Original Research Article

Event related potentials in cases of amblyaudia

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ABSTRACT

Background: Amblyaudia is a weakness in the listener's binaural processing of auditory information. Subjects with amblyaudia also demonstrate binaural integration deficits and may display similar patterns in their evoked responses in terms of latency and amplitude of these responses. The purpose of this study was to identify the presence of amblyaudia in a population of young children subjects and to measure mismatch negativity (MMN), P300 and cortical auditory evoked potentials (CAEPs) for those individuals.

Methods: Subjects included in this study were divided into 2 groups control group that consisted of 20 normal hearing subjects with normal developmental milestones and normal speech development. The study group (GII) consisted of 50 subjects with central auditory processing disorders (CAPDs) diagnosed by central auditory screening tests.

Results: With using dichotic tests including dichotic digits test (DDT) and competing sentence test (CST), we could classify these cases into normal, dichotic dysaudia, amblyaudia, and amblyaudia plus with percentages (40%, 14%, 38%, 8% respectively). Using event related potentials, we found that P300 and MMN are more specific in detecting neurocognitive dysfunction related to allocation of attentional resources and immediate memory in these cases.

Conclusions: The presence of amblyaudia in cases of central auditory processing disorders (CAPDs) and event related potentials is an objective tool for diagnosis, prognosis and follow up after rehabilitation.

Keywords: Central auditory processing disorders, Mismatch negativity, Cortical auditory evoked potentials, Dichotic digits test, Competing sentence test

INTRODUCTION

Amblyaudia is a new diagnostic category in auditory processing disorders (APD). When one ear is deprived during early developmental periods, it causes the other ear to compensate and leads to weaknesses in the listener's binaural processing of auditory information. Children who experience temporary hearing loss, most commonly from ear infections, are at an increased risk of developing amblyaudia.[1]

Children with amblyaudia may complaint of speech comprehension difficulties, reading difficulties, information processing deficits, poor verbal working memory, poor adaptive skills, and inattention.[2]

A recent diagnostic category of auditory processing disorder, amblyaudia, is characterized by an abnormally large performance discrepancy between the individual's two ears. The asymmetrical processing abilities lead to weaknesses in the binaural processing of auditory information, much in the same way as lazy eye (amblyopia).[3]

During critical periods of brain development, imbalanced auditory input associated with HL may lead to

abnormalities in binaural processing. Amblyaudia patients may demonstrate long-term deficits in auditory perception even with correction or resolution of HL. The greatest impact is recognized in sound localization and hearing in noisy environments, both of which rely on bilateral auditory cues.[4,5]

There is significant controversy in using behavioral, speech-based tests to assess children with auditory processing disorders via current diagnostic protocols. So, studying their evoked responses to various stimulus presentation paradigms, such as the P300 responses, MMN responses and other cortical responses, may give an idea about abnormalities in their central auditory processing in terms of latency and amplitude of their responses.[6]

The purpose of this study was to identify the presence of amblyaudia in a population of young children subjects and to measure MMN, P300 and cortical auditory evoked potentials (CAEPs) for those individuals and other control subjects without amblyaudia, and to investigate whether any of the objective electrophysiological measures show reliable differences in individuals with amblyaudia.

METHODS

This work was done in audiology unit, Tanta university in the period from February 2018 to April 2019.

This study is a prospective study. The idea of the research was explained in detail to the participants. An informed consent was obtained from all participants in this research. The participation was voluntary, and that the subjects may discontinue participation at any time without penalty or loss of benefits . The idea of the research will be explained in detail to the participants. Every participant will have a code number. The duration of the study will range from 9-12 months.

Subjects
Subjects included in this study will be divided into 2 groups.

A-control group (GI)

It consists of 20 normal hearing subjects with normal developmental milestones and normal speech development. They were 11 males and 9 females. Their age ranged from (5 to 12) years.

B-study group (GII)

It consists of 50 subjects with central auditory processing disorders (CAPDs) diagnosed by central auditory screening tests. They were 27 males and 23 females. Their age ranged from (5 to 12) years.

