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Review Article

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Auditory Processing Deficits Following Sport-Related or Motor Vehicle Accident Injuries

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Abstract

This brief clinical study was designed to investigate further the possible link between traumatic brain injury (TBI) and/or whiplash injury (WI) with acquired auditory processing disorder (APD). Other studies have shown long standing effects of TBI and WI, and a study by Turgeon et al., examined the link between sport-induced concussion and APD. Four participants ages 18 to 30 years of age who self-reported a history of sport-related or motor vehicle accident head injuries participated in the following procedures: case history, behavioral testing, electrophysiological testing including auditory brainstem responses (ABR) and middle latency responses (MLR), and self-report questionnaires of post head and/or whiplash injury symptoms. The results of the testing were individually analyzed to see if results were consistent with a diagnosis of APD, or some evidence of a non-sensory deficit to the auditory system. The overall results of this study were also compared with the results of Turgeon et al., study. The results of the study shows that electrophysiological testing may be outside of normal limits even when behavioral testing does not support an APD diagnosis. Furthermore, the degree of reported symptoms and difficulties in the participants' case history does not always carry over to the behavioral and electrophysiological testing results.

Keywords: Auditory processing deficit; Sport-related injury; Motor vehicle accident

Introduction

Auditory processing disorder (APD) is a complex disorder characterized by difficulties in understanding spoken language. APD can be described as an auditory input disorder that affects the processing of sound at various central auditory nervous system levels. For most individuals with APD, air and bone conductions thresholds are within normal limits they have uncharacteristically poor performance on diagnostic tests designed to tax or challenge the auditory system. There have been many definitions of APD and its symptoms provided by different authors, though the formal standpoint of The American Speech Language Hearing Association (ASHA) states:

(Central) auditory processing disorder [(C)APD] refers to difficulties in the processing of auditory information in the central nervous system (CNS) as demonstrated by poor performance in one or more of the following skills: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal integration, temporal discrimination (e.g., temporal gap detection), temporal ordering, and temporal masking; auditory performance in competing acoustic signals (including dichotic listening); and auditory performance with degraded acoustic signals." [1].

These deficits or breakdowns in the ability to process auditory input makes listening and communication difficult, especially in the academic setting. A definitive cause or location of the auditory deficit in the brain for those who present with APD is not known. There is, however, a significant amount of research available which suggests that there may be a connection between APD and head injuries, such as traumatic brain injury (TBI) [2-9]. Whiplash injury (WI) has also been associated with the impairment of auditory processing [10]. These patients were found to have normal pure tone thresholds but presented with speech understanding test results that were disproportionately low. It should be noted, however, that APD as a diagnostic label is a secondary to the primary issue of head and/or neck injury.

TBI, even mild TBI, is known to cause symptoms that last anywhere from seconds to years post-injury [11,12]. Closed head injuries caused by these events can forcefully accelerate the brain within the cranium causing mild contusions, headache, sleep difficulties, and irritability (CDC, 2010). According to the CDC, 1.7 million individuals are treated for TBI annually in the United States. Of those treated, 52,000 die, 275,000 are hospitalized, and 1.37 million receive emergency room treatment. Approximately 80% of TBI patients are treated and released the same day and may receive little follow up care. TBIs can range from mild often seen as a mild or minor concussion to severe resulting in comma, amnesia, other severe long term injuries and impairments, and even death. The leading causes of TBI are falls, motor vehicle accidents, blunt force trauma, and assaults. Motor vehicle accidents are a daily occurrence in the United States as well as other parts of the world. These often life-altering incidents can strike anyone, though evidence shows that a significant percentage of teenage and college-aged drivers are involved in motor vehicle accidents each year [13].

Another group of individuals who are at increased risk for TBI are athletes. Most frequently, head injuries from motor vehicle accidents are a one-time occurrence. In contrast, sport-related head injuries have a greater likelihood of being repeated with continued [14,15]. Athletes who suffer a mild TBI are often not followed up with for medical treatment. Many athletes who suffer TBIs also return to athletic activities before they have had time to fully recover. This makes the athlete at risk for worse injury if a second TBI is suffered before the athlete has recovered from the initial injury [14,16].

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The number of sports-related TBIs has been of increasing concern as the medical community gains a better understand of the long-term effects that even a mild TBI can have on an athlete's life. The connection between TBI and sports has led to research into the possible connect between sports related TBI and the development of APD [17]. The Turgeon et al. study examined sixteen university students, eight of whom had suffered sports related TBI and eight matched control participants with no known history of TBI. The study found that all sixteen participants had normal pure tone hearing thresholds, but five of the eight participants with a history of sports-related TBI presented with auditory processing deficits in one or more of the test used in the APD test battery. In contrast, all eight of the control group participants presented with normal auditory processing.

