International Journal of Otorhinolaryngology and Head and Neck Surgery
Dhara S et al. Int J Otorhinolaryngol Head Neck Surg. 2020 Aug;6(8):1477-1483
http://www.ijorl.com
pISSN 2454-5929 | eISSN 2454-5937

DOI: http://dx.doi.org/10.18203/issn.2454-5929.ijohns20203199

Original Research Article

Comodulation masking release effect in children with and without dyslexia

Sovon Dhara[1], Indranil Chatterjee[2], Himanshu Kumar[2], Susmi Pani[2]*

[1]iHEAR, Jadavpur, Kolkata, West Bengal, India
[2]Department of Audiology and Speech-Language Pathology, AYJNISHD, Kolkata, West Bengal, India

Received: 12 May 2020
Revised: 05 July 2020
Accepted: 08 July 2020

***Correspondence:**
Dr. Susmi Pani,
E-mail: panisusmi@gmail.com

ABSTRACT

Background: Speech recognition in a modulating noise background can be facilitated by a process attributable to comodulation masking release (CMR). CMR is usually assumed to depend on comparisons of the outputs of different auditory filters. There was an immense importance to study to find the CMR effect in children with and without dyslexia.

Methods: The study was to find the CMR effect in children with and without dyslexia. The current research was carried out through five steps i.e. auditory attention task stimuli preparation, auditory performance test, CMR stimuli preparation, CMR task and statistical analysis. Through these processes for measuring the CMR was done for the children with and without dyslexia. All the data were tabulated and statistically computed for the analysis of the data. SPSS software version 16 was used for the statistical analysis of the data.

Results: Independent t-test was used for the statistical analysis while the comparison between groups. Paired t- test was used for the statistical analysis while the comparison within the group at 95% confidence interval. These results indicated that the amount effect of CMR is greater in children with dyslexia. There was not a significant difference of CMR between the children with and without dyslexia to the effect of CMR was not significantly different between the ears in children without dyslexia and with dyslexia.

Conclusions: The present study indicates that children with dyslexia have selective inability to use the temporal and spectral cues necessary for signal extraction in CMR.

Keywords: Comodulation masking release, Masking, Dyslexia, Noise, Auditory performance

INTRODUCTION

The word “masking” to denotes the threshold shift by which the threshold of a sound is raised due to the presence of another sound. The basic masking experiment is really quite straightforward. First, the unmasked threshold of the test stimulus is determined and recorded. This unmasked threshold becomes the baseline. Next, the masker is presented to the subject at a fixed level. The test stimulus is then presented to the subject and its level is adjusted (by whatever psychoacoustic method is being used) until its threshold is determined in the presence of the masker. This level is the masked threshold.

Masking is not necessarily a symmetrical phenomenon. This spread of masking to frequencies higher than that of the masker has been repeatedly demonstrated for tonal maskers.[1] The masked threshold of the signal will not be changed by widening the noise bandwidth beyond the critical band (CB) or adding one or more other bands outside of the CB. The noise band centred on the test tone to be called the on-signal band, and for any other bands of noise to be called flanking or off-frequency bands. The masked threshold of the signal actually becomes better (lower) for the comodulated bands compared to what it was for just the on-signal band alone. This improvement is called comodulation masking release (CMR).

Masking refers to render a tone inaudible due to the presence of a noise in the same ear as the tone. The masking of the right ear means that a noise is put into the right ear, so that a tone cannot be heard in the right ear. The maintenance of the individuality of the various sounds simultaneously confronting the listener is very important rather than these sounds fusing together to form a unitary sound perception. It is quite possible for the presence of one sound to influence the detection of another sound. This phenomenon is called masking.[2]

CMR is usually assumed to depend on comparisons of the outputs of different auditory filters. However, these have shown that modulation of a masker can produce a release from masking even when the masker's bandwidth is less than the auditory filter bandwidth. This release from masking cannot arise from comparisons of the outputs of different auditory filters. Rather, it results from a cue or cues available in the output of a single auditory filter. Schooneveldt et al called such cues "within-channel cues".[3] One example of such a cue is a change in the pattern of envelope modulation that occurs when the signal is added to the masker; the envelope fluctuates less and the minima in the envelope tend to be less deep when the signal is present. This cue appears to be used in band-widening experiments, but it can only be used when the signal duration is greater than about 100 ms given by Schooneveldt et al.[3,4] CMR can be demonstrated by using narrow bands of noise, which inherently have relatively slow amplitude fluctuations. The on-frequency band is centered at the signal frequency. A second band, the flanker band is remote from the signal frequency. When the flanking band was uncorrelated with the on-frequency band, there was typically no effect on signal threshold.