All participating subjects had normal hearing sensitivity at audiometric test frequencies 250 Hz to 8000 Hz. All participating subjects had normal middle ear function with present ipsilateral and contralateral acoustic reflex.

All participating subjects in this study were Rt handed. The main complaint of study group subjects was scholastic underachievement, inability to discriminate speech especially in noise and memory defects.

Methods

All participates in this study will be subjected to: basic audiological evaluation, central auditory tests including low pass filter for children (LPF), memory tests (recognition memory, memory for content and memory for sequence) and dichotic speech tests including dichotic digits test (DDT) and competing sentences test (CST). Also, event related potentials including: cortical auditory evoked potentials using speech stimuli /da/ and /ga/. P300 test using oddball paradigm using /da/ as standard stimulus and /ga/ as a deviant stimulus. MMN test using oddball paradigm using /da/ as standard stimulus and /ga/ as a deviant stimulus.

Equipment

Sound treated room which consists of transacoustic model no RE241. Pure tone audiometry of AC 40 two channel clinical audiometer with CD/tape player. Immittancemetry which includes interacoustic AT235h. Pre-recorded test materials of central auditory tests (LPF, Memory, DDT, CST). Event related potentials of smart EPs of intelligent hearing system (IHS). Software version microsoft windows XP intel 1945 bios.

Inclusion criteria

Bilateral normal peripheral hearing (with hearing threshold level not exceeding 25 dB at any frequency from the range of 250 to 8000 Hz). Age range from (5-14) years. No systemic diseases (e.g., any endocrinal, vascular, renal or neurological complaints).

Exclusion criteria

Subjects with any hearing complaints or history of audiological diseases. General health problems (e.g., any endocrinal, vascular, renal or neurological complaints).

Method

Central auditory tests

Low pass filter test (LPF)

Using pre-recorded CD of low pass filtered words (500,800 Hz) presented monoaurally at 50 dB SL (sensation level according to subject SRT). 25-word 4% score for each.

Dichotic digits test (DDT)

Two digits from 1 to 10 are presented binaurally to each ear simultaneously using headphones at 50 dB SL (sensation level according to subject SRT). The test consists of 20 stimulus presentations (40 per years), 80 digits in all. The listener is instructed that he will hear different numbers in each ear at the same time and to repeat all of the number heard regardless of order. The test contains four traing presentations. The test is scored in terms of precent correct per ear (for double digits each digit equals 2.5%).

Competing sentence test (CST)

Dichotic procedure use sentence as stimulus, it consists of simple sentences presented dichotichally using headphones. CST consists of 25 sentence pair each of the sentences is of similar length and content. Each pair of sentences (primary message and competing message). Ten target sentences are presented to one ear, followed by ten to the other. The remaining five stimuli may be used for practice. The target signal is presented to one ear at 35 dB SL and the competing signal is presented to the opposite ear at 50 dB SL.

Memory tests

Goldman-fristoe-woodcock auditory skills battery (GFWB)

The GFW includes three tests. GFW recognition memory test: the test consists 110 words divided into five lists. Each list contains 11 words represented twice to form a 22-word list. GFW memory for content test: The subject is instructed to repeat the list without regard for the sequence its elements. GFW memory for sequence test: This test employs the temporal strings as a mechanism of the declarative long-term memory processing.

Event related potentials

Cortical auditory evoked potentials (CAEPs)

Speech stimuli CV syllable */da/* and */ga/* were used. They were pronounced by a native Arabic male speaker. The recording window was starting from -50 m/sec before stimulus onset to 500 m/sec after stimulus presentation, giving a total time window of about 512 msec. The number of sweeps in an average was 50 sweeps. The stimuli intensity was 70 dB n HL.

The filter settings (recording bandwidth): 1 Hz to 30 Hz (low pass 30 Hz and high pass 1 Hz). Stimuli were presented monaurally to both ears via an ER3A insert phone starting with right ear.

