Night Eye Guardian

Project Plan

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Problem Statement

Doctors that are performing research in Sudden Infant Death Syndrome (SIDS) need better tools for collecting and analyzing data from infant sleep studies. Our client's theory is that a major factor in determining the risk of SIDS is the percent of time the infant spends in the Slow Wave Sleep (SWS) sleep state versus the Rapid Eye Movement (REM) sleep state and the sleeping pattern overall. The issue with analyzing when the infant is in these sleep states is a challenging one. Parents do not want intrusive tools in their child's sleep area and they want their child to be safe. Reliability and effectiveness of the monitoring product is essential also. Researchers are looking for a way to gather the sleep data of infants without inconveniencing the parents or child.

Project Description

We will be creating a system built upon previous work from another senior design team to record a sleeping infant and use the video to determine the percent of time the infant is in each sleep state. There will also be charting of the detected activity level and breathing rates along with simulated heart rates that will be displayed as a function of time.

This project consists of developing a web enabled tool by integrating a web camera with special software which graphically displays infant sleep data to researchers conducting Sudden Infant Death Syndrome (SIDS) Polysomnography (sleep studies). The project requires integration of existing open source components to detect activity and customizing a user interface to display the video, activity and heart rate graphs. This also includes developing an algorithm to determine sleep states as a function of time based on the activity and simulated heart rate.

The team will make use of special software developed by MIT called, Eulerian Video Magnification (EVM), which is available for non-commercial research purposes and can be downloaded from: http://people.csail.mit.edu/mrub/vidmag/#code. This software will allow for video enhancement, making motion much more evident. The software may be extended in future projects to incorporate open source heart monitoring software that analyzes video with red detection to determine heart rate. However, that is out of the scope of this project.

The system hardware components consists of a motion detection camera, remote server, user's website and an optional wireless mobile device, to monitor infants as they sleep inside their cribs. Figure 1 in Appendix B shows the high-level system overview. The video data is currently uploaded to a server at SIDSKnowMore.net (hosted by 1and1.com). The researchers will use the system and data to evaluate the infant's SWS/REM sleep states and cycles.

Concept Sketch

See Appendix B, Figure 1: Concept Sketch.

System Block Diagram

See Appendix B, Figure 2: Functional Block Diagram.

Operating Environment

The system would be designed to keep track of the duration and number of the infant's SWS and REM sleep states. The system determines the SWS and REM sleep states and cycles with the help of Eulerian Video Magnification (EVM) software. A web camera collects the infant's video data and uploads the data to a secure web site. The EVM software performs a cross correlation of the movement and color and presents the enhanced video. The team can then correlate the movement rates and simulated heart rate to derive the SWS and REM sleep states and cycles. The duration and time for each sleep state and cycle is plotted graphically for an entire night and is presented to SIDS researchers via the internet.

User Interface

Based from what we know of the user, we are creating a user interface that will work the best for them. The backend will be ran by a program called ZoneMinder which already includes a user front end. There are two essential modules our client asked for, the first is for the video to be visible on the main page and for a graph of the data based off the information in the video. The video portion will be the raw footage after it is computed through our software to look for sleeping patterns. A graph of the sleeping patterns will accompany the video so researchers have a better perspective of the cycles. An example of the user interface can be found in the appendix as Figure 3 in Appendix B, which contains a basic overview of the elements found in the main page. There will also be an archive page for previous nights which contains the same information but from all previous nights. From our specifications there will be three user cases, each one displaying different data for research or just video output. Depending on who needs to see specific information a user might be granted access to view more than others. Figure 4 in Appendix B shows the page to access archived data and review it. The users are defined as follows:

- Admin: Has the most options available to any user, used to control most of the website and other user accounts.
- Researcher: This user will be able to view all the video and the data that is necessary to the project. The researcher needs to be able to view everything on the site but does not need to change other user account statuses.
- Parent: Allows the parents to view what the researchers see but without the actual data they are collecting. This is a simplistic view just so the parents get a basic understanding of what the researchers are doing.

