Original Article

# Effect of Hormones on Auditory Processing Abilities in Females

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## Abstract

**Introduction:** Central auditory information processing is influenced by the changing hormonal levels across the menstrual cycle, which might affect auditory perception. The present study aimed to assess auditory processing abilities in females across different phases of the menstrual cycle. **Methods:** A total of 21 participants (11 females and 10 males) in the age range of 18 to 25 years were recruited in the study. Group 1 included 11 healthy female participants with a regular menstrual cycle and Group 2 included 10 healthy male participants. The participants were evaluated for all the major auditory processes to assess central auditory processing. Auditory closure was assessed through speech perception in noise test in Kannada; binaural integration was assessed through the dichoticconsonant vowel (CV) test. The temporal processing was assessed through a gap detection test (GDT) and working memory was assessed using a digit span test. The central auditory assessment in Group 1 was done during the three menstrual phases namely early follicular stage (days 1 to 3), late follicular and early luteal (days 12 to 14), and late luteal (days 23 to 26). In Group 2, the central auditory assessment was done three times with each trial separated by the same number of days equaling the different phases as in females. **Results:** Results showed no significant differences in dichotic CV test, speech perception in noise test, GDT and working memory test ($P > 0.05$) in both Groups 1 and 2. **Conclusion:** To conclude, there is no difference in central processing abilities across three different phases of the menstrual cycle.

**Keywords:** Auditory processing, hormones, menstrual cycle

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## Introduction

The reproductive hormones, such as estrogen and progesterone, have been seen affecting the auditory functioning. The amount of these reproductive hormones changes in females depending on the time of the menstrual cycle. The menstrual cycle has the following phases, namely, the early follicular stage (days 1 to 7), the late follicular stage (days 8 to 13), the early luteal stage (days 14 to 22), and the late luteal stage (days 23 to 28).[1] The ovarian hormones changes during these phases of the menstrual cycle. In the early follicular stages, there are low estrogen and progesterone levels. By the end of the late follicular stages, the estrogen in the follicle increases rapidly before the amount drops during the luteal stage, where there are low estrogen and higher progesterone.[2]

Hormones play an essential role in numerous physiological functions. Estrogen regulates or directly alters auditory processing of acoustic signals in the brain,[3-5] interprets auditory information, enhances the representation of sounds in auditory cortex,[3] which is transmitted to sensory-motor parts of the brain.[6,7] Few earlier studies on the effect of hormones on the auditory processing of acoustic signals have reported that estrogen regulates or directly modifies auditory processing of acoustic signals in the brain[3-5] and enhances the representation of sounds in the auditory cortex.[3] Through receptors spread in the different parts of the central auditory nervous system (CNS), estrogens and progesterone can alter neuronal functioning. In general, progesterone mainly has a inhibitory action on the CNS, which may balance the excitatory action of estrogen.[8]

Studies have shown significant changes in latencies of various auditory evoked potential across different phases of the menstrual cycle, indicating changes at the level of the central auditory pathway.[9-11] Estrogen levels in the brain regions influence auditory processing.[12] Similar results have been obtained for speech perception in noise, where increased levels

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of progesterone interferes with the identification of the speech sounds.[13] Dichotic listening was studied across different phases of the menstrual cycle, and it was noted that the right ear advantage was more in the high estrogen-progesterone phase, compared to the low estrogen-progesterone phase.[14]

Thus, studies have shown that hearing sensitivity in women is poor during the menstrual phase.[15] Further, it is also reported in the literature that ovarian hormones influence central auditory processing abilities.[3-5] Studies on animals have shown that estrogens enhance auditory perception, and central auditory information processing is influenced by the changing hormonal levels across the menstrual cycle, which affects auditory perception. The present study aimed to assess auditory processing abilities in females across different phases of the menstrual cycle. To fulfill the aim of the study, auditory closure abilities, binaural integration, and temporal processing abilities were assessed across the different phases of the menstrual cycle.

## Methods

A total of 21 participants (11 females and 10 males) in the age range of 18 to 25 years were recruited in the study. Group 1 included 11 healthy female participants with a regular menstrual cycle and Group 2 included 10 healthy male participants. All the participants were native Kannada speakers, and none of the participants had a history of hearing loss, ear disease, head trauma, ototoxic drug intake, ear surgery, speech-language problems, or neurological. Also, the female participants reported no irregularity in their menstrual cycle or any condition like Polycystic Ovarian Syndrome (PCOD). None of them reported any illness during the time of testing.

