Implications of Biological Rhythms on the Neuroscience of Learning and Health



Dr. Moses Satralkar (PhD) Associate Professor, Education, CHRIST (Deemed to be University) Bangalore, India

> National Webinar on Neuroscience St. Philomena's College, Mysuru 25-08-20

CHRONO-BIOLOGY

Def: Science of the study of effects of time on living organisms

Introduction of Chronobiology

- Study of biological time in relation with cyclic rotation of the earth in it's axis which is completed within 24 hrs.
- Biological rhythm varies from milliseconds in ocular field potential to years
- Circadian rhythm is the most extensively studied and best understood biological rhythm.
- Chronobiology comes from the ancient Greek (*chrónos*, meaning "time"), and biology, which means "the study, or science, of life"





What is a BIOLOGICAL CLOCK

A molecular / physiological device which synchronizes activities in the living organisms



Oscillation CLOCKS hourglass time chain of events

http://www.chronobiology.ch/glossary/

CHRONOBIOLOGY

Franz Halberg (FC), Jurgen Aschoff, Colin Pittendrigh, Serge Daan, Erwin Bunning



Nobel Prize in Chronobiology – Medicine, 2017



The 2017 Nobel Prize in Physiology or Medicine



Jeffrey C. Hall Born in New York, USA in 1945



Michael Rosbash Born in Oklahoma City, USA in 1944



Michael W. Young Born in Miami, USA in 1949

for their discoveries of mechanisms controlling circadian rhythms

Nobel Prize in Neuroscience – Medicine, 2014



London

Norwegian University of Science and Technology, Trondheim

Circadian Rhythms

Circadian rhythms: Self-sustaining biological rhythms characterized by a *free-running period* of about 24h (*circa diem*) Franz Halberg, 1959: ie. They occur periodically over 24 hours

Characteristics of circadian rhythms:

- Occur in bacteria, fungi, plants, flies, fish, mice, humans, etc.
- Entrainment by light-dark cycles, temperature, social cues, etc (*ie – synchronised to external environmental time cue or 'zeitgeber'*)
- Phase shifted by light pulses
- Endogenous in nature
- Adaptive in nature

Circadian rhythms occur at a molecular

level: (per, tim, cry, bmal g).

These rhythms are the product of an internal biological timekeeping system which is controlled by a biological clock located in the Brain



Biological Rhythms

<u>Rhythm</u> = sequence of events that repeat themselves in the same order and with the same time interval, over and over again. Circadian Rhythms and Biological Rhythms are terms used interchangeably and are essentially the same scientific concept

Biological Rhythm: a biological event or function with a pattern of activity that is repetitive at a constant time interval. Examples of Human Biological rhythms or Human Circadian Rhythms are:



Daily variations in physiology and behaviour are an integral part of life



Light is the key environmental signal that regulates the clock in living organisms

Effects of 'natural' and 'artificial' light?



00:00

00:00

00:00

00:00

Time of day

Goel et al. 2013; Coldwells et al. 1994; Dijk and Czeisler, 1994



Our body clock adjusts slowly to changes in the environment



Goel et al. 2013; Coldwells et al. 1994; Dijk and Czeisler, 1994





Observed that during a prolonged period of sleep deprivation, sleepiness increases

Early Studies of Human Circadian Rhythms



Michel Siffre

- A French cave explorer
- Six months living in a cave
- His biological clock was allowed to 'free-run',
- He was wired and monitored
- Erratic sleep-wake pattern at first
- Then averaged just over 25 hours
- When he emerged it was the 179th day but in his days it was only the 151st.



Siffre's Cave Experiment in Texas, 1972. He emerged after 179 days, but he thought he had been in the cave for only 151 days

Michel Siffre - The Cave Study





In 1962, a French speleologist named Michel Siffre spent two months living in total isolation in a subterranean cave, without access to clock, calendar, or sun.

Sleeping and eating only when his body told him to, his goal was to discover how the natural rhythms of human life would be affected by living "beyond time."

• Nathaniel Kleitman, (1938) : physiology of sleep and circadian rhythm





b38ce-f3a9-11e2-b516-0019bb2963f4.html







NEUROSCIENCE: Neurons, Glial Cells





SCIENTIFIC BASIS OF LEARNING

OVERVIEW: Brain cells responsible for learning are the NEURONS.

When the neuron gathers information, it grows appendages called **DENDRITES**. Learning takes place when two neurons communicate via axons and dendrites through a **SYNAPSE**.

A synapse TRANSMITS ELECTRICAL-CHEMICAL MESSAGES between neurons via NEUROTRANSMITTERS (Sprenger, 2002).