Functional Requirements

- The video stream needs to be processed through the MIT Eulerian Video Magnification Software.

- The amplified video will be live streamed to a website for the target users to view at all times.

- The REM/SWS sleep states would be determined based on the IR motion detection on the FOSCAM IPcam and the simulated heart.

- Graphs of REM/SWS sleep states versus time, activity (motion), and simulated heart rate would also be displayed on the website.

Non-Functional Requirements

- The graphs displayed on the website should be descriptive and concise for reading.
- The entire project including the IPcam, server and website should be easy for our client and target users to set-up.
- The final product has to be reliable enough to deliver the information that is available to the end users at all times.

Background Research

The previous group project was designed around using ZoneMinder, a Linux program for controlling and monitoring security cameras, and we will continue using this system for secure storage of the videos. ZoneMinder is an open source project designed to be used in home video security system but is great for handling the storage of video received over a network. ZoneMinder supports a range of video encodings.

A team at MIT has developed an open-source project called Eulerian Video Magnification that standard video as input and applies spatial decomposition, followed by temporal filtering to the frames. The resulting signal is then amplified to reveal hidden information. This method makes it possible to see small motions and changes in color, such as the change in color as blood flows through a person's face. Our project will use this software to enhance video taken from the IP camera in order to detect the subject's level of activity. Future projects may also be able to use this software to detect the pulse and blood pressure.

We are currently undergoing research in to software that can be used to gather the required information from the enhance video. We are looking into various image and video analysis projects online and at ISU.

At this moment, there is only one competitor product on the market. This product records the activity of the test subject via a mat with sensors placed under the subject. Our project, on the other hand, will broadcast live stream video and gather data solely from this video. This choice is much more appealing to parents because it is not intrusive.

Deliverables

The project goal is to provide video and infant REM/SWS sleep data to SIDS researchers via the web. The data consists of keeping track of the number of infant sleep states and cycles, as well as the time of occurrence and duration SWS and REM sleep states for multiple infants. Lack of motion detection is associated with SWS states, while continuous infant movement is associated with the REM sleep state. The REM sleep states, are charted and displayed for each infant studied. Figure 5 in Appendix B show a graph of REM/SWS sleep cycles.

The primary deliverable will the system itself. This will include a configured server ready to receive and analyze video. We will also provide all source code and documentation to the client so that it can be extended further, if necessary. The second deliverable will be the algorithm used to detect sleep states from the input video. This algorithm will be based on the simulated heart rate and movement information that is gathered from the video.

Work Plan

9/30/13	• Project Plan Drafting
10/7/2013	• Project Plan Finalizing
10/14/2013	• Previous Senior Design Set-Up
10/21/2013	• Design Document Drafting
10/28/2013	• Finalizing Design Document • All Necessary Software Installed and Familiar
11/4/2013	• Project Plan Revisions • Some Prototyping with Enhanced Video Display
11/18/2013	• Finalizing Project Plan • Group Presentation
11/25/2013	• Design Document Revisions
12/2/2013	• Design Document Due
12/9/2013	• Final Presentations
12/16/2013	• Winter Break
12/23/2013	• Winter Break
12/30/2013	• Winter Break
1/6/2014	• User Interface Development
1/13/2014	• Begin Drafting Sleep State Algorithm
2/3/2014	• Testing and Revising of Sleep State Algorithm
2/10/2014	• Extensive Testing of Sleep State Algorithm
2/17/2014	• User Interface: Display of Sleep States
2/24/2014	• Determining Risk Factors/Abnormal Patterns Highlighted
3/3/2014	• Testing of Overall System
3/10/2014	• Bug Fixing/Testing
3/17/2014	• Testing/Demos
3/24/2014	• Testing with Live Streaming
3/31/2014	• Begin Sampling with Volunteer Parents/Infants
4/7/2014	• Finalize Code and Documentation
4/14/2014	• Final Presentation Drafting
4/21/2014	• Final Presentation Finalizing
4/28/2014	• Final Presentation
5/5/2014	• Graduate! (Hopefully!)

