Original Article

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Physiology Section

Comparison of Cognitive Functions Between Male and Female Medical Students: A Pilot Study

NAMRATA UPADHAYAY[1], SANJEEV GURAGAIN[2]

ABSTRACT

Background: There are gender differences in cognitive abilities. The major enigma is whether males or females perform better in various cognitive tasks. The reports were found to be contradictory. Studies have shown that oestrogen and testosterone accentuate cognitive functions. But the effects of progesterone on cognitive functions are still contradictory.

Objective: To assess and compare the cognitive functions between male and female students.

Methods: This study was conducted on healthy male (n=21) and female (n=21) volunteers who were aged between 19-37 years. Cognitive functions which were assessed in males (one time) and females (two times: during preovulatory and postovulatory phases of the menstrual cycle) were attentional: visual reaction time (VRT) and Go/No-Go VRT; perceptual: fast counting (FC), executive: Erisken Flanker Test (EFT) and Stroop Test (ST), and working memory. Data were compared by using Mann-Whitney U-test.

Results: Cognitive functions in female preovulatory phase were comparable to male cognitive functions. In addition, the female postovulatory phase cognitive functions were also similar to those of males in all the tasks, except those seen in VRT and ST. Male performed better than females in VRT (M: 331.66 ms, IQR: 286.99-375.33 vs. M: 367.8 ms, IQR: 340.66-435.66; p=0.05). However, in ST, females showed higher accuracies in reading colour interferences than males (M: 100%, IQR: 95.12-100 vs. M: 95.24%, IQR: 86.36-100; p=0.04). In addition, males showed trend of a poorer performance than females in Go/No-Go VRT, ST colour reading normal time and interference time and in working-memory time.

Conclusion: Male cognitive functions were comparable to female preovulatory phase cognitive functions. However, females, during postovulatory phase of their cycle, may have advantages in executive tasks (Stroop test) and disadvantages in attentional tasks (VRT), as compared to males.

Keywords: Attention, Menstrual cycle, Stroop test

INTRODUCTION

Mental skills or cognitive abilities include attributes like perception, attention, memory (short-term or working and long-term), motor, language, visual and spatial processing, and executive functions [1]. These cognitive attributes are different in males and females. Generally, females show advantages in verbal fluency, perceptual speed, accuracy and fine motor skills, while males outperform females in spatial, working memory and mathematical abilities [2,3]. In females, mental skills vary during different phases of the menstrual cycle (MC) [4]. This is because, in the circulation, the bio-availability of oestrogen is high during the follicular phase of the menstrual cycle and that of progesterone is high during the luteal phase. It has been reported that the high levels of gonadal steroids which are present during the luteal phase of the menstrual cycle may facilitate skills which favour females, but which are detrimental to skills which favour males [5].

In addition, studies have also shown that oestrogen and testosterone accentuate cognitive functions in a similar fashion [6]. Because testosterone is converted to oestrogen in many tissues, including the central nervous system, it could exert its influence directly or indirectly through its conversion to oestrogen via the aromatase enzyme [7,8.] Therefore, it could be considered that female cognitive profile seen during the oestrogenic phase (preovulatory phase) of the menstrual cycle may be similar to that of the male cognitive profile.(?) If not, who performs better in the cognitive tasks? With this question, we compared the male (testosterone) cognitive tasks with the female preovulatory (oestrogen) and postovulatory phase (progesterone) cognitive tasks in medical students who were in the age range of 19-37 years.

METHODS

This study was conducted on 42 healthy volunteers (males=21 and females=21) with ages which ranged from 19 to 37 years. Informed consents were taken from all the participants. Volunteers who received steroid hormones or therapy for depression, those who had a history of head injury, stroke, or heart attack were excluded. Subjects who were enrolled did not report any dysendocrinism or metabolic neoplastic pathologies.

Participants were undergraduate and postgraduate medical students. Female volunteers who had normal gynaecological histories, who had menstrual cycles of 28 ± 7 days were included. Those who had constant days of menstrual cycles for two months were recruited in the study. But pregnant or lactating mothers and ladies with drug dependence, in whom steroid hormone secretions or neuronal plasticities were likely to be affected, were excluded.

