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RESEARCH ARTICLE

The relationship between working memory capacity and temporal and dichotic auditory processing in teachers

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Abstract

Background and Aim: Because speech perception is disturbed in people who are exposed to noise, this study aimed to investigate the effect of work environment noise on working memory capacity, temporal, and dichotic auditory processing and relationship between them in elementary school teachers.

Methods: Fifty-six female aged 30−50 years were enrolled in our study case and control groups. A total of 28 teachers with normal hearing and poor speech perception in noise were in the case group, and 28 women were controls with normal hearing and good scores in speech perception in noise who did not work in a noisy environment. Working memory tests, dichotic digit test (DDT) and gap-detection test (GDT) were performed for both groups. The mean score of each test was obtained from the two groups and the results were analyzed.

Results: Comparison of means between the two groups in DDT, GDT, and working memory capacity test showed that the scores of the case group were significantly lower than those in the control group ($p < 0.05$). There was no correlation between working memory capacity test, DDT, and GDT scores. ($p > 0.05$, $r < 0.1$).

Conclusion: Noise exposure in the work environment causes weakness in temporal and dichotic auditory processing, and working memory capacity. But there was no correlation between working memory capacity and auditory processing. The findings of this study show the effects of noise exposure on speech perception and the need to protect hearing from noise.

Keywords: Noise; working memory; auditory processing; gap-detection; dichotic hearing

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Introduction

Today noise avoidance is impossible. Most people are exposed to noise in their working place. Classrooms, especially at elementary schools, are among noisy places. Teachers, who are working at schools for years, are susceptible to adverse effects of noise. Noise has extensive effects on subjects' health, including pathophysiologic problems and hearing loss [1,2]. Occasionally in spite of normal hearing threshold, noise involves supra threshold functions, especially temporal processing and dichotic listening which lead to speech perception and recognition disorders [3].

Normal speech processing and perception, especially in a noisy environment, are based on auditory (temporal, dichotic) and cognitive processing (working memory and attention) [4]. Dichotic listening is a scale for evaluation of brain hemisphere asymmetry and based on this asymmetry other issues such as attention, speech perception, memory, and learning are investigated [5]. For speech perception, fine temporal processing is vital, too. For quick speech processing, temporal processing is more important than spectral processing so that temporal processing deficit, even as small as of 10 ms, is observed in many linguistic disorders [6].

Working memory is a brain function for temporary storage of data in order to perform complex cognitive activities such as speech perception, learning, and reasoning. This memory is composed of four components; central executive systems, phonological loop, visual-spatial sketchpad, and episodic buffer [7,8]. Working memory has a major role in language understanding and word recognition [9]. Working memory has contributions in five areas of language processing; word acquisition, speech production, speech perception, reading progress, and fluent reading. These roles are made possible via phonological loop for processing and retaining verbal materials and executive centers for general data processing [10]. As speech perception needs following, retaining, and integrating auditory data flow, working memory probably has a key role in speech perception [11]. Working memory has limited capacity. Target speech in the presence of irrelevant auditory signals will result in speech perception difficulty. The existence of noise along with the stimuli which must be stored in and recalled from working memory make the process difficult [12]. Subjects with limited memory span are in more need of a quieter place (less noise) for speech perception. Subjects with expanded working memory do not experience such difficulty [13]. Those with extended working memory display better performance in segregating target signals in complex conditions [14].

As both auditory processing (temporal and dichotic) and working memory are involved in speech perception, the present study aimed at studying auditory processing (temporal and dichotic) and cognitive processing in teachers who work in noisy environments and finding the relationship between these two processes.