When neurons repetitively communicate with each other, a neural network is formed to process information (Sprenger, 2002) and this facilitates LEARNING.



Neurological basis of learning: Neuronal Circuits



Implications of Biological Rhythms on the Neuroscience of Learning and Health

- 1. Circadian Rhythms and Biocognitive Cycles
- 2. Age Dependent Learning Windows of Opportunity
- 3. Neuro-systemic influence on Learning and Career
- 4. Learning and Brain Development
- 5. Gender Differentiation in Learning
- 6. Diet and Cognitive Cycles
- 7. Sleep, Rhythms and Excercise
- 8. Special Education (SEN) and Mirror Neurons
- 9. Circadian Rhythms, Genetics, Health and Wellness
- **10. Integrated Science of Holistic Development**

1). CIRCADIAN RHYTHMS AND BIOCOGNITIVE CYLES



Degree of Focus

Chronotyope - The Larks

The larks prefer to start early in the morning and sleep early; People in the category of larks are generally found to study best during the early hours of the morning



Chronotype - The Owls

The owls start their day late and sleep late They study late into the nights



Horne and Ostberge, 1976, International Journal of Chronobiology <u>MEQ Questionnaire</u> Chronotypes peak and set during late Teenage years

Are You An Early Bird Or A Night Owl?

NIGHT OWL

intelligent indulgent goal-oriented dreamer fun

EARLY BIRD

perfectionist planner wakes up smiling ideas

Correlation: Circadian Chronotypes and Academic Achievement

Research Team from Oral Roberts University, USA.

Research Published in the International Journal of Psychology and Neuroscience (IJPN).

https://www.researchgate.net/publi cation/334442485_Chronotype_as a Predictor_of_Academic_Succe ss_of_University_Freshmen



INTERNATIONAL JOURNAL OF PSYCHOLOGY AND NEUROSCIENCE

Chronotype as a Predictor of Academic Success of University Freshmen

Claire Ferguson¹, Laura Kaneta¹, Ailin Li¹, Philip Nelson¹, Moses Satralkar², & Andrew Lang¹

- 1. Oral Roberts University, Tulsa, OK, USA
- 2. Redbridge International Academy, Bengaluru, India

Corresponding Author: Andrew Lang Email Address: alang@oru.edu

Abstract

An individual's endogenous circadian rhythm or chronotype tends to become later during adolescence, with peak lateness typically experienced during the freshman year of college, and slowly shifting earlier thereafter. Studies evaluating the impact of a student's chronotype on academic performance have shown that early chronotypes have an academic advantage over late chronotypes. However, it is not clear how this advantage depends on the time of the student's class and whether this advantage persists into the late afternoon or evening. Course grades were obtained by time of class and morningness-eveningness scores of 402 traditional first-time freshmen (aged 17-19 years) to examine the impact of both time of class and chronotype on academic performance. The strength of the effect of chronotype on grades was most significant for early morning classes, even when controlling for gender. As the time of day progressed, early chronotypes had similar grades as late chronotypes, specifically for classes between 15:00 -18:00. For definite morning types, a decline in academic performance was predicted over the course of the day and into the evening. Additionally, definite morning types would be at a severe disadvantage in classes that started later than 18:00. However, none of the 18-19-year-old freshmen identified as definite morning types, so this is only likely to be a problem for older, non-traditional students who tend to have earlier chronotypes. Thus, the typical college demographic, of young, traditional students in morning classes and more mature non-traditional students in evening classes, seems counterproductive for preparing students for academic success.

Keywords: chronotype, GPA, morningness-eveningness, academic performance

MEMORY VARIES BY THE CLOCK

- It's been shown that time of the day effects memory. We incorporate 2 different types of memory in learning:
- literal (facts, names, numbers, formulas);
- inferential (poetry, fiction, art, music).

In the morning literal memory is favoured and afternoon our brain integrates prior learning into inferential.



10 steps to a better brain; Kate Douglas et al, 2006, New Scientist







③ Advanced Research Laboratory, Hitachi, Itd. H. Koizumi

By Optical Topography, and MRI

Broca's area: word generation

Wernecke's area: understanding

In collaboration with Iwata, M., et al., Tokyo Women's Medical

By 6 months of age, infants develop a map in the auditory cortex of the phonetic sounds in the native language their mother or caretaker speaks.

By 12 months, infants lose the ability to discriminate between sounds that are not made in their native language.

While subtle phonetic distinctions might be lost in the first year, children have the ability to learn a second, third and fourth language quickly until about age 10.