Females were instructed to note down their menstrual calendars for at least two months, along with their basal body temperatures (BBTs), for detecting the days of ovulation. Their cognitive functions were assessed during the preovulatory and postovulatory phases of the cycle. Preovulatory phase cognitive function was tested 2–4 days prior to the expected day of the ovulation and postovulatory cognitive function was tested between 9-11 days after ovulation, according to their menstrual cycles [9]. Ovulation was estimated by measuring BBT.

Four aspects of cognitive function were assessed in both males and females (viz: attentional, perceptual, executive and working memory). Attentional tasks were assessed by checking for visual reaction time (VRT) and Go/No-Go VRT, perceptual tasks were assessed by fast counting (FC), executive tasks were assessed by doing Erisken Flanker Test (EFT) and Stroop Test (ST)-colour interference

reading and working memory task was assessed by picture 2-back remembering was assessed by using a cognitivefun.net program. All tasks were performed by males on the same day, after they were given proper demonstration. Females performed all the tasks in preovulatory and postovulatory phases of their menstrual cycles.

Details of the Tasks That were Assessed are as Follows:

1. Attentional Task

a. Visual Reaction Time: Subjects pressed the space bar of the computer key-board on the appearance of a green signal on the screen, for 5 times. Their average reaction times were then calculated.

b. Go/No-Go VRT: This test had a stimulus that needed to be responded to, as well as another stimulus that needn't be responded to. In other words, response to the alternate stimulus needed to be inhibited. Subjects had to press space bar on appearance of a green signal (green dot) on the screen and they had to avoid pressing space bar if there was appearance of a pattern signal. It consisted of 12 trials. Results were displayed after averaging responses of all the 12 performed trials.

2. Perceptual (Fast Count) Task

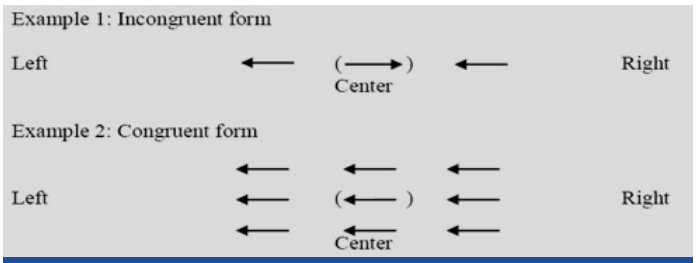
It measured subjects' familiarities with small quantities of objects. Subjects had to press the number key that equalled the number of dots which were shown. Dots which were shown were from 4 to 7. The results were displayed after the completion of 12 trials.

3. Executive Task

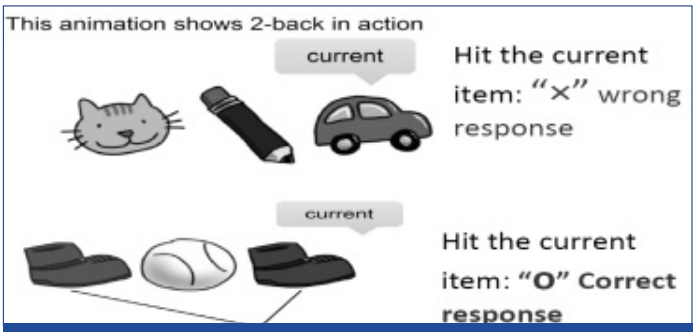
a. Eriksen-Flanker Test: The Flanker test is an interference task where different inputs compete with the target, thus slowing down the response speed. This is a basic variant which uses arrows, in which subjects should identify the direction of the centre arrow. Estimated completion time was less than 1 minute per session. Arrows were displayed in congruent or incongruent forms, as has been shown in Example1 and Example 2 [Table/Fig-1].

In example 1, central arrow faced towards right and so, one had to press right arrow key (→) on the key board. Whereas in example 2, central arrow faced towards left and so, subjects had to press left arrow key (←) on the keyboard. It consisted of 20 trials, which randomly constituted both the congruent or incongruent forms.

b. Stroop Test: One had to read ink colour in place of written words. It displayed results after 12 trials.



[Table/Fig-1]: Illustrations of incongruent (Example 1) and congruent form (Example 2) of the test



[Table/Fig-2]: Instruction for the working memory picture 2-back test

Example of Interference: If word 'yellow' was written in red ink, then ink colour had to be read as red and subjects had to press R on the keyboard for getting correct responses.

