Concurrent auditory perception difficulties in older adults with right hemisphere cerebrovascular accident

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Abstract

Background: Older adults with cerebrovascular accident (CVA) show evidence of auditory and speech perception problems. In present study, it was examined whether these problems are due to impairments of concurrent auditory segregation procedure which is the basic level of auditory scene analysis and auditory organization in auditory scenes with competing sounds.

Methods: Concurrent auditory segregation using competing sentence test (CST) and dichotic digits test (DDT) was assessed and compared in 30 male older adults (15 normal and 15 cases with right hemisphere CVA) in the same age groups (60-75 years old). For the CST, participants were presented with target message in one ear and competing message in the other one. The task was to listen to target sentence and repeat back without attention to competing sentence. For the DDT, auditory stimuli were monosyllabic digits presented dichotically and the task was to repeat those.

Results: Comparing mean score of CST and DDT between CVA patients with right hemisphere impairment and normal participants showed statistically significant difference (p=0.001 for CST and p<0.0001 for DDT).

Conclusion: The present study revealed that abnormal CST and DDT scores of participants with right hemisphere CVA could be related to concurrent segregation difficulties. These findings suggest that low level segregation mechanisms and/or high level attention mechanisms might contribute to the problems.

Keywords: Older adults, Cerebrovascular accident (CVA), Auditory attention, Auditory segregation.

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Introduction

Cerebrovascular accident (CVA) is one of the most important and common disorders in older adults. This disorder needs special attention because of its high prevalence, symptoms (e.g. imbalance, confusion, and speech perception problems), and death toll. In western countries, strokes including CVA are the third most common cause of death and the most common cause of disabling neurologic damage. CVA is much more common among older people than among younger adults, usually because the disorders that lead to CVA progress over time (1).

It has been shown that older adults with CVA show evidence of auditory and speech perception difficulties (2). In addition, it is confirmed that patients with CVA sustain impaired top-down mechanisms in central auditory system e.g. auditory attention, lexical decoding, and tolerance fading memory (TFM). Effects of these impairments on communication state of patients with CVA are very significant (3).

In order to diagnose CVA, most of the medical specialists identify only clear signs and symptoms and generally do not assess hidden and uncommon problems such as central auditory processing problems. The-

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se problems may have significant effects on speech processing and communication of patients with CVA (1). Furthermore, these patients do not have any complains related to auditory processing at the first time and common auditory assessments (audiometry and tympanometry), also they do not complain about any related problem. Central auditory tests are cost-benefit and very beneficial for assessment of complex auditory functions(2). In order to evaluate concurrent auditory segregation, which is the basic level of auditory scene analysis and auditory organization in auditory scenes with competing sounds (4). In patients with CVA, we could use specific tests of central auditory system including competing sentence test (CST) and dichotic digits test (DDT) with real-world and speech stimuli (5). These tests have an important role in assessing auditory segregation since dichotic auditory conditions are special auditory scenes.

Several studies used CST to show functional impairment in the brain due to left-handed CVA (2). Some researchers conducted CST in patients with cerebrocranial injuries (CCI) and subjects with CVA (right and left hemispheres) and reported abnormal responses in both groups (6). In another research, DDT was used to monitor auditory function improvement in a woman with left-handed CVA involving Heschl's gyrus. Results indicated 67% of improvement in DDT responses after 12 months (7).

In the present study, we particularly examined effects of right-handed CVA on auditory segregation. In other words, the study focused on identification of auditory segregation and related perception difficulties in patients with right hemisphere CVA. It was found that frontal and parietal areas of right hemisphere strongly play a role in many cognitive functions including attention and working memory. These functions have important roles in other higher level processes such as auditory perception in older adults(8). In the present study, all of the patients showed impairment of parietal and frontal lobes in their MRI results. Thus, it was hypothesized that central auditory processing and auditory segregation could be affected. The primary objective of this study was highlighting and showing hidden auditory impairments (i.e. auditory segregation problems) of patients with right hemisphere CVA using simple central auditory tests (CST and DDT).