Appendix A

Sleep States and Cycles

We introduce a proposition regarding the biogenetic evolution of sleep cycles and states. Our hypothesis considers that our need for sleep evolved through millions of years and was shaped by its survival benefits. Human sleep behavior that we observe today can be directly attributed to these inherited survival traits.

Millions of years ago, when humans were still part of the animal world, the traits which we adopted were based on giving humans some form of survival advantage over other animals. The animal world is based on a predator and prey scenario. A plausible reason for the function of sleep, from a human evolutionary standpoint, may be that sleep served to disable our physical movement at night, so as to minimize the risk of detection by predatory animals. However, total lack of physical movement with sensory shutdown while sleeping has the disadvantage of inhibiting our ability to detect a nearby approaching predator and escape, should the need arise.

A likely evolutionary compromise would be to minimize physical movement, but also maintain some form of sensory detection to alert us of possible danger while sleeping. Enter the two states of sleep: 1) Rapid Eye Movement (REM), or active sleep and 2) Non REM (NREM), or Slow Wave Sleep (SWS). These two states together make up one sleep cycle. We propose that sleep evolved with multiple sleep cycles, due to two major reasons. First, sleep allows our body the obvious benefits of health regeneration, and second, our genetics are preprogrammed with millions of years of survival traits, including sleep with alertness standby (REM State) to survive the predator and prey animal world.

Today, we observe sleep in two states. One state is the SWS sleep state and the other is the REM sleep state. Throughout the night, these states occur in multiple cycles. Both the SWS sleep and REM sleep states cause the body to be physically immobile to minimize the risk of detection by predatory animals, but during the REM sleep state, our senses are on standby mode with a higher level sense of alertness to improve the probability to detect movement and sound as an inherited survival trait against predatory nocturnal animals.

During the SWS state, the alertness levels decrease as seen by lower body temperature and cardiac and respiratory rates, which improves the probability to go undetected by predatory animals. However, the decrease in cardiac and respiratory rates must not go so low as to become unable to maintain proper homeostasis. Therefore, when the minimum homeostasis threshold level is reached, our neurological survival mechanism triggers a higher level of cardiac and respiratory rate to maintain proper oxygenation levels and stable homeostasis. This transition from lower cardiac and respiratory rates to higher cardiac and respiratory rates occurs from the SWS sleep state to the REM sleep state. Therefore, by going through alternate REM and SWS sleep states during the night, this scenario most likely provided humans the best of defense against predatory animals while asleep. We proposed that this maybe a plausible explanation for the REM and SWS sleep states.

REM/SWS and Thalamocortical Neurons

SIDSKnowMore believes that a key factor associated with SIDS, relates to sleep states and cycles. At birth, infants have chaotic EEG waveforms due to exponentially extreme neuronal growth. As part of the infant's adaptation to its environment, the wake/sleep cycles are attempting to synchronize with light as well as auditory and other environmental clues. During sleep, the infant's neurological system is still coupled to electromagnetic environment and the thalamocortical neurons are in the intrinsic oscillatory state. Changes between Slow Wave (SWS) and Rapid Eye (REM) states are dependent on frequency and amplitude changes in the thalamocortical neurons and can be measured with EEG charts. The membrane potential is -85 mV during the SWS state and -65 mV during the REM sleep state, as detailed in Figure 6 in Appendix B.