Four disposable electrodes were fixed according to the Smart EP manual specification as the following: one high frontal Fz (positive electrode), one low frontal Fpz (ground electrode). The last two electrodes were placed on the left and right mastoids (as negative electrode or reference electrode) depending on the recording side. During test acquisition, every participant was instructed to lie down calmly on a comfortable coach.

P300 and mismatch negativity (MMN)

Both P300 and MMN were calculated with the same stimulus parameters as follow but the only difference was in the patient participation (in P300 the patient is calculating the deviant stimulus but in MMN, the patient is distracted from stimulus by playing silent game or watching pictures and stories in a book).

CV syllables /da/, /ga/ which were used. The selected signals were arranged in an oddball paradigm in which /da/ syllable was the standard and /ga/ syllable was the deviant stimulus.

Stimulus intensity was 70 dB nHL. Repetition rate (RR) was 1/sec with a stimulus duration of 200 msec. The deviant stimulus was presented randomly within the train of standard stimuli in an oddball paradigm. The probability was 20% for speech stimuli. Stimuli were presented monaurally to both ears via an ER3A insert phone starting with right ear.

The recording window was starting from 50 m/sec before stimulus onset to 400 m/sec after stimulus presentation, giving a total time window of about 450 m/sec. The low pass filter was at 30 Hz and high pass filter was at 0.1 Hz.

After finishing the test, off-line manipulation of the traces was done by detection of N100 presence and calculation of its latency for both the standard and deviant traces of each paradigm. N100 was determined on both standard and deviant traces as the negativity that occur at about 80-160 m/sec after stimulus presentation.

MMN was calculated in the difference waveform. This was done by creating a new destination buffer. The resulting difference between the standard and deviant traces represented the MMN responses which were identified visually as the prominent negativity following N100 occurring between 100 and 250 ms. Onset, peak, and offset latencies were measured. MMN duration was computed by subtracting the onset latency from the offset latency.

Statistical analysis

The collected data were statistically analyzed using SPSS version 19 (statistical package for social studies created by IBM, Illinois, Chicago, USA). For numerical values the range, mean and standard deviations were calculated. For each list and at different noise level, the X variable was presented as range, mean and standard deviations. Comparison of values using ANOVA tests. The level of significant was adopted at $p \leq 0.05$.

RESULTS

Subjects included in this study will be divided into 2 groups.

A-control group (GI)

It consists of 20 normal hearing subjects with normal developmental milestones and normal speech development. They were 11 males and 9 females. Their age ranged from (5 to 12) years with the mean of 9 ±1.45 years.

B-study group (GII)

It consists of 50 subjects with central auditory processing disorders (CAPDs) diagnosed by central auditory screening tests. They were 27 males and 23 females. Their age ranged from (5 to 12) years with the mean of 10 ±1.65 years.

Results of central auditory tests

All children in study group (GII) were subjected to dichotic tests including dichotic digits test (DDT) and competing sentence test (CST).

According to the results of these two tests, the findings allow for a child to be placed into one of four diagnostic subcategories: normal, dichotic dysaudia, amblyaudia, and amblyaudia plus.[7]

Testing within normal limits in both ears will lead to placement into the normal category. Having significantly low results in both ears without a significant interaural asymmetry leads to a dichotic dysaudia diagnosis. Normal results in the dominant ear with a significantly poorer performance in the non-dominant ear (i.e. a larger interaural asymmetry) leads to an amblyaudia diagnosis. Results that are significantly low in both ears with a large asymmetry leads to an amblyaudia plus diagnosis.[7]

Among 50 children, 40 % (20 children) were placed in the normal category. 14 % (7 children) in a dichotic dysaudia category. In an amblyaudia category, there were 38% (19 children). In an amblyaudia plus category, there were 8 % (4 children). So, in this study the study group (GII) was subdivided into 4 sub-groups (G II N, GII DD, GII AMB and GII AMB+).

