Is the mind of a software developer similar to that of an artist? Focus on drawing

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Abstract

For the past decade, software development has been claimed to be similar to an art. However, researchers to date have not presented empirical evidence to support their claims on classifying software development as an art. This paper focuses on one of the artistic disciplines, drawing. It discusses the experimental results of comparing the brain activity of a person drawing and the brain activity of a person programming, as it is collected using electroencephalography. Twenty software developers participated in the experiments. The analysis of the results using Kolmogorov–Smirnov test and visual inspection strongly suggest the similarity between such activities. This results have the potential of a strong impact on how our IT-centered society is structured under multiple perspectives, including work organization, education, rewarding schema, etc.

Keywords: Software development, art, brain waves, electroencephalography

1 Introduction

Programming involves more than just typing logical rules and combining them to create software; it is a creative endeavor akin to composing a song, writing a poem, or drawing a picture. Like artists, programmers use their creativity to bring something new into existence while adhering to specific rules. There is no one correct way to program, as it ultimately depends on the programmer's intellect, creativity, and imagination. The possibilities for what can be created with a set of carefully constructed logical rules are endless, and it is up to the developer to design and architect high-quality software. Just as with creating a symphony or a literary epic, there are numerous options available to successfully carry a programming project from conception to completion. While there is debate about the extent to which programming can be considered an art form, it is clear that it involves a significant degree of creativity and imagination, which are hallmarks of many artistic activities.

During the process of software development, programmers combine their individuality, imagination, and logical skills to create something new. Programming can therefore be viewed as more than just typing logical rules on a screen, but rather as an artistic activity. Good developers have a distinct sense of programming beauty, and strive to create elegant and aesthetically pleasing code. This has led to a conclusion that programming is similar to any other artistic activity. However, to this day, this claim has no conclusive empirical evidence in the literature. Therefore further research is needed to explore the possible artistic aspects of programming and the extent to which programming can be considered a form of creative or artistic expression.

This paper presents empirical evidence to investigate claims about the artistic nature of programming by focusing on one artistic discipline, drawing. Electroencephalography (EEG) is used to measure the brain activity of individuals while drawing a picture and programming. The results are analyzed visually and using the robust Kolmogorov-Smirnov statistical test.[1] We found a remarkable similarity that appears to support the notion of programming as an art form. Moreover, the similarity relates to the aspects of concentration, focus, and immersion inside the work that are typical to artistic disciplines.[2,3,4] These findings provide initial evidence for the artistic aspects of programming and suggest that further research should be conducted to explore this relationship in more detail. If further confirmed, the findings of this paper could have a strong implication on how the work is organized in IT companies, on the education of future software developers and engineers, and on several other aspects of our so-called "Information Society."

This paper is organized as follows. Section 2 presents the background of our work both in terms of analysis of brain signals and of the employed statistical approach. Section 3 describes the experimentation that we have conducted. Section 4 presents the results that we have obtained and discusses them. Finally, Section 5 draws some conclusions and outlines our future research.

2 Background

2.1 Measuring brain activity with EEG

The claim that programming is similar to other artistic activities, such as drawing a picture, has been made over the past decades without empirical evidence.[5,6,7,8] Donald Knuth, one of the pioneers of computer science, was among the first stating that "computer programming is an art because it applies accumulated knowledge to the world, because it requires skill and ingenuity, and especially because it produces objects of beauty".[5] However, all claims and arguments made by Knuth and other researchers lack concrete and solid support from evidence.

In our work, we aim to test the claims presented by researchers by comparing brain activity during programming and drawing a picture. To measure brain activity, we use electroencephalography (EEG), a non-invasive method used to measure electrical signals in the brain.[9] The human brain consists of neurons that contain ionic current and based on various brain activities, the neurons create voltage fluctuations that EEG devices can measure.[10] EEG can be accurately performed by portable devices and can therefore be used at work as well.