Methods

This is a comparative cross-sectional study. The study population comprised teachers of Tehran elementary schools with at least 5 years of working experience. A total of 56 females, 28 teachers with speech perception difficulty in noise environment were assigned as the case group and 28 normal subjects as the control group. Subjects were selected from elementary schools of Tehran districts 2, 5 and 6 via convenience sampling method. The inclusion criteria were as follows: written informed consent for participation, 30−50 years old (the reason for choosing this age range was to include cases with 5 years of working experience and excluding aging effect), monolinguals (Persian), right-handedness (Edinburgh handedness inventory) [15], normal hearing threshold (< 25 dB HL) at 250−8000 Hz in both ears, normal distortion-product otoacoustic emission (DPOAE), abnormal results in quick-speech in noise (Q-SIN) test which was defined as more than 1 error [16]. The control group members were selected from subjects who did not work in a noisy environment and had normal results in Q-SIN. The control and case groups were matched. In Q-SIN test, two-word lists were presented at the beginning for instruction. In each stage, examinees had to repeat sentences which were spoken by a male talker and were presented in noise. Then the correct repeated keywords were scored (each list had 30 keywords). The mean signal to noise ratio (SNR) in which subject can recognize 50% of speech in noise is referred to as SNR 50% [16]. This value was calculated for each individual. All subjects completed a form about their individual health and their personal evaluation of their hearing status. The form had questions about hearing protection tools and hearing in quiet and noise. The subjects with music experience were excluded. Air-conduction audiometry was conducted with

OB822 (Madsen; Denmark) and TDH39 headphone at octave frequencies from 250−8000 Hz. Then the DPOAE test was conducted by Otometrics (Denmark). DPOAE was present in all cases, indicating outer hair cell integrity. Then Q-SIN test [16] was performed by Asus x450c (China) with Sennheiser HD 200 Pro (Germany) headphone which was calibrated by using a one third octave sound level meter type 2250-L (Bruel & Kjaer; Denmark). Forward digit span, backward digit span, n-back test, dichotic digit test (DDT) and gap-detection (GDT) were used. Forward digit span included 7 digit series and each series had 2 exercises. The number of digits in each exercise was from 3 to 9. The digits were presented in 1-s intervals. The longest string of digits that examinee could recall was considered forward digit span [17,18]. The backward digit span had 7 digit series. The number of digits was from 2 to 8. The digits were presented in 1-s intervals. The examinee had to repeat digits from the end to the beginning. The longest string of digits that examinee could recall in this manner was considered backward digit span [17,18]. In the n-back test, a set of stimuli (digits) were presented and the examinee was asked to repeat n stimuli before the end stimulus. The number n can be 1, 2 or 3 [19]. GDT is one of the best methods for evaluation of temporal resolution. In this study, the time interval between two similar tones were 0, 2, 5, 10, 15, 20, 25, 30 and 40 ms. This test was conducted at a comfortable level (60 dB SPL). Then the subject would be asked to tell if he had heard one or two consecutive tones. The smallest gap that was recognizable (hearing two separate tones) was the GDT result [20]. In DDT, digits from 1 to 10 (except 4 which is a two-syllables word in Persian) were presented binaurally. Each test item was composed of 4 digits (two digits for each ear) to 6 digits (three digits for each ear). The examinee had to repeat all presented digits. The score was calculated for each ear [21]. After recording the mean scores for both groups in all mentioned tests, comparisons were made between mean scores and auditory processing and memory span relationship was studied by using SPSS 22. Shapiro-Wilk and Mann-Whitney non-parametric tests were used for comparing means in working memory capacity tests and GDT in 500, 1000 and 2000 Hz. The t-test was used for comparing right and left ear results for DDT and GDT in 4000 Hz and the Spearman test was used for data analysis. At the present study, all ethical considerations recommended by University of Social Welfare and Rehabilitation Sciences Ethical Committee were taken into account (Ethical Code IR.USWR.REC.1396.260). All participants completed a written informed consent.

Results

This study was conducted on 56 adults in the age range of 30−50 years old, including 28 teachers with speech perception difficulty in noise as the case group with a mean (SD) age of 42 (±6) years and 28 normal subjects with the mean (SD) age of 38 (±5) years. Q-SIN was performed in both groups and mean errors in the case group was 2 and in the control group was 1. SNR 50 in the case group was 0.28±1.2 and in the control group was -1.32±0.57.

The results of comparing means between the two groups are summarized in Table 1. As it is shown, there was a significant difference between two groups in DDT (right and left ear), GDT in 500, 1000, 2000, and 4000 Hz and forward and backward digit span ($p < 0.05$).

There was not any significant relationship between working memory capacity in forward, backward digit span and n-back test with temporal and dichotic processing in the case group based on the Spearman correlation test ($p > 0.05$).