All participants were Rt handed. 70 % (21 child) of children in affected group (including dichotic dysaudia, amblyaudia and amblyaudia plus) were complaining of recurrent otitis media with effusion documented by several tympanometry reports and trials of medical treatment. 62 % (13 child) of theses complaining children had bilateral Grommet Tube insertion. All children parents recorded complaints as scholastic underachievement, infrequent response to ordinary sounds, poor speech in noise abilities and memory affection.

Results of cortical auditory evoked potentials (CAEPs)

Comparison between P1, N1, P2 and N2 latency and amplitude of /da/ and /ga/ stimuli between control group and all study subgroups revealed no statically significant difference. The point of significance of $p \leq 0.05$ (Table 1 and 2).

Table 1: Comparison of CAEPs' waves' latencies of /da/ speech stimulus between the control and studied sub-groups.

CAEPs waves	GI	G II N	G II DD	G II AMB	G II AMB +	P value
P1 x (SD)	50.55 (4.86)	53.22 (5.95)	55.52 (7.53)	57.13 (4.13)	57.51 (3.55)	0.271
N1 x (SD)	103.13 (11.85)	104.96 (10.67)	106.13 (6.75)	108.23 (4.15)	110.55 (5.85)	0.320
P2 x (SD)	176.9 (10.48)	181.66 (14.63)	183.09 (18.52)	187.33 (13.12)	189.54 (15.77)	0.290
N2 x (SD)	232.8 (15.96)	233.3 (13.65)	233.8 (20.63)	236.61 (15.03)	241.11 (10.77)	0.326

Table 2: Comparison of CAEPs' waves' latencies of /ga/speech stimulus between the control and studied sub-groups.

CAEPs waves	GI	G II N	G II DD	G II AMB	G II AMB +	P value
P1 x (SD)	49.67 (7.59)	51.30 (6.01)	50.55 (7.34)	48.58 (9.01)	50.05 (4.35)	0.345
N1 x (SD)	103.35 (11.53)	108.7 (9.34)	107.09 (12.53)	106.55 (7.34)	104.22 (8.77)	0.234
P2 x (SD)	177.57 (20.39)	181.7 (16.99)	179.9 (18.59)	181.76 (13.11)	179.25 (12.53)	0.145
N2 x (SD)	233.90 (18.96)	237.10 (22.55)	245.5 (24.02)	239.44 (12.43)	243.5 (18.05)	0.365

Table 3: Comparison of P300 latency between the control and studied sub-groups.

P300 latency	GI	G II N	G II DD	G II AMB	G II AMB +	P value	Significance between which groups
X (SD)	288.58 (0.46)	311.37 (0.77)	322.40 (0.45)	357.33 (0.51)	367.72 (0.41)	0.002*	GI and GII AMB GI and GII AMB +

**Table 4: Comparison of P300 amplitude between the control and studied sub-groups.**

P300 amplitude	GI	G II N	G II DD	G II AMB	G II AMB +	P value	Significance between which groups
X (SD)	3.35 (0.68)	2.77 (0.34)	0.48 (0.75)	1.02 (0.76)	0.52 (0.87)	0.001*	GI and GII DD GI and GII AMB GI and GII AMB +

Table 5: Comparison of MMN latency between the control and studied sub-groups.

MMN latency	GI	G II N	G II DD	G II AMB	G II AMB +	P value	Significance between which groups
X (SD)	180.44 (20.9)	188.77 (0.34)	288.48 (0.75)	279.02 (0.76)	290.57 (0.37)	0.002*	GI and GII DD GI and GII AMB GI and GII AMB +

Table 6: Comparison of MMN amplitude between the control and studied sub-groups.