Methods
Participants
In this study, we assessed 30 male older adults (15 normal controls and 15 with right hemisphere CVA as test group) in the same age groups (60-75 years old). All of them were right-handed; and Farsi speaking. Both groups had the similar education level (diploma or higher level). All of the participants had the same pure tone average (PTA) and speech recognition threshold (SRT) i.e. lower than 25 dBHL. Participants with ear infections, epilepsy and neurologic disorders such as Alzheimer, head trauma, low cooperation, and speech problems were excluded. All of the patients did not represent any signs of aphasia (clarified by speech and language pathologist) and dementia revealed by Mini Mental Examination (MMSE)(9). The Persian version of MMSE (10) was conducted for screening of cognitive impairments including dementia. Both groups had average IQ (11). Cases with CVA were recruited from the neurology clinic at University of Social Welfare and Rehabilitation Sciences (USWR), Tehran, Iran. All of the patients showed impairment of right parietal and frontal lobes in their MRI results. The patients reported stable symptoms and were in rehabilitation phase (approximately 5 months after discharging). This study was conducted in Audiology Department of USWR between 2012 and 2013. Normal older adults were relatives of recruited patients. Both groups provided informed written consent in accordance with the Helsinki Declaration. We received approval for the research from USWR Review Board of Ethics.

Hearing assessments

The instruments used in this study were immitance acoustic (Interacoustics, AZ7), two channels audiometer (Amplaid, 311), CD player with microphone input, and compact disk (CD) related to Persian version of CST and DDT. Case history was taken precisely for all of the participants to rule out any confounding factors. In the next step, middle ear function was assessed with immitance acoustic and acoustic reflex threshold test. If the middle ear showed normal function, the patient would pass to the next step. Then, we conducted audiometry to measure auditory thresholds in all of the audiometric frequencies (125, 250, 500, 1000, 2000, 4000, and 8000 Hz). In this study, all of the participants had auditory thresholds ≤ 25 dBHL. Additionally, we measured speech recognition threshold (SRT) and speech discrimination score (SDS) with spondaic and monosyllabic words, respectively. If the patient's SRT & PTA were approximately the same (maximal difference ± 8dBHL) and SDS result was between 80 and 100%, he would pass the criteria (2).

Central auditory assessments and task

CST and DDT were conducted for all eligible participants. The CST involves the simultaneous presentation of dichotic sentences of similar duration, word length (six to eight words), and semantic content (12). We conducted Persian version of CST (2). We presented target message at 35dBSL (dependent to SRT and PTA in 3 frequencies 500, 1000, 2000 Hz) and competing message at 50 dBSL over TDH-49 headphones. Therefore, signal to competing sentence (SCR) was -15dB. We instructed the participant to listen to target sentence and repeat back without attention to competing sentence entered to the other ear. Prior to the experiment, participants were presented with 3 sample stimuli prior to data collection to familiarize them with the task and the response. Then, ten paired sentences were sent to each ear. These sentences had 10 scores. If the participant was not repeat-

ing back any word, scores were subtracted. All of the participants responded to stimuli in an open set.

The DDT entails presentation of two-digit pairs (from 1 to 10, excluding 4) to each ear simultaneously, and the listener is asked to repeat the numbers in both ears in any order (free recall). The test consists of 20 digits to each ear, presented at 50 dBSL over TDH-49 headphones (13). We conducted this test and scored in percent all of the digits repeated perfectly(14). For the DDT, 2.5% was indicated for score of every digit (15). Participants did not receive any feedback on their performance. Prior to the experiment, they were presented with sample stimuli prior to data collection to familiarize them with the task and the response.

Statistical analysis

Shapiro-Wilk test was conducted to analyze normal distribution of data using SPSS (version 16). We analyzed the data of CVA patients and normal subjects using independent t-test. $p < 0.05$ was indicated as a statistical significant level.

