An Investigation of the Effects of Mental Fatigue on Programming Tasks' Performance

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ABSTRACT

Mental fatigue reduces the cognitive and physical performance of people. I propose to investigate how mental fatigue affects programmers to perform poor in software industries, causing system developed by them to fail in the long run. This project is the part of my thesis research project with *Dr. Parnin*[1]. We will be validating our hypothesis with the help of surveys and user studies. This project is to define the research guidelines to further investigate different methods to automatically determine the fatigue level of programmers. We can use this information to help programmers avoid their fatigue state to control errors in programming, and eventually aid them to be more productive.

Keywords

Software Engineering, Psychology, Fatigue, Work Environment

1. INTRODUCTION

Fatigue is a physiological state of reduced mental or physical mental capability. Fatigue is always ambiguous to be defined. It results from excessive workload(both physical and mental), exhaustion, or sleeploss. Fatigue (also called exhaustion, tiredness, lethargy, languidness, languor, lassitude, and listlessness) [14] is a complex happening and have all physiological and psychological characterisctics [10]. Fatigue can be categorized accordin to its effects and distinctiveness. Workload causes muscle pain and bruning sensation in body. The inability to perform any physical activities at the level of one's normal activities is *physical/muscular fatigue*. *Mental fatigue* is defined as a state of weariness, with a feeling of boredom/saturation and declines motivation [9]. Fatigue is one of the 13 mood states [1]. Stress causes emotions and mood swings. Dull emotional responses is cahracterized as *Emotional Fatigue*. People have capabilities of doing certain tasks. *Skills Fatigue* deals with their ability to perform those tasks. People are susceptible to fatigue and its effects, that hamper their daily activities, their ability to perform and ultimately affects the results.

Mental fatigue is caused due to exhaustion and tiredness, triggered by long and demanding tasks [9]. Exhaustion due to extreme mental and physical work causes performance degradation in execution of human tasks. Mental fatigue also has a negative effect on memory and cognitive functionalities and these functionalities play a vital role in program construction and modeling [4]. Mental fatigue is universal to all software developers [11]. Studies have shown possible relations between mental fatigue and specific programming tasks such as a program construction, modeling and debugging [4].

Primary reasons for system failures are due to low performance of programmers, caused by their absentmindedness or exhaustion. Mental fatigue can also lead to system failures in the long run. Mental fatigue can also lead to system failures in the long run [5]. Exhaustion due to extreme mental and physical work causes performance degradation in execution of human tasks. In today's competitive world, software programmers are motivated to work hard, and hence keep themselves involved in numerous projects. Sometimes they work in teams and sometime they work individually on a project. Again, this all lead to sleepless nights resulting in more exhaustion and tiredness. Several times programmers suffer from psychological diseases which they themselves are not aware of [11]. Programmers may make mistakes and therefore introduce bugs during software development. These mental errors are due to cognitive failures like distraction, low decision making power, less reasoning capabilities, and poor attention and focus [8].

Tests [12] quantifies few subjective symptoms of fatigue in performing general tasks, that relates to programming domain:

1. Exhausted & Drowsy
   (a) Sleepiness
   (b) Restlessness
   (c) Feeling tired
   (d) Sluggish
   (e) Lethargy
2. Mental decline

[1]http://www.chrisparnin.me/

(a) Nervousness
(b) Unwillingness
(c) Lack of focus
(d) Absentmindedness
(e) Anxiety
(f) Weariness

3. Incongruity in body & nervous systems
   (a) Physical Strength
   (b) Pain in limbs
   (c) Strain in eyes
   (d) Dizziness

There is not a lot of work done in this problem area, so my approach would be to create incremental models that can be refined over time with continuous evaluation of the research. My contribution intends to define some measurements for measuring the mental fatigue and analyzing its effect on developers' performance. This is a step towards working to solve the problem of programmers' mental fatigue affecting various programming tasks in the software development process. In Section 2, we illustrate the related works in the field of fatigue and what other cognitive aspects have been researched in programming domain. Section 3 presents design and limitations of our approach towards the problem. In Section 4, we discuss the results of our study and give a detailed analysis of the observations providing a vision of our research. In summary, we make the following contributions [TODO]:

2. RELATED WORK

Empirical studies have been conducted in the cognitive aspects of software engineering. Khan et. al. [7] have worked on the effect of programmers' moods on the performance of programming debugging, which also comes under the umbrella of psychological causes. My approach takes mental fatigue as the psychological factor rather than mood and focuses on all the programming tasks than just on program debugging. Pimenta et. al. [2] [3] have worked on monitoring and analyzing the human performance with respect to the computers and the effects of fatigue on it. My proposal is the extension of this approach by using different ways to analyze the effects of fatigue and providing an aid to the programmer. Saito [12] has worked on assessment of physical fatigue in industries. Several works have been done on the risk of cognitive incapability of other types of work like driving or physical activities in industries, however, few works have been done about finding risk in the programming tasks of IT personals.