The brain activity of programmers has been measured using various methods during software development, such as fMRI (Functional Magnetic Resonance Imaging), fNIRS (functional Near-Infrared Spectroscopy), and MEG (Magnetoencephalography).[11,12,13,14,15,16] However, these methods may not be suitable for our study because they require specialized settings that are not typical of standard working conditions, or they have low resolution. In contrast, EEG has proven to produce comparable results to high-resolution and high-penetrating power devices such as MEG and fMRI[17,18,19] while having a minimal impact on the working pattern of the participants.

Table 1: **EEG bands and their frequency ranges**

Band Name	**Frequency range (Hz)**	**Band Symbol**
Theta	4 - 7.5	θ
Alpha	7.5 - 14	α
Beta	14 - 30	β

As mentioned, EEG detects electrical signals present in the brain. Such signal are typically classified based on their frequency bands. To this end, three major bands have been identified (Table 1): alpha (typically indicated by the greek letter α), beta (β), and theta (θ). Alpha band waves were discovered in 1929 by Hans Berger;[20] they are related to memory, mental workload, sensor and motor tasks.[21] Beta band waves are associated to movements and active thinking. The beta waves originate from posterior and frontal regions and could be detected on central cortex part of the human brain.[22] The combination of the alpha and beta bands gives us alpha beta ratio (α/β). α/β increases with cognitive states, such as, among others, attention and concentration.[23,24]

The theta band waves are correlated to the high level of mental workload, attention and memorising.[25] A decrease in theta waves at almost all channels indicates concentration,.[26,25] Dividing the theta band by alpha band (θ/α) results in an inverse indicator for immersion, the lower the ration, the higher the immersion.[27] Immersion is the state of mind when surroundings or personal problems get forgotten, while being focused on a particular object or activity, such as programming or drawing a picture.

2.2 Interpretation of the collected data

To test whether there is a significant difference in brain activity when a person is drawing a picture, programming, or resting, we used the two-sample Kolmogorov-Smirnov (KS) test.[1] This nonparametric test does not require any assumptions about the underlying distribution of the data, making its conclusions quite robust. We considered three pairs of samples: programming vs. drawing, programming vs. resting, and resting vs. drawing. For each pair, we formulated the null hypothesis (H_0) that the data in the two samples come from the same distribution, and the alternative hypothesis (H_1) that they come from different distributions.

To evaluate the power of the KS test in detecting differences between the samples, we followed recent statistical approaches.[28] This allowed us to determine whether we could accept the null hypothesis, which is often overlooked in statistical analysis. Additionally, we visually examined the scatterplots of the data and their empirical distributions to confirm that the results of the statistical tests were consistent with our intuitive perceptions.

3 Experimentation

3.1 Assumptions

We conducted our research under the following main assumptions: (i) the mental activity of painters and developers can be properly described by EEG and by the ratios α/β and θ/α,[29,27,30] (ii) the tasks that we have given are good representations of typical tasks of developers and painters;[31,32,33] (iii) subjects are a good representation of painters and developers and (iv) our statistics are a good representation of the work.[1,34] Indeed, we claim that such assumptions are all verified, but even if they were not, we can still assume a solid experimental setup providing at least strong evidence of our claim even if not conclusive.

3.2 Participants

Twenty participants (35% female; 65% male) with a mean age of 21.05 ($STD = 4.28$) were recruited from Innopolis, Russia. The recruited participants were Innopolis university students and software developers. The participants gave their written informed consent and received compensation for taking part in the experiments. The study was reviewed and approved by the local ethics committee.

3.3 Procedure

Before the experiments, the participants were introduced to EEG, EEG recording devices, and the nature of the experimental tasks. Each participant was then seated in a quiet, isolated room to avoid external distractions and magnetic field interference. The participants were also asked to put their phones into silent mode and take them away.

During the first twenty minutes, the experimenters put on the EEG cap to the participant's head, applied gel on the electrodes, and connected the cap to a computer. If any of the electrodes was not working despite the application of gel, it was hidden or ignored. If any of the electrodes was not working, it was hidden or ignored. A maximum of three electrodes could be hidden or ignored. To calibrate the EEG cap, the participants spent two minutes with their eyes open and two minutes with their eyes closed before solving the experiment tasks.

