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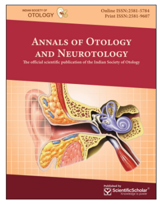

Original Article

Effect of Diurnal Changes on Auditory Stream Segregation Using Spectral Profile Analysis in Young Adults with Normal Hearing

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ABSTRACT

Objectives: The current study sought to examine the auditory stream segregation abilities of three participant groups (moderately morning, intermediate, and moderately evening).

Material and Methods: Sixty participants aged 18–25 with no otological complaints and normal hearing sensitivity participated in the study. Based on the Morning–Eveningness Questionnaire, sixty participants were divided into three groups, with twenty participants in each group (moderately morning, intermediate type, and evening type) included in the study. Using MATLAB software, a spectral profile analysis test was administered to each participant in the morning and evening at the most comfortable level.

Results: The findings showed that there were diurnal preferences in the performance of morning and evening types, with morning types doing better when tested in the morning and evening types performing better when evaluated in the evening. However, the intermediate type showed no discernible diurnal impacts.

Conclusion: Low scores may be caused by poor cognitive function and a lack of inhibitory control during off-peak hours.

Keywords: Diurnal, Spectral profile analysis, Spectral profiling, Stream segregation

INTRODUCTION

The time of day that affects a person's capacity to execute both mental and physical tasks is known as a diurnal change. Every individual's sleep-wake cycle is regulated by a 24-hour internal clock called the Circadian rhythm. These timing processes and the homeostatic physiology regulate the alertness and sleepiness of human beings.[1] Based on the circadian rhythm, individuals can be categorised as morning-type (M-type), evening-type (E-type), or intermediate (those who do not show major morning or evening preferences) based on their circadian rhythm. Individuals who are morning-type are more active in the morning (early in the day), and individuals who are evening-type are more active in the evening (late in the day).[2] Research indicates that these choices have a major impact on people's memory, alertness, and attention.[3] Numerous studies in the field of audiology have been investigated to determine the distinctions between these preferences by identifying the impacts through behavioural and electrophysiological tests.[4–11]

For morning-type people, an electrophysiological test employing P300 to assess diurnal shifts revealed greater amplitude and shorter latencies, while evening-type people exhibited the opposite results.[5] Literature has shown the effect of diurnal changes in younger adults on various auditory processing abilities, such as dichotic listening tests and temporal processing tests, such as gap detection tests, duration discrimination tests, temporal modulation function tests, and tests of differential sensitivity and temporal resolution.[7–10] Also, auditory working memory and spatial tasks in younger adults revealed similar results.[4] In contrast, diurnal changes in younger adults on auditory working memory showed no significant effects on the responses of individuals in all three categories, i.e., M-type, E-type, and intermediate category.[9] Similar findings were reported on screening tests of auditory processing, within-channel auditory gap detection, and recall tasks.[12,13]

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Auditory stream segregation refers to the cognitive process by which listeners group sounds that share similar characteristics, distinguishing them from other, unrelated sounds.[14] This process, also known as auditory streaming, is crucial for individuals with normal hearing, especially in environments where multiple sound sources are present, helping to prevent the confusion of different auditory signals.[14] One important cue that facilitates auditory stream segregation is spectral profiling. Spectral profiling allows the listener to identify changes in the spectral characteristics of a sound, such as when the amplitude of a component within a complex tone is altered.[15] This alteration results in a change in timbre, which can be analysed to evaluate spectral profiling abilities.[15] Therefore, spectral profile analysis tasks can be used to assess the sensitivity of the auditory system to changes in the spectral composition of sounds.

Moreover, individuals with cochlear pathology or auditory neuropathy spectrum disorder exhibited poorer spectral profile thresholds compared to those with normal hearing.[16] Previous studies have underscored the importance of factors such as participant attention and the timing of testing in influencing the results of audiological assessments.[4,7–10] In particular, research has recommended investigating the diurnal effects—how different times of day might affect audiological test outcomes—for more accurate and generalisable findings.[4,7–10] However, there is still a lack of sufficient research evidence to understand the effect of diurnal preferences on auditory streaming abilities in younger adults. Given this gap, the present study aims to investigate auditory stream segregation abilities through spectral profile analysis in younger adults with normal hearing. Specifically, the study's objective was to compare the spectral profile thresholds between morning and evening testing sessions across three groups of participants: those who are moderately morning, those with intermediate, and those who are moderately evening.

