentage of right answers.

4) **Duration Pattern Test (DPT):** The duration pattern test is comprised of a series of three tone bursts, two of which have the same length as one another while the third has a duration that is distinct from the first two. Twenty different patterns are shown to each ear as part of the administration process. The proportion of accurate patterns will serve as the criterion for scoring on this exam..

5) **Dichotic Digits test (DDT):** The participant was instructed that 'you will be hearing 2 numbers (one on each ear) in version 1 and 4 numbers (two in each ear) in version 2. **Scoring** was determined by counting the number of correctly repeated digits.

6) **Auditory memory battery of Goldman–Fristoe–Woodcock (GFW):** Tests were performed in a sound treated room through loudspeaker.
   - **A. Recognition memory test:** There are five different lists of Arabic words that are bi-syllabic. On each list, there were 11 terms that were repeated twice. The total score for each list is determined by deducting the number of incorrect replies from eleven..
   - **B. Memory for content test:** There were two sets of listings shown here, denoted by the letters A and B. Each set had eight different lists of single-syllable, straightforward Arabic words. The participant in the study was given instructions to remember the whole list that he had just heard in any order that he chose. The scoring is determined by selecting the subject's top and second-highest consistent results.
   - **C. Memory for sequence test:** There are two sets of listings here, denoted by the letters A and B. Each group had seven different lists of monosyllabic Arabic words that were easy to understand. The participant was instructed to remember all the words in the exact same sequence as they were presented. The scoring is determined by selecting the subject's top and second-highest consistent results.

7) **Auditory continuous performance test (ACPT):** The test consisted of nineteen monosyllabic simple Arabic words repeated many times to form long list of ninety-six Arabic words in which the target word and was repeated 20 times The subject was asked to raise his hand each time he hears the word. For scoring, incorrect responses were subtracted from 20 then multiplied by 5.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) version 23 was used to accomplish the sorting of the data as well as the analysis of the results. In this particular research project, the qualitative data were summarized using numerical and percentage formats. The mean and standard deviation were performed to represent the quantitative data. Independent Samples t-test was used to compare continuous unrelated variables, while Paired Samples t-test was used to compare related variables. One Way ANOVA test was used to compare continuous data between more than two groups. Chi-square test was used for analysis of categorical data in the absence of any linked factors. To determine whether or not there was a link between two quantitative factors that belonged to the same group, the Spearman correlation coefficient was used. The threshold of significance chosen was set at P ≤0.05.

RESULTS

The current study was conducted on a total number of 60 participants divided into 3 groups. Group (1): 20 participants ages ranged from 20-39 years old, mean was 31 ± 4.7 years. There were 10 females (50%) and 10 males (50%). Group (2): 20 participants ages ranged from 40-59 years old, mean was 47± 4.9. There were 15 females (75%) and 5 males (25%). Elderly group: 20 participants ages above 65 years old, mean was 71± 4.2. There were 10 females (50%) and 10 males (50%). There was highly significant difference between the 3 groups as regard age (table 1). The elderly group showed significant low scores in SPIN and SSI-ICM when compared to group 1 & group 2. Significant difference was observed (table 2).