Results
Normal results

We considered CST and DDT scores in normal controls. CST scores were between 92% and 100% (97.06%±3.19 and 97.60%±2.94 in right and left ears respectively). DDT scores were between 90% and 100% (94.33%±3.19 in both ears). There was not statistically significant difference in CST (F=0.123 & p=0.638) and DDT (F<0.0001 & p>0.999) scores between both ears.

Results of patients with CVA

All of the participants with CVA had impairment in right hemisphere. There was not statistically significant difference between normal participants and CVA patients' age (p= 0.698). In CVA participants, CST scores were between 76% and 100% in both ears (95.73% ± 7.00 and 90.40% ±7.21 in right and left ears respectively). Mean difference of CST scores in both ears

Table 1. Comparison of statistics between normal and right hemisphere CVA subjects

Case		N	Mean	SD	p
Age (Yr)	Normal	15	67.00	7.43	0.698
	Right hemisphere CVA	15	66.07	5.45	
CSTr (%)	Normal	15	97.06	3.19	0.508
	Right hemisphere CVA	15	95.73	7.00	
CSTl (%)	Normal	15	97.60	2.94	0.001*
	Right hemisphere CVA	15	90.40	7.21	
DDTr (%)	Normal	15	94.33	3.19	<0.0001*
	Right hemisphere CVA	15	70.03	11.78	
DDTl (%)	Normal	15	94.33	3.19	<0.0001*
	Right hemisphere CVA	15	54.76	5.96	

*$p < 0.05$ is significant.
CSTr & CSTl: CST scores in right and left ears respectively. DDTr & DDTl: DDT scores in right and left ears respectively.

was statistically significant (F=0.319 & p=0.049). DDT scores were between 50.00% and 95.00% (70.03%±11.78 and 54.76%±5.96 in right and left ears respectively). Comparison of DDT mean scores of both ears indicated significant difference statistically (F=3.283 & p<0.0001).

We compared mean score of CST in the right ear between CVA patients with right hemisphere impairment and normal subjects. Results represented no significant difference statistically (p=0.508). It is believed that the right hemisphere impairment did not effect on the right ear score. In contrast, comparing left ear score between these groups showed statistically significant difference (p=0.001). This result indicated that the ear opposite to impaired one could be affected.

Comparing mean score of DDT in the right ear between CVA patients with right hemisphere impairment and normal persons indicated statistically significant difference (p<0.0001). Also, comparing left ear scores indicated this result (p<0.0001). Table 1 represents these results.

Discussion

The primary objective of our study was to assess concurrent auditory perception in patients with right hemisphere cerebrovascular accident. It is believed that right hemisphere, fronto-parietal localization, strongly plays a role in cognitive function. It is proposed that this hemisphere is one plausible candidate for mediating networks for arousal, novelty, attention, awareness, and working memory, which collectively provide for a set of additional, cognitive, mechanisms that help the brain adapt to age-related changes including auditory attention and perception(8). Any disorder of this localization causes to attention and memory dysfunctions. In the present study, all of the patients showed impairment of parietal and frontal lobes in their MRI results. Thus, it was premised that auditory attention and segregation could be affected.

An important aspect of the study was that we used real- world sounds (speech) and involved many of the complications associated with using these sounds such as the activation of expertise-related processes. Thus, such high-level processes can be studied with relative ease. In the present study, we used two central auditory tests (CST&DDT) to measure concurrent auditory segregation. For the CST, participants were presented with target message in one ear and competing sentence to the other ear.