MMN amplitude	GI	G II N	G II DD	G II AMB	G II AMB +	P value	Significance between which groups
X (SD)	2.21 (0.53)	1.87 (0.67)	0.78 (0.45)	0.52 (0.53)	0.73 (0.87)	0.004*	GI and GII DD GI and GII AMB GI and GII AMB +
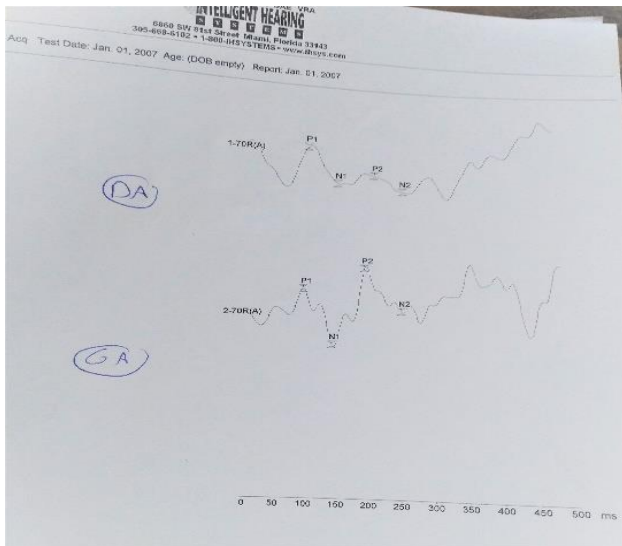
Figure 1: Traces of CAEPs of the study group using /da/ and /ga/ stimuli at 70 dB n HL showing within normal latencies and amplitudes.

Results of P300 event related potential

P300 response was absent in 8 cases (42%) of amblyaudia and in 2 cases (50%) of amblyaudia plus but present in all other cases sub-groups.

Comparison of P300 latency between control and study sub-groups revealed statistically significant difference between control and study groups. As regards amplitude, there was also statistically significant difference between control and study groups (Table 3 and 4).

Results of MMN event related potentials

MMN response was absent in 10 cases (52.63%) of amblyaudia cases, 3 cases (42.86%) of dichotic dysaudia and in 1 case (25%) of amblyaudia plus but present in all cases in normal sub-group II.

Comparison of MMN latency and amplitude between control and study sub-groups revealed statistically significant difference mainly between GI and GII AMB, AMB + and GII DD (Table 5 and 6).
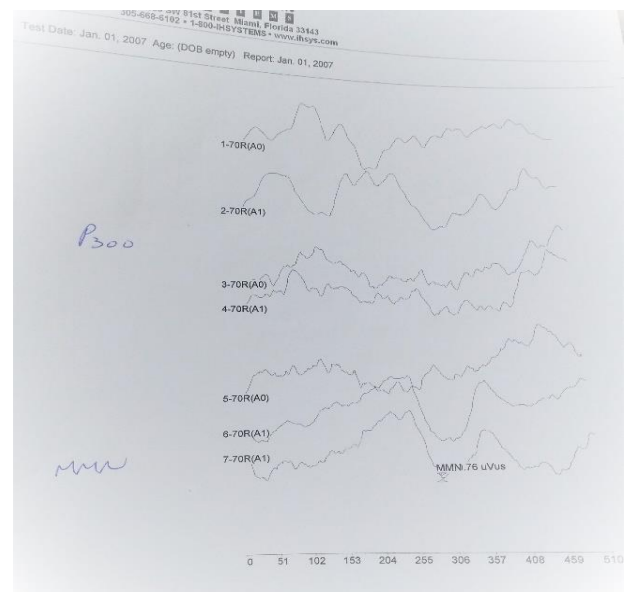
Figure 2: Traces of P300 and MMN of study group showing absent p300 and delayed MMN latency.
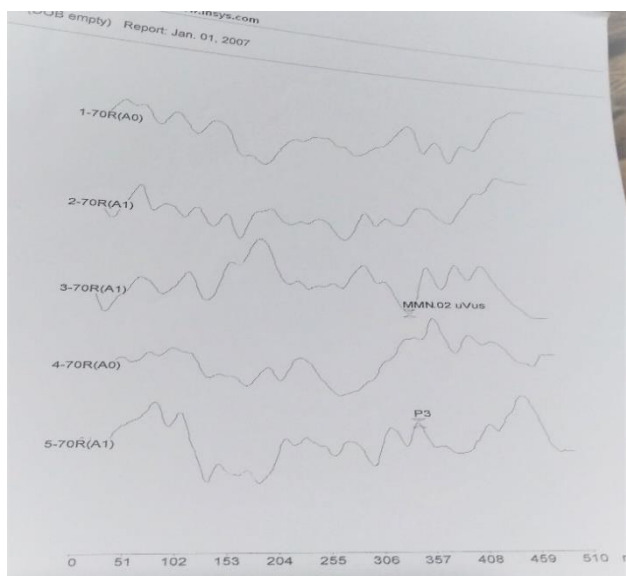
Figure 3: Traces of P300 and MMN of study group showing delayed p300 and MMN latency.