The routine audiological evaluation was done to ensure normal hearing sensitivity in all the participants. All the participants had bilateral normal hearing sensitivity, i.e., a pure tone average of less than 15 dBHL for air conduction thresholds for octave frequencies from 250 Hz to 8000 Hz and bone conduction thresholds from 250 Hz to 4000 Hz.[16] All the participants had a speech recognition threshold of ±12 dB relative to their pure tone thresholds and normal middle ear functioning. Written informed consent was taken from all the participants for their willingness to participate in the study. Ethical clearance was taken from the relevant ethics committee at the institute earlier to start of experimentation.[17]

### Assessment of central auditory processing skills

The participants were evaluated for all the major auditory processes to assess central auditory processing. Auditory closure was assessed through speech perception in noise test in Kannada (SPIN); binaural integration was evaluated through the dichotic CV test. The temporal processing was evaluated through a gap detection test (GDT). These tests are sensitive enough to tap the subtle changes in auditory processing.

### Test to assess auditory closure

The test used to assess auditory closure was SPIN in Kannada. In the SPIN task, words were given in the presence of speech noise. Phonemically balanced word lists developed by Manjula *et al*.[18] were used. In the present study, six lists of 25 words each were taken, and the words were mixed with speech noise at 0 dB SNR using MATLAB software. The participants were instructed to repeat the words heard by ignoring the noise. The percent correct score was calculated for all the participants. It was ensured that different lists were used to assess SPIN during three phases of the menstrual cycle.

### Test to assess binaural integration

The test used to assess the binaural integration was a dichotic CV test.[19] Stimuli consisted of six syllables/pa/,/ta/,/ka/,/ba/,/da/and/ga/which were presented five times randomly to make it a total of 30 presentations. The syllables are presented simultaneously to both ears with a 0 ms lag time. The stimuli were presented through a calibrated laptop connected to HDA 200 headphones. The headphones were connected to a laptop through a splitter-adaptor to present two different syllables to the two ears simultaneously. The participants were instructed to listen to the two syllables presented simultaneously and write down the syllables heard from both the ears. The scoring involved assessing for single correct scores and double correct scores. The single correct scores were calculated for right and left ears separately, and a score of "one" was given for the correct response and "zero" for an incorrect response.

### Test to assess temporal processing

The temporal processing was assessed using GDT. The participant's ability to detect a temporal gap in the center of 500 ms broadband noise was measured[20] using the maximum likelihood procedure employed in MATLAB software. The noise with 0.5 ms cosine ramps at the beginning and the end of the gap was used for the estimation of the gap detection threshold. In a three-block alternate forced-choice task, the standard stimulus was always a 500 ms broadband noise with no gap, whereas the variable stimuli contained the gap. The participant was instructed to listen to the three stimuli and tell the examiner which one of the three had the gap. GDT was measured for each ear separately.

The central auditory assessment in Group 1 was done during the three menstrual phases, namely early follicular stage (days 1 to 3), late follicular, and early luteal (days 12 to 14), and late luteal (days 23 to 26). In Group 2 also audiological assessment was done three times, with each trial separated by the same number of days equaling the different phases as in females.

## Results

The data obtained were subjected to Shapiro–Wilk's test for normality. The results revealed a normal distribution of data ($P > 0.05$). Therefore parametric tests were done to assess the significant difference in central auditory processing abilities across different phases of the menstrual cycle in Group 1 and

across three trials in Group 2. Figure 1 shows the mean scores and standard deviation of various auditory processing abilities across three phases of the menstrual cycle in Group 1. As shown in Figure 1 the mean scores of SPIN and dichotic CV tests are better during the late follicular phase. However, the same trend is not seen for the GDT.

Figure 2 shows the auditory processing abilities across three trials in Group 2. From Figure 2, it can be noted that the scores are similar across three trials, and no particular trend is seen across the three trials.

Further, repeated measures of analysis of variance was done to compare the scores of different central auditory processing tests across each phase in females and across three trials in males. Results showed no significant differences in SPIN-right ($F$ [2, 20] = 0.947, $P > 0.05$), SPIN-left ($F$ [2, 20] = 0.046, $P > 0.05$); dichotic CV test for SCS-right ($F$ [2, 20] = 0.110, $P > 0.05$), SCS-left ($F$ [2, 20] = 0.467, $P > 0.05$), and DCS ($F$ [2, 20] = 0.458, $P > 0.05$); GDT for right ear ($F$ [2, 20] = 0.928, $P > 0.05$), GDT for left ear ($F$ [2, 20] = 1.962, $P > 0.05$) across three phases of menstrual cycle in Group 1. This indicates that there is no difference in central processing abilities across three different phases of the menstrual cycle in Group 1.