CMR is largest if the total masker's bandwidth is large, the modulation frequency is low, the modulation depth is high, the envelope is regular and the masker's spectrum level is high.

The physiological correlates of CMR are observed at different levels of the auditory pathway. CMR occurs by the underlying physiological mechanisms of auditory pathway, including wide-band inhibition or the disruption of masker modulation envelope response.

Dyslexia is commonly described as a disorder manifested by difficulties in learning to read and spell, despite adequate intelligence and conventional instruction. Dyslexic children have an underlying deficit concerning the representation, storage, and processing of information about speech sounds or phonological processing.[5]

The “temporal processing hypothesis” suggests that individuals with specific language impairments (SLIs) and dyslexia have severe deficits in auditory processing rapidly presented or brief sensory information, both within the auditory and visual domains. The masking results can be better explained by an “auditory efficiency” hypothesis. If impaired or immature listeners have a normal temporal window, but need a higher signal-to-noise level (poor processing efficiency). The difference in performance on the masking tasks can be predicted from the compressive nonlinearity of the basilar membrane. The model also correctly predicts that backward masking is more prone to training effects, has greater inter- and intrasubject variability, and increases less with masker level than do other masking tasks.[6]

Dyslexic listeners have significantly higher thresholds of amplitude modulation depth than did match control listeners. Dyslexic listeners have reduced sensitivity to amplitude modulation (AM). This deficit in AM sensitivity may result in impaired perception of the AM present in speech. CMR reveals that the auditory system is able to capitalize upon information provided across critical band filters. It was anticipated that if children with dyslexia possess relatively poor temporal processing and frequency resolution, they would show less CMR than similar-aged children without dyslexia. It also was anticipated that children with dyslexia would show poorer processing efficiency. The children’s performance was compared with that of a group of children without dyslexia.

METHODS

Experimental research design was applied for the research. Subjects were selected into two groups from February 2014 to September 2014. First, thirty normal hearing male participants with normal scholastic performance were used for this study within the age range of 10-16 years (mean age- 12.7 years, SD-1.71). These participants were selected from Natibpur High School, Uluberia, Howrah. Second, thirty normal hearing male participants diagnosed with dyslexia by the psychologists or special educators were included for the study. The age range for the subjects was within the age range of 10-16 years (mean age-11.9 years, SD-1.29). These subjects were selected from Rajabazar Science College; University of Kolkata and some speech therapy centers. The inclusion criteria for the subject selections were for Group one, Normal auditory sensitivity across the total auditory range, normal scholastic performance, normal middle ear function which were determined with tympanometry and ENT evaluation. The exclusion criteria for subject selections in Group one were problems in sound tolerance through loudness discomfort level, uncomfortable level and most comfortable level, neurological impairment, cognitive impairment, auditory neuropathy spectrum disorder. In group two, the inclusion criteria were as similar with group one with including the subjects with dyslexia which were assessed by psychologists and special educators. The exclusion criterias for group two were same as Group one's exclusion criterias. Instruments were used dual channel audiometer (Maico MA 53) with supra aural (TDH 39) headphone, B-41 bone vibrator using ANSI S3.6-2004 specifications, Audio player. (Model- Sony NWZ-B172F), audacity software (version 2.0.5) MATLAB software version 8.1. One windows based personal computer with CD ROM (model- HCL AE2V0009-I), Digital sound level meter (model- Bruel & Kjaer type 2240), high definition (HD) headphone (model- Sennheiser HD 201). A two room audiometric setup was used. The test environment was met with ANSI S3.1-1999 specifications for the background noise.

Procedure

The auditory continuous performance test was consisting of two orally presented test lists in which a target phoneme /p/ will occur 21 times in a list of 100 randomly sequenced letters. All remaining phonemes in the Bengali consonants were used. Allophones of Bengali phoneme were treated as a single. The presentation intensity for the list1 was in between 54-62 dB(A). The presentation intensity for the list2 was in between 65-78 dB(A). Auditory attention stimuli were recorded by a female speaker at a rate of 1 stimulus per second. The recorded stimuli was burned onto a compact disk with Nero 8 software by one widows based personal computer with CD ROM (Model- HCL AE2V0009-I). The recorded were played to the participants through high definition headphones (model- Sennheiser HD 201).