MATERIAL AND METHODS

Participants

A total of sixty participants, aged 18–25 and with no otological complaints, took part in the study. Each participant was asked to complete the Self-assessed Morningness–Eveningness Questionnaire[17] responding based on their personal preferences. The participants' total scores, which ranged from 70 to 86, were classified into the "definitely morning" category. Scores in the following ranges were categorised as 59–69 for "moderately morning," 42–58 for "intermediate," 31–41 for "moderately evening," and 16–30 for "definitely evening." Based on these classifications, the sixty participants were grouped into three sub-categories: moderately morning, intermediate, and moderately evening, with twenty participants in each group. Categories of "definitely morning" and "definitely evening" were excluded from the analysis due to the insufficient sample size in these groups.

Instrumentation

To determine the pure-tone threshold, a bone conductor (B-71, RadioEar, Denmark) and an acoustically matched headphone (TDH-39, Telephonics, Farmingdale, New York (NY), United States) were used in conjunction with a calibrated audiometer (Piano, Inventis). With a calibrated immittance meter [Grason-Stadler Inc. (GSI) Tympstar Pro], tympanometry and acoustic reflex thresholds were determined. Otodynamics distortion product (DP) Echoport otoacoustic emission instrument (ILO292-USB-II, V6) was utilized to measure distortion product otoacoustic emissions (DPOAEs). The spectral profile threshold was calculated using a personal laptop running MATLAB (R2014a) software, in which the maximum likelihood procedure (MLP) was used.

Procedure

Pure tone audiometry was conducted to assess participants' hearing sensitivity. For this, Telephonics Dynamic Headphones 39 earphones, enclosed in MX 41/AR supra-aural ear cushions, and Radio Ear B-71 bone vibrator transducers were utilised alongside a calibrated clinical audiometer (Inventis Padova, Italy) to determine air and bone conduction thresholds. Participants were included in the study if they had normal pure tone thresholds [≤15 decibels in hearing level (db HL)] for bone conduction between 250 and 4000 Hz and air conduction between 250 and 8000 Hz.[18] A calibrated middle ear analyser (GSI Tympstar Pro) was used to evaluate the functioning of the middle ear. The current study only included participants who had bilateral "A" type tympanograms with acoustic reflexes present at 500–4000 Hz.[19,20] Also, DPOAE in both ears are present.[21] The spectral profile analysis test was administered at the F0 = 330 Hz frequency in the MATLAB software with the psychoacoustics toolbox.[22] During the test, participants listened to three complex tones, two of which were identical (standards). The standard stimuli consisted of five harmonics at the same amplitude. The variable stimulus tone had a similar harmonic structure but with the amplitude of the third harmonic component increased, producing a different timbre compared to the standards. Participants were asked to identify the tone with the odd timbre in a three-alternative forced-choice (3AFC) task, selecting the correct number from three alternatives. Appropriate feedback was provided after each response.

To prevent predictability, the overall level of the standard and variable tones was randomised within a 5 dB range between trials. Two rising cosine ramps, spaced 10 ms apart, were used to gate the onset and offset of the tones. Participants were shown a total of thirty stimulus trials. The profile analysis threshold was calculated in decibels (dB), with the MLP applied to determine the threshold using a 79.4% criterion. All stimuli were delivered at 60 decibel sound pressure level (dB SPL) (sound pressure level) via supra-aural headphones connected to a personal laptop.

Spectral profile analysis tests were conducted twice daily for all participants: once in the morning (between 7:30 AM and 9:00 AM) and again in the evening (between 5:00 PM and 7:00 PM).

Statistical Analyses

Data were analysed using SPSS Statistics for Windows, Version 26 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test of normality was first applied to assess whether the data followed a normal distribution. Since the data were found to be normally distributed, parametric inferential statistics were used to analyse the results.

RESULTS

Descriptive statistics were used to calculate the mean and standard deviation of the profile analysis thresholds for both morning and evening test conditions across the three groups. The results are illustrated in Figure 1.

The findings indicated that individuals in the moderately morning group performed better in the morning compared to the evening, while those in the moderately evening group demonstrated superior performance in the evening. In contrast, the intermediate group showed no significant difference in performance between the morning and evening testing sessions.

To determine whether these differences in performance between the morning and evening sessions were statistically significant, inferential statistics were conducted for all three groups. Given that the data were normally distributed ($p > 0.05$), parametric paired t-tests were performed to compare the profile analysis thresholds for morning versus evening testing within each group. The results of these inferential statistics are presented in Table 1.

