Review : Use of EEG on measuring stress levels when painting and programming

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Abstract: For years, brain activity, stress level during programming and painting have been analyzed separately. As the world gets more digital and human life gets more dependent on technology, it has become more important to analyse the relationship between programming, software developers' brain activity, creative practices (i.e painting) and stress level. In this paper, we present the results of a systematic literature review whereby the research questions are centred around analysing the relationship between stress levels and brain activity when a person is painting or writing a piece of software. The search for relevant studies was done on google scholar and IEEE Xplore. The results of our review show that: (1) EEG can be used to accurately measure stress levels, (2) there is limited research in the analysis of stress level pattern of the stress level when people paint depending on different situations and styles of painting. In light of the systematic literature review result, using EEG we plan to conduct experiments to measure the stress level when a person is painting a picture or programming.

1 INTRODUCTION

In the era where technology has become the main instrument for a human being to accomplish daily tasks, the demand for high-quality software is increasing from day to day. The increase in high-quality software has induced demand for software developers to produce creative software in a limited time. Consequently, this results in increased stress levels for programmers. The impact of certain stress levels can lead to increased performance and productivity. However, excessive stress levels can result in deterioration of abilities (Hassan et al., 2006). Certain levels of stress can impair technical skills, creativity skills, as well as memory, concentration and other cognitive processes (Hassan et al., 2006; Klein, 1996).

Stress is usually described as the condition when threatened homeostasis happens in the body, followed by the responses of two types: physiological as well as behavioural (Chrousos, 1998). After the brain notices the 'threat', the hypothalamus, along with the pituitary gland, and also adrenal glands make the whole body react by producing hormones and other things.

Centuries ago, by 'threat' people usually meant wild animals, feuding tribes. But today, when most people work in safe conditions and can get food without hunting by visiting the local shop, stress did not disappear. Scientists analyse stress levels and emotional well-being across many fields, involving the Information Technology field, as many programmers face burnout (Hetland et al., 2007). In our research, we are curious to find out the impact of certain stress levels on software quality and how it relates to creativity. In addition, we are aimed at analysing the brain waves patterns when developing creative software.

Painting is one of many forms of art which evokes creativity. Some do it for living, some do it for fun, some do not do it at all. While painting can be taught and the skill can be improved, in theory, almost anyone can draw at least something. In another form of art, such as playing music, it is hard to repeat a familiar melody without knowing the notes and how to play correctly. However, with painting nearly anyone can try to reproduce a picture that they see or something that they imagine. On the other hand, a person can imagine and draw something that never existed instead of reproducing a thing they have already seen. This kind of creativity is to be adopted in software development in order to produce useful technology.

Compared to painting, programming requires some skill level to start writing. At least the knowl-

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edge of the structure of some programming language is required, and even the clear code may work incorrectly, possibly attributing to the stress level. Programming still involves creativity as the programmer needs to plan everything ahead, creating a program that was never done before. Painting would be a suitable activity to be compared to programming, since it also introduces some level of creativity, instead of some monotonous routine. The questions behind this research are : what exactly affects programmers' stress levels? Could the programming itself reduce or increase a person's stress level? How can we adopt some practices from painting and mimic the state of mind observed during painting to produce creative software? To answer the aforementioned questions we decided to conduct a systematic literature review whereby we defined our research questions as follows:

RQ1 Can stress level be accurately measured using an EEG device?

RQ2 What is the pattern of the stress level when people paint depending on different situations and styles of painting?

RQ3 Does the stress level of programmers somehow follow some specific pattern during code writing?

RQ4 Can we draw a comparison between specific situations or activities that are done while programming and done while painting according to the pattern of the level of stress?

The rest of this paper is organized as follows: Section 2 presents background information on EEG together with related works. Section 3 outlines our approach in answering the aforementioned research questions (**RQ1**, **RQ2**, **RQ3** and **RQ4**). Section 4 and 5 presents the results together with the results discussions. Threats to validity are presented in section 6. Section 7 draws the conclusions and introduces future work.

2 BACKGROUND

This section presents background on brain waves, electroencephalography (EEG) analysis techniques and studies related to stress measurement using EEG. It can be skipped by readers already familiar with the matter.

2.1 Brain waves

Electroencephalography is a an approach for measuring brain activity using electrodes attached to a scalp.

The brain activity is measured from from the electric signals produced by the firing of neurons in the brain. The electrodes attached to the scalp capture oscillations at a range of frequencies. The oscillation frequencies are classified into frequency ranges (i.e delta, theta, alpha, beta, and gamma). Researchers have suggested that the different frequencies captured with neuroimaging device are correlated to different mental states and has a biological significance (Imperatori et al., 2014; Imperatori et al., 2019).