After calibration, two minutes were spent explaining the task and the steps to be taken when the task is completed. At the end of each of the three tasks, participant was instructed to send a signal to the experimenter. The details about the three tasks for programming and drawing are presented in Appendix A. Tasks from programming and drawing were solved in different sessions. During each session, a participant could only solve three tasks from either drawing or programming.

3.4 EEG recording and knowledge synthesis

The EEG data were recorded using the 32-channel Mitsar SmartBCI with international 10-20 system montage. The EEG sampling rate was 512 Hz and Cz was a reference electrode. The first step in data processing was artifact removal of ocular, muscle, extrinsic and cardiac artifacts using independent component analysis (ICA).[35] The second step was sub-bands calculations using the frequencies indicated in Table 1.

As mentioned, to measure the differences in brain activity when a person is programming, drawing, or resting we have used the two-sample KS test on the three possible pairs of sample, that is, programming vs. drawing, programming vs. resting, and drawing vs. resting, using as null hypothesis (H_0) that the data of two samples comes from the same distribution and as alternate hypothesis (H_1) that it comes from different distribution.

4 Results and Discussions

Table 2 contains the results of applying the KS test on the collected data – as common practice in statistics we have used an α level of 0.05. As mentioned for each pair we could **(a)** reject the null hypothesis (H_0), meaning that the data appear to come from different underlying distributions, **(b)** fail to reject H_0 without accepting it, meaning that we could not conclude on the data, and **(c)** accept H_0. We have found that definitely programming and drawing are

Table 2: **Kolmogorov-Smirnov test using wave bands ratios**

Bands Ratio	Activities	P-value	Statistic	Conclusion	Power
α/β	resting & programming	$< 10^{-5}$	0.70	Reject $\mathbf{H_0}$	0.90
	resting & drawing	$< 10^{-5}$	0.80	Reject $\mathbf{H_0}$	1.00
	drawing & programming	0.571	0.25	Accept $\mathbf{H_0}$	0.17
θ/α	resting & programming	$< 10^{-5}$	0.70	Reject $\mathbf{H_0}$	1.00
	resting & drawing	0.0003	0.65	Reject $\mathbf{H_0}$	0.99
	drawing & programming	0.081	0.40	Fail to Reject $\mathbf{H_0}$	0.54

both different from resting. On the other side, under the perspective of the α/β ratio programming and drawing appeared to come from the same brain activation, and for θ/α we could not conclude.

We have further visually inspected the data. Figure 1 presents a scatterplot of α/β vs. θ/α, providing a clear picture of the similarity of the samples of drawing and programming and of the difference of both of them from resting. Analogous visual very strong similarity has been evidenced looking at the the data empirical distribution functions of the α/β ratio (Figure 2).