Dendrites grow fastest during early years of life, hence rapid learning usually takes place during early years of life (till the age of 10)

Developing a Value in Children

eg: Self-Control/Patience/Delayed Gratification

Marshmallow Experiment 1

Marshmallow Experiment 2





The Marshmallow Test

- Walter Mischel (Stanford psychology faculty)
 - children were offered a marshmallow, but if they waited (~15 min), they were given 2 treats
 - children who waited longer for greater rewards tended to have better life outcomes
 - SAT scores
 - educational attainment
 - body mass index
 - □ similar to grit(!)



Biological Time changes with Age



Time of day

during morning tests

Roenneberg et al. 2003; 2007; Harazsti et al 2014

3). NEUOSYSTEMIC INFLUENCE ON LEARNING AND CAREER



Transfer of Stimuli : Multi-Sensory Neural Pathways



Neurosystemic Influence on Learning

Surface Reading on digital media = concept thinking : Deep Reading on print media = critical thinking









4). LEARNING AND BRAIN DEVELOPMENT

Left Brain

- Math
- Science
- Languages
- Computer Sciences
- General knowledge

Right Brain

- Art
- Craft
- Music
- Sports
- Theatre-Drama

Kathleen Cercone, 2006 - Brain Based Learning

Left Brain - Right Brain Conflict

Look at the chart below



The right side of the brain tries to say the colour while the left side tries to say the word.

Left vs. Right Brain

Is the girl rotating clockwise or anticlockwise?





Look carefully using both eyes



Brain Development influences Personality

LEFT BRAIN USER

(ANTICLOCKWISE)

uses logic detail oriented facts rule words and language present and past math and science can comprehend knowing acknowledges order/pattern perception knows object name reality based forms strategies practical safe

Left Brain, Right Brain



RIGHT BRAIN USER

(CLOCKWISE)

uses feeling "big picture" oriented imagination rules symbols and images present and future philosophy & religion can "get it" (i.e. meaning) believes appreciates spatial perception knows object function fantasy based presents possibilities impetuous risk taking

5). GENDER DIFFERENTIATION IN LEARNING

Boys tend to start school up to 1.5 years behind girls in language and fine motor development	While girls are more easily developing verbal skills
Boys generally see better in bright light	<i>Girls generally see better when there is dimmer light.</i>
Boys tend to be deductive in their reasoning, moving from the general to the specific.	Girls tend to favor inductive thinking. They tend to move from specific to the general.

Lise Eliot, Scientific American, 2009

https://www.scientificamerican.com/article/girl-brain-boy-brain/

Observations about boys and girls as writers

Boys tend to want immediate feedback and hope the reader just likes it the way it is.	Girls like the way their writing captures their voices. They are more willing to take time with feedback.
Boys tend to ponder and fester about what they are going to write.	Girls tend to 'attack' a writing assignment and get it done quickly.
Boys use their drawings to pump up the action in their narratives.	Girls tend to draw nouns - people and faces

Lise Eliot, Scientific American, 2009

https://www.scientificamerican.com/article/girl-brain-boy-brain/

Anatomical Differences

- Human brains show 99% similarity it's the 1% that makes a difference.
- The limbic cortex is larger in females- better emotional bond
- Frontal lobe (problem-solving), temporal cortex is larger in females
- Women have ten times more white matterbetter multi-taskers
- Males better at math due to better logistics in the left hemisphere (larger inferior-parietal lobule)
- Women equally utilize both hemispheres, better linguistic abilities

Gender Differentiation and Brains

The male and female brain

A new way of showing the connectivity of the brain - called "connectome" maps - reveals significant differences between men and women

Typical male brain (top view)

Most connections run between the front and back parts of the same brain hemisphere, which could account for the better spatial skills and motor (muscle) control in men



Typical female brain (top view)

Many more neural connections go from side to side across the left and right hemispheres of the brain. Scientists say this could account for women's better verbal skills and intuitive abilities

Neurological differences between boys and girls

Girls:	Boys:	
Verbal communication ability develops earlier	Spatial ability develops earlier	
Verbal communicator	Nonverbal communicator	
More sensitive to sensory data	Better in gross motor skills	
Express emotions through words	Express emotions through actions	
Cooperative	Competitive	
Use both left and right hemispheres of brain	Mainly use the right side of the brain	

©Arlene R. Taylor PhD Realizations Inc



Female Brains

A larger anterior commissure, and often a larger corpus callosum

↑ connections provide for a more generalized style of processing



A smaller anterior commissure, and likely a smaller corpus callosum

↓connections provide for a more lateralized style of processing

6). DIET AND COGNITIVE CYCLES

The brain functions as the master organ of the Central Nervous System. The brain makes up 2.5-5% of the body but uses 30% the of body's energy ie. appx 700 Cal for normal functioning every day.