During the REM sleep state, the infant's cardiorespiratory rate increases and more oxygen flows to the brain. Also, the infant's temperature increases slightly during REM sleep. During sleep, the thalamocortical neurons are in an intrinsic oscillatory state. In the oscillatory/bursting mode, the neurons in the thalamus become synchronized with those in the cortex, essentially "disconnecting" the cortex from the outside world. This disconnection of the cortex translates into the body, becoming physically immobile during sleep. During the SWS sleep state, the EEG recordings show the lowest frequency and the highest amplitude. When the infant is awake, the thalamocortical neurons are in tonic active state. Figure 7 in Appendix B illustrates the thalamocortical neurons showing oscillatory mode in a sleep state and tonically active mode in an awake state. In the tonic state, the thalamocortical neurons transmit information to the cortex that matches the spike trains encoding peripheral stimuli.

The system makes use of these medical findings to derive epochs of SWS and REM sleep states and cycles and proposes that infants are at their highest risk to die due to SIDS during the Slow Wave Sleep (or non-REM) stages of sleep due to lower Inter Spike Intervals which are dependent on complex bursts of neuronal network behavior associated with limit cycle functions, which become unstable due to neuronal bifurcations associated with non-linear systems, such as an infant's brain.

Appendix B: Figures

Figure 1: System Overview

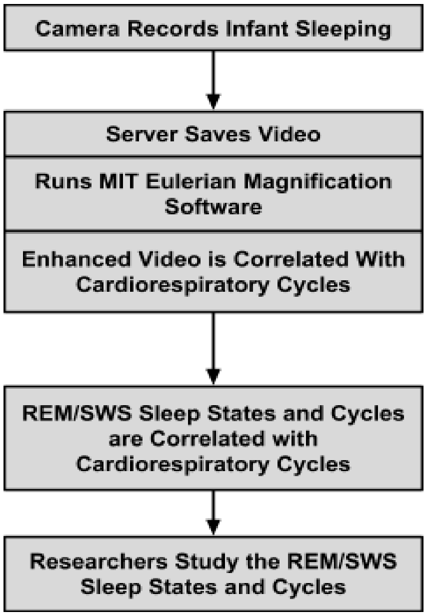


Figure 2: Functional Block Diagram

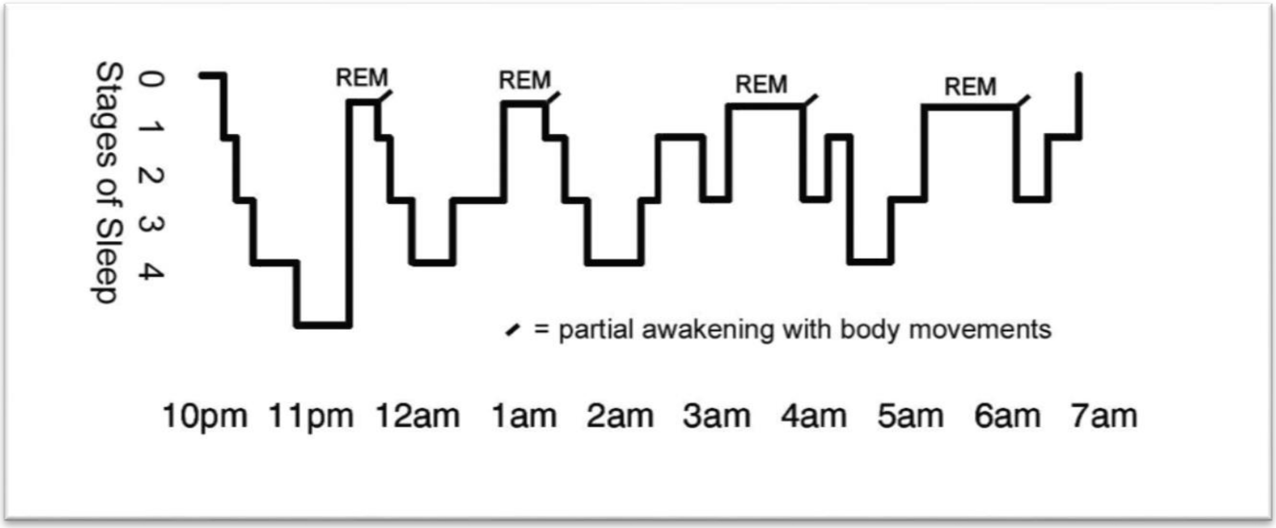
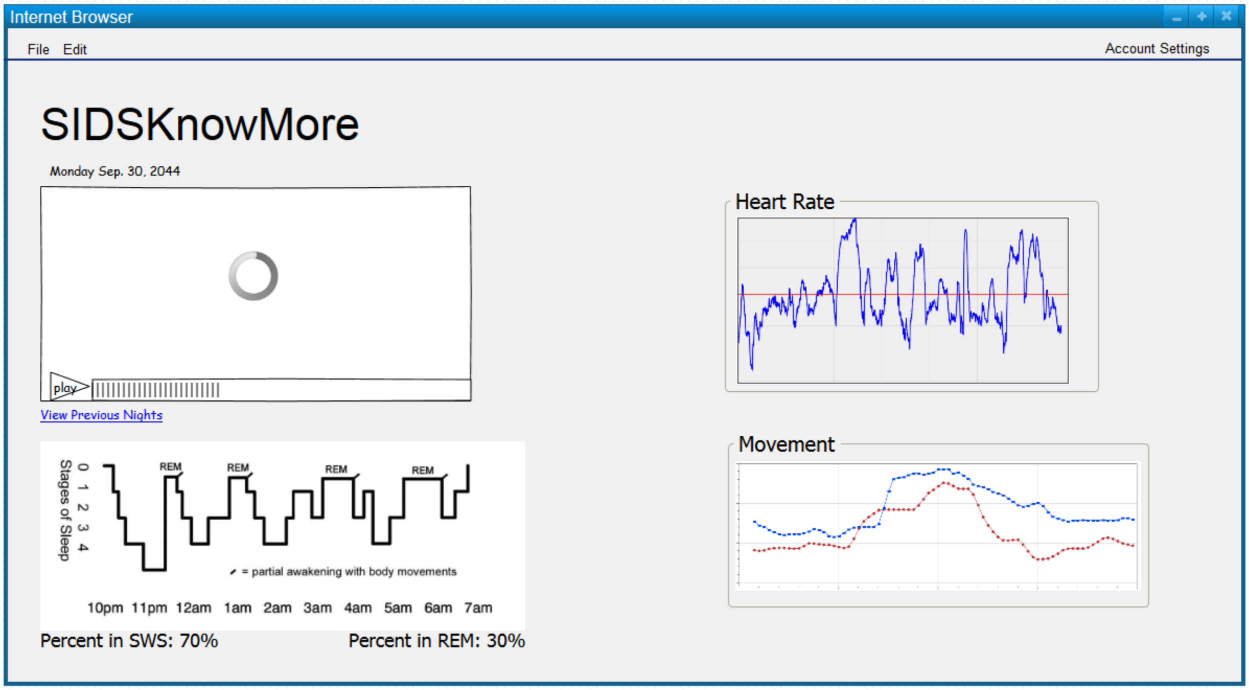