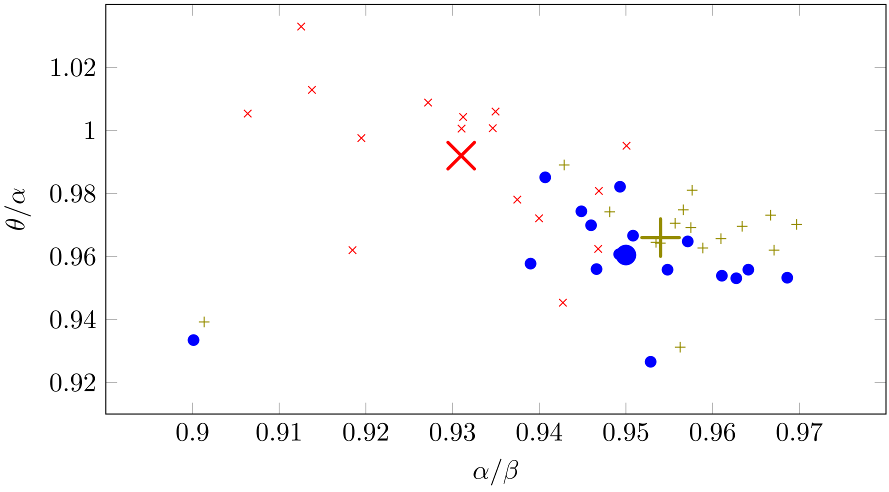

Fig. 1: **Clusters of values of α/β and θ/α when resting (the red $\times$), programming (the blue $\bullet$), and drawing a picture (the olive $+$); the centers of the clusters have the same symbols but in a bigger size.**

Moreover, we considering the meaning of such mental activity, we notice both in programming and drawing similar higher level of concentration, as evidenced by the increase of α/β, and of immersion, as evidenced by the decrease of θ/α. This confirms the earlier intuition of other researchers claiming the similarity of programming with artistic activity involving translation of emotional,

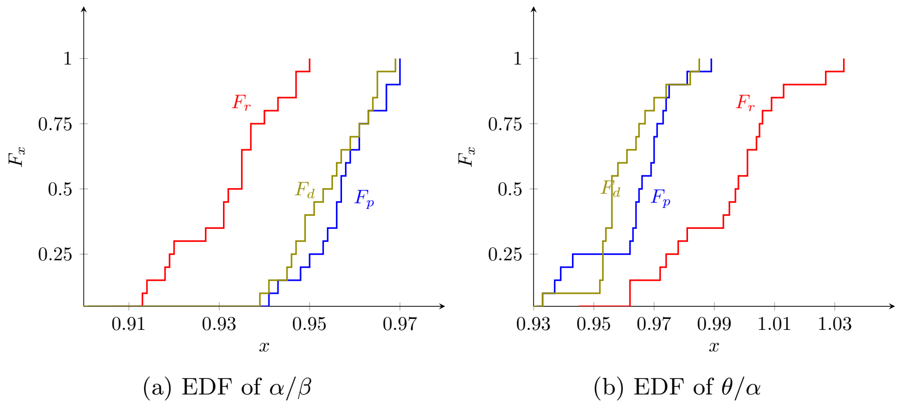

Fig. 2: **Empirical distribution functions of (a) α/β and (b) θ/α for resting (F_r), programming (F_p), and drawing (F_d)**

subconscious, expressive, impressive, intellectual and creative communication into two-dimensional plane through application of dyes.[36]

5 Conclusions

In the framework of understanding the extent to which programming can be considered an artistic activity, we have analysed whether the brain activity of a person is similar when programming and when drawing. To measure the brain activity we have used the EEG. Twenty programmers participated in the experiments. The experimental results showed no significant difference in brain activity when a person is writing code or is drawing a picture, confirming our original hypothesis and setting the path for further experimentation. For future, we plan to increase the number of experiment participants, to use the EEG to measure other aspects of the work of the mind, and to consider other artistic disciplines. It would also be interesting to analyse how we could transpose patterns of work of the millenniums old discipline of drawing to the very young IT industry.

All the experimentations described in this paper have been conducted adhering to the ethical requirements and protocols of the institution hosting the experiments.

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Appendix A Tasks assigned during the experiments

A.1 Programming tasks

Pt$_1$: Put pieces of code spinets together. Lines of code are intentionally given in a random order and participant has to assemble them to result in a specified algorithm. The lines of code are in either Python or C++.

Pt$_2$: Write a piece of code that deletes repeating numbers in an array using a binary heap. There are no restriction on the programming language.

Pt$_3$: Develop a program simulating vending machines using the terminal for interacting with a user. The choice of programming language is up to the participant.

A.2 Drawing tasks

Dt$_1$: Color a coloring book.
Dt$_2$: Draw a picture with specific details : a campfire, a tent, a dog, a tree and a book. The resulting picture should look cohesive and not with objects randomly placed in a white space.
Dt$_3$: Represent Innopolis city in the future in the way each participant wants.