The study by Turgeon et al., led to the question of whether participants who range in age from 18 to 30 years of age who have suffered a sport-related or motor vehicle accident TBI or WI would present with similar test results. Studies involving post-secondary students with a history of TBI suggest that this question is significantly pressing in post-secondary education due to the negative impact that APD can have on an individual's ability to function in the educational and work setting [18-21]. As stated earlier, research has shown that there appears to be a pattern of abnormal auditory evoked potentials in individuals who have sustained TBI and WI as well as individuals with APD [9,11,22]. As with some behavioral test there have also been studies that have found asymmetric evoked potential results in individuals with a history of TBI, WI, and APD [7,22,23].

The purpose of this study was to further examine if there is a relationship between TBI and WI as a result of motor vehicle accident or sport-related head injuries in college students who self-disclose and experience some residual academic difficulties post injury [24,25]. The APD test battery results will be compared and contrasted, between the test participants and published by Turgeon et al., [17].

Method

Participants

Participants were recruited within the local campus community via flyers. Test participants inclusion criteria consisted of individuals who were 18 to 30 years of age and who had suffered one or more TBI or WI as a result of a motor vehicle accident or sports-related injury. Participants gave their consent for the study with approval of the University of Arkansas at Little Rock Institutional Review Board (#12-043). The participants had to have normal pure tone thresholds and speak English as a first language. Potential participants were excluded from the study if: the participant had any known neurological impairments, had undergone any surgeries of the ear other than pressure equalization tubes, had any known speech and language impairment, or those for whom it had been less than six months since acquisition of the last TBI or WI. Although not directly related to the study, participants who presented with APD or hearing loss were counseled and given information about the University disability resource center or the Speech and Hearing Clinic for further testing or therapy, if deemed appropriate. In the event that the hearing test was not within normal limits, participants were also counseled about their options for further testing.

Procedure

All test participants completed a comprehensive evaluation that consisted of a case history, tympanometry, pure tone thresholds (octave frequencies from 0.25 to 8 kHz) for both ears, speech perception in quiet (25 phonemically balanced words presented at 50 dB HL), Frequency Pattern (FP) Sequence test, Duration Pattern (DP) Sequence test, Synthetic Sentence Identification test (Contralateral Competing Message; SSI-CCM), Dichotic Digits (DD) test, the Rivermead Post Concussion Symptom Questionnaire or the Whiplash Disability Questionnaire, auditory brainstem response (ABR), and middle latency response (MLR).

Case history and hearing evaluation

The case history provided information about the type of injury (TBI or WI) and whether or not there were any other conditions that might have precluded them from participation in this study (e.g., hearing loss, ear disease, unrelated neurological problems, etc.). Pure tone audiometry seeks to find the softest level the participants could hear at octave frequencies between 0.25 and 8 kHz. For pure tone audiometry, the participants wore insert earphones in a sound booth. Tympanometry involves assessing the status of the middle ear system, specifically to check if there is normal eardrum mobility and other abnormalities (e.g., fluid or ear infection). These procedures were performed to help determine eligibility for the remainder of the study, since hearing loss can affect all remaining tests.

Temporal ordering tasks

Temporal ordering is the brain's ability to process information presented in a sequence or pattern in a given time window. This involves not only recognition of the presented information but also the ability to place the information in chronological order. For example if a participant hears a series of tones such as one long, one short, one long the participant has to repeat the pattern not only that there were two long tones and one short tone but also the order in which the tones were presented. A key component of the temporal ordering tasks is the ability to process the presented patterns in a short time window since spoken word must be quickly processed in daily listening situations. Temporal ordering tasks are designed to test how well a participant is able to process the presented patterns in a short time window, and information gathered from the tasks is used to assess how well a participant may be able to process the time-sensitive information present in daily listening situations. The two temporal order tasks that were used for this study were Frequency Pattern and Duration Pattern tests.