Neurotransmitters are chemicals responsible for cognition and they are often the by-product of digestion. Hence nutrition is important to modulate optimum levels of neurotransmitters in the Brain especially in Pre-adolescent Years.

Few of these Neurotransmitters/Bio-chemicals in the Brain include

- Dopamine
- Serotonin,
- Acetylcholine
- GABA
- Histamines

https://www.newscientist.com/article/dn9968-top-10-steps-to-a-better-brain/

NEUROTRANSMITTER/ BIO-CHEMICALS	FOOD/DIET	FUNCTIONS IN BRAIN
Serotonin	Chicken, Fish, Eggs, Turkey, Mango, Pineapples Nuts, Flaxseed	Mood, Memory Processing, Sleep, Cognition
Dopamine	Cheese, Tofu, Nuts and Seeds , Legumes	Pleasure, Reward, Motor Functions, Compulsion, Preservation
Acetylcholine	Eggs, Beans, White Meats	Short-Long Term Memory
Tyrosine	Curds/Yoghurt, Milk	Sleep
Antioxidants, Beta- carotene (Vit C and E)	Salads, Green Vegetables Strawberries, Blueberries	Combat Aging
DHA-Omega 3 Fatty Acids	Fish, Salmon, Kiwi, Walnuts	Alertness, Focus, Retention

10 steps to a better brain; Kate Douglas et al, 2006, New Scientist

7). SLEEP, RHYTHMS AND EXCERCISE

-	Frequency band (cycles/second)	Name of Brain Wave Band	Description	Beta 15-30 Hz Awake, normal alert consciousness
-	1 - 3	Delta	Generally strongest when a person is in a deep dreamless sleep.	Alpha 9-14 Hz Relaxed, calm, meditation creative visualisation Theta 4-8 Hz
	4 - 7	Theta	May be associated with dreamy, creative, intuitive states.	Deep relaxation and meditation, problem solving Delta 1-3 Hz Deep, dreamless sleep
-	8 - 10	Alpha	Associated with a calm and relaxed state when the person is not thinking.	
	15 - 30	Beta	Associated with being alert, with normal thinking, with processing information.	

Melatonin and the biologicalook



Restorative Functions

- growth and repair

Adaptive Functions

- predator avoidance
- energy conservation

Cognitive Functions

learning, unlearning, reorganization

SLEEP RHYTHM



CIRCADIAN RHYTHMS



SWS VS. REM SLEEP

TABLE 14.1 Properties of Slow-Wave and REM Sleep

Property	Slow-wave sleep	REM sleep
AUTONOMIC ACTIVITIES		
Heart rate	Slow decline	Variable with high bursts
Respiration	Slow decline	Variable with high bursts
Thermoregulation	Maintained	Impaired
Brain temperature	Decreased	Increased
Cerebral blood flow	Reduced	High
SKELETAL MUSCULAR SYSTEM		
Postural tension	Progressively reduced	Eliminated
Knee jerk reflex	Normal	Suppressed
Phasic twitches	Reduced	Increased
Eye movements	Infrequent, slow, uncoordinated	Rapid, coordinated
COGNITIVE STATE	Vague thoughts	Vivid dreams, well organized
HORMONE SECRETION		
Growth hormone secretion	High	Low
NEURAL FIRING RATES		
Cerebral cortex	Many cells reduced and more phasic	Increased firing rates; tonic (sustained) activity
EVENT-RELATED POTENTIALS		
Sensory-evoked	Large	Reduced

© 2001 Sinauer Associates, Inc.

Human Circadian Rhythms: Functions for Homeostasis





Exercise and the Brain

The Brain Benefits of Exercise



INCREASES PRODUCTION OF NEUROCHEMICALS THAT PROMOTE BRAIN CELL REPAIR



PROMOTE BRAIN CEL

MEMORY

LENGTHENS ATTENTION SPAN



BOOSTS DECISION-MAKING SKILLS

PROMPTS GROWTH OF NEW NERVE CELLS AND BLOOD VESSELS

IMPROVES MULTI-TASKING AND PLANNING





www.satvikshop.com

8). SPECIAL EDUCATIONAL NEEDS AND MIRROR NEURONS

- Dyslexia
- ADHD/Attention Deficit Hyperactivity Disorder
- Dyscalculia
- Dysgraphia
- Autism
- Anxiety
- Aphasia
- Asperger's syndrome.
- Auditory processing disorder.
- Autistic spectrum disorder.
- Behavioural difficulties- EBD, SEBD, SEMH.
- Anorexia







