



Effect of diurnal changes on dichotic listening in younger adults with normal hearing

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ABSTRACT

Background: Diurnal changes can be defined as the time of the day over an individual's performance level for different activities that involve physical and mental tasks.

Objective: The current study aimed to evaluate the effect of diurnal changes in scores obtained for the Dichotic Consonant-Vowel paradigm by young adults with normal hearing sensitivity.

Method: Based on the 'Morningness-Eveningness questionnaire' given by Horne & Ostberg, the subjects were divided into moderately-morning, intermediate and moderately-evening categories. The Dichotic Consonant-Vowel tests were performed during morning and evening, and the right ear, left ear and double correct scores were compared between morning and evening for each category.

Results: There was significant diurnal changes noted for moderately morning and evening categories, where morning-type individuals performed better during morning and evening-type individuals performed better during the evening. The scores of intermediate individuals remained unchanged between morning and evening test results.

Conclusion: Diurnal change is a phenomenon associated with an individual's biological clock mechanism. Hence, attention and inhibitory controls aid them in carrying out tasks that require sufficient physical and mental efforts. The current study suggests that clinicians and researchers consider diurnal changes as an extraneous variable that could affect the reliability of the Dichotic Consonant-Vowel test results.

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1. Introduction

Dichotic listening occurs when two different stimuli are presented at each side simultaneously (Kimura, 1967). It has been extensively utilized in experimental and clinical studies to explore the maturation of the auditory pathway, functional lesions, and interhemispheric transfer of complex auditory information (Moncrieff and Wilson, 2009). Two auditory processes that are defined under dichotic listening are binaural separation and binaural integration. Both the processes are executed based on the instructions provided to the listener prior to the stimulus presentation. The former refers to the ability to focus on target stimuli by

avoiding unwanted stimuli such as listening in competing noise. The latter refers to the ability to bring together the information that was heard in both ears simultaneously (Kimura, 1967). Different stimuli like consonant-vowel (CV), digits (single, double, and triple), sentences, and rhymes have been used in evaluating the dichotic listening performances (Fifer et al., 1983; Moncrieff and Wilson, 2009; Shankweiler and Studdert-Kennedy, 1967; Wexler and Halwes, 1983). The dichotic listening performances could be predominantly stimulus-dependent and are also affected by factors like maturational delays, auditory processing disorders, demyelinating disorders, attentional deficits, cerebral dominance, and cerebral asymmetries (Musiek and Weihing, 2011).

The Right-ear advantage (REA) is another phenomenon associated with dichotic listening, which could be explained by a stronger contralateral neural linkage of the right ear to the left (language dominant) hemisphere, whereas the connection to the left hemisphere from the left ear is mediated via corpus callosum which underlies a comparatively longer neural pathway and thereby require longer transmission time for the stimulus to reach the left

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hemisphere from the left ear (KIMURA, 1961). Even a transmission delay of about 25 msec has been reported between the right and the left ear stimuli reaching the left temporal lobe (Ringo et al., 1994). A test-retest reliability correlation of about 0.86 has been reported by Kenneth Hugdahl & Hammar (1997) for the Dichotic consonant-vowel testing paradigm. However, there could be various known as well as unknown factors influencing the dichotic listening performance when these tests are carried out each time.

The circadian rhythmicity can be defined as a biological clock mechanism that is driven by the suprachiasmatic nuclei at the level of the hypothalamus (the circadian pacemaker) in humans (Katzenberg et al., 1998a). It is an intracellularly balanced process that helps an organism to follow the biological clock mechanism (Katzenberg et al., 1998a; Schmidt et al., 2007a). As a result, individuals tend to have a morning and evening effect on the activities involving mental and physical efforts (Giannotti et al., 2002). Even though few inter and intra-individual changes have been reported, one complete cycle of the biological clock is approximately equal to 24 h (Kerkhof, 1985). This clock mechanism is regulated by the photoreceptors in the retina, that pick up the light and thus serve as input to the suprachiasmatic nuclei via the retinohypothalamic tract (Revell and Eastman, 2005).