The Frequency Pattern test requires the participants to verbally indicate the pattern they heard for two tones presented in one of six different triads (e.g., high-high-low, low-high-low, etc). The patterns are presented to one ear at a time. There are thirty sets of tone presentations presented to each ear. Any reversals or incorrectly repeated patterns are scored as wrong. If a participant correctly repeats fourteen or fifteen of the first fifteen presentations correctly then the test can be stopped. The same is true if the participant repeats fourteen or fifteen of the first fifteen presentations incorrectly. If a participant scores 75% or better, the participant is considered within normal limits. Each ear is scored independently for this test. The Duration Pattern test is similar to the Frequency Pattern test except that it involves one tone that is presented in one of six different triads that are either long or short in duration (e.g. long-short-long, short-short-long, short-long-short, etc).

Dichotic listening tests

Dichotic listening tests are designed to test the participants' binaural integration skills or their ability to process competing signals such as those experienced while listening to a signal in background noise. If one has difficulty with such tasks it typically manifests as a weakness in one ear, often the left ear. Two tests were administered: Dichotic Digits and Synthetic Sentences Identification. The Dichotic Digits test requires the subject to repeat a set of four different numbers to which two are presented in each ear simultaneously. The order the participant repeats the number is not important; the participant need only repeat the correct numbers in any order. The participants have as much time as they need to respond to each presentation, and the CD may be paused if necessary to allow the subject extra time to respond. Each ear is scored separately; the number of correct responses is divided by the number of items presented. A participant is considered to be within normal limits if they score 90% or better.

The Synthetic Sentence Identification with Contralateral Competing Message (SSI-CCM) test gives the participant a printed list of ten nonsense sentences. These sentences are presented in one ear while a competing message is presented in the opposite (contralateral) ear; both the sentences and the competing message are presented at the same intensity level for this study. The participant is asked to identify which nonsense sentence is heard while ignoring the competing message presented in the opposite ear. The number of correct responses is recorded for each ear individually and the number of correct responses is divided by ten for each set of ten nonsense sentences presented. The percentage correct is compared to the message to competition ratio (MCR). In this study the MCR is zero, based on the test norms any score of 85% or better is within normal limits while any score below 85% is considered outside normal limits for a MCR of zero.

Self-report questionnaires

The Rivermead Post Concussion Symptom Questionnaire or the Whiplash Disability Questionnaire were used with each test subject to assess their post TBI or WI residual symptoms. These questionnaires are designed to allow individuals to self-report symptoms such as headache or difficulty concentrating that were not present prior to the individual's injury. As stated previously symptoms of TBI and WI can last for seconds to years post injury. These questionnaires were employed to help assess how much difficulty participants reported having and what symptoms the participants reported having post injury.

Electrophysiological measures

Auditory brainstem responses (ABR) and middle latency responses (MLR) using conventional stimulus and recording parameters were recorded each participant. During the auditory evoked potentials recordings, the participants were seated in a reclining chair. Soft foam insert ear phones were placed in each ear canal, and it was through these inserts that the test stimuli were presented. The brainwave responses to the stimuli given to the participants were recorded separately for each ear. The responses were collected via six (6) small medical grade disc electrodes placed at specific locations on the subject's head, forehead, and earlobes. In order to ensure adequate connection between the skin surface and the electrodes the skin was cleaned with skin preparation cream to remove dirt and oils. After skin preparation, the electrodes filled with conduction paste were affixed to the spot that has been prepped and held in place with medical grade tape. During the recordings, the participants were asked to relax and remain still and quiet with their eyes open. The participants were not asked to do any other task during the process. The stimuli presented were standard stimulus 80 dB nHL acoustic clicks. The ABR is presented one ear at a time and is recordings are made from the same side as the stimulus is presented. For the MLR the stimuli were also presented one ear at a time but recordings are made from both the right and the left hemispheres of the brain at the same time. The tracings are then compared to see if there is an asymmetry or difference between the tracings from each ear [26,27]. Asymmetry is found when the peak to peak amplitude of the tracings for one ear are significantly less than those of the other ear. If there is a greater than 50% difference between ears then results are considered abnormal.

Results

Case histories

The case histories of the four participants in this study varied greatly in their cause, degree, and length of time since the initial injury. Despite the differences all four participants reported difficulties in daily living ranging from intense headaches to significant academic difficulties. Specifically participant 1 has had one motor vehicle accident-related concussion at the age of seven that resulted in a loss of consciousness. This participant reported no known academic difficulties but a long standing history of migraine headaches and a high level of fatigue. Participant 2 has had three concussions one due to impact on each side of the head and one to the base of the skull and reported a history of academic difficulties. Participant 3 had two concussions, one sport-related to the base of the skull and one motor vehicle accident leading to whiplash injury. This participant reported a history of migraine headache, fatigue, daily communication difficulties, academic difficulties, and short term memory difficulties. Participant 4 had one sport-related concussion to the base of the skull that resulted in a loss of consciousness. This participant had had the least recovery time of all the participants have sustained the injury less than a year prior to the study. The participant reported difficulties with academics, headaches, memory, fatigue, and activities of daily living.