Brain Imaging Techniques:

Genetic, Brain Damage, Abnormal Growth







Diagnosing Brain Disorders, Learning Disorders fMRI, PET, CAT

MIRROR NEURONS



monkey sees action



Implications



Response is similar for: Performing the action Witnessing the action Hearing about the action

Mirror Neurons enable: Empathy Skill building through mimicry Vicarious experience

- First discovered around 1990 Giacomo Rizzolatti, a neuroscientist at the University of Parma, Italy.
- studying brain activity in macaque monkeys
- neurons in an area of monkeys' premotor cortex F5 fired
- individual neurons- only respond to very specific actions. (peanut grasp)
- (1992, in Experimental Brain Research)
- (1996, *Brain*)- "Mirror Neurons"



Implications of Mirror Neurons







9). CIRCADIAN RHYTHMS, GENETICS HEALTH AND WELLNESS

Precise nutritional recommendations based on your unique genetic make-up.

GGAGGATAACATGO

CACGAGTTCGAGA

AGTTCATCTACA





THE HUMAN GENOME PROJECT (HGP) 1990 - 2003



"The human genome underlies the fundamental unity of all members of the human family, as well as the recognition of their inherent dignity and diversity. In a symbolic sense, it is the heritage of humanity."

Universal Declaration on the Human Genome and Human Rights

https://www.ags-health.com/

HUMAN GENOME PROJECT (HGP)

CRACKING DOWN THE LIFE'S CODE

Molecular Genetics of Circadian Rhythms

The intrinsic 24 h rhythms arise from the molecular interaction of key "clock genes". This molecular clockwork is in turn adjusted to the external world by recently discovered photoreceptors within the eye.



Circadian Rhythms and Health



Jet Lag

Shift-Work

Insomnia

Chronomedicine



CIRCADIAN MEDICINE The Body Clock in Health and Disease

Dr. Satchin Panda

https://www.youtube.com/watch?v=VHKHXxALHMQ







10. INTEGRATED SCIENCE OF HOLISTIC DEVELOPMENT

- 1. Cognitive (Alfred Binet IQ, Jean Piaget, Lev Vygotsky, Benjamin Bloom)
- 2. Aesthetic (Howard Gardner- MI)
- 3. Physical (Kurt Hahn EL)
- 4. Social-Emotional (Daniel Goleman EQ)
- 5. Spiritual (John Dewey, Abraham Maslow SQ)









Higher Order Thinking Skills - HOTS



Acknowledgements - Neuroscientists

Dr. Kathleen Cercone





Chapter XIII

Brain-Based Learning

Kathleen Cercone, Housatonic Community College, USA

Abstract

Neuroscience research that explains how the brain learns is a dynamic field. Since the 1990t, there has been explained policies growth in information about the neurophysiology of learning. A discussion of the neuroanatomy that is necessary to understand this research is presented first. Following the discussion of anatomy and physiology, current brain research is described, with particular focus on its implications for teaching adult students in an online environment. In addition, two instructional design theories (Gardner's multiple intelligence and Kovalik's integrated thematic instruction) that have a basis in neuroscience are examined. Recommendations founded on brain-based research, with a focus on adult education, follow, including specific activities such as crossel-lateral movement patterns and detailed online activities that can be incorporated into an online learning environment or a distance learning class (and faceto-face classroom) for adults. Comprehensive recommendations and guidelines for online learning design have been provided as suggestions for making maximum use of the brain-based principles discussed in this chapter.

Copyright © 2006, Idea Group Inc. Copying or distributing in print or electronic forms without written

Dr. Eric Jensen





Martha Kaufeldt







MARTHA KAUFELDT

Acknowledgements - Chronobiologists

Dr. Ronald Konopka (L) Dr. Seymour Benzer (R) Neurogenetics of *Drosophila*

Dr. Yvan Touitou

Medical Studies in Pharmacology, Chronomedicine and Chronotherapy

Dr. Ueli Schibler

Karolinska Research Lecture At Nobel Forum









Dr. Joseph Takahashi Clock Genes



Dr. Timothy Browne University of Manchester Dr. Vinod Kumar International Congress on Chronobiology



Dr. Satchin Panda v Circadian Medicine

Thank you

Few references, articles, links, slides and photographs collated from the world wide web