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Commentary

'To Regulate the Awakening State of Mind': Regulate Circadian Cycle

Santa Misra*

Department of Psychology, Satya Sai Women's College, Rama Devi Women's University, Odisha, India

Abstract

Awakening of one's body and mind is one of the important aspects of life leading process. This awakening of self determines the activity and arousal cycle of the organism that has unique effect in cognitive behavioural manifestations. The state of activating level in the series of different cycles of sleep and wakefulness is explained in terms of circadian cycles. Based on this idea this paper deals with the concept of circadian cycle/rhythm and how it affects the differential behavioural manifestations in species specific contexts. The facts are part and partial of D.Litt (Post Doctoral) research work. The findings and interpretations consist of facts dealing with accomplishments of several aspects of behaviour like, correlation between maternal & fetal circadian activities, circadian cycle & adolescents' nonverbal intelligence, circadian cycle & attention span of the adolescents in cultural context, circadian cycle of mother & the arousal level of fetus, circadian rhythms in cognitive performance, and the relationship of maternal circadian cycle with the locomotor activity of the fetus. In this way the research implicates the analysis of human time structure from the beginning of life (during prenatal period) and accordingly how to provide the awareness to the mother and others around her about their own circadian cycle that can affect the fetal activity. This can help in maintaining, regulating and modifying circadian cycle of the future generations to make them fit, both physically and mentally for their better future life style. Hence this paper describes the effects of circadian cycle upon the behavior.

Keywords: Biological clock; Circadian Cycle; FHR; MHR; Morning people; Night people

***Corresponding author:** Santa Misra, Department of Psychology, Satya Sai Women's College, Rama Devi Women's University, Odisha, India, Tel: 9437211371; E-mail: dr.santamisra@gmail.com

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Introduction

Awakening of one's own body and mind is having its origin from the very date of creation. In this age of 21st century the awakening of self is having much more importance in promoting good mental health of the human beings.

The state of activating level in the series of different cycles of sleep and wakefulness is generally explained in terms of circadian cycle [1]. This activating level of the mind in most of the cases generated, controlled and guided by the circadian cycle which has its origin from the very childhood stage of the organism based on different ecological, anthropological, sociological and psychological perspectives.

"Circadian Cycle" is the cyclic changes in bodily process occurring within a single day basing on our conscious awareness [2]. It is a biological rhythm which explains the cycle of our working states of consciousness in everyday. That means, it is the levels of awareness of organization from external stimuli in a cyclic changes of bodily process. These cyclic fluctuations in basic bodily functions are reflected in the performance on the several tasks - the tasks relating to physical activities and cognitive tasks which are having very close relationship with the circadian rhythms. However, basing on the complexity of the tasks it increase or decreases [3].

According to Moore - Ede, Sultzman and Fuller our body in each and every day show daily cyclical changes like production of hormones, the body temperature, the blood pressure etc., that fluctuates across the day [4]. Some are highest in late afternoon and still some are lowest in the evening and night. They not only affect the physical activities but also affect learning, memory, perception and other mental processes. The reason behind this is the biological clock within the organism that times various circadian rhythms, even during sleep, located in a portion of hypothalamus in the brain, specifically in suprachiasmatic nucleus [5]. The nucleus responds to the visual inputs from the eyes and it either stimulates or inhibits the pineal gland. This gland in turn, secretes melatonin hormone with far - reaching effects. Melatonin exerts a sedative effect, reducing activity and increasing fatigue.

Exposure to day light stimulates suprachiasmatic nucleus, and this is in turn reduces the secretion of melatonin. But darkness enhances the secretion of melatonin. Thus as the day light increases our activities increase but as the darkness proceeds our activities gradually decreases. Perhaps this is the reason of complaining by some people regarding their feelings of depression if they can't get a dose of sunlight at least occasionally during the winter months, which is known as Seasonal Affective Disorder (SAD) [6]. If the nucleus is somehow or other damaged or several pathways connecting to the eyes are destroyed, then circadian rhythm tends to disappear totally [5]. But the interesting point is when left to its own activities the biological clock seems to operate in twenty - five hour duration rather than twenty - four hours a day [4,7].