Similarly in Group 2 also, no significant difference was noted across three trials in dichotic CV test for SPIN-right ($F$ [2, 18] = 2.443, $P > 0.05$), SPIN-left ($F$ [2, 18] = 4.171, $P > 0.01$); SCS-right ($F$ [2, 18] = 1.872, $P > 0.05$), SCS-left ($F$ [2, 18] = 0.987, $P > 0.05$), and DCS ($F$ [2, 18] = 1.273, $P > 0.01$); GDT for right ear ($F$ [2, 18] = 2.438, $P > 0.05$), GDT for left ear ($F$ [2, 18] = 0.394, $P > 0.05$). This indicates that there is no difference in central processing abilities across three trials in Group 2.

## Discussion

The present study showed no significant difference in central auditory processing abilities across three stages of the menstrual cycle in females and across three trials in males. These findings are not consistent with the literature. Studies have reported

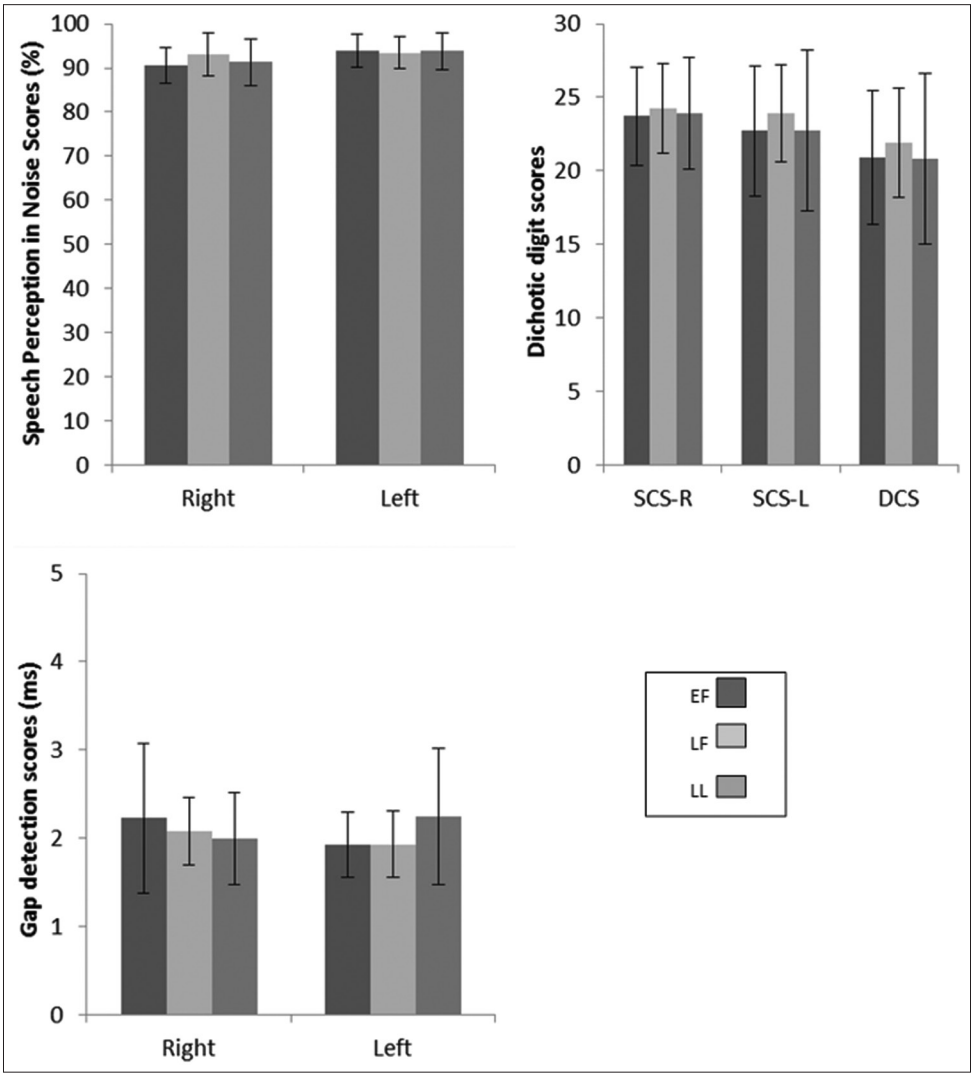


**Figure 1:** Mean and standard deviation of the auditory processing abilities across three phases of the menstrual cycle in Group 1