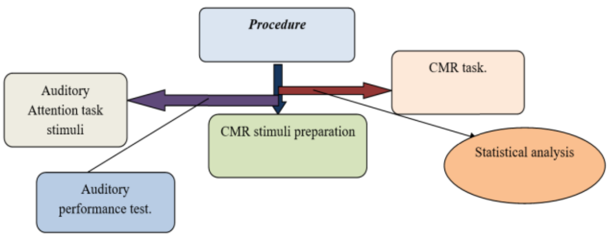

Figure 1: Steps of procedure used in this study.

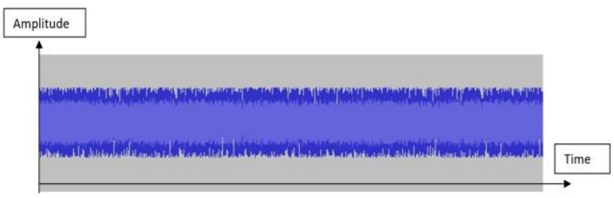

Figure 2: Spectral view of NBN used in this study.

Each participant was randomly assigned to receive one of the two lists of letters of auditory attention stimuli. Participants were instructed to lay a hand flat on the table and raise the thumb every time he hears only the phoneme /p/ spoken, and then place the hand flat again. The list was administered before CMR testing to ensure that the participants understood the task. The auditory continuous performance test administered immediately prior to the CMR task to determine the most accurate representation of participant's attention state at the time of auditory testing of CMR. The participants were selected after the correct response in at least 80% of the target phoneme. The auditory performance task was also used as the inclusive criterion.

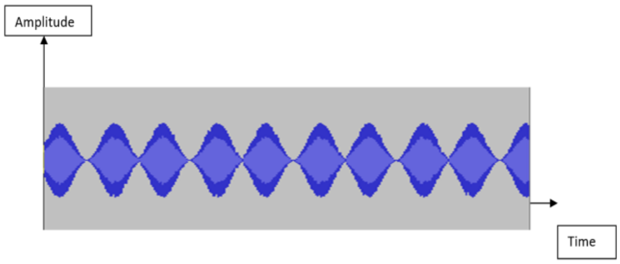

Figure 3: Spectral view of comodulation masking noise used in this study.

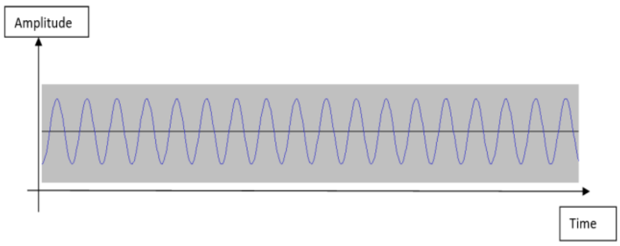

Figure 4: Spectral view of pure tone of 1 kHz used in this study.

CMR stimulus parameters were selected by using the parameter level that will bring the maximal amount of masking release given by Zetler et al. This procedure was lead to the greatest chance that the CMR stimuli will bring about the maximum masking release possible by the participants. A pure-tone (signal) and two noise maskers were generated. The signal stimulus was a 1000-Hz pure-tone signal will have 400-ms duration, including a 50-ms cosine^2 rise/fall time. Signal levels will be ranged from 10 dB to 100 dBHL. As 10 dBHL tone was inaudible in the participants for the identification of 1 kHz pure tone without making. The unmodulated masker was a 75 dB(A) SPL 20-Hz wide bandpass noise centered on the signal frequency (990–1010 Hz). The duration of the masker was 600 ms. The signal and masker was gated on simultaneously, and the signal will be gated off before the masker.

The comodulated masker was the on-signal masker in combination with eight flanking bands comodulated at a rate of 10 Hz. The flanking bands were 590–610 Hz, 690–710 Hz, 790–810 Hz, 890–910 Hz, 1090–1110 Hz, 1190–1210 Hz, 1290–1310 Hz, and 1390–1410 Hz. Each of the flanking bands was 20 Hz wide and separated from the others by 100 Hz. That was 100% amplitude modulated at 20 Hz. This comodulated noise and the non modulated noise both were designed by the use of MATLAB software version 8.1.

The comodulated masker's level was set at 75 dB(A)SPL, including all eight flanking bands. A custom software program digitized (MATLAB software version 8.1) the signals and maskers for CMR with a 20-kHz sampling rate using an Intel i3 processor board. The signal and maskers were burned in a CD ROM and played in a CD player and plugged in to MAICO MA53 audiometer audio cable, were routed through a TDH 39 headphone.