There have been reports of physiological processes like body temperature and blood pressure being influenced by diurnal changes (Kerkhof, 1985). A study by Jarraya et al. (2013) reported that there was a significant increase in reaction time for trained athletes while performing a cognitive task during the days, where they had short intervals of sleep deprivation during the initial or final hours of the sleep cycle, compared to regular days where normal sleep hours were met. The performance seemed to decrease in the afternoon hours significantly, whereas morning hours didn't exhibit much effect on sleep deprivation. A few studies have attempted to explore the time of the day's effects on the processing and perception of auditory information. One of them was reported by Huang et al. (2005), where they found an increased amplitude and shorter latency for P300 waveforms in morning type and evening type of individuals when assessed during their peak hours of performance. A couple of recent studies reported that differential sensitivity of intensity and frequency and temporal processing abilities are influenced by diurnal changes (Nikhil et al., 2018; Prakash et al., 2021). The above-mentioned studies put forward the significance of diurnal effects on the abilities to detect those minute and transient changes in the auditory stimuli, where a comparatively higher amount of attention is demanded from the listener. There is limited literature that has tried to document diurnal effects on binaural processing abilities. Apart from these, stronger diurnal effects have been observed on cognitive functions like attention and short-term memory. So, audiological tests that utilize a higher level of attention of subjects to stimuli are likely to be affected by circadian rhythmicity. Among the binaural auditory processes, dichotic listening is a major test that has been used in various Central Auditory Processing (CAP) test batteries as well as used for training binaural separation in individuals CAP disorders (Jerger and Martin, 2006). So, it may be interesting to explore the presence of diurnal effects and its extent if present on dichotic listening abilities. Hence, the current study aims to evaluate the diurnal changes in individuals hearing sensitivity within normal limits. The objectives are to analyse the effect of diurnal changes on scores obtained for the right ear, left ear, and double correct scores for the dichotic consonant-vowel (D-CV) paradigm.

2. Methods

2.1. Participants

Sixty individuals (30 male and 30 females) who were right-handed and had normal hearing sensitivity took part in the study. The age of the participants ranged from 18 to 28 years (mean age: 21.85, SD = 2.28). None among them had any reported otological issues like tinnitus, ear discharge, pain, or vertigo. All the participants had normal middle ear functioning and a hearing sensitivity within 15 dB for air conduction (AC) and bone conduction (BC) measurements with an air-bone gap of ≤ 10 dB. Based on the 'Morningness-Eveningness Questionnaire' by Horne and Ostberg (1976), the subjects were categorized into moderately morning, moderately evening, and intermediate types. The age range of the moderately-morning category individuals was 19–26 years (mean = 21.50), intermediate category individuals was 18–26 years (mean = 21.70) and moderately-evening category individuals was 19–28 years (mean = 22.85). Each category had 20 participants (10 males and 10 females) who were selected after administering the Morningness-eveningness questionnaire and the audiological evaluation that followed.

2.2. Audiological evaluation

To evaluate hearing sensitivity, the Pure tone audiometry was performed at octaves from 250 Hz to 8000 Hz using a Grason Stadler GSI-61 clinical audiometer (Grason Stadler Inc.-GSI-61; Milford, NH, USA). The modified version of the Hughson and Westlake procedure was used to conduct testing (Carhart and Jerger, 1959). The participants had normal hearing sensitivity (threshold ≤ 15 dB for AC and BC). The Phonemically Balanced word list in Kannada (Yathiraj and Vijayalakshmi, 2005) was used to determine the speech discrimination scores. All the participants had a speech discrimination score of 100%. Immittance evaluations to monitor middle ear functioning were performed using a 226 Hz probe tone, and middle ear muscle reflex (MEMR) thresholds were obtained at frequencies 0.5, 1, 2 and 4 kHz with a Grason Stadler Middle ear Analyser (GSI-Tympstar) (Grason Stadler Inc.-GSI-61; Milford, NH, USA). Bilateral A-type tympanogram and MEMR thresholds recorded within normal sensation levels were obtained, indicative of normal conductive pathway and no significant functional lesion up to the level of lower brainstem.