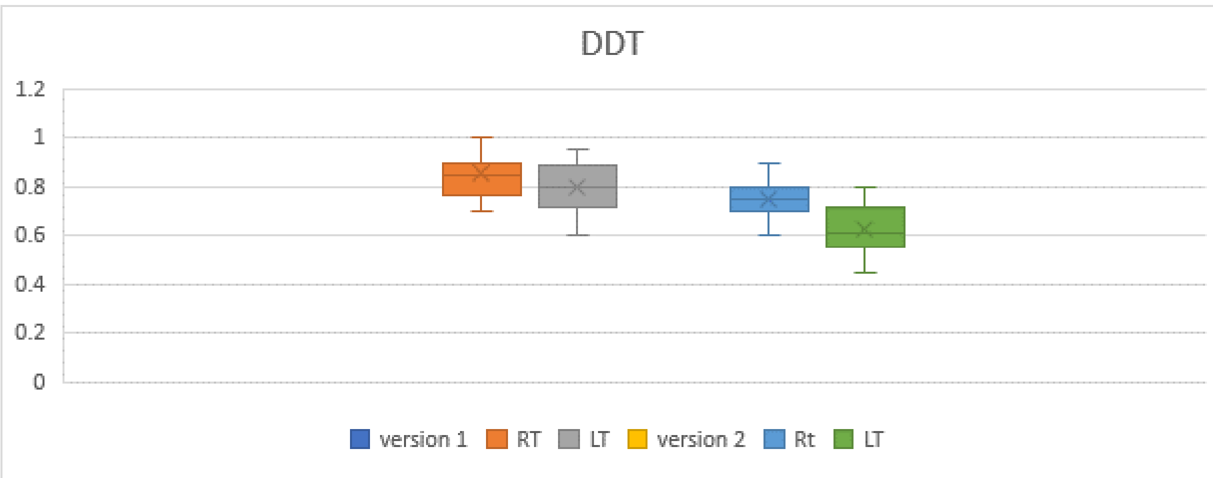

Figure (1): Box plot showing difference between median, standard deviation and range of DDT scores (version 1, version 2) in (group 3: >65 Ys group) in right and left ear showing Right ear advantage.

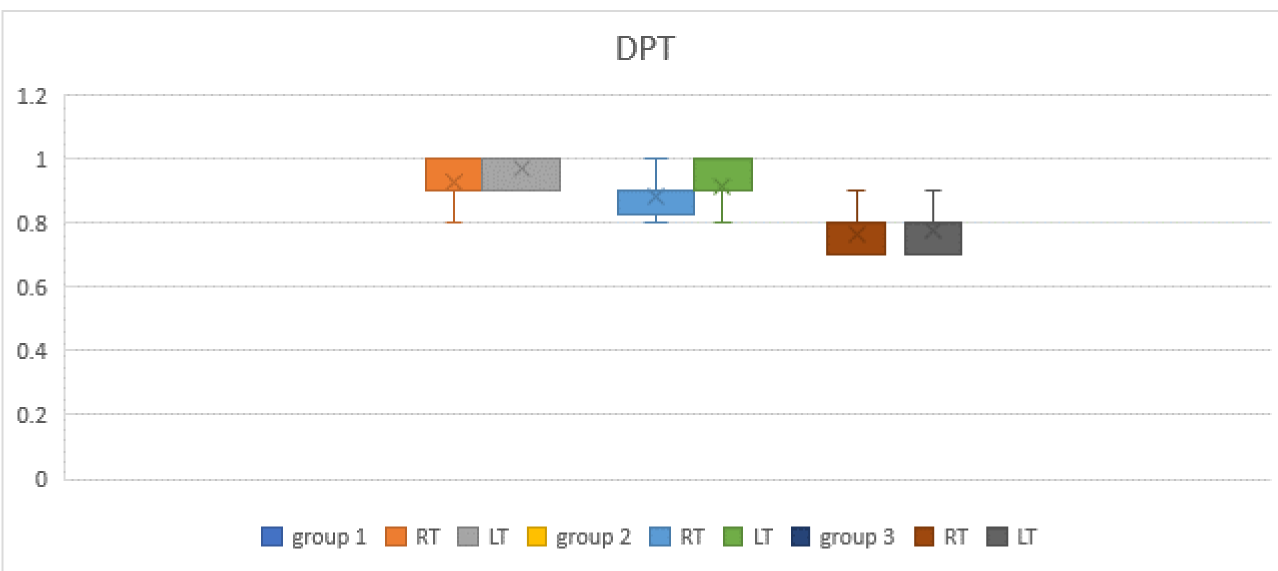

Figure (2): Box plot showing comparison between median, standard deviation and range of DPT scores between: (Group 1: 20-39ys group), (Group 2: 40-59ys group) and (Group 3: >65ys group)