Numerous articles and blogs discuss about the effect of fatigue on the efficacy of programmers in tasks like program understanding, construction, modeling, debugging and decision making. Industries need a tool which can help programmers detect the mental fatigue state and work on it.

This proposed project is first of the many steps taken in this direction, opening a wider scope for more research in the domain.

3. METHODOLOGIES

The approach is to validate our hypothesis and then set some research guidelines to investigate methods to determine fatigue state of programmers. In order to set the research guideline, few research questions must be answered first:

- RQ1: *How severe and frequent fatigue is a problem for programmers?*
- RQ2: *What are the factors that lead to mental fatigue state in a programmer's life?*
- RQ3: *What are the effects of mental fatigue in a programmer's life?*

We conducted a formative study to get answer these questions. Additionally, the methodology comprises a case study to try setting some benchmark, which includes initial experimental validation using an instrumentation tool (Eclipse plug-in).

3.1 Validating Hypothesis: Survey

In order to validate the hypothesis of mental fatigue deteriorting programmers' performance and to resolve the dilemma of quantifying and measuring fatigue with respect to the programming tasks, we intend to build a novel model to classify fatigue and relate it. However, to achieve that, we must set some guidelines on the basis of which we will be able to quantify and define fatigue. This will help us answer the above mentioned research questions.

We conducted a survey and got 311 participants to respond. This survey was distributed with *checkbox.io*[2]. Participants entered in a drawing for three $50 gift cards. Links to this survey were posted on reddit groups, Quora, posted in Computer Science Facebook groups, and emailed out to list servs that were directed towards software developers. The age distribution of the participants lies mostly between 20 and 60 [Figure 1]. Repondents' answers helped us gather data about fatigue and investigate possible detection and alleviation mechanisms. The survey consists of three parts: questions about sleep habits and fatigue levels, questions about fatigue and work performance and question about work habits. The survey questions can be found in Table 1.

3.1.1 Results

The results of our survey show programmers' view towards fatigue. It helped us identify the factors leading to mental fatigue and it's influence on the performance of any programming task. In addition, several implications allow us to speculate on the way programmers behave when they are in the fatigue state.

- Analysis of the survey questions S1-S9 to answer the research questions R1-R3 [Sample: Figure 2-4]
  1. S1
  2. S2
  3. ...

Table 1: Survey Questions

S.No.	Part	Questions
S1	Sleep	How many hours do you sleep typically, in a day?
S2		How long did you sleep last night?
S3		What are the factors, you think, lead to mental fatigue in your life mostly?
S4	Fatigue at Work	Do you think fatigue is a severe and frequent problem for programmers?
S5		Do you feel when you are tired that it influences your performance? If yes, what are some examples?
S6		What makes to conclude that your performance is deteriorating or you need a break at the moment?
S7	Work	Describe your daily work routine. Does this routine occur during the morning, afternoon, or night?
S8		What factors might reduce your energy/concentration level as you code, throughout the day?
S9		Age:

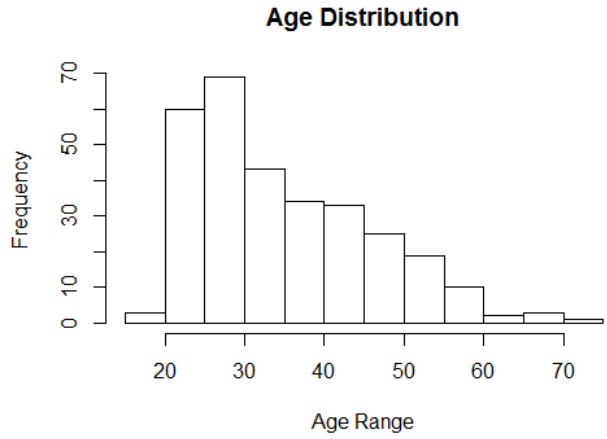

Figure 1: Age distribution of the survey participants.