In this test, the participants' task is to listen and attend to the target message and segregate it from simultaneous competing sentence. For the DDT, participants were presented dichotically to monosyllabic digits and their task is dividing attention to both ears, segregating all of the presented digits, and recalling the digits in free order. Findings from the previous studies suggest that older adults have difficulty following a conversation especially in noisy listening situations (e.g., cocktail party) where the task-relevant signal is embedded in multi-talker babble (16-19). Inherent to solving the 'cocktail party problem' is the ability to segregate and identify concurrent sounds. In the present study, it was noted that normal older adults showed normal scores in CST and DDT, but participants with right hemisphere CVA presented abnormal scores in these assessments. These results suggested that normal older adults have normal function in listening to dichotic auditory stimuli and segregating those from competing sounds while older adults with right hemisphere CVA show impairments in this function. We assume the possibility that low level segregation mechanisms and/or high level attention mechanisms might contribute to the problems. To explain these results, Cusack et al. (20) proposed a hierarchical model of stream segregation. According to this model, pre-attentive mechanisms segregate streams based on acoustic features (e.g., Δf) and attention-dependent buildup mechanisms further breakdown outputs (streams) of this earlier process that are attended to. Consistent with this model, Snyder et al. (21) provided event- related potential (ERP) evidence for at least two mechanisms contributing to stream segregation: an early pre-attentive segregation mechanism and an attention-dependent buildup mechanism. These studies have supported a gain model in which attention to a target stream enhances neural processing of sounds within that stream while suppressing unattended streams. Since CST and DDT also measure auditory attention functions (5), we think

that auditory segregation difficulties might be related to attention problems. In the present study, cases with right hemisphere CVA obtained low scores in both central auditory tests indicating that simultaneous auditory segregation is possibly modulated by attention and suggesting the involvement of high-level factors in concurrent auditory perception. Snyder et al. (22) assumed that top-down mechanisms within central auditory areas, multimodal pathways, and/or bottom-up mechanisms in peripheral areas (such as cochlea and low level auditory brainstem) might be contributed in auditory segregation. An ERP study conducted by Alain and Woods (23) showed that selective attention to a stream facilitated early sensory processing (sensory gating) of that stream and inhibited processing of unattended streams.

Since all of the patients with right-handed CVA showed impairment of parietal and frontal lobes in their MRI results, it was indicated that these regions possibly are some sources of auditory attention (auditory selective and divided attention). Sarter (24) studied divided attention process in a group of old adults and patients with dementia. In this study, neuropsychological measurements and functional imaging represented active dorsolateral and ventrolateral areas of cortex; prefrontal, cingulated, parietal, and premotor when modulating dual activities.

Our results (DDT scores) indicated that right hemisphere CVA mostly affects concurrent auditory segregation followed by auditory divided attention problems. A few studies have been conducted in the field of identifying mechanisms and sources related to auditory divided attention. However, their finding showed that sources such as two hemispheres, parietal and frontal lobes, association cortex areas (precentral area in both sides), and supplementary motor area were active when allocating auditory divided attention (25). In contrast, these results were not the case in the auditory selective attention.

In this study, because older adults with

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right hemisphere CVA represented evidence of difficulties in central auditory tests including CST and DDT, we could premise that they have problems in concurrent auditory segregation and speech perception. It could be suggested that further research in the same participants by other central auditory tests is needed to measure auditory segregation using a task that does not also require auditory attention. We also suggest that this study could be conducted in female patients with right-handed CVA to identify any differences of auditory segregation between males and females. Finally, as this study was conducted in patients with right hemisphere CVA, further studies could be conducted in patients with left hemisphere CVA to compare and clarify any differences of auditory perception and segregation difficulties between both groups.

Conclusion

In the present study, we showed impairments of concurrent auditory segregation and perception in older adults with right hemisphere CVA. This study highlighted the important role of auditory segregation process in speech perception. Also, it is confirmed that while many patients with CVA have normal results in audiometry tests (e.g. pure tone audiometry and simple speech tests; SRT and SDS), but they acquire abnormal results of CST and DDT indicating abnormal segregation process that might be contributed to high level functions.

Acknowledgments

Conflict of interest

None of the authors have any financial or other interests relating to the manuscript to be submitted in the Medical Journal of The Islamic Republic of Iran.

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