Behavioral results

All behavioral results are shown in Figure 1. All behavioral testing results were found to be within normal limits for two of the four participants, and participant four was outside normal limits on only one of the test. Participant 3, on the other hand, was outside normal limits for all behavioral tests except SSI-CCM. Frequency Pattern Test results were found to be within normal limits for three of the four study participants. Participant 3's scores were outside normal limits for the left ear presentation, but within normal limits for right ear presentation. Duration Pattern Test results were within normal limits for participants 1 and 2 while participants 3 and 4 were outside normal limits in the left ear presentation and within normal limits for the right ear presentation. Dichotic Digits Test results were within normal limits for participants 1,2 and 4 while participant 3 was outside normal limits with a greater weakness in the left ear. Synthetic Sentences Identification with Contralateral Competing Message testing results were within normal limits for all four participants (Figure 1).

Self-report questionnaires

All four participants reported experiencing continued symptoms of concussion and whiplash injury. These symptoms were reported to be persistent not only several months post injury but to also continue several years after the initial injury and recovery period. Based on the questionnaires, participants 3 and 4 reported the most significant degree of persistent symptoms. Participant 3 was the only participant to present with abnormal behavioral test results, while participant 4 had had the least amount of recovery time but was outside normal limits for only one behavioral test. Results of this study also appear to indicate that participants can present with significant complaints years after the injury without behavioral testing results supporting the complaints.

Electrophysiological measures

The electrophysiologic testing results showed that despite reported difficulties and even multiple injurious events for all four participants

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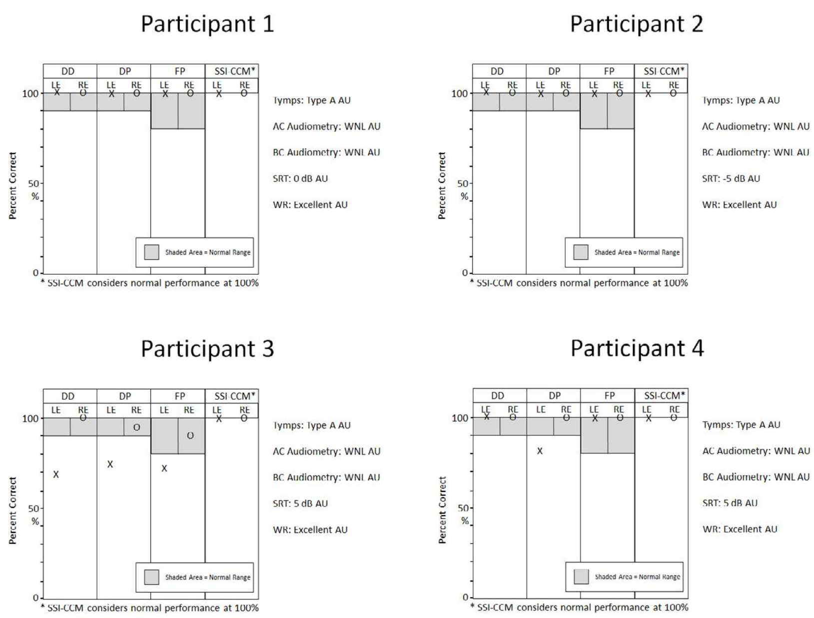

Figure 1: Behavioral results on Dichotic Digits (DD), Duration Patterns (DP), Frequency Patterns (FP), and Synthetic Sentence Identification (SSI-CCM). The shaded area represents normal limits. All results are reported in percent correct. To the right of all graphs are audiometric results. Key: Tymps (Tympanometry); AC (air-conduction); BC (bone-conduction); SRT (speech recognition threshold); WR (word recognition); AU (both ears); WNL (within normal limits); dB (decibels).