Example of Normal: Names of colours were written in their respective ink colours, i.e. if word 'green' was written in green ink, then subjects had to read it as green and they had to respond by pressing G.

4. Working Memory Task: In this task, ten pictures (viz. ball, book, car, cake, cat, fish, heart shape, pencil, boot, and spoon) appeared on the screen randomly and subjects had to click on the target box when the current picture was a repeat of what they had seen or picked 2 pictures ago. Therefore, the target had to be hit if the same picture was repeated in the third place. It constituted of 30 trials. After completion of the 30 trials, results were displayed, [Table/Fig-2].

All these tasks were performed by 42 right handed volunteers. The data are compared between males and females by using Mann-Whitney U-test. The obtained data were expressed in median (Quartile1-Quartile 3). p-values of less than 0.05 were considered as significant.

RESULTS

In this study, anthropometric variables were comparable between males and females, as has been depicted in [Table/Fig-3].

We found no significant differences between cognitive profiles of males and those of females who were in their preovulatory phases [Table/Fig-4]. However, on comparing cognitive functions of males and female postovulatory phase cognitive functions, we found significant differences in attentional visual reaction times and in Stroop test (colour accuracies), [Table/Fig-5]. Males showed general trend of poorer performances than those of females who were in their postovulatory phases in Go/No-Go VRT (correct response percentage), Go/No-Go VRT, ST (normal reading time and interference time) and working-memory (average time) tests [Table/Fig-5].

Groups	Age (years)	Height (m)	Weight (kg)	BMI (kg/m^2)
	Median	Median	Median	Median
	(Q1, Q3)	(Q1, Q3)	(Q1, Q3)	(Q1, Q3)
Male (n=21)	27 (26, 29)	1.71 (1.64, 1.76)	67 (62, 70)	22.4 (21.23, 24.02)
Female(n=21)	28 (24, 29)	1.60 (1.58, 1.61)	59 (52, 63)	23.11 (19.89, 24.9)

[Table/Fig-3]: Anthropometric variables of the subjects, n=42

DISCUSSION

Male and female brains show anatomical, functional and biochemical differences throughout life. Many factors are involved in this differentiation; physiological factors along with social norms, is another factor, that brings changes. Males outperform females in tests of visual-spatial ability, and mathematical reasoning, whereas females do better in memory and language use [10]. Moreover, females have different mental skills at different phases of the menstrual cycle [11,12]. Therefore, we compared pre-and postovulatory cognitive tasks of females with male cognitive tasks by using cognitivefun.net program.

It is known that females, during their preovulatory phases, are under the influence of high oestrogen levels and that males are under the influence of high testosterone levels. In our study, despite males and females having different hormone profiles, [male (testosterone) and female (preovulatory-oestrogen)], the cognitive profiles of females, which were tested during their preovulatory phases, were comparable to the male cognitive profiles. This might have occurred due to the analogous actions of these hormones in the brain. Studies have shown that oestrogen and testosterone accentuate cognitive functions in a similar fashion [6]. For the

Variables		Male (n=21)	Female (n=21)	p-value
		Median (Q1, Q3)	Median (Q1, Q3)	
Visual reaction time (ms)		331.66 (286.99, 375.33)	350.8 (342.66, 460.66)	NS
Go/No-Go VRT	Time (ms)	517.4 (480, 603.6)	541.67 (487.09, 581.93)	NS
	Correct response (%)	91.67 (82, 100)	90.91 (78.57, 95.83)	NS
Eriksen flanker test	Correct response (%)	100 (95, 100)	95 (93.75, 100)	NS
	Congruent time (ms)	548.25 (490, 686.46)	609 (520.33,776.61)	NS
	Incongruent time (ms)	531.64 (519.25, 738.57)	707.22 (492.76, 742.18)	NS
Stroop test	Correct response (%)	95.24 (86.36, 100)	95.24 (90.36, 100)	NS
	Normal response time (ms)	1142.78 (1018.37, 1286.63)	1019.73 (976.42, 1124.71)	NS
	Interference response time (ms)	1359 (1266.25, 1521)	1428 (1318.85, 1559.18)	NS
Working memory	Correct response (%)	70 (62, 81.25)	62.5(51.66, 68.63)	NS
	Average time (ms)	871.92 (800.67, 939.33)	856 (815.18, 1040.96)	NS
Fast count	Correct response (%)	75 (65, 80)	83.33 (68.83, 95)	NS
	Average time (ms)	998 (955.3, 1179)	1130.6 (1071.46, 1186.18)	NS