2.2 Measuring Stress

Hans Seyle (Selye, 1985) initially defined stress as the nonspecific result of any demand upon the body, be the effect mental or somatic. Detecting stress and identifying the effects of stress on daily life has been a objective for researchers in the social science domain. However recently software engineers have started investigating the impact of different mental states on software quality and development process.

Some cross-sectional studies suggest an association between brain activity, creativity and stress (Andersson et al., 2001). Over the years researchers have proposed systems and approaches the human physical and mental states such as stress in the working environment using different biophysical signals. A new apparatus (Andersson et al., 2001) was designed to assess the stress levels of call-centre operators. The study uses two types of sensors to monitor the working environment: environmental and physiological. The evaluation of stress relies more on the latter signals. The goal of the authors was to design the system to improve the well-being of the employees with the application of multi-sensor analysis.

The portable system described in (Aljuaid, 2019) measures biophysical signals in real-time and notifies unwanted mental behaviour. The notifications are sent in case the following conditions in the worker are detected: 1) absent-minded/inattentive, 2) stressed, 3) extreme fear, 4) anger, 5) stun/daze, 6) overloaded with work, 7) drowsiness, and 8) dizziness. The author focuses on neuroergonomics as a primary field of study. As well as the previous study, this one aimed to design a system to predict human mental and physical state and increase productivity and well being at work. However, the range of biological signals collected was significantly broader than in (Andersson et al., 2001) and brain, muscle activity analysis was used.

The device proposed in (Amores et al., 2018) determines the relaxation level of the user. It consists of the Virtual reality headset and the olfactory necklace. The necklace changes the intensity of aroma,

depending on the subjects' EEG datagrams. In (Saidatul et al., 2011), mental stress was measured while solving arithmetic tasks. The (Duraisingam et al., 2017) detected the difficulty of program comprehension tasks among the students. The (Sun et al., 2015) describes a method to determine the drivers' vigilance level. In the context of the studies mentioned above the following biophysical signals were used:

- heart rate (Aljuaid, 2019) (Andersson et al., 2001);

- galvanic skin resistance (Andersson et al., 2001)

- body temperature (Aljuaid, 2019);

- blood pressure (Aljuaid, 2019) - a sensor is placed in the temple part of the head or in the upper part of the shoulder depending on the type of device;

- EEG (Aljuaid, 2019) (Amores et al., 2018) (Duraisingam et al., 2017) (Duraisingam et al., 2017)

- EMG (Aljuaid, 2019);

3 METHODOLOGY

Our proposed approach is a literature review to answer the posed research questions. The following sections outline the details about each stage. Our literature review follows the approach defined in (Kitchenham and Charters, 2007).

3.1 Search strategy

To retrieve the literature to answer our research questions, we used digital libraries namely: Google Scholar and IEEE Xplore. Based on the research questions, we compiled a set of keywords corresponding to each RQ. Search strings were developed considering the keywords which were joined with the operator OR and AND. Table 1 shows the overall keywords, search queries and the corresponding research questions.

RQ4 answer will be derived from **RQ1**, **RQ2** and **RQ3**, therefore we did not make keywords and search query corresponding to the research question (**RQ4**). The search for publications was manual.

3.2 Data Extraction

The data retrieved from the selected digital libraries were manually assessed and relevant information was extracted and stored for further analysis. For each and every retrieved study, the full names of all authors, full titles, years of publication, publication journals or conferences, abstracts information was stored in a

spreadsheet. As part of preprocessing the retrieved data, we filtered out all duplicates to create a list of studies for further analysis (i.e if the same article appeared multiple times in different digital libraries engines for one RQ or in the same search engine for multiple RQs, it was only recorded once).

3.3 Inclusion and Exclusion criteria

After compiling the data extracted using the specific search queries, it is important to determine which publications are relevant to the topic, since some articles may include given keywords despite covering a non-related topic (i.e the development of software that analyses EEG results or covers art not related to painting). For a study to be considered in our literature review, it should meet the following criterion:

1. The study should be available in the English language

2. The study should include experiments

3. These experiments should involve painting or programming.

4. The article must be published not more than 30 years ago

Moreover, some other studies were excluded based on the following criterion:

1. The studies involving verbal creativity experiments, imagination experiments must be omitted

2. The studies where no code is written during experiments despite involving programmers or covering a topic related to software development (UML creation, code analysis).

3.4 Quality Assessment

"Overview Quality Assessment Questionnaire (OQAQ)" has been proposed by A.D.Oxman and G.H.Guyatt to assess certain aspects of the scientific quality of research overviews (Oxman, 1991). For further and finer filtering of the retrieved publications we applied a quality assessment using the following questions:

QA1. Does the paper contain data resulting from the experiments on stress authors had using EEG?