The important noticeable fact in this context is the role of individual differences in circadian rhythm. Some people are more alert and active in morning than some other people who are more active in the night. The morning people (more alert in morning like a lark) experience peak in alertness and energy in the day whereas night people (more alert in night like an owl) experience alertness and energetic in the afternoon and evening. Not only this but also both morning and night people do differ in some other respects like morning people are having more and higher adrenaline secretion, peak in body temperature, and susceptible to hypnosis in the morning and early afternoon than in night, in contrast to the night people. The best example in this context is "Jetlog" and "Shift work" in industry [8-13]. Some studies showed that circadian rhythms are predominant in preterm neonates while others showed ultradian rhythms to be dominant in preterm neonates. The reason is the automatic pilot [14-16].

Circadian rhythms that is the internal clock or biological clock within the organism, exists in mammals, birds, fungi, insects, etc., and run on approximately 20-24 hour cycle. Although the clocks do not function exactly the same way in all species, yet they are very similar. In case of *Drosophila*, the activating cycle is more as the day increases and in the middle of the night. But in case of mammals the process is more complex and less understood at this time. In case of human beings there is a disease called Familial Advanced Sleep-Phase System (FASPS) which causes people to have sleep schedules that move ahead by about 4 hours. In other words, they wake up around four hours earlier than they would otherwise [17-23].

There are evidence for social influences on mammalian circadian rhythms, and their possible mechanisms of action. Crowley, et al., found that sleep-wake timing shifts later in young humans during the second decade of life in adolescence, and there is evidence for the role of environmental, psychosocial, and biological factors underlying these changes. Social stimuli may affect circadian behavioral programmers by regulating the phase and period of circadian clocks (i.e., a zeitgeber action, either direct or by conditioning to photic zeitgebers), by influencing daily patterns of light exposure or modulating light input to the clock, or by associative learning processes that utilize circadian time as a discriminative or conditioned stimulus. There is good evidence that social stimuli can act as zeitgebers. In several species maternal signals are the primary zeitgeber in utero and prior to weaning. Adults of some species can also be phase shifted or entrained by single or periodic social interactions. The circadian phase-dependence of clock resetting to social stimuli or arousal (the 'nonphotic' Phase Response Curve (PRC)) were known, is distinct from that to light and similar in diurnal and nocturnal animals. There is some evidence that induction of arousal can modulate light input to the clock, but no studies yet of whether social stimuli can shift the clock by conditioning to photic cues, or be incorporated into the circadian programme by associative learning [24]. But these phase-shifted effects entrained by single or periodic social interactions are often weak, and appear to be mediated by social stimulation of arousal.

Review reveals that, findings relating to the rhythmicity in the human fetus are not yet conclusive [25-28]. But circadian rhythms have been described in the human fetus and have been attributed either to the maternal environment or to the maturation of the fetal nervous system [29-34]. Some studies showed that circadian rhythms are pre-dominant in pre-term neonates while others showed ultradian rhythms to be dominant in preterm neonates [35-37].

Similarly some research conveyed the idea that physical and mental health of the mother during pre-natal period is equally important as in post-natal nurturance for overall development of the baby and the circadian rhythm plays a vital role in the activity and arousal cycle of the human beings which is generated endogenously by a biological clock, located in the anterior hypothalamic suprachiasmatic nuclei, and are modulated by exogenous factors [21,38]. The bodily changes due to this cyclic processes influence physical tasks like production of hormones, the body temperature, fetal breathing blood pressure, heart rate etc., that fluctuate across the day and most of the important higher mental functioning, like learning, memory, attention, perception, intelligence, cognition etc., [3,4,39-41].

Many physiological processes are now known to be cyclically organized [42]. They show different cycles: like, circadian cycles (lasts approximately 24 hours), ultradian cycles (shorter than 24 hours/a day, such as the REM cycle of sleep), and infradian cycles (longer than 24 hours, such as the menstruation cycle), Diurnal cycles (25.4 hrs cycle without cyclical cues provided by natural light, occur during the waking day), circannual rhythm (a period of about a year such as hibernation/activity cycle), etc., and interact mutually as well as with the outside fluctuating environment under the control of feedback systems [24,43].