DISCUSSION

In the current study, by using dichotic tests we could classify these cases into normal, dichotic dysaudia, amblyaudia, and amblyaudia plus with percentages (40 %, 14 %, 38%, 8 % respectively).

Moncrieff et al reported a total of 79% of the children's scores into diagnostic categories (13% normal, 19% dichotic dysaudia, 35% amblyaudia, 12% amblyaudia plus). Amblyaudia, characterized as an abnormally large interaural asymmetry during DL tests with or without poor DL performance in both ears, was made in 66 of the 141 children referred for testing (47%). The high prevalence of DL score results that lead to a diagnosis of amblyaudia in this population of children suggests that many children suspected of APD suffer from this binaural integration deficit.[7]

Amblyaudia may result from any form of asymmetric auditory deprivation, including conductive and sensorineural causes, occurring during a critical period of development.[8]

Our finding revealed that 70% (21 child) of children in affected group (including dichotic dysaudia, amblyaudia and amblyaudia plus) were complaining of recurrent otitis media with effusion documented by several tympanometry reports and trials of medical treatment. 62% (13 child) of theses complaining children had bilateral Grommet tube insertion. Several studies have linked recurrent OM to deficits in binaural processing and language and learning disabilities.[9, 10,11,12]

In this study we measured MMN, P300 and CAEPs in children with amblyaudia to investigate any abnormalities

in any of these objective electrophysiological measures in amblyaudia cases.

Our study found no statistically significant difference in P1, N1, P2 and N2 latency or amplitude of /da/ and /ga/ stimuli between control group and all study subgroups.

On the other hand, Perera, 2018 found that many electrophysiological testing measures resulted in significantly larger average amplitudes at certain peaks. This evokes a similar thought that there is difficulty with suppression, which is leading to a magnified amplitude from overexcitement.[6]

As regards P300, delay of P300 latency between control and study sub-groups was also observed and reached the statistically significant difference. As regards amplitude, there was also statistically significant difference between control and study groups.

Moncrieff et al found longer latencies and reduced peak to-peak amplitudes of the P300 response in LED children.[13]

P300 has been used to assess discriminative responses thought to represent cognitive processes involved in conscious recognition, attention and discrimination of the acoustic characteristics of the stimuli.[14]

Our findings confirmed that the problems related to amblyaudia are multimodal, and may be caused by cognitive, memory, attention and language deficits. The delayed P300 latencies and reduced mean amplitudes in the children with amblyaudia suggest neurocognitive dysfunction related to allocation of attentional resources and immediate memory.

Muniz et al found that in children with auditory processing disorders group, the MMN was not elicited in all individuals. Furthermore, higher latency values and lower amplitudes were observed. This may mean that children with auditory processing disorders showed some impairment at neural levels to accurately discriminate the contrasts from the stimuli.[15]

CONCLUSION

From this work, we can conclude the presence of amblyaudia in the population of young children subjects complaining of central auditory processing disorders. With using dichotic tests including dichotic digits test (DDT) and competing sentence test (CST), we could classify these cases into normal, dichotic dysaudia, amblyaudia, and amblyaudia plus with percentages (40%, 14%, 38%, 8% respectively). Using event related potentials is an objective tool for diagnosis, prognosis and follow up after rehabilitation. Among these potentials, we found that P300 and MMN are more specific in detecting neurocognitive dysfunction related

to allocation of attentional resources and immediate memory in these cases.

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