QA2. Do experiments involve more than 3 people?

QA3. Do the volunteers from the experiments belong to the same age group?

Publications that are more suitable for further review, should have more than 1.5 points after assigning scores according to the criteria outlined below:

Research Questions	Keywords	Search Query
RQ1	Measuring, Monitoring, Stress, Devices, EEG	"EEG" OR "devices" AND "stress" AND "measuring" OR "monitoring"
RQ2	EEG, Painting, Pattern, Stress	"EEG" OR "electroencephalogram" AND "painting" AND "pattern" AND "stress"
RQ3	EEG, Programmers, Programming, Developers, Stress, Pattern	"EEG" AND ("programming" OR "developers" OR "programmers") AND "experiment" AND "stress"

Table 1: Keywords and Search Queries

QA1. 1, does have experiment held by authors, 0 - authors analyse available data from experiments related to other studies

QA2. 1, experiments involve more than 3 people, 0.5 - 3 people, 0 - less than 3 people

QA3. 1, all people involved in the experiments belong to the same age group, 0 - people in experiments do not belong to the same age group.

4 Results

This section presents the results achieved after following the steps outlined in section 3. The studies that were left after applying inclusion and exclusion criteria along with quality assessment were considered to be relevant to the discussed fields.

By using the keywords in Table 1 above, we found 74,900 articles on Google Scholar, applied inclusion and exclusion criteria to 50 of them, performed quality assessment on 20 of them, and only 10 were assumed to be relevant. The studies distributions according to the year of publication is presented in Fig. 1. Tables 2, 3 and 4 present all the included studies in correspondence to research questions together with the quality assessment scores.

Names of authors	Year	QA1	QA2	QA3	Score
Hou *et al.*	2016	+	+	+	3
Hosseini and Khalilzadeh	2010	+	+	+	3
Jun and Smitha	2016	+	+	+	3
Saeed *et al.*	2015	+	+	+	3

Table 2: Papers Related to RQ1 Which Passed the Quality Assessment.

Name of the paper	Year	QA1	QA2	QA3	Score
Zhang *et al.*	2021	+	+	-	2
Wang and Huang	2016	+	+	+	3
Wang and Shih	2016	+	+	+	3

Table 3: Papers Related to RQ2 Which Passed the Quality Assessment.
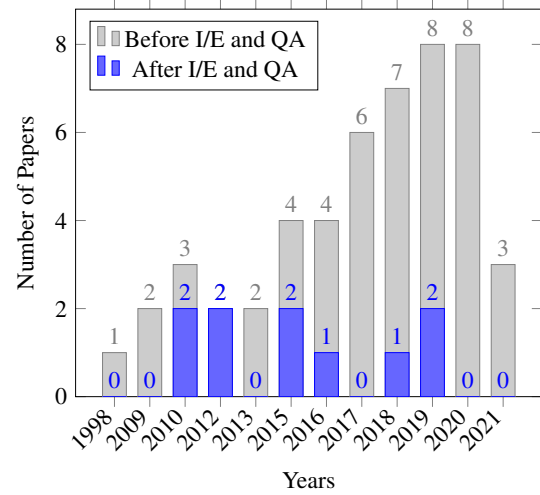
Figure 1: Distribution Of The Reviewed Literature Ror SQ1 Over The Years

Name of the paper	Year	QA1	QA2	QA3	Score
Salma *et al.*	2017	+	+	-	2
Yamamoto *et al.*	2016	+	-	+	2
Desai	2017	+	+	+	3

Table 4: Papers Related to RQ3 Which Passed the Quality Assessment.

5 DISCUSSION

In this section, we discuss the answers to our research questions.

RQ1. Can we accurately measure the level of stress using EEG devices?
Based on the data and experimental results retrieved from selected studies, we conclude that an EEG device is a reliable tool for measuring stress levels with decent accuracy. Hou *et al.* (Hou et al., 2015) and Jun (Jun and Smitha, 2016) separately conducted experiments based on the same test and classified the results using the same classifier for differentiating stress levels, each achieving accuracy higher than 75%. Hosseini (Hosseini

and Khalilzadeh, 2010) used the Elman classifier and the accuracy was 82.7%. Saeed *et al.* (Saeed et al., 2015) used three different classifiers, and every single one of them had at least 64% accuracy. The high accuracy with different types of classifiers shows that EEG is an effective way to precisely record the brain signals to measure the stress level.