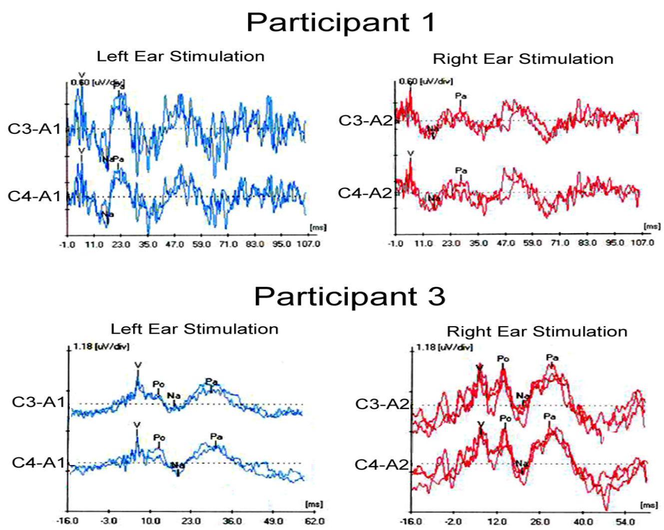

Figure 2: Middle latency response (MLR) waveforms for participants 1 and 3. Both participants exhibit ear effects with participant 1 showing larger left versus right Na-Pa amplitudes, while participant 3 has the opposite. Although the recording time windows differ between the two participants, all waveforms for the each participant is on the same amplitude scale for within-subject comparison.

presented with normal ABR recordings. This may be indicative of a more cortical site of lesion. At least two participants had abnormal MLR waveform morphologies. Figure 2 shows the MLR waveforms for participants 1 and 3, which were both abnormal and asymmetric for ear of stimulation (i.e., ear effect). Participant 1 presented with a mild right ear weakness despite having the least self-reported difficulties, normal behavioral test results, and the longest recovery time of all the participants. Participant 3 presented with a significant left ear weakness that was mirrored in the behavioral testing. This participant presented with a left ear weakness on all but one of the behavioral test and self-reported significant residual symptoms and academic difficulties (Figure 2).

Thus far results indicate that electrophysiological tests are able to identify subtle weaknesses with and without behavioral testing supporting an ear effect. It has also been shown that electrophysiological results can be within normal limits even when a participant reports significant difficulties in daily life. This was also seen in the behavioral testing; even though participants reported significant difficulties the standardized testing did not always support the participants' complaints.

Discussion

In comparison with the study conducted by [17], our study results found less of a direct correlation between TBI or WI and poor performance on one or more diagnostic auditory processing test. In this study only one participant showed significant difficulty on behavioral tests and one other presented with difficulty on one behavioral test. Though both studies found similar results on behavioral testing, the addition electrophysiology in the present study corroborated behavioral test results for one participant and also indicated an ear weakness in one participant who did not have abnormal behavioral test results. The results obtained in this study appear to indicate that electrophysiological tests are able to identify subtle abnormalities in some individuals with and without abnormal behavioral test results. Additionally, when MLR results were abnormal, they revealed an ear effect pattern. This is interesting since it has been argued that an ear effect finding is not as diagnostically significant as the electrode effect [28,29]. Also interesting is that Schochat, Rabelo, and Loreti suggest an ear effect is more likely to be found in cases of APD with an electrode effect than in cases of CANS lesions [30]. Even without abnormal behavioral results supporting the participants' reported difficulties, individuals can present with significant complaints of post concussive difficulties as revealed by the questionnaires. These complaints potentially point to some subtle, lingering quality of life issues that deserve greater attention. Specifically, there may be an underlying secondary diagnosis of APD. For these participants (and others with similar histories), formal auditory training may be helpful [7,31].

Conflict of Interests

The authors declare no potential conflict of interests.