The paired samples t-test results revealed that for the moderately morning group, the profile analysis thresholds were significantly better in the morning ($p < 0.05$) compared to the evening. Similarly, for the moderately evening group, performance was significantly better in the evening ($p < 0.05$). However, no significant difference was observed for the intermediate group, as their performance in both morning and evening sessions was similar ($p > 0.05$).

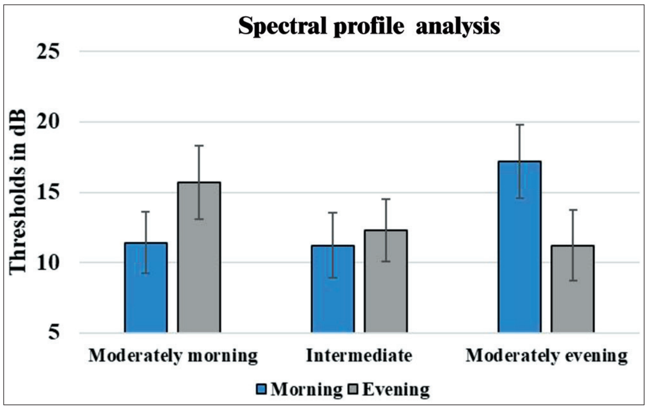

Figure 1: Mean and standard deviation of profile analysis thresholds for morning and evening tests across all three groups. dB: decibel.

Table 1: Results of paired samples t-test comparing the morning and evening test results for each group.

Group	t value	Degrees of freedom	Significance value (p)
Moderately morning	2.351	19	$p < 0.05$
Intermediate	1.899	19	$p > 0.05$
Moderately evening	2.462	19	$p < 0.05$

DISCUSSION

The present study revealed a significant diurnal effect on spectral profile analysis tests. Specifically, profile analysis thresholds were found to be better in the morning for morning-type individuals, while evening-type individuals performed better in the evening. In contrast, the intermediate group exhibited no significant variation in thresholds when tested at different times of the day. These findings are consistent with previous literature, which has documented significant diurnal preferences in various auditory behavioural tests.[4,7–10] Studies have shown that morning-type individuals tend to demonstrate superior auditory temporal processing skills, dichotic listening abilities, and auditory spatial and working memory performance in the morning, while evening-type individuals perform better on similar tasks when evaluated in the evening.[4,7–10] Diurnal effects on speech perception in noise have also been observed in previous studies.[11] Furthermore, electrophysiological measures such as P300 latency and amplitude for tonal stimuli have shown similar diurnal effects.[5]

However, some studies have reported no significant diurnal effects in certain auditory processing tasks, such as within-channel auditory gap detection, auditory processing screening tests, and recall tasks.[3,12,13] These differences may be attributed to variations in the nature of the tasks or differences in methodology.

One possible explanation for the diurnal effects observed in spectral profile analysis could be related to individual variations in circadian arousal levels during different cognitive tasks.[6,23–25] Morning-type individuals tend to feel more alert and perform better in the morning, often preferring to engage in work or exercise during this time. Conversely, evening-type individuals generally experience their peak alertness in the late afternoon or evening, leading to better performance in tasks during this period.

Another potential explanation for these diurnal effects is inhibitory control, which plays a crucial role in cognitive functions such as working memory, speech comprehension, and selective attention.[26] It is reported that inhibitory control is less effective during off-peak hours, which could contribute to poorer performance on spectral profile analysis tests during these times.[26]

In contrast, the intermediate group, lacking a distinct peak in arousal, showed no significant diurnal variation in their performance. This suggests that psychoacoustic test outcomes might be influenced by variations in inhibitory control depending on the time of day when testing occurs.[4,7–10,26] Additionally, factors such as sleep patterns, levels of exhaustion, and general alertness at different times of day may further impact the results of psychoacoustic tests.

CONCLUSION

This study aimed to investigate the impact of diurnal variations on spectral profile analysis tests in morning-, evening-, and intermediate-type individuals with normal hearing. The results demonstrated a significant diurnal effect, with morning-type individuals outperforming in the morning and evening-type individuals showing better performance in the evening. No diurnal effect was observed for the intermediate group. The findings suggest that poor cognitive performance and reduced inhibitory control during off-peak hours could account for poorer test scores at those times. Therefore, diurnal variations should be considered as a potential extraneous variable in future research on psychoacoustic tests in younger adults.

Ethical approval: The research/study approved by the Institutional Ethics Committee at All India Institute of speech and hearing, number SH/AIISH/ERB/2024-25/32, dated 05th June 2024.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent.

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