According to Reppert &Weaver, most body functions follow a rhythmic pattern adjusted to 24 h cycle (circadian rhythms), which is controlled by the circadian timing system. In mammals, this system comprises peripheral oscillators located in most tissues of the body and a central rhythm generator located in the Suprachiasmatic Nucleus (SCN) of the hypothalamus. At the cell level, circadian rhythms are driven by the self regulatory interaction of a set of genes (Bmal-1, Per1-2, Cry1-2, and Clock; named clock genes) and their protein products. The heterodimer of the proteins CLOCK: BMAL-1 binds E-box elements (CACGTG/T) at the promoter region of Per1-2 and Cry1-2, inducing their transcription. Conversely, PER1-2 and CRY1-2 proteins, by interacting with the CLOCK: BMAL-1 heterodimer operate as negative regulators inhibiting their own transcription. In adult animals, oscillatory expression of clock genes has been demonstrated in the SCN and in several peripheral tissues. The circadian oscillation of clock genes expression controls the expression of genes involved in multiple cellular functions in the 24 hours, and results in the overt circadian rhythms in the individual.

The external environment also influences the circadian cycle of the fetus, as provided by its mother. The fetal SCN shows rhythms of metabolic activity early in gestation in squirrel monkeys of c-fos in sheep and of metabolic and electric activity in rodents. In addition, fetuses of precocious species like the human, rhesus, and sheep, present circadian rhythms respiratory movements, limb movements, heart rate, and production of cortisol in the human fetus, DHAS in rhesus, prolactin in sheep, suggesting a circadian organization that uses maternal signals to adapt to the maternal environment [34].

The biological processes also influence the later timing of adolescent sleep. In a study published in November 2005 issue of the journal Sleep, Carskadon described that adolescents had later circadian rhythm timing, based on melatonin secretions in saliva samples. This finding shows that melatonin secretion occurs at a later time in adolescents as they mature. Thus, it is difficult for them to go to sleep earlier at night. The melatonin secretion also turns off later in the morning,

which makes it harder to wake up early. Another important finding by Carskadon is that the circadian timing system can be reset if light exposure is carefully controlled. This means with time, effort, and money researchers can get adolescents to reset their clocks. Findings of the tendency for adolescent sleep patterns to be delayed have been reported not only in North America, but also in South America, Asia, Australia and Europe. The diversity of such research supports the view that intrinsic developmental changes play a role in delayed sleep patterns in adolescents. This biological shift sets the stage for other social and environmental conditions that make it easier for these adolescents to stay awake at night and wake up sleep deprived. The effects of changing sleep patterns are compounded by the demands older students face in academics, extracurricular activities, social opportunities, after school, jobs and other obligations.

Research findings suggest that physical and mental health of the mother during prenatal period is equally important as in postnatal nurturance for overall development of the baby [44]. The bodily changes due to this cyclic processes influence physical tasks like production of hormones, the body temperature, fetal breathing blood pressure, heart rate etc., that fluctuate across the day and most of the important higher mental functioning, like learning, memory, attention, perception, intelligence, cognition etc., many physiological processes are now known to be cyclically organized. They show different cycles like, circadian cycles (last approximately 24 hours), ultradian cycles (shorter than 24 hours), and intradian cycles (longer than 24 hours), diurnal cycles (is 25.4 hours cycle without cyclical cues provided by natural light), etc., and interact mutually as well as with the outside fluctuating environment under the control of feedback systems [3,4,24,38-43,45]. Circadian rhythms have been described in the human fetus and have been attributed either to the maternal environment or to the maturation of the fetal nervous system [29-34,46,47]. Some studies showed that circadian rhythms are predominant in preterm neonates while others showed ultradian rhythms to be dominant in preterm neonates [15,16,35-37]. Review of literature in this context reveals that findings relating to the rhythmicity in the human fetus are not yet conclusive [8,9,25-28,48]. Still the circadian rhythmic effect of mother upon the fetus cannot be overlooked. The story of Abhimanyu from the great Indian Epic MAHABHARATA is the best example regarding the maternal and fetal relationship in prenatal stage with regard to the activity and arousal cycle of sleep and wakefulness.