Calibration for the signal, narrowband and the comodulated masking noise were measured through a digital sound level meter (model- Bruel & Kjaer type 2240).

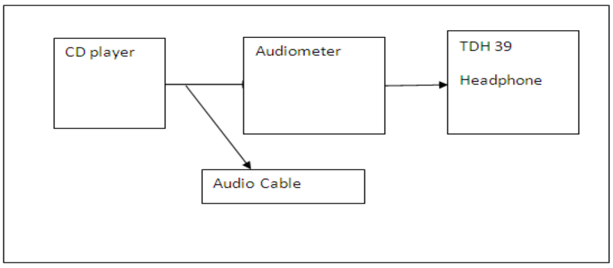

Figure 5: Block diagram of the arrangement used for the masking task with both modulated and comodulated masker.

The tone and the masker were presented in the same ear. The both maskers were set at 75 dB(A)SPL with the range of signal varying option from 10-100 dBHL. Signal length was 400 ms and the length of each of the masker was 600 ms. During masking session each of the masker and the signal started simultaneously, signal was gated off before the masker.

Two conditions were used to determine CMR in each participant. The first condition was consisted of the signal plus the on-signal masker (reference condition), and the other condition was consisting of the signal and the masker containing flanking bands (modulated-masker condition). The participants were randomly assigned to receive either the reference or the unmodulated condition or the modulated masker condition first. Signal range was varied in 1 dB step. The participants were given samples of the tone through headphones, the tone with the noise, and the noise alone. Using the patient response switch, they indicated whether the tone was presented or not by pressing patient response switch. After the completion of practice trials, testing in the relevant condition was began. All participants were tested with a single-interval yes–no procedure because previous research suggested that children with dyslexia may have problems making judgments of temporal order similiar to the finding of Pierzcki and Seeber.[7] Signal levels and threshold estimates were determined according to a maximum-likelihood algorithm. According to Gu and Green, this technique estimated reliable thresholds with fewer trials compared to other psychophysical methods.[8] The first trial was presented a stimulus level between 95 and 100 dB for which it was assumed that all listeners with normal hearing would be able to hear the tone within the noise masker, and the second trial presented the 10 dBHL stimulus level for which it was assumed that all listeners with normal hearing would not be able to hear the tone within the masker. Signal levels on subsequent trials were based on the participant's responses to the previous trials. The threshold for the both unmodulated (NBN) and the comodulated masker were tabulated. The CMR was determined by subtracting unmodulated masking threshold from the threshold with the comodulated masker. The threshold for the both unmodulated (NBN) and the comodulated masker were tabulated. The CMR was determined by subtracting unmodulated masking threshold from the threshold with the comodulated masker. This process for measuring the CMR was done for the children with and without dyslexia.

All the data were tabulated and statistically computed for the analysis of the data.

SPSS software version 16 was used for the statistical analysis of the data. Independent t-test was used for the statistical analysis while the comparison between groups. Paired t- test was used for the statistical analysis while the comparison within the group. All the statistical tests were done at the level of 95% confidence interval.

RESULTS

Table 1 indicates the age distribution of normal and dyslexic children participated in the study.

Table 1: Demographic data of participants.

Age range (in years)	Number of normal participants	Number of dyslexic participants
10-11	1	3
11-12	8	9
12-13	7	11
13-14	5	4
14-15	4	2
15-16	5	1

Table 2 indicates there is no significant ear effect of CMR in the study which indicates ear variability was not present.

Table 3 indicates that there was significant CMR effect present between the children with and without dyslexia that also indicates there is a relationship between the auditory processing and the CMR effect, as there is auditory processing deficit present in dyslexic child.

Table 2: Comparison of CMR in both ears, right ear, left ear between the participants without dyslexia and the participants with dyslexia through Levene's test for equality of variances.

Ear			F	Sig.	t	df	Sig. (tailed)	Mean	S.D.	95% confidence interval of the difference	
										Lower	Upper
Through both ears	CMR	Equal variances assumed	0.003	0.957	7.629	118	0.000	3.20000	0.4194	2.36941	4.03059
		Equal variances not assumed			7.629	118	0.000	3.20000	0.4194	2.36941	4.03059
Right ear	CMR	Equal variances assumed	0.063	0.803	6.978	58	0.000	3.80000	0.54457	2.70993	4.89007
		Equal variances not assumed			6.978	57.66	0.000	3.80000	0.54457	2.70980	4.89020
Left ear	CMR	Equal variances assumed	0.174	0.678	4.109	58	0.000	2.60000	0.63276	1.33340	3.86660
		Equal variances not assumed			4.109	57.948	0.000	2.60000	0.63276	1.33337	3.86663

Table 3: Paired t-test score of CMR between right ear score of participants with and without dyslexia (RTCMR1) and left ear score of participants without dyslexia (LTCMR1).