2.3. The 'morningness -eveningness questionnaire'

The questionnaire categorized the individuals into five categories based on the total scores obtained (Horne and Ostberg, 1976). A total of nineteen test items comprised the questionnaire, focusing on an individual's report of his/her best rhythm in carrying out mental and/or physical tasks during a day and included the questions focusing on level of alertness, fatigue, and sleep-wake patterns. The subjects were asked to complete all the nineteen questions and depending on the scores, the grouping of subjects was done. A total score ranging from 70 to 86 was considered a definitely-morning category. Similarly, scores ranging between classes of 59–69, 42–58, 31–41, and 16–30 were grouped into moderately-morning, intermediate, moderately-evening, and definitely-evening categories, respectively. Due to a limited availability of participants falling under definitely morning and evening

categories in the current study, those categories were excluded. Hence, the current study comprised of moderately-morning, intermediate and moderately-evening categories of individuals.

2.4. Procedure

The Dichotic-Consonant-Vowel (CV) test developed by Yathiraj (1999) was presented via a laptop calibrated with a TDH supra-aural headphones, and the stimulus was delivered at a level of 50 dB SL (ref. Speech reception threshold). The stimulus track consisted of syllables presented to both ears with 0 msec lag between ears. The subjects were asked to write down the syllables that were heard on a sheet of paper as two separate columns indicating right and left ear responses separately. All the subjects were tested in a quiet and distraction-free room. As mentioned in the questionnaire, the tests conducted during the morning were carried out between 7.30 a.m. and 9.30 a.m. and during the evening were carried out between 5.30 p.m. and 8 p.m. as per the available convenient time of the subjects. The time of the day (morning and evening) for performing the initial test was randomized among subjects. The scores obtained for the right ear, left ear and combined correct responses were calculated and compared between morning and evening test results for each category.

2.4.1. Ethical Considerations

The present study was conducted using non-invasive non-hazardous procedures and adhering to the “Ethical Approval Committee of the Institute and compiled with the Declaration of Helsinki.” All the participants were informed regarding the objective and procedures of the study, and informed consent was obtained from all the participants.

2.4.2. Statistical Analyses

The results were statistically analyzed using the Statistical Package for the Social Sciences (SPSS) software version 20.0 (Frey, 2017). The Shapiro-Wilk test of normality was conducted to check the normal distribution of data. Descriptive statistics were conducted to calculate mean, median, standard deviation, and range of scores obtained during morning and evening by all three categories. The scores were compared for the right correct, left correct and double correct responses. Since the data were normally distributed, a parametric paired *t*-test was used to assess the level of significance of scores obtained during morning and evening by moderately-morning, intermediate and moderately-evening categories of individuals. The above-mentioned analyses were conducted for all three parameters, respectively.

3. Results

There was a notable increase in mean scores for moderately-morning category individuals when tested during the morning and for moderately-evening individuals when tested during the evening. There was no difference in scores seen for intermediate

category individuals with respect to different times of the day. The mean scores, median, standard deviations, and interquartile ranges of moderately-morning, intermediate and moderately-evening categories have been shown in Tables 1–3, respectively.

Figs. 1–3 show mean scores obtained for the right ear, left ear and both ears respectively by each category of individuals.

Inferential statistics were performed to identify whether there existed statistically significant differences between morning and evening scores for each category. Since the data were normally distributed according to the Shapiro-Wilk test ($p > 0.05$), a parametric paired *t*-test was conducted. The findings indicated a statistically significant difference between the scores obtained during morning and evening sessions obtained by moderately-morning and moderately-evening individuals ($p < 0.01$). The above-mentioned difference was evident in the right ear, left ear, and double correct scores respectively. The intermediate category showed no significant difference between morning and evening scores in any of the three parameters ($p > 0.05$). The results of paired *t*-tests have been depicted in Table 4.

The differences in right ear and left ear scores obtained by each category during morning and evening were compared using a parametric paired *t*-test which revealed no significant difference in right ear-to-left ear differential scores during different times of the day in all the three categories ($p > 0.05$).