Circadian rhythm also exists in mammals, birds, fungi, insects, etc., and run on approximately 20-24 hours cycle in a day. Although the clocks do not function exactly the same way in all species, yet they are very similar. In case of *Drosophila*, the activating cycle is more as the day increases and in the middle of the night. But in case of mammals the process is more complex and less understood at this time. In case of human beings there is a disease called Familial Advanced Sleep-Phase System (FASPS) which causes people to have sleep schedules that move ahead by about 4 hours. In other words, they wake up around four hours earlier than they would otherwise [18-23].

A healthy fetus at gestational age of 16 to 20 weeks reveals pronounced rhythms of activity and locomotion. Absence of distinct rhythmicity within the term of 20 to 24 weeks points to developmental retardation. The "Z"-type fetal reaction, recorded during the "quiet" hours, does not indicate unsatisfactory state, but rather is suggestive of definite reduction of functional levels of the fetal physiological systems necessary for vital activity.

Many physiological processes are now known to be cyclically organized [42]. They show different cycles: like, circadian cycles (lasts approximately 24 hours), ultradian cycles (shorter than 24 hours/a day, such as the REM cycle of sleep), and intradian cycles (longer than 24 hours, such as the menstruation cycle), diurnal cycles (25.4 hours cycle without cyclical cues provided by natural light, occur during the waking day), circannual rhythm (a period of about a year such as hibernation/activity cycle), etc., and interact mutually as well as with the outside fluctuating environment under the control of feedback systems [24,43].

Thus the effects of circadian rhythm is biological (body temperature, blood pressure, heart rate, etc.,), psychological (Familial Advanced Sleep-Phase System (FASPS) sleep schedules that move ahead by about 4 hours) and socio-cultural (social stimuli may affect circadian behavioral programmers by regulating the phase and period of circadian clocks i.e., a zeitgeber action).

Relevance of the Study

Based on the above stated facts that,

- Biological rhythmicity, particularly circadian rhythmicity as is considered to be the key mechanism in the maintenance of physical and mental functioning of the living beings
- Very little is known, however, about the cultural significance of biological rhythmicity pattern in adolescents' intelligence
- No particular study reveals any tentative conclusion on the circadian rhythmic effect on intelligence
- And very few evidence on the relationship of circadian rhythm of urban and tribal adolescents with regard to their intelligence level are available

The present theme of research aims at expressing the following objectives;

Objectives

- To describe the differential relationship between the maternal circadian cycles with the activity and arousal level of the fetus and how accordingly the time structure of the human being can be predicted, controlled and modified
- To determine the rhythmicity of the heartbeat of the mother and locomotor activity of the human fetus, including the interdependence between maternal and fetal biological rhythms. Accordingly to describe whether the baby will be a morning people or a night people in its future life style
- To analyze the relationship between circadian cycle and intelligence
- To explain the activity level on ecological basis of adolescents' intelligence scores in different shifts of the day
- On the basis of the above observations to determine whether there is any ecological and environmental significance of circadian rhythm on behavior

Hypothesis

On the basis of the above objectives, the following hypotheses can be suggested;

- Maternal circadian cycle affects the activity and arousal cycle of the fetus
- The fetus that are active more in day time can be stated as morning people and more active in night time can be stated as night people, so that their future life style can be regulated accordingly
- There would be a significant relationship between the rhythmicity and intelligence between environmental factors and biological rhythm would be significant
- Differential circadian rhythmicity would be found in different shifts of the day
- Higher circadian activity rate would be expected during the day shifts than the night shifts