Table (1): Comparison of age and sex between the three studied groups

items		Group 1 20-39 yrs. n = 20	Group 2 40-59 yrs. n = 20	Group 3 >65 yrs. n = 20	Stat. test	P-value
Age (years)	Mean± SD	31± 4.7	47± 4.9	71± 4.2	F=390.5	0.001*
	Range	25 – 38	40 – 55	65 – 79		
Gender	Female	10 (50.0%)	15 (75.0%)	10 (50.0%)	X^2=3.4	0.180
	Male	10 (50.0%)	5 (25.0%)	10 (50.0%)		

F: One Way ANOVA test, X^2: Chi-square test, *: Significant p value (≤0.05)

Table (2): Comparison between speech in noise test (SPIN) and synthetic sentence identification with ipsilateral competing message (SSI-ICM) at MCR (-15, 0) between studied groups

Items		Group 1 20-39 yrs. n = 20	Group 2 40-59 yrs. n = 20	Group 3 >65 yrs. n = 20	ANOVA	P-value	Post Hoc analysis by LSD P1	P2	P3
SPIN									
Right	Mean ± SD	99.4± 1.5	95.2± 3.8	89.20± 5.0	F=37.5	0.001*	0.001*	0.001*	0.001*
	Range	96 – 100	88 – 100	80 – 96					
Left	Mean ± SD	99.4 ± 1.96	95.4± 3.3	88.8 ± 4.8	F=46.1	0.001*	0.001*	0.001*	0.001*
	Range	92 – 100	88 – 100	80 – 96					
SSI-ICM -15									
Right	Mean ± SD	47.5± 7.2	44.5± 6.9	15 ± 5.13	F=155.2	0.001*	0.147	0.000*	0.001*
	Range	40 – 60	40 – 60	10 – 20					
Left	Mean ± SD	44± 5.03	41± 7.2	13.5± 4.9	F=168.2	0.001*	0.107	0.001*	0.001*
	Range	40 – 50	30 – 50	10 – 20					
SSI-ICM 0									
Right	Mean ± SD	93.5± 7.5	91± 9.7	83± 4.7	F=10.54	0.001*	0.300	0.001*	0.001*
	Range	70 – 100	60 – 100	80 – 90					
Left	Mean± SD	97± 5.7	94 ± 7.5	85± 6.9	F=17.1	0.001*	0.166	0.001*	0.001*
	Range	80 – 100	70 – 100	70 – 100					

SPIN: Speech in noise test, SSI-ICM -15 : Synthetic sentence identification with ipsilateral competing message at MCR -15, SSI-ICM 0: Synthetic sentence identification with ipsilateral competing message at MCR 0, F: One Way ANOVA test, P1: Group 1 Vs. Group 2, P2: Group 1 Vs. Group 3, P3: Group 2 Vs. Group 3, *: Significant p value (≤0.05)

Table (3): Comparison between the groups as regard dichotic digits test (version 1 and version 2)

Dichotic digits test		Group 1 20-39 yrs. n = 20	Group 2 40-59 yrs. n = 20	Group 3 >65 yrs. n = 20	ANOVA	P-value	Post Hoc analysis by LSD P1	P2	P3
DDT (version 1)									
Right	Mean ± SD	96.3± 4.6	92± 6.8	85.3 ± 9.4	F=11.94	0.001*	0.07	0.000*	0.004*
	Range	85 – 100	70 – 100	70 – 100					
Left	Mean ± SD	95.5 ± 4.8	91.3± 7.8	80± 10.8	F=19.3	0.001*	0.12	0.000*	0.000*
	Range	85 – 100	65 – 100	60 – 95					
DDT (version 2)									
Right	Mean ± SD	92.3 ± 6.9	88.9± 3.99	74.6 ± 8.97	F=36.42	0.001*	0.13	0.000*	0.000*
	Range	70 – 100	82.5 – 95	60 – 90					
Left	Mean ± SD	89.6± 6.4	86.2 ± 6.5	62.9± 10.95	F=62.55	0.001*	0.197	0.000*	0.000*
	Range	75 – 100	72 – 95	45 – 80					