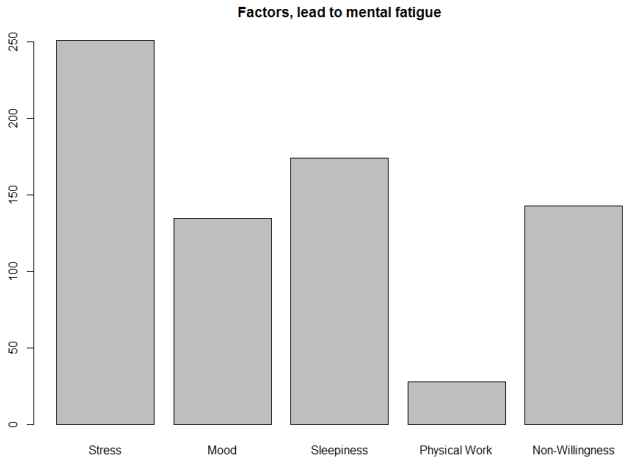

Figure 3: Factors leading to mental fatigue.

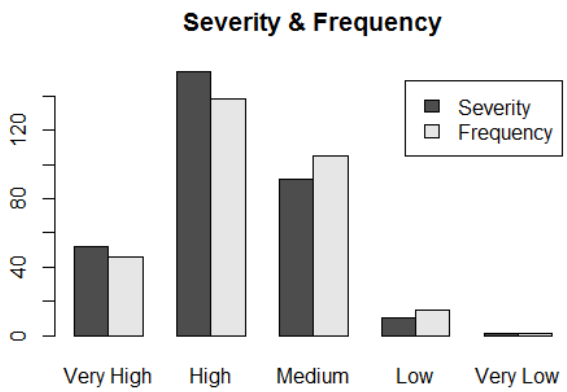

Figure 2: Severity & Frequency of fatigue.

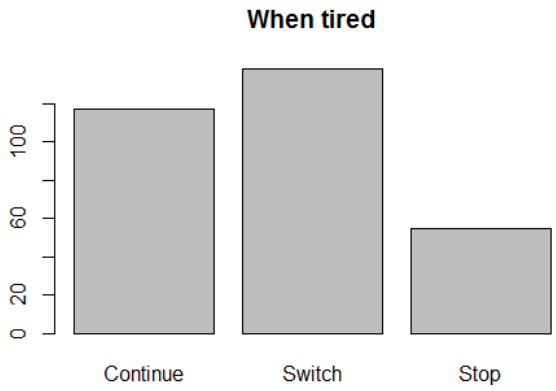

Figure 4: Actions taken when tired.

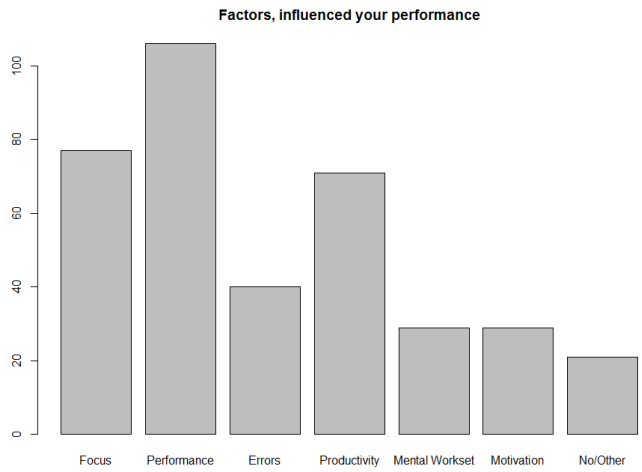

Figure 5: Factors influencing the performance.

- Implications of the research questions to set guidelines for investigation [Sample: Figure 5]
- Although our formative study provides data on how programmers think of fatigue and how fatgiue affect their performance in programming tasks. There are several threats to validity that should be considered when interpreting our results.

3.2 Experimental Validation: Instrumentation

To investigate the usefulness of identifying fatigue during programming tasks and recognizing its impact on the performance, we evaluated the outcome of the survey study by conducting some other empirical studies of programmers.