4. Discussion

Dichotic listening simply means listening and identifying to two stimuli at a time where each stimulus is presented to each ear. Depending on the similarities and differences in the spectrum and the duration presented stimuli, the difficulty faced by the brain in separately identifying these stimuli varies. This process constitutes complex auditory processing which involves integrating multiple inputs from different parts of the central auditory nervous system (Kimura, 1967). Dichotic listening tasks are strongly influenced by an individual's attention and alertness level during the time of testing (Asbjørnsen and Hugdahl, 1995; Kimura, 1967).

Chrono-psychologists refer to circadian rhythmicity as an influence of day and night-related changes in an individual state of feeling most active. It can be observed in both physical as well as mental tasks performed (Katzenberg et al., 1998a). In the current study, we found out a strong diurnal influence on morning and evening type individuals in carrying out dichotic listening tasks. Those individuals falling under the moderately morning category performed better during the morning, whereas a decline in performance levels was observed during the evenings. Similarly, those under the moderately evening category performed well during late evenings rather than in the morning. Individuals belonging to the intermediate category showed neither morning nor evening effect on listening performances. The attentional component that underlies this listening task which is likely to be influenced by time of the day, is the primary reason behind this effect (Guerrien et al., 1993). On comparing the right ear-to left-ear score differences

Table 1

Table 1 depicts mean, median, standard deviation, and interquartile range of scores obtained by 3 categories of individuals for right correct scores.

		Right correct scores			
	Time of the day	Mean	Median	SD	Inter Quartile range
Moderately Morning	Morning	27.05	28.50	3.14	4
	Evening	24.05	25.50	4.37	5
Intermediate	Morning	26.85	26.50	2.30	4
	Evening	26.50	26.50	2.04	3
Moderately Evening	Morning	22.70	22.50	4.67	6
	Evening	25.35	25.50	2.89	5

Table 2

Table 2 depicts mean, median, standard deviation, and interquartile range of scores obtained by 3 categories of individuals for left correct scores.

		Left correct scores			
	Time of the day	Mean	Median	SD	Inter Quartile range
Moderately Morning	Morning	26.20	27.00	3.58	6
	Evening	23.90	24.50	4.35	5
Intermediate	Morning	23.00	25.00	4.39	8
	Evening	23.65	25.00	4.67	8
Moderately Evening	Morning	20.65	19.00	5.29	9
	Evening	24.05	24.00	3.63	4

Table 3

Table 3 depicts mean, median, standard deviation, and interquartile range of scores obtained by 3 categories of individuals for double correct scores.

		Double correct scores			
	Time of the day	Mean	Median	SD	Inter Quartile range
Moderately Morning	Morning	24.40	25.50	4.58	6
	Evening	20.90	22.50	5.50	8
Intermediate	Morning	20.35	21.00	4.78	9
	Evening	20.55	21.00	5.45	8
Moderately Evening	Morning	17.40	16.00	6.05	10
	Evening	21.25	22.00	4.76	7

Mean right ear scores

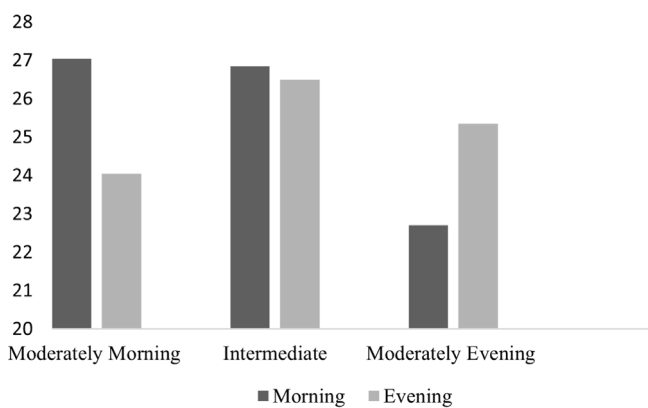


Fig. 1. Showing mean right ear scores obtained during morning and evening by each category of individuals.