Figure 3: Chart of Infant Sleep States and Cycles



SIDSKnowMore

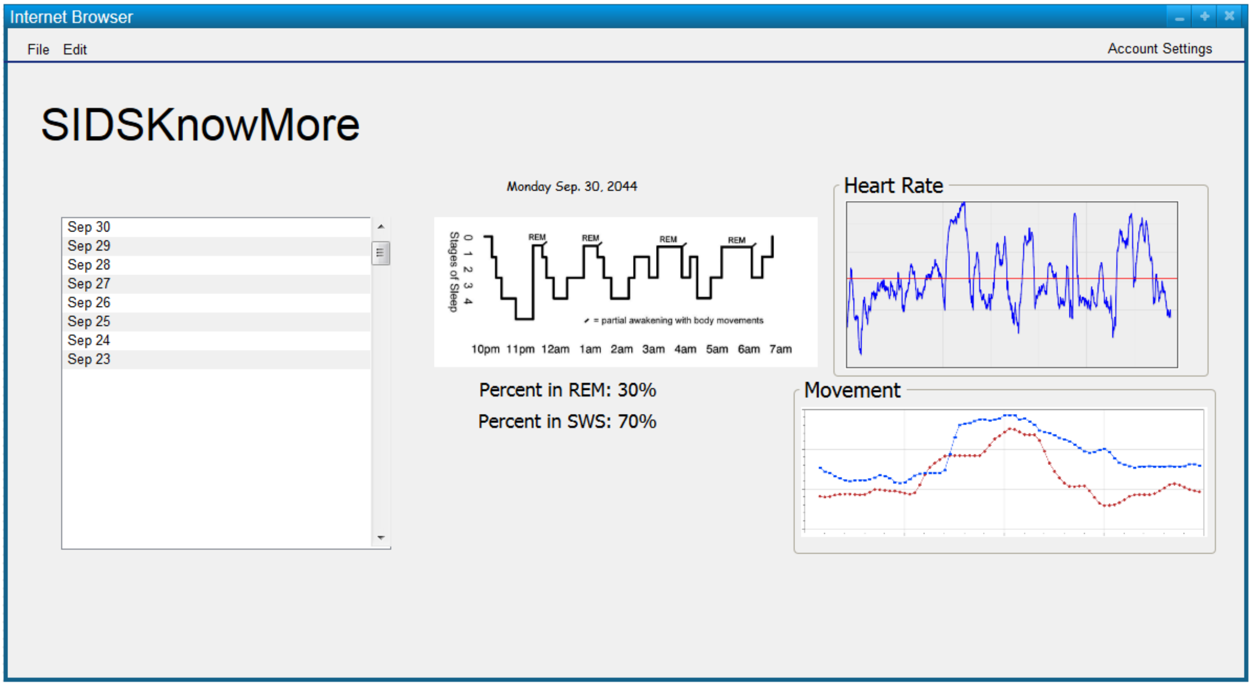
Monday Sep. 30, 2044

View Previous Nights

Percent in SWS: 70%

Percent in REM: 30%

Figure 4: Conceptual User Interface Main Page.



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Sep 30
Sep 29
Sep 28
Sep 27
Sep 26
Sep 25
Sep 24
Sep 23

Monday Sep. 30, 2044

Percent in REM: 30%
Percent in SWS: 70%

Figure 5: Conceptual Image of Archived Data.