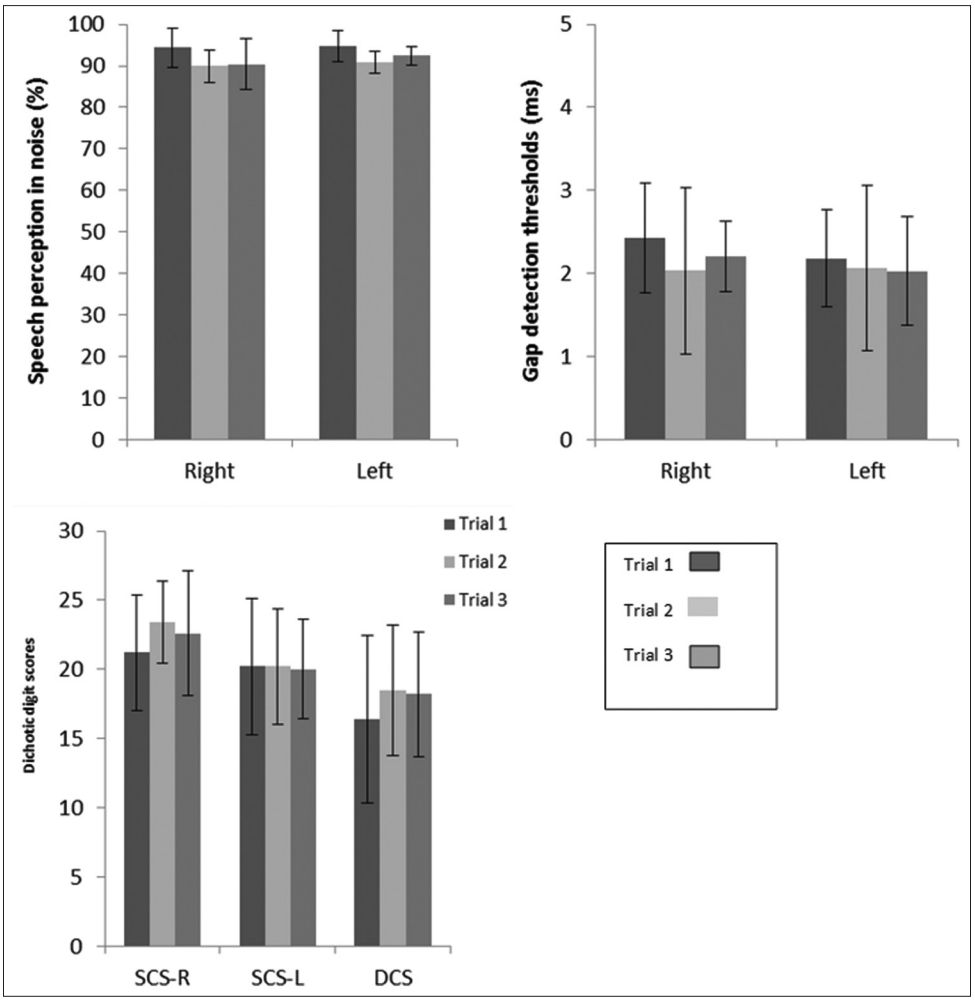


**Figure 2:** Mean and standard deviation of the auditory processing abilities across three trails in Group 2

better auditory processing during the mid-cycle phase, i.e., at 12–15 days.[21,22] Higher levels of estrogen during the mid-cycle phase/ovulation phase excites auditory nerve resulting in faster axonal conduction of auditory processing at the cortical level. The acute estrogen level increases glutamate excitatory neurotransmitters resulting in better auditory processing during the ovulation phase compared to menstrual and luteal phases. In the present study, also mean scores of SPIN and dichotic CV were higher during the late follicular phase/ovulation phase; however, it was not significant.[23]

Studies related to hormonal influence on auditory perception have used salivary assays or blood samples to estimate estradiol levels across different phases of the menstrual cycle.[21,24] In the present study, the different phases of the menstrual cycle were decided based on the number of days from the previous menstrual cycle. Thus more research is needed on these lines using a larger sample size and by estimating the estrogen levels, which will further add the information in the literature. Male participants in the present study were taken to serve as controls in case any difference was seen in central auditory tests across different phases of the menstrual cycle.

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## Conflicts of interest

There are no conflicts of interest.

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