DDT: Dichotic digits test, F: One Way ANOVA test, P1: Group 1 Vs. Group 2, P2: Group 1 Vs. Group 3, P3: Group 2 Vs. Group 3, *: Significant p value (≤0.05)

Table (4): Comparison between groups as regard Auditory Memory tests: Recognition memory test, Memory for content test, Memory for sequence test

Items		Group 1 20-39 yrs.	Group 2 40-59 yrs.	Group 3 >65 yrs.	Chi-square test	P-value	Chi-square test		
		no. (%)	no. (%)	no. (%)			P1	P2	P3
Recognition Memory Test	6/11	0 (0.0%)	0 (0.0%)	1 (5.0%)	X^2=44.293	0.001*	0.480	0.001*	0.001*
	7/11	0 (0.0%)	0 (0.0%)	7 (35.0%)					
	8/11	0 (0.0%)	0(0.0%)	4 (20.0%)					
	9/11	2 (10.0%)	6 (30.0%)	7 (35.0%)					
	10/11	7 (35.0%)	9 (45.0%)	1 (5.0%)					
	11/11	11 (55.0%)	5 (25.0%)	0 (0.0%)					
Memory for content Test	3/9	0 (0.0%)	0 (0.0%)	8 (40.0%)	X^2=48.245	0.001*	0.132	0.001*	0.001*
	4/9	1 (5.0%)	5 (25.0%)	11 (55.0%)					
	5/9	3 (15.0%)	8 (40.0%)	1 (5.0%)					
	6/9	11 (55.0%)	5 (25.0%)	0 (0.0%)					
	7/9	5 (25.0%)	2 (10.0%)	0 (0.0%)					
	8/9	0 (0.0%)	0 (0.0%)	0 (0.0%)					
Memory for sequence Test	2/8	0 (0.0%)	0 (0.0%)	1 (5.0%)	X^2=45.333	0.001*	0.190	0.001*	0.001*
	3/8	0 (0.0%)	2 (10.0%)	13 (65.0%)					
	4/8	2 (10.0%)	5 (25.0%)	6 (30.0%)					
	5/8	8 (40.0%)	10 (50.0%)	0 (0.0%)					
	6/8	8 (40.0%)	2 (10.0%)	0 (0.0%)					
	7/8	2 (10.0%)	1 (5.0%)	0 (0.0%)					

X^2: Chi-square test, P1: Group 1 Vs. Group 2, P2: Group 1 Vs. Group 3, P3: Group 2 Vs. Group 3, *: Significant p value (≤0.05)

Table (5): correlation factor between central auditory processing tests and age (in elderly group)

	Age /years (Group 3)	
	r	P-value
Right		
SPIN	-0.698	0.001*
SSI-ICM -15	-0.557	0.011*
SSI-ICM 0	-0.608	0.004*
DDT (version 1)	-0.542	0.014*
DDT (version 2)	-0.737	0.000*
DPT	-0.256	0.001*
Left		
SPIN	-0.699	0.001*
SSI-ICM -15	-0.337	0.146
SSI-ICM 0	-0.483	0.031*
DDT (version 1)	-0.607	0.005*
DDT (version 2)	-0.735	0.000*
DPT	-0.241	0.011*

SPIN: Speech in noise**,** SSI-ICM -15: Synthetic sentence identification with ipsilateral competing message at MCR -15**,** SSI-ICM 0: Synthetic sentence identification with ipsilateral competing message at MCR 0**,** DDT: Dichotic digits test, DPT: Duration pattern test, **r**: Correlation coefficient, **: Significant p value (≤0.05)

In current study, there was highly significant difference between 3 groups especially in elderly group in DDT and DPT (table 3, figure 2). On other hands, as regard DDT (version 1, version 2) Especially among the older population, there was a statistically significant difference between the right and left ears (figure 1). Significant difference between elderly group, group 1 and group 2 was found as regard auditory memory tests. (table 4). In comparison between group 1, group 2 and elderly group, we found highly statistically significant difference in ACPT. Using Spearman correlation coefficients, there was negative correlation between age and all central auditory processing tests in elderly group except for SSI-ICM at SNR -15 at left ear there was no correlation (table 5).