References

1. American Speech-Language-Hearing Association (2005) (Central) Auditory Processing Disorders: The Role of the Audiologist Position Statement.
2. Abd al-Hady MR, Shehata O, el-Mously M, Sallam FS (1990) Audiological findings following head trauma. J Laryngol Otol 104: 927-936.
3. Bergemalm PO, Borg E (2001) Long-term objective and subjective audiologic consequences of closed head injury. Acta Otolaryngol 121: 724-734.
4. Bergemalm PO, Lyxell B (2005) Appearances are deceptive? Long-term cognitive and central auditory sequelae from closed head injury. Int J Audiol 44: 39-49.
5. Fligor BJ, Cox LC, Nesathurai S (2002) Subjective hearing loss and history of traumatic brain injury exhibits abnormal brainstem auditory evoked response: a case report. Arch Phys Med Rehabil 83: 141-143.
6. Flood GM, Dumas HM, Haley SM (2005) Central auditory processing and social functioning following brain injury in children. Brain Inj 19: 1019-1026.
7. Musiek FE, Baran JA, Shinn J (2004) Assessment and remediation of an auditory processing disorder associated with head trauma. J Am Acad Audiol 15: 117-132.
8. Musiek FE, Chermak GD (2008) Testing and treating (C)APD in head injury patients. The Hearing Journal 61: 36-38.
9. Musiek FE, Chermak, GD (2009) Diagnosis of (central) auditory processing disorder in traumatic brain injury psychophysical and electrophysiological approaches. The ASHA Leader 14: 16-19.
10. Van Toor T, Neijenhuis K, Snik A, Blokhorst N (2006) Evaluation of auditory processing disorders after whiplash injury. Audiol Med 4: 191-201.
11. Gaetz M, Bernstein DM (2001) The current status of electrophysiologic procedures for the assessment of mild traumatic brain injury. J Head Trauma Rehabil 16: 386-405.
12. Dean PJ, Sterr A (2013) Long-term effects of mild traumatic brain injury on cognitive performance. Front Hum Neurosci 7: 30.
13. NHTSA's National Center for Statistics and Analysis, Initials (2009) Traffic safety facts 2009 data. US Department of Transportation, National Highway Traffic Safety Administration, USA.
14. Gamble KH (2011) A new game plan for concussions as new research on the dangers of concussions is uncovered, treatment on sports sidelines is changing from the little leagues to the professional level. Neurology Now 7: 28-35.
15. McKee AC, Cantu RC, Nowinski CJ, Hedley-Whyte ET, Gavett BE, et al. (2009) Chronic traumatic encephalopathy in athletes: progressive tauopathy after repetitive head injury. J Neuropathol Exp Neurol 68: 709-735.
16. Bailes JE, Cantu RC (2001) Head injury in athletes. Neurosurgery 48: 26-45.
17. Turgeon C, Champoux F, Lepore F, Leclerc S, Ellemberg D (2011) Auditory processing after sport-related concussions. Ear Hear 32: 667-670.
18. Laforce R Jr, Martin-MacLeod L (2001) Symptom cluster associated with mild traumatic brain injury in university students. Percept Mot Skills 93: 281-288.
19. Gerberich SG, Gibson RW, Fife D, Mandel JS, Aeppli D, et al. (1997) Effects of brain injury on college academic performance. Neuroepidemiology 16: 1-14.
20. Marschark M, Richtsmeier LM, Richardson JT, Crovitz HF, Henry J (2000) Intellectual and emotional functioning in college students following mild traumatic brain injury in childhood and adolescence. J Head Trauma Rehabil 15: 1227-1245.
21. Johnstone B, Pinkowcki M, Farmer J, Hagglund K (1994) Neurobehavioral deficits, adolescent traumatic brain injury, and transition to college. J Clin Psychol Med Settings 1: 375-386.
22. Baran JA, Bothfeldt RW, Musiek FE (2004) Central auditory deficits associated with compromise of the primary auditory cortex. J Am Acad Audiol 15: 106-116.
23. Jerger J, Johnson K, Jerger S, Coker N, Pirozzolo F, et al. (1991) Central auditory processing disorder: a case study. J Am Acad Audiol 2: 36-54.
24. King NS, Crawford S, Wenden FJ, Moss NE, Wade DT (1995) The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. J Neurol 242: 587-592.
25. Pinfold M, Niere KR, O'Leary EF, Hoving JL, Green S, et al. (2004) Validity and internal consistency of a whiplash-specific disability measure. Spine 29: 263-268.
26. Chermak GD, Musiek, FE (1997) Central auditory processing disorders: New perspectives. Singular Publishing Group, San Diego, California, USA.
27. Musiek F, Charette L, Kelly T, Lee W, Musiek E (1999) Hit and false-positive rates for the middle latency response in patients with central nervous system involvement. Journal of the American Academy of Audiology 10: 124-132.
28. Kelly T, Lee W, Charette L, Musiek F (1996) Middle latency evoked response sensitivity and specificity. Paper presented at the annual meeting of the American Auditory Society, Salt Lake City, UT, USA.
29. Shehata-Dieler W, Shimizu H, Soliman SM, Tusa RJ (1991) Middle latency auditory evoked potentials in temporal lobe disorders. Ear Hear 12: 377-388.
30. Schochat E, Rabelo CM, Loreti RCDA (2004) Sensitivity and specificity of middle latency potential. Revista Brasileira de Otorrinolaringologia 70: 353-358.
31. Maranagoni AT, Gil D (2014) Behavioral assessment of auditory processing before and after formal auditory training in traumatic brain injury patients. Audiol Comm Res 19: 33-39.