Discussion

In the present study, there were two primary goals: first to compare the mean score of working memory span and temporal and dichotic processing in two groups. Second, the relationship between auditory processing (temporal and dichotic) and cognitive processing (working memory) in teachers with speech perception difficulty in noise were investigated.

After collecting and analyzing data, it was

Table 1. Mean (standard deviation) scores of the dichotic digit test in right and left ear, forward digit span test, bakward digit span test , n-back test, gap detection test in 500, 1000, 2000 and 4000 Hz in both groups

	Mean (SD) score		
Test	**Case group**	**Control group**	**p**
DDT (Right ear)	89.29% (7.84)	95.08% (4.54)	0.001
DDT (Left ear)	81.16 (12.23)	91.16 (6.30)	< 0.001
Forward digit span test	4.96 (1.03)	5.89 (0.83)	< 0.001
Bakward digit span test	3.82 (0.86)	4.39 (0.90)	< 0.019
N-back test	2.68 (0.98)	2.96 (0.69)	> 0.05
Gap detection 500 Hz	17.00 (10.92)	6.96 (4.24)	< 0.001
Gap detection 1000 Hz	16.32 (11.57)	6.68 (4.30)	< 0.001
Gap detection 2000 Hz	17.46 (10.95)	7.21 (3.31)	< 0.001
Gap detection 4000 Hz	19 (10.18)	8.54 (4.27)	< 0.001

DDT; dichotic digit test

revealed that the performance of the case group was significantly weaker than the control group in temporal processing. In both groups, GDT for 4000 Hz was significantly weaker than that in 500, 1000 and 2000 Hz. This finding is in agreement with Kumar et al. [1] and Paul et al. [22] findings. They investigated the temporal processing in normal hearing subjects who worked in noisy environments. It seems that after noise exposure, even with normal outer hair cell function (based on DPOAE), the impaired synapses between hair cells and afferent fibers produce a permanent deficit in temporal encoding.
In the present study, the performance of the case group was lower than the control group in dichotic processing which is in agreement with Liberman et al. [23] and Kraus and White-Schwoch [24] results. They studied adverse effects of noise on auditory nerve and synapses between hair cells and afferent fibers.
In the present study, working memory span in teachers was tested by three tests; forward and backward digit span and n-back tests. The mean of forward and backward digit span tests showed that the case group had significantly lower performance than the control group but n-back showed no difference. It seems that difficulty of n-back test, in relation to forward and backward digit span tests reduce its sensitivity and efficacy to differentiate the performance of these two groups. Coway et al. [14] and Salvi et al. [25] studied working memory and showed the same results in the presence of noise. They reported that when noise and digit span test materials were presented simultaneously, memory capacity reduced.
In the present study, the relationship between working memory capacity and temporal and dichotic processing was investigated that showed no significant correlation. For interpretation of the auditory processing test results, we need to consider the effects of cognitive factors, too. Many studies have shown that cognitive processing can affect auditory processing significantly and there is a significant correlation between them. Maerlender et al. showed a strong relationship between working memory capacity and dichotic processing and used working memory capacity test as an index for recognizing auditory processing disorder [26]. In this

manner, the present study is different from Maerlender et al. study. Murphy et al. [27] maintained that the difficulty level of auditory processing tests can affect degree and type of correlation between auditory and cognitive processing. According to the place of processing inside the brain, there might be a different correlation between auditory and cognitive processing. It must be considered that cognitive processing is a top-down process but the temporal and dichotic process is a bottom-up one. Therefore it is recommended that we use both auditory and cognitive processing for predicting subjects' performance [28]. Some working memory tests do not have any correlation with auditory processing [29]. Also in some studies, the subjects with lower cognitive performance had weaker auditory performance but there was not a clear correlation [28]. It seems that the difficulty level of tests and sample size in the present study has led to this result. Maybe by using tests with different difficulty levels and choosing tests that evaluate different levels of the central auditory system, the results might be different.

Conclusion

Based on the temporal and dichotic processing and working memory tests in teachers and control groups, the adverse effects of noise is clear and prevention from noise exposure is recommended. These tests can help the early identification of noise adverse effects. The study showed that noise before developing a hearing loss has irreversible effects on memory and central auditory processing.

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Conflict of interest

The authors declared no conflicts of interest.

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