Research Findings by the Author on the Issues

Four studies were made by the researcher on the above said facts. In one study on "Circadian Cycle and Adolescents' Nonverbal Intelligence" it is observed that activating level of the mind has its origin from the very childhood stage of the organism and reaches its peak in adolescence, basing on different ecological, anthropological, sociological, and psychological points of view. An investigation was made on the effect of circadian cycle on the intelligence level of 100 urban and 100 tribal school children (age 10-14 of class IV and class VI) of Nayagarh district, different government schools, Sai Saraswati Sishumandiir School, and from the KISS School of KIIT University, Bhubaneswar, Odisha. After being randomly selected the subjects were individually administered the Raven's advanced progressive matrices tests of intelligence in their natural environment. All of them were tested for four times a day: in morning, afternoon, evening and night, and accordingly their IQ scores were recorded. The analysis of results revealed that irrespective of culture, the IQ of the subjects was differentially affected by varying degrees of circadian cycles. It was more in noon than evening and morning and more in morning than night. The difference in intelligence scores between urban and tribal children, analyzed by two ways ANOVA, was found to be statistically significant. The interaction of circadian cycle and culture was also found to have highly significant effect on intelligence scores of the subject. The most interesting part of the findings was, in night shifts, tribal adolescents were more active than their urban counterparts indicating their ecological and anthropological stand point of circadian cycle (t=3.62). The means of the intelligence scores of urban and tribal children were 9.81 (SD=1.62) and 9.56 (SD=1.75) respectively. This group difference was found to be statistically significant. In other words both urban and tribal children are more or less not equal with regard to their intelligence scores. The means of the intelligence scores of the subjects at morning, afternoon, evening and night irrespective of socio cultural groups were 8.29 (SD=1.76), 11.59 (SD=1.72), 10.31 (SD=1.66) and 8.57 (SD=1.62) respectively. This mean difference was found to be statistically significant. In other words circadian rhythms have significant effects on the intelligence score of the subjects. More important is subsequent Newmann - Keuls post hoc test revealed significant differences among all possible group comparisons in favor of afternoon shift.

In another study the author found the maternal stress affects the fetus. McEwen reported that circadian cycle of the pregnant women is seriously disbursed by stress arising from difficult relationships, lack of support, and negative emotional experiences. Plumbman reported that fetal heart rate and locomotion is correlated with emotional experiences of the mother even along a day. Basing on the above reports, the present study sought to examine the effects of stress of the mother on the circadian rates of the fetus. Occupational Stress Inventory-R was administered to 200 pregnant women in their gestation period of 32 to 40 weeks as a requirement of another research work by the author (for D.Litt research work). Among the subjects, two groups of 25 each were identified as having maximum and minimum occupational stress. Then the circadian rates of their fetuses including heart rate and locomotion were compared applying 't' test. Results revealed that in both the measures, fetuses of the stressed mothers have significantly higher rates of activities (heart rate t=7.64 & locomotors t=9.16) than those of the unstressed mothers. The findings help to understand the physiological mechanisms through which mothers' stress affects the fetus.

Similarly in a study on circadian cycle of mother and the arousal level of fetus, the effect of maternal circadian rhythm on fetal heart rate in beats per minute is being explored. Randomly selected 25 pregnant mother (Age=25-30) after a pilot study (N=100), with normal physical and mental condition, volunteered to participate in their gestation period of 32-35 weeks, and were observed for four times in a day (morning, afternoon, evening and night), each with five minutes schedule for two days continuously. The Maternal Heart Rate (MHR) was observed by the physicians manually and at the same time the Fetal Heart Rate (FHR) was recorded through an ultra sonographic machine. The analysis of results revealed that subjects were differently affected by varying degrees of circadian cycle (shifts of the day) with regard to their heart rate and the group difference was found to be statistically significant. None of the fetus was found to be tachycardiac or bardycardiac. There is a significant relationship between MHR and FHR with regard to their activity and arousal cycle. Based on shifts of the day the increment and decrement of MHR is positively related to increment and decrement of FHR. As the day moves up both MHR and FHR were increased from the morning to afternoon, but gradually decreases towards the evening and night. All the statistical analysis including two ways ANOVA corroborate the hypothesis that, circadian cycle of mother affects the arousal level of fetus. Thus the study implicates the analysis of human time structure from the beginning of life (during prenatal period) and can provide the awareness to the mother about their own circadian cycle that can affect the fetal activity, and accordingly maintaining, regulating and modifying circadian cycle of their babies to make them fit for their future life style.