Mean double correct scores

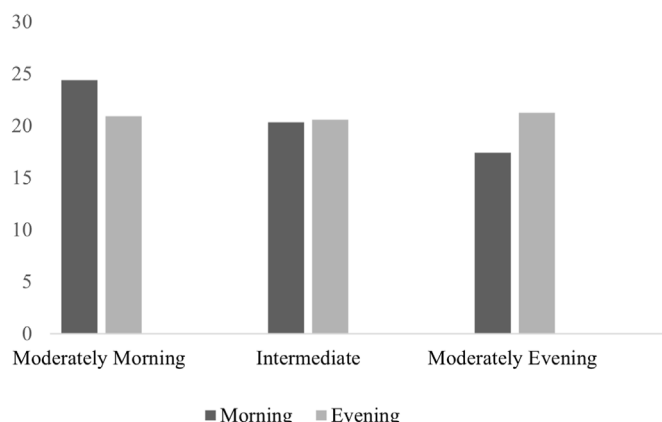


Fig. 3. Showing mean double correct scores obtained during morning and evening by each category of individuals.

Mean left ear scores

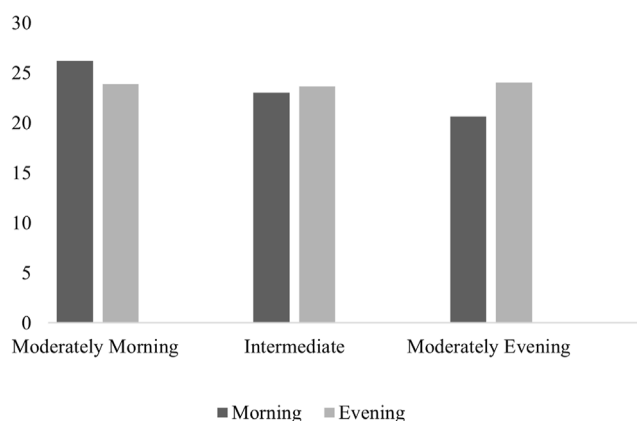


Fig. 2. Showing mean left ear scores obtained during morning and evening by each category of individuals.

Table 4

Inferential statistic (*t* and *p* values) between the morning and evening test results of moderately morning, intermediate and moderately evening categories of individuals. *- statistically significant difference was present between morning and evening test results ($p < 0.01$).

	Right correct scores		Left correct scores		Double correct scores	
	<i>t</i> value	<i>p</i> value	<i>t</i> value	<i>p</i> value	<i>t</i> value	<i>p</i> value
Moderately Morning	5.02	0.002*	3.93	0.005*	6.723	0.002*
Intermediate	0.91	0.38	-0.73	.48	-0.26	0.80
Moderately Evening	-3.35	0.001*	-3.80	.001*	-4.94	0.001*

(right ear advantage) between the morning and evening results, it was found that there was no significant change in interaural differential scores. The above result is thereby suggestive of an overall reduction in dichotic listening scores as a function of time of the day influences rather than a reduction in specific ear scores or any changes in dominant ear performances.

Apart from, this numerous physical and physiological processes like body temperature, blood pressure, hormone secretions,

glucose metabolism, sleep-wake cycles, the release of neurotransmitters, and cognitive functions like attention and short-term/sensory memory have been extensively reported to be influenced by circadian rhythmicity (Dyar et al., 2014; Giannotti et al., 2002; Katzenberg et al., 1998b; Kerkhof, 1985; Schmidt et al., 2007b). All these factors are directly or indirectly related to the functioning of the auditory system and the overall activity of the nervous system. Beginning from the micromechanics of the cochlea, which are regulated by the adequate blood supply and nutrients that mediate the appropriate functioning of the sensory hair cells till the binaural auditory processing, which involves both ipsilateral and contralateral ascending auditory pathways along with corpus callosum functions are dependent can be affected by the above-mentioned factors (Al-Mana et al., 2008; Neely and Kim, 1998; Portas et al., 2000).