[Table/Fig-4]: Comparison of the cognitive functions between male and female (preovulatory phase), n=42

Variables		Male (n=21)	Female (n=21)	p-value
		Median (Q1, Q3)	Median (Q1, Q3)	
Visual reaction time (ms)		331.66 (286.99, 375.33)	367.8 (340.66, 435.66)	0.05*
Go/No-Go VRT	Time (ms)	517.4 (480, 603.6)	494.39 (450, 572.34)	NS
	Correct response (%)	91.67 (82, 100)	93.33 (87, 100)	NS
Eriksen flanker test	Correct response (%)	100 (95, 100)	100 (95, 100)	NS
	Congruent time (ms)	548.25 (490, 686.46)	632.4 (547.7, 716.67)	NS
	Incongruent time (ms)	531.64 (519.25, 738.57)	656.23 (594.4, 829.4)	NS
Stroop test	Correct response (%)	95.24 (86.36, 100)	100 (95.12, 100)	0.04*
	Normal response time (ms)	1142.78 (1018.37, 1286.63)	980.5 (921.57, 1142.78)	NS
	Interference response time (ms)	1359 (1266.25, 1521)	1346.39 (1100, 1497.11)	NS
Working memory	Correct response (%)	70 (62, 81.25)	60 (50, 73.33)	NS
	Average time (ms)	871.92 (800.67, 939.33)	856 (677.53, 1059.67)	NS
Fast count	Correct response (%)	75 (65, 80)	80 (65, 90)	NS
	Average time (ms)	998 (955.3, 1179)	1073.09 (999, 1147.18)	NS

[Table/Fig-5]: Comparison of the cognitive functions between male and female (postovulatory phase), n=42
Foot note: * represents significant p-value at p≤0.05

reason that testosterone is converted to oestrogen in many tissues, including the central nervous system, it could exert its influence directly or indirectly through its conversion to oestrogen via the aromatase enzyme [7,8]. However, there are different reports on the effects of testosterone and oestrogen on the cognitive profiles of males and females. In a study, it was reported that men with higher levels of total and bio available oestradiol showed poorer scores in the Blessed Information-Memory-Concentration (BIMC) Test and in the Mini-Mental State Examination. Whereas in another study, men with higher levels of bioavailable testosterone showed better scores in the BIMC Test and in the Selective Reminding Test [13]. These contradictions to our results which were seen, may have occurred due to the different cognitive function assessing tools that had been used in those studies. Moreover, there are reports that older men who possess higher levels of bioavailable testosterone, but no bio-available oestradiol, are associated with better cognitive functions [14]. In addition, a report has shown that in eugonadal men, increase in testosterone has a differential effect on cognitive function, which inhibits spatial abilities and improves verbal fluency [15]. It has been reported that testosterone supplementation improves working memory in older men, but a similar enhancement of working memory was not found in older women who were supplemented with oestrogen [16]. But contrary to this, we did not find any difference in female oestrogenic phase (preovulatory) working memory and male (testosterone) working memory. This contrast may have been caused by the differences in methodologies which were used to assess cognitive functions. They assessed cognitive functions in older men and women after supplementation of hormones, whereas we assessed cognitive functions in young adults who were not given any supplementation of hormones.

Our results support that males outperformed females in the tests of visuo-spatial ability [10] or visual reaction time [17,18]. We found that the visual reaction times of females in postovulatory (progesterone) phase of the cycle were poorer than those of males. In contrast to our results, it was reported that during the menstrual and mid-luteal phases (high progesterone and oestrogen phases) which is characterized by low levels of sex hormones potentiate the typical male cognitive profile [19].

Contrary to other reports, we found no significant differences between males and females (preovulatory or postovulatory phases) in perceptual fast count, working memory, and Eriksen Flanker test. But, it was reported that the oestradiol levels correlated negatively with mental rotations and perceptual priming, which suggestec that oestrogen, and not progesterone, was responsible for the changes which were observed in cognition [11]. Contrary to our results, it was reported that males showed advantages in working memory, mathematical abilities [2-3] and Eriksen Flanker test [20]. However, in our study, males showed trend of poorer performances than females in Go/No-Go VRT correct response, time to complete the Go/No-Go VRT, ST normal and interference time and in working-memory average time.