We implemented our technique as a plug-in for the Eclipse IDE. DevFatigue is an activity tracking plug-in for Eclipse. It is an extension of Rabbit *https://code.google.com/p/rabbit-eclipse/*. Alike Rabbit, it works in the background with Eclipse and tracks all the activities you perform. It only tracks the actions when Eclipse is active. And logs the data in XML (human readable) format at specific location. Update site and information URL for installation:
http://www4.ncsu.edu/ ssarkar4/fatigue/eclipse/updatesite/

The Rabbit features [content taken from Rabbit Information Page], which it supports by default:

- Commands - How often you use each commands (cut, copy, paste etc), do you know which is your favorite?
- Editors and Views - Time spent using different tool within Eclipse, such as Java Editor, Outline view.
- Perspectives - Time spent using different perspectives.
- Sessions - Time spent using Eclipse.
- Resources - Time spent working on difference resources such as files, projects.

[2]http://checkbox.io/

- Java Elements - Time spent working on Java elements such as classes, methods.
- Launches - Launches such application runs, debug runs etc, and the relevant files will be recorded too when you step into them using the debugging.
- Task - Time spent working on tasks (tasks in Task List view) and resources.

Additional features in DevFatigue:

- User Activity - The typing speed (key board usage) of the user with respect to a time period.
- Focus Events - The activities related to keys and mouse usage, like Key Up, Key Down, Mouse Clicks, Mouse Velocity, etc. with specific to time period.
- Project Events - Information regarding the projects like ŚimportsŠ, and commands used with respect to time period.

The architecture of the proposed framework is the extension of the used in some of the previous studies [3]. Indicators of mental fatigue recorded by DevFatigue

1. Keydown Time
2. Errors per Key Pressed
3. Mouse Velocity
4. Mouse Acceleration
5. Time between Keys
6. Double Click Speed
7. Number of Double Clicks
8. Distance While Clicking etc ...

All the above mentioned indicators have been proved useful in previous studies [2] [3]. These indicators provide us informations we need to analyze the working patterns of the users and to figure out any fatigue state in it.

3.2.1 Hack-a-thons

Overnight programming competition are always motivating and provides a platform for programmers to work towards solving a problem. A hackathon is an coding event where computer programmers collaborate in building a software product. LexisNexis organized a fall hack-a-thon on 23rd Oct 2014. We approached few of the participants. All of the participants were graduate students of the Computer Science department at North Carolina State University (here after refered as NCSU).

Participants were mostly graduate students in the computer science department at NCSU. Of the 13 participants invited to participate in the study, only 2 participants finished the study and turned in the data by DevFatigue. We collected data using the log files dumped by DevFatigue, and a post-study questionnaire [Table 2]

Table 2: Post-Hackathon Questionnaire

S.No.	Questions
Q1	Age?
Q2	Any industrial experience?
Q3	How would you rate the quality of your code in a scale of 1 to 10, 1 being the least?
Q4	What factors do you think might have affected your performance?
Q5	Hours slept/rested during the hack-a-thon?
Q6	Do you think you could have done better, if you had proper rest in between?
Q7	Did you win?

- Data selection [TODO]
- Building a model and classifying mental fatigue [TODO]
- Observations from analysis [TODO]
  We intend to come up with a focus curve [Figure 6] that can show some working pattern of the user and build a model based on the data collected to classify fatigue depending on the user's activities.

3.2.2 In class study

Dr. Parnin is teaching CSC 510 Software Engineering in Fall 2014 at NCSU. Most students in the course have some coding experience. Dr. Parnin asked the students to install DevFatigue and let it track their activies on Eclipse, for a time-period. In addition, we asked them to log their daily sleep hours. Of the 100 students enrolled in the course, 4 [till now] students responded against the extra credit offered in the course.

- Data selection [TODO]
- Building a model and classifying mental fatigue [TODO]
- Observations from analysis [TODO]

  We intend to come up with a focus curve [Figure 7] that can show some working pattern of the user and build a model based on the data collected to classify fatigue depending on the user's activities.

4. STUDY RESULTS & DISCUSSION

- Discussing how the set research guidelines are used in analysis.
- How the user patterns & analysis results depicts fatique, with respect to the indicators.
- Discussion about the observations from the result and other methodologies which can be used in order to achieve the goal.