Another explanation of the possibility of being influenced by diurnal changes is the difficulty of the task carried out. Petros et al. (1990) conducted an experiment on sentence recall tasks that included easy and difficult materials. The results revealed an effect of diurnal changes only for recall of difficult material, whereas easy material recall tasks were not affected by the time of the day. The extent of neuronal networks and subfunctions which assist in carrying out a task, the difficulty of the stimulus used, and the level of attention required to perform the task could be correlated with the extent of being affected by diurnal changes.

The findings of the current study are in agreement with the previous literatures in speech identification in noise and temporal processing abilities, which were reported to be influenced by circadian rhythms (Fostick et al., 2014; Nikhil et al., 2018; Prakash et al., 2021). Our results hereby denote that the potential to suppress unwanted information or so-called as inhibitory control has an effect on the binaural processing of speech stimuli. Binaural integration and separation are two key elements that aid in the central auditory processing of speech and non-speech stimuli (Galbraith et al., 1983). These phenomena are crucial for a child's development and learning from acoustic inputs present in the environment. Even for adults, listening in a daily environment strongly rely on these phenomena (Kohlrausch et al., 2013). Dichotic listening is a test that evaluates the functional impairments or asymmetries of bilateral ascending auditory pathways, Heschl's gyri of both the hemispheres and corpus callosum (Cohen et al., 1992; K. Hugdahl, 1995; Kimura, 1967). Additionally, studying syllable processing helps identify phonological decoding problems and phonological processing deficits, as in cases of dyslexia or language impairment.

The current study indicates that an individual can exhibit poor performance in dichotic listening when tested during their off-peak hours of the day as their inhibitory influence is less effective in processing information during these hours. Another important factor to be noted is that the current study included only moderately morning and evening categories. According to the Morningness-eveningness questionnaire (MEQ) (Horne and Ostberg, 1976), definitely-morning type and definitely-evening type; the two categories of individuals who are believed to have a strong dependency on circadian rhythms for performing activities that require considerable physical and mental efforts are likely to exhibit even more reduction in performance scores during their off-peak hours of the day. Hence the study suggests that diurnal changes to be considered as an extrinsic variable that could affect test scores of dichotic consonant-vowel identifications and could be one of the factors that could potentially affect the overall reliability of the Dichotic-CV scores.

5. Conclusions

The present study aimed to evaluate the influence of the diurnal change over the dichotic-CV paradigm. The findings revealed a significant difference in the scores, indicating a diurnal effect over dichotic listening tasks. The moderately morning individuals performed better when tested during the morning and moderately evening individuals performed better when tested during evenings. There was no notable differences seen in intermediate category individuals when scores of mornings and evenings were compared. This effect is present in the morning and evening-type individuals as their inhibitory control mechanisms are less efficient during the off-peak hours, which is reflected as a deterioration of sustained attention to presented stimuli. From the study, it can be inferred that dichotic consonant-vowel testing can be influenced by diurnal effects in individuals who seem to show a preference for a particular time of the day to perform tasks that involve sufficient mental and/or physical efforts. Hence, the study suggests diurnal changes to be considered as an extraneous variable while conducting dichotic listening tests.

5.1. Limitations of the study and future directions

The current study was done on younger adults and extending the research into older adults could help to generalize the findings. The definitely -morning and -evening categories could not be included in the study due to limited subject availability. So, including them in future research could enlighten more intensive effects of circadian rhythms over dichotic-CV performances. The effects of diurnal changes could also be studied on objective audiological test findings.

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Nil.

Authors' contributions

PP was involved in study design, data collection, analysis of the data, interpretation and writing the manuscript, VK was involved in study design, data collection, analysis of the data, interpretation and writing the manuscript, DM was involved in study design, data collection, analysis of the data, interpretation, and writing the manuscript, PP* was involved in study design, stimulus preparation, data collection, analysis of the data, interpretation and writing the manuscript.

Ethics approval

AllSH ethical committees approved the study method for bio-behavioral research.

Consent to participate

Written informed consent taken prior commencing the data collection.

Consent for publication

Yes, informed content was obtained from subjects for participating in the study.

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