Our study was supported by the fact that in those tasks which required fine motor skills, the highest efficiency would be seen in the late follicular or midluteal phases [11,12] in females. Therefore, in Stroop test (executive task), during postovulatory phase, females had higher accuracy rates while they read colour interferences than males. This might have been caused by the effect of hormone, progesterone, which was probably responsible for modulating the female executive functions at this phase of the cycle. Few studies have shown that the biological significance of progesterone synthesis in the brain and that its autocrine or paracrine actions played an important role in the viability of neurons and in the formation of myelin sheaths, thus preserving the cognitive functions. In addition, the neuroprotective effects of progesterone were documented in a murine model of spinal cord motoneuron degeneration which was seen in Wobbler mouse [21]. Moreover, progesterone also enhanced the performance across a variety of tasks, even in the progesterone receptor knocked out mice [22]. However, there are contradictory reports on the action of progesterone on cognitive functions. It has been reported that progesterone masks the effect of oestrogen and that it attenuates the cognitive functions [23]. As well as, the sexual incongruities in progesterone's effects on working memory have reported that progesterone-based hormone therapies had a negative impact on cognition [24]. But few reports have also shown no differences in cognitive functions across the menstrual cycle [25], indicating that there was no influence of gonadal hormones on cognitive functions.

LIMITATIONS

1. The cognitive functions were assessed without the estimation of sex hormones.
2. The ovulation time relied on the basal body temperature.
3. Sample size of the study was small and therefore, studies need to be done on larger populations, to elucidate the gender differences in cognitive functions.

CONCLUSION

In conclusion, male cognitive functions (viz: attentional, perceptual, executive and working memory) were comparable to those of the female preovulatory phase cognitive functions. This might be due to the analogous actions of testosterone (male) and oestrogen (female-preovulatory) on the brain. Thus, our study supported the fact that testosterone and oestrogen accentuated cognitive functions in a similar fashion. Both males and females (preovulatory phase) can compete with each other equally in cognitive tasks. However, males outperformed females in attention state (as was assessed by visual reaction time) during the postovulatory phases of their menstrual cycles. This might be due to the effect of testosterone, that favoured males to be more attentive than females. But females, during their postovulatory phases, outperformed males in the Stroop test. This might be due to the hormone, progesterone that favoured females to properly discriminate the different colours and also able to execute the tasks better than males. This elucidated the fact that in tasks which required fine motor skills, females showed the highest efficiency (in postovulatory phase) as compared to males. For a more generalization of the findings, studies should be conducted in larger populations, along with the estimation of the sex hormone profiles of males and females, to make the results more conclusive.