4.1 More Methodologies [might not include in the final draft]

4.1.1 In-Lab study

- The study of mental fatigue, including its causes and symptoms, is traditionally supported by data collected through instrumentation, self-reporting mechanisms (generally questionnaires) or, more recently, through the use of physiological sensors. [2]
- Specific programming tasks [TODO]
- We will collect data using the pre-study questionnarire, log files dumped by DevFatigue, and a post-study questionnaire.
- Electrical conductance is the method of measuring Galvanic skin response (GSR) monitoring sweat gland activity. We are using GSR to measure the fatigue activity level and validate the data collected and analysed by DevFatigue.
  - Detect
  - Validate
  - Analysis
  - Result
- Finding patterns and setting benchmark [TODO]

4.1.2 Industrial study

- Our research aims to help programmers avoid their fatigue state to control errors in programming, and eventually aid them for a better productivity. The application would be most suitable for the software industry. We have a lot of different programming tasks in an industry and fatigue might affect the performance/productivity of any of those activities. Thus, we will try conducting some studies on the real environment programming activities.
- In today's competitive world, software programmers are motivated to work hard, and hence keep themselves involved in numerous projects. Sometimes they work in teams and sometime they work individually on a project. Again, this all lead to sleepless nights resulting in more exhaustion and tiredness.
- To check the relation between mental fatigue and performance, We plan to review bug and code logs. My research would be taking the factors like working scenarios and behaviors, which affect performance, into consideration as well. Smith et. al. [13] studied the effects of intake of coffee on alertness and performance. Coetzer and Richmond [6] performed an empirical analysis on working in teams and its relation with performance.
- Analysing their work patterns & daily routines [TODO]

5. CONCLUSION & FUTURE WORK

- A summary about the whole process. What all we have achieved. How the model and the study can be used in helping the software industry. Talking about few contributions the study can make to the industry. Application of the proved hypothesis.

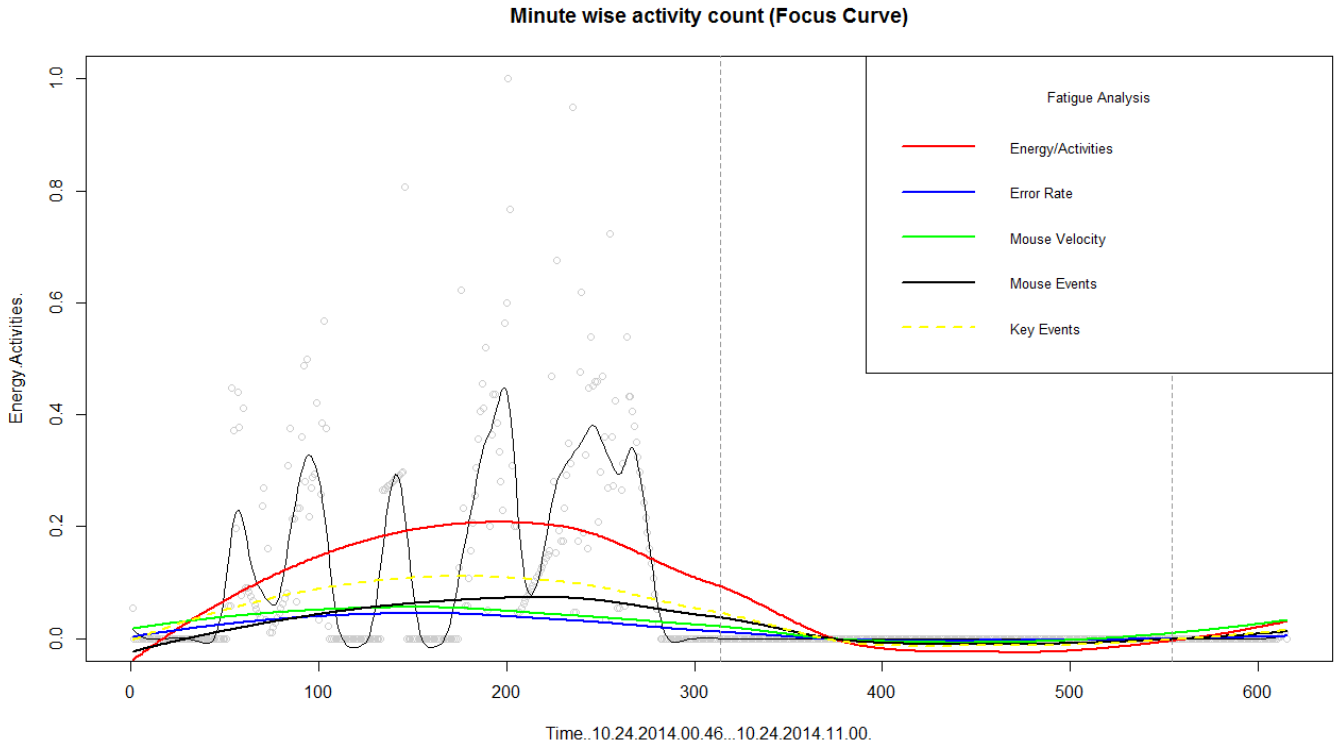

Figure 6: Focus Curve - Hack-a-thon Data.