With the idea that maternal circadian cycle also affects locomotor activity of the fetus, 100 pregnant women (age=20-25 years) in their gestation period (30-35 weeks), were tested rhythmic effect of their heart rate with fetal BPT profile (for 2 consecutive day, 4 shifts daily). Result confirmed (r=0.58) the circadian rhythmic relationship between maternal and fetal activities.

Discussion and Conclusion

This paper is the conglomeration of empirical research made by the author using differential variables with different samples. The results revealed the following conclusions;

- Circadian cycle occurs due to the effect of Cryptochrome, Suprachiasmatic Nucleus (SCN), NPAS2 (Neuronal PAS Domain Protein 2, also known as MOP4), Frequency (FRQ), White Collar-1 (WC-1) and White Collar-2 (WC-2) and other different proteins in different organisms

Circadian cycle of the mother influences the heart beat of the fetus in prenatal stage of development and on the basis of above discussions the following conclusions can be drawn

- Circadian cycle has significant effect on heart rate of the mother and fetus
- Both maternal and fetal heart rate is significantly related with regard to shifts of the days
- In a normal physical and mental condition maternal circadian cycle has significant effect on heart rate of the fetus
- There is a significant main effect and interaction effect of the variables between MHR and FHR in different shifts of the day
- All the mothers and fetus have normal heart rate. Mothers are considered as "Morning people" and the fetus are predicted to be the "Morning people" in future
- Culture has significant effect on intelligence scores of the children up to 10-11 years
- Circadian rhythms have differential effect on the intelligence of the subjects in favor of evening shift
- Circadian rhythms may interact with culture in order to have its significant effect on the intelligence scores of the subjects
- Culture has significant effect on intelligence test scores of the adolescents
- Circadian rhythms have differential effect on the intelligence test scores of the subjects in favor of the afternoon shift
- Circadian rhythms may interact with culture in order to have its significant effect on the intelligence test scores of the subjects

Implications

- The study implicates the analysis of human time structure from the beginning of life from prenatal period and can provide the idea to the mother to make themselves aware of their own circadian cycle that can affect the fetal activity, accordingly maintaining the circadian rhythmic effect of their babies throughout their life span
- The study also conveys the idea that, mother-child relationship starts from the very beginning of life & also the ability to learn
- Circadian cycle of the mother (the biological clock within the organism) plays a vital role in the activity and arousal cycle of the fetus, hence babies should be aroused from the beginning of life in ecological context that can increase their efficiencies in future
- Besides babies are also extremely sensitive to the environmental condition in the mother's womb. If mother is assaulted, babies will learn about violence. The traumatic experience of the mother influence the baby's thought process throughout the life. If mother is generously loved during pregnancy the child will learn love and peace
- Thus the nature and characteristics of the mother and the behavior of others towards the mother counts a lot in shaping the human mind even inside the mother's uterus from which the bits and chunks of World Peace Technology (WPT) can be expected
- Culture has significant effect on intelligence test scores of the adolescents
- Circadian rhythms have differential effect on the intelligence test scores of the subjects in favor of the afternoon shift
- Circadian rhythms may interact with culture in order to have its significant effect on the intelligence test scores of the subjects
- Adolescents consist two-thirds of our population and need to be treated as a distinct segment of our society. In this stage they are more vulnerable to any risk taking behavior. For this reason it is essential to look after their intellectual development and cognitive manifestation in modulating their activity and arousal cycle
- As circadian cycle plays a vital role in physiological and mental development of the adolescents the parents should be aware of the fact of setting and modifying the circadian cycle of their children from the beginning of the life
- Cultural facilitation of the circadian cycle should be implemented in adolescents' behavior

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