DISCUSSION

ARHL is the kind of sensory impairment that affects the elderly population at the highest rate. When our cochlea, which is the organ in the periphery of our auditory system, becomes older, we often notice a deterioration in our hearing and are at an increased risk of cochlear sensory-neural cell degeneration [14].

In the present study, all of patient of group one and group two fulfilled the audiological criteria for normal hearing While elderly group matched with presbycusis as there was high frequencies (4-8 KHZ) hearing loss in most of participants. According to Mohamed et al. [15] and Heinrich et al. [16], there was a highly statistically significant difference between groups 1 and 2 as well as the elderly group in terms of pure tone threshold. This finding is in keeping with our findings. Hearing loss in the periphery, also known as presbycusis, may be of a sensory, neurological, strial, or conductive nature. The cochlear alterations that are to blame for peripheral ARHL have a causal effect in the volume reduction of grey matter in the auditory cortex [17].

In our research on the effects of aging on Central Auditory Processing Disorders (CAPD), we discovered that becoming older has a noticeable impact on one's ability to comprehend speech when there is background noise present. There was a statistically and clinically significant difference between the three groups that showed declining performance with increasing age. Moore et al.[18] conducted an observational study that found a drop in speech perception against noise was observed from the age of 50. This finding is also in agreement with Vermeire [19], who discovered that there was a significant effect of aging on speech recognition in noise. According to the findings of this research, a negative association was found between the SPIN test and the age of the patient in both ears among the elderly group. Based on these data, one possible was consistent with the findings of Calais et al. [20].

It would seem that the SSI-ICM is a reliable benchmark for the diagnosis of ARHL as well as for the forecasting of cognitive impairment in the elderly [21]. The latest research came to the same conclusions as the previous one in both the 0 dB and the -15 dB MCR measurements. There was a substantial difference between groups 1 and 2, as well as the older group. The fact that elderly people tend to have lower scores than younger people could indicate a gradual but steady engagement of auditory pathways in the brainstem as people become older. According to Mohamed et al. [15] the elderly group had statistically significantly lower scores on the SSI-ICM in comparison to the adult group, and this was true for both the right and the left ear. This finding was in agreement with Soha et al. [22] and Heidari et al. [23] and it was also supported by Mohamed et al.[15].

According to the findings of this research, there was an inverse relationship between the SSI-ICM test and age. The significance of this is that as one gets older, their scores on the test tend to become lower, which indicates that their brainstem is becoming less effective. This was consistent with Mohamed et al .[15] findings.

Skills in binaural integration are evaluated using DDT. In the present research, there was a very significant difference between the three groups, particularly with regard to the senior group. The findings of Jain et al.[24] and Roup et al.[25] were consistent with this finding. An underlying hemisphere bias in the processing of several kinds of auditory information is being reflected as an asymmetrical pattern in behavioral performance. However, the mean score for the right ear was 74.63, with a standard deviation of 8.97, while the mean score for the left ear was 62.88, with a standard deviation of 10.95, demonstrating a significant disparity between the two ears, particularly in the older group. This suggests that older individuals had higher hemispheric asymmetries than younger ones. This was consistent with the findings of Mohamed et al. [15] as well as Fisher et al. [26]. This is due to cortical impairment and deterioration in the corpus callosum and this agreed with Zenker et al. [27] and Mohamed et al. [15]. In the current study, there was a negative correlation between the dichotic digits test and age in the elderly group as the scores decreased by increasing age. This was observed in the elderly group. On the other hand, Martini and colleagues [28] observed that the age did not have an impact on dichotic listening tests.