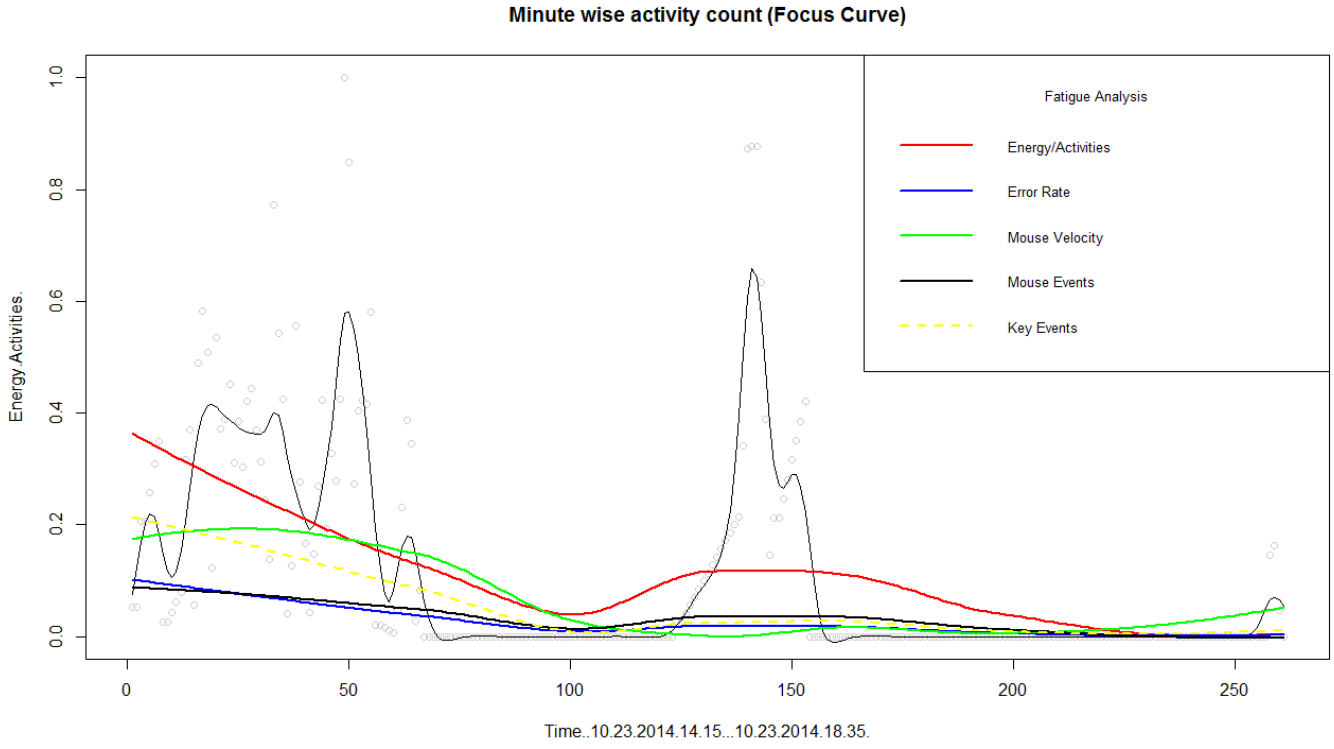

Figure 7: Focus Curve - CSC 510 Data.

- After setting the baseline and recognizing fatigue states, the next step would be to help programmers to overcome the fatigue state. It could be achieved by various alerts, screen freezes or even suggesting Pomodoro technique. The research is to conduct, monitor, and analyze data in a non-invasive and non-intrusive way and present the results in a cordial manner.

6. ACKNOWLEDGEMENT

Thanks to the CSC510 class at North Carolina State University for their participation throughout the process of developing this research. As this is a CSC710 course submission, authors Dr. Christopher Parnin are not listed at the top; they are included on any official submission.

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