REFERENCES

[1] Michelon P. What is a Cognitive Ability/. What are Cognitive Abilities and Skills? URL:http://www.sharpbrains.com/blog/2006/12/18/what-are-cognitive-abilities/. Dec 18, 2006, Accessed on: Oct. 14, 2012.
[2] Sherwin BB. Estrogen and Cognitive Functioning in Women. *Endocrine Reviews*. 2003; 24 (2): 133-51.
[3] Zaidi ZF. Gender Differences in Human Brain: A Review. *The Open Anatomy Journal*. 2010; 2:37-55.
[4] Phillips SM, Sherwin BB. Variations in memory function and sex steroid hormones across the menstrual cycle. *Psychoneuroendocrinology*. 1992; 7 (5):497-506.
[5] Hampson E. Variations in sex-related cognitive abilities across the menstrual cycle. *Brain and Cognition*. 1990;14(1): 26–43.
[6] Janowsky JS. Thinking with your gonads: testosterone and cognition. Trends in Cognitive Sciences. *Review*. 2006; 10 (2): 77-82.
[7] Taxel P, Stevens MC, Trahiotis M, Zimmerman J, Kaplan R. F. The Effect of Short-Term Estradiol Therapy on Cognitive Function in Older Men Receiving Hormonal Suppression Therapy for Prostate Cancer. *JAGS*. 2004; 52: 269–73.
[8] MacLusky NJ, Walters MJ, Clark AS, et al. Aromatase in the cerebral cortex, hippocampus, and mid-brain: Ontogeny and developmental implications. *Mol Cell Neurosci*. 1994;5: 691–8.
[9] Upadhayay N, et al. Pre- and Postovulatory Auditory Brainstem Response in Normal Women. *Indian Journal of Otolaryngology and Head and Neck Surgery*. 2011; DOI 10.1007/s12070-011-0378-4.
[10] Downing K, Chan S, Downing W, Kwong T, Lam T. Measuring gender differences in cognitive functionin. *Multicultural Education and Technology Journal*. 2008; 2 (1): 4-18.
[11] Maki PM, Rich JB. Rosenbaum RS. Implicit memory varies across the menstrual cycle: estrogen effects in young women. *Neuropsychologia*. 200;, 40: 518–29.
[12] Rosenberg L, Park S. Verbal and spatial functions across the menstrual cycle in healthy young women. *Psychoneuroendocrinology*. 2002; 27 (7): 835–41.
[13] Barrett-Connor E, Goodman-Gruen D, Patay B. Endogenous sex hormones and cognitive function in older men. *J Clin Endocrinol Metab*. 1999; 84 (10): 3681-5.
[14] Yaffe K, Lui L-Y, Zmuda J, Cauley J. Sex Hormones and Cognitive Function in Older Men, *JAGS*. 2002; 50: 707–12.
[15] O'Connor D. B, Archer J, Hair WM, Wu FC. Activational effects of testosterone on cognitive function in men. *Neuropsychologia*. 2001; 39 (13): 1385-94.
[16] Janowsky JS, Chavez B, Orwoll E. Sex Steroids Modify Working Memory. *Journal of cognitive neuroscience*. 2000; 12 (3): 407-14.
[17] Kosinski R. J. A Literature Review on Reaction Time, Sept. 2012 (updated). URL:http://biae.clemson.edu/Bpc/Bp/Lab/110/Reaction.Htm#Gender, Accessed on June 25, 2013.
[18] Shelton J, Kumar G. Comparison between Auditory and Visual Simple Reaction Times. *Neuroscience and Medicine*. 2010; 1 (1): 30-32, doi: 10.4236/nm.2010.11004.
[19] Šimic N, Santini M. Verbal and spatial functions during different phases of the menstrual cycle. *Psychiatria Danubina*. 2012; 24 (1): 73-9.
[20] Stoet G. Sex differences in the processing of flankers. *The Quarterly Journal of Experimental Psychology*. 2010; 63 (4): 633-8.
[21] Schumacher M, Guennoun R, Robert F, Carelli C, et al. Local synthesis and dual actions of progesterone in the nervous system: neuroprotection and myelination. *Journal of the Growth Hormone Research Society and the International IGF Research Society*. 2004; 14 Suppl A:S18-33.
[22] Frye CA, Walf AA. Progesterone enhances learning and memory of aged wildtype and progestin receptor knockout mice. *Neuroscience Letters*. 2010; 472: 38–42.
[23] Wegesin DJ, Stern Y. Effects of hormone replacement therapy and aging on cognition: Evidence for executive dysfunction. *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn*. 2007; 14 (3): 301-28.
[24] Sun WL, Luine VN, Zhou L, Wu HB, Weierstall KM, Jenab S, et al. Acute progesterone treatment impairs spatial working memory in intact male and female rats. *Ethn Dis*. 2010; 20 (1 Suppl 1): S1-83-7.
[25] Gordon HW, Lee PA. No difference in cognitive performance between phases of the menstrual cycle, *Psychoneuroendocrinology*. 1993;18(7): 521–31.

PARTICULARS OF CONTRIBUTORS:
1. PhD Student, Department of Physiology, BP Koirala Institute of Health Sciences, Buddha Chowk, Dharan-18, Nepal.
2. PhD Student, Department of Pharmacology, Manipal College of Medical Sciences, Nepal.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Namrata Upadhayay,
PhD Student, Department of Basic and Clinical Physiology, BP Koirala Institute of Health Sciences,
Buddha Chowk, Dharan-18, Nepal.
Phone: 977-9842168716, Landline: 977-25-525555 Ext: 2476 and 3278, E-mail: namrataupadhayay@gmail.com

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