The DPT evaluates a patient's ability to organize events in time and evaluates their aural perception, as well as their immediate memory and attention. According to Viviane et al. [29] research reported that there was a consistent association between age and DPT. They found that as participants' ages grew, the proportion of right responses declined. Our findings are consistent with their findings.

The attention of the patient as well as their immediate memory are evaluated using ACPT. According to McAvinue et al. [30] sustained attention reveals significant age-related reductions like the present research, however other studies, such as Giambra and Quilter [31] demonstrate preservation with age. It's possible that various tests that evaluate sustained attention are to blame for this disparity. Bopp and Verhaeghen [32] found relatively large overall effects of age on working memory and this totally agree with this current study.

CONCLUSIONS

There was a marked decline in central auditory processing abilities with increased age as Pure tone thresholds were significantly different amongst the three groups especially in high frequencies, SPIN, SSI-ICM, DPT and DDT. Working memory and sustained attention are markedly decreased with aging and this suggests that there is decline in cognitive abilities as there was significant difference between adult groups and elderly. The audiologic evaluation for older people should include measures of central auditory processing, memory, and attention. The use of cognitive and auditory processing assessments enhances the effectiveness of therapeutic treatments and raises the senior population's behavioral performance across the board for all auditory abilities.

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الملخص العربي

تأثير السن علي وظائف السمع المركزي و القدرات الحسية

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الملخص:

المقدمة: يسبب ضعف السمع المصاحب للتقدم بالسن صعوبات في التواصل و الانعزال و ضعف في القدرات الحسيه و يعتبر من اكثر عوامل الخطر المؤدية لفقدان الذاكرة. وقد لوحظ أن القدرات السمعية في المواقف الصعبة مع ضمور الخلايا السمعية قد يغير من الاستجابات الحسيه من المخ. كما أن ضعف السمع المصاحب للتقدم بالسن يؤثر علي العصب السمعي و علي القشرة المخية المسؤولة عن وظائف السمع المركزي و أيضا يؤثر علي القدرات الحسيه.

الهدف: تهدف هذه الدراسة إلى تقييم قدرات السمع المركزي و الذاكرة و التركيز في اعمار مختلفة و تقييم كامل لهذه القدرات مع تقييم القدرات الحسيه و الإدراكية.

الطرق: شارك في هذه الدراسة ستون مشاركا و تم تقسيمهم الي ثلاث مجموعات:

- المجموعة الأولي: تضم عشرون مشاركا من الاصحاء تتراوح اعمارهم من 20 و حتي 39 عاما.
- المجموعة الثانية: تضم عشرون مشاركا من الأصحاء تتراوح اعمارهم من 40 و حتي 59 عاما.
- المجموعة الثالثة: تضم 20 مشاركا تتراوح اعمارهم اكبر من 65 عاما.

تم أخذ تاريخ مرضي كامل من المشاركين و فحصهم فحص سمعي شامل من ضغط اذن و مقياس سمع و نسبة تفسير الكلام و اختبارات السمع المركزي و اختبارات الذاكرة و الانتباه.

النتائج: أوضحت نتائج هذه الدراسة ان جميع قدرات السمع المركزية تقل بصورة ملحوظه مع التقدم بالعمر فتقل القدرة علي تفسير الكلام فى الضوضاء و تقل القدرة علي التعرف علي الارقام و تقل قدرة القشرة المخية الصدغية و ايضا تقل قدرات ادماج الاشارات السمعية من الجهتين. كما تقل القدرات الحسيه حيث تقل الذاكرة العاملة و الانتباه المتصل لدي كبار السن. كما انه كلما يزيد السن كلما يكون التأثير أكثر وضوحا.

الاستنتاجات: أكدت الدراسة علي التأثير الشديد للسن علي القدرات السمعية حيث يتأثر عصب السمع خصوصا بترددات الصوت العليا 2 و 4 كيلو هرتز كما تتأثر وظائف القشرة السمعية بشدة.

الكلمات المفتاحية: ضعف السمع الناتج من تقدم العمر، السمع المركزي، اضطرابات السمع المركزي.

الباحث الرئيسي

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