RQ2. What is the pattern of the stress level when people paint depending on different situations and styles of painting?
As noted by Wang and Huang (Wang, 2016b) and also Wang and Shih (Wang, 2016a) during one-time experiments, concrete figure painting reduces stress despite using different styles of art. Zhang *et al.* (Zhang et al., 2021) proved via a long experiment with Chinese bird painting that stress relief can help to cure depression. The common outcome seems to be that in all painting experiments, the drawing which is not abstract and has many details helps to decrease the stress level. But since not many studies were found relevant and did contain information on EEG experiments, we can determine that the research gap is present.

RQ3. Does the stress level of programmers somehow follow some specific pattern during code writing?
Salma *et al.* (Salma et al., 2018) noted that the stress level for the task with a time limit is higher than for the task without a time limit. Yamamoto *et al.* (Yamamoto et al., 2016) proved that stress level is the same for the authors of successful and unsuccessful solutions if both have a time limit. Desai (Desai, 2017) showed that extending the time limit reduces stress and that certain programming languages cause more stress with the same tasks. All the found studies do not directly address the question about the stress level pattern while writing code. Therefore, we can conclude that there is a need for additional research into the stress patterns that occur while programming.

RQ4. Can we draw a comparison between specific situations or activities that are done while programming and done while painting according to the pattern of the level of stress?
To this end, we cannot make a concrete conclusion because of the lack of research that is directed in the analysis of stress levels comparison for painting and painting. However, from the retrieved studies in the study, we noticed that painting reduces stress (Zhang et al., 2021; Wang, 2016b; Wang, 2016a)

and programming may increase stress levels (Salma et al., 2018),(Yamamoto et al., 2016), the change during coding could be explained by the presence of a time limit, which was not present during art experiments. We refrain from making a solid conclusion since the situations and types of tasks from the studies differ so much. There is a need for further research in the covered fields using EEG with similar setups and similar kinds of activities to analyse the stress levels change during programming and painting properly and to be able to compare them.

6 THREATS TO VALIDITY

Here, we discuss the threats to the internal and external validity of our results. Based on Wohlin et al. (Wohlin et al., 2012) the following subsections present the different threats to validity.

6.1 Construct validity

(Wohlin et al., 2012) defines construct validity threats as threats linked to the generalization of the results to the concepts behind the study. During the analysis of selected studies, we noticed that some studies did not give full details on the protocol and theoretical bases for selecting specific techniques. To minimize the impact of such issues we formulated a much more strict quality assessment (i.e presented in section 3.4). In addition, we carefully analysed the experiment protocol and research objective for each and every primary study.

6.2 Internal validity

Internal validity threats may affect the results due to incorrect conclusions. Guidelines proposed by Kitchenham (Kitchenham and Charters, 2007) were used to avoid this kind of risk. We defined a review protocol to include all relevant EEG, stress and painting studies in the search. All the relevant and major digital libraries related to brain waves analysis in software engineering were selected as sources for studies to minimize internal validity.

6.3 External validity

These threats arise from the generalization of the results of the review to the real-world scenarios (Wohlin et al., 2012). In the review presented, we excluded

studies not written in English and this poses a limitation on generalizing our results since in our data retrieval and data analysis we found studies written in other languages (i.e Russian). However, it is worth noting that these studies written in Russian did not meet the other inclusion/exclusion criterion as they were analysed by the first author who is native a Russian language speaker.

6.4 Conclusion validity

Similar to what is known as interpretive validity, conclusion validity is concerned with the formulation of inaccurate conclusions from the given data. This could be the small set of primary studies we have collected. To mitigate the risk of excluding primary studies we did the following: (i) the search strings are defined by considering the concepts and their acronyms, (ii) the related works of all the primary studies are carefully analyzed, (iii) Duplicates were removed based on the title, author, publisher, and year of publication. The full text of selected studies was carefully read through to mitigate misinterpretations and extract accurate data.

7 CONCLUSIONS AND FURTHER WORK

The goal of this study was to find the relationship between observed stress levels while programming and while painting a picture. The relationship was aimed to be recognised at the mental state level with the help of EEG. To achieve the aforementioned goals, we conducted a systematic literature review using guidelines proposed by Kitchenham (Kitchenham and Charters, 2007). We formulated four research questions and based on inclusion/exclusion criteria and quality assessment we found 14 studies that were used to answer the research questions. The review shows that EEG devices can be used to accurately measure stress. Secondly, the review revealed that there exists a research gap and there is a need to conduct more experiments for analysis of the stress level pattern when a programmer is writing the code.

For future works, we plan on conducting experiments whereby we will focus on the comparison between specific situations or activities that are done while programming and done while painting according to the pattern of the level of stress. In addition, we aim at analysing a specific pattern of stress levels of programmers during code writing in the experiments.

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