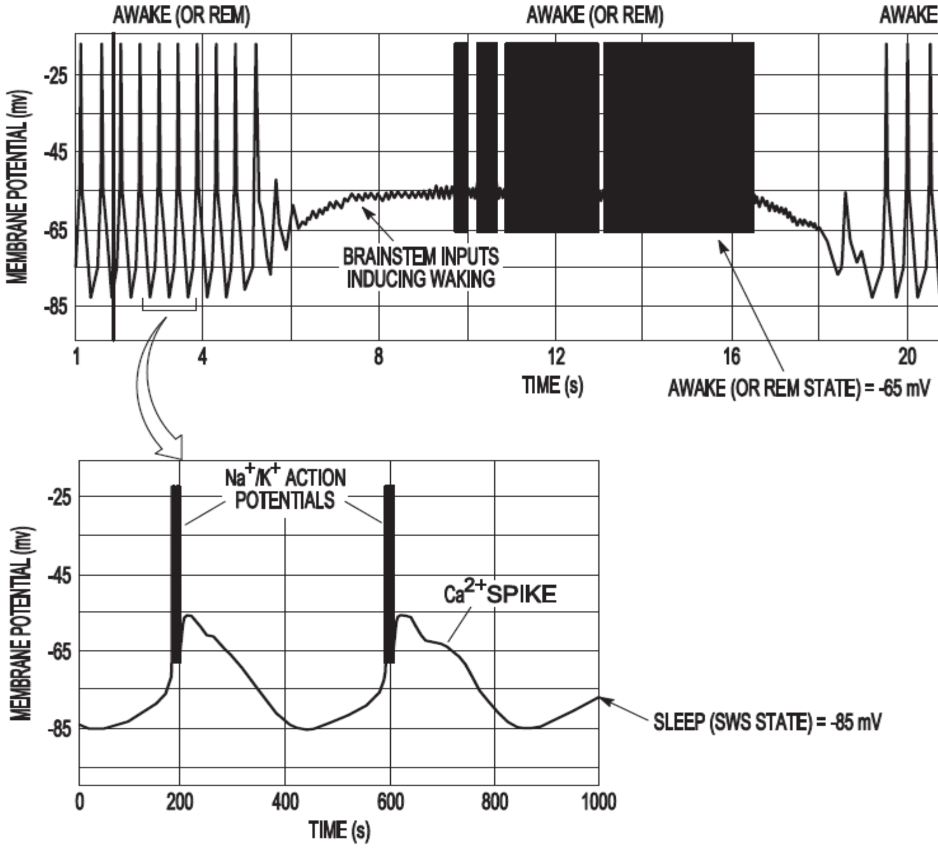

Figure 6: Thalamocortical Neurons - During SWS and REM Sleep States

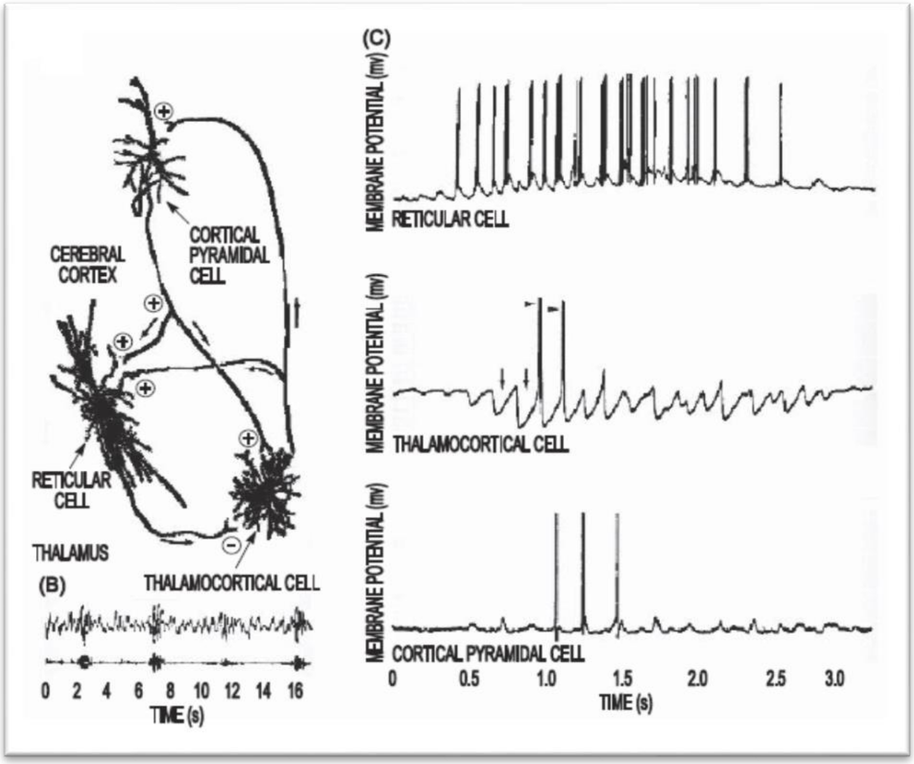

Figure 7: Thalamocortical Neurons - Oscillatory Mode in a Sleep State and Tonically Active Mode