Pair		Mean	S.D.	Std. error mean	95% confidence interval of the difference		t	df	Sig.(2 tailed)
					Lower	Upper			
Pair 1 without dyslexia	RTCMR1 - LTCMR1	0.16667	3.21723	0.58738	-1.03467	1.36800	0.284	29	0.779
Pair 1 with dyslexia	RTCMR2 - LTCMR2	-1.03333	3.46891	0.63333	-2.32865	.26198	-1.632	29	0.114

DISCUSSION

The present study aimed to find the CMR effect in children with and without dyslexia. The following headlines were discussed beneath.

CMR effect between the children with and without dyslexia. CMR effect between the ears within children with and without dyslexia.

CMR shows a significant improvement in the detection threshold of a masked signal that occurs when the masker envelopes are comodulated across frequency which correlates with this study.[9]

A study was found little evidence to suggest that neural comodulation detection difference resulted from the across-channel processing of auditory grouping cues related to common envelope fluctuations and synchronous onsets between the signal and flanking bands.[10]

Zettler et al found in their study that the children showed significantly less CMR than adults.[11] The trend for CMR to increase with increasing age and the significant difference between children's and adults' thresholds suggests that the abilities necessary to achieve an adult-like CMR are not fully mature until beyond 10 years of age. This study supports the findings in our study. Similar results were found in our study.

In our study there was a significant difference observed in the children with and without dyslexia. Table 2 and 3 showed ear specific difference and arbitrary difference both were statistically significant at α=0.05. These results justified the auditory processing inefficiency and poor speech processing skill in children with dyslexia. Short-term and working memory deficits have been reported in children with dyslexia by Swanson, 1999 that might have played a role in the relatively higher thresholds found by the children in the present study, as a majority of children heard and practiced the stimuli only once at the beginning of each set of stimuli and had to keep the target stimulus in mind throughout a threshold run.[12] However, this possibility cannot be determined, as working memory was not evaluated in the present sample of children. As the maximum-likelihood estimation procedure used herein was designed to alleviate potential temporal order judgment confounds, which could result from the forced choice estimation procedure, it is apparent that methodological considerations such as these must be considered when working with individuals with impairments. The result of table II was indicated that the effect of CMR was present between the children with and without dyslexia. The result also indicated that the amount effect of CMR was lesser in children without dyslexia. These results indicated that the amount of CMR effect was greater in children with dyslexia. Table 3 showed the effect of CMR was not significant between the ears in children with dyslexia, there was not be any ear effect of CMR in children without dyslexia. Subsequent research showed that the right ear advantage could not be attributed to a generic advantage for the left hemisphere (or the right ear). When the stimuli were melodies, the advantage shifted to the left ear by Kimura.[13] The fact that processing efficiency seems particularly poor in the modulated masker condition suggests that across channel processing may be undergoing an especially protracted course of development. Future research with flanking bands spaced at wider frequencies is needed to lend support to this possibility. The dyslexic condition can predict CMR and also predict thresholds in the reference or modulated masker condition. Thus, this sample of children with (RD) showed no deficit in achieving a benefit from AM coherence. CMR appears to be a relatively slowly developing auditory skill, with the amount of masking release increasing significantly between middle childhood and adulthood. Likewise, processing efficiency, as reflected in children's high thresholds in the masking condition, appears to be undergoing development beyond 10 years of age. Further research that manipulates stimulus parameters is needed (i.e., a faster rate of AM than that used in the current study might tax the temporal abilities that are hypothesized to be sluggish in children with dyslexia and increasing the spacing between flanking bands to ensure a cross-channel processing) to determine whether altering stimulus parameters in CMR would have a significant impact on thresholds in children with dyslexia. Some studies intended to investigate a cross-channel processing but actually studied mostly within-channel cues due to the specific choice of the stimuli by Mott et al.[14] Additionally, testing large groups of children with multiple stimulus parameters will continue to clarify the developmental course of CMR. CMR appears poor for dyslexia at higher rates of which indicated a poor perception of auditory signal in children with dyslexia. CMR, however, is not a pure AM detection task, and other cues (e.g., spectral cues) are available to the listener, which were also involved in speech processing deficit, resulting in discernible impact on CMR by Moore et al.[15] Banai et al suggested that the type of task, along with the demands placed on working memory by the task, influenced whether or not children with dyslexia had difficulty performing the task.[16] This suggestion, along with the results of the present study, indicates that CMR appears to be a task that is not sensitive to dylexia.

This study is supported by the above studies, as they supported that there is no certain rule for ear effect, in this study there was both amplitude modulation and the effect of the flanking bands which played a key role for the perception of CMR. There was no ear effect of CMR in both the groups. These results revealed that the ear effect of CMR was insignificant in this study.

CONCLUSION

Lastly, we can conclude that in children with dyslexia children with dyslexia, have not only auditory processing difficulty but also poor speech processing skills because speech is also a comodulated signal as it varies with frequency and intensity over time. Ear specific difference could not be observed as there were various affecting parameters like only amplitude modulation and frequency modulation were counterpart to each other which resulted in similar value of CMR. Lastly, these results indicating that children with dyslexia have selective inability to use the temporal and spectral cues necessary for signal extraction in CMR.

ACKNOWLEDGEMENTS

Here I am finally complete my research. Months of effort and hard work finally shows the result. There are number of people who are to be thanked for all the help they have rendered, for being with my ups and downs and above all for being an important part of my life...I would like to thank judges for allowing me to carry out this study.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee of AYJNISHD, RC, Kolkata

REFERENCES

1. Wegel R, Lane C. The Auditory Masking of One Pure Tone by Another and its Probable Relation to

the Dynamics of the Inner Ear. Physical Review. 1924;23(2):266-85.
2. Durrant JD, Lovrinic JH. Bases of Hearing Science, Williams and Wilkins; 1995.
3. Schooneveldt G, Moore B. Comodulation masking release (CMR): Effects of signal frequency, flanking-band frequency, masker bandwidth, flanking-band level, and monotic versus dichotic presentation of the flanking band. The Journal of the Acoustical Society of America. 1987;82(6):1944-56.
4. Verhey J, Dau T, Kollmeier B. Within-channel cues in comodulation masking release (CMR): Experiments and model predictions using a modulation-filterbank model. J Acoustical Society Am. 1999;106(5):2733-45.
5. Snowling MJ. Dyslexia. Blackwell Publishing; 2000.
6. Hartley D, Moore D. Auditory processing efficiency deficits in children with developmental language impairments. J Acoustical Society Am. 2002;112(6):2962-6.
7. Tallal P. Auditory temporal perception, phonics, and reading disabilities in children. Brain Language. 1980;9(2):182-98.
8. Gu X, Green D. Further studies of a maximum-likelihood yes–no procedure. J Acoustical Society Am. 1994;96(1):93-101.
9. Pierzycki RH, Seeber BU. Comodulation masking release in electric hearing. J Association Res Otolaryngol. 2014;15(2):279-91.
10. Bee MA, Buschermöhle M, Klump GM. Detecting modulated signals in modulated noise:(II) neural thresholds in the songbird forebrain. European J Neurosci. 2007;26(7):1979-94.
11. Zettler C, Sevcik R, Morris R, Clarkson M. Comodulation Masking Release (CMR) in Children and the Influence of Reading Status. J Speech Language Hearing Res. 2008;51(3):772-84.
12. Swanson H. Reading Comprehension and Working Memory in Learning-Disabled Readers: Is the Phonological Loop More Important Than the Executive System?. J Experimental Child Psychol. 1999;72(1):1-31.
13. Kimura D. Cerebral dominance and the perception of verbal stimuli. Canadian J Psychology/Revue Canadienne De Psychologie. 1961;15(3):166-71.
14. Mott J, McDonald L, Sinex D. Neural correlates of psychophysical release from masking. J Acoustical Society Am. 1990;88(6):2682-91.
15. Moore B, Shailer M, Schooneveldt G. Temporal modulation transfer functions for band-limited noise in subjects with cochlear hearing loss. Br J Audiol. 1992;26(4):229-37.
16. Banai K, Ahissar M. Auditory Processing Deficits in Dyslexia: Task or Stimulus Related?. Cerebral Cortex. 2005;16(12):1718-28.

Cite this article as: Dhara S, Chatterjee I, Kumar H, Pani S. Comodulation masking release effect in children with and without dyslexia. Int J Otorhinolaryngol Head Neck Surg 2020;6:1477-83.