

Design and Evaluation of an Interactive Art Installation to Introduce ‘de novo’ Mutations to Different Audiences: “Music Within” Project

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ABSTRACT

Installation projects are frequently used in education as they are functional in explaining complex scientific concepts by making them intuitive. Mutation is such a scientific concept—mostly misunderstood by those lacking a scientific background. The “Music Within” project explains the term “mutation” via an art installation which combines music and Light Emitting Diode (LED) signals. In the project, ‘de novo’ mutations, which are specific to an individual, are used in order to create music and light signals. Genomic positions of mutations from 5 different individuals were placed on a “virtual” guitar string and the corresponding frequency values were converted to sound and Red-Green-Blue (RGB) values. The comprehensibility of the system was tested using a short questionnaire which was applied to 92 volunteers from different backgrounds and age groups. Questions from System Usability Scale (SUS) and EGameFlow were used in the survey to measure user-friendliness. Survey results show that age or having different backgrounds do not affect the comprehensibility of the system and explaining the mutation concept using art installations is helpful and engaging.

CCS CONCEPTS

• Human-centered computing → Interaction design → Interaction design process and methods → Interface design prototyping

KEYWORDS

Mutations, Art Installation, System Usability Scale, Human-Object Interaction

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1 Introduction

Interactive learning is a method of online learning that utilizes educative feedback. Methods supporting interactive learning, such as games or installations, are widely used in education. They provide an easier understanding of topics and are applicable to most areas. They tend to be enjoyable and attract people’s attention to more complex topics such as quantum physics or space studies, and keep them immersed during the process of learning [1-3]. Complex scientific concepts are one of the possible application areas of such stimulating installations.

Rote-learning education systems and the alien jargon of the science are two main reasons that make scientific topics less understandable. Especially as a scientific field progresses, its terms and concepts become more complicated and its terminology is further removed from daily life as the topic is researched in detail and depth. Thus, generally to understand a scientific term, people first need to gain a significant amount of background in related topics, as otherwise it is not possible to understand the term. If a term requires background knowledge, the term could easily be misunderstood by people when such background information is not available to them [4]. In this project, one of these terms, namely ‘mutation’, is explained with an art installation. We thus attempt to challenge and ameliorate some of the misunderstandings and misinformation surrounding the concept of genetic mutation.

Mutations are simply differences in the DNAs of individuals. DNA is primary genetic material in the cell and it copies its information by transferring it to daughter cells in each division. It is a long chain of nucleotide molecules that are composed of a five-carbon sugar, a phosphate group and one of four nitrogen-containing bases. The genetics of each individual is encoded in the sequence composed of an alphabet of these four bases, which are

adenine (A), thymine (T), cytosine (C) and guanine (G) [5]. International genome consortium produces reference genome assemblies for different organisms. Reference genome of a species (e.g. human) is the sequence of the bases which are common to all members of a species [6]. In places of the code where individuals vary (e.g. blue eyes vs. brown eyes), the reference genome has the most frequent variant.

These differences between individuals as reflected in their genetic sequences are called mutations and they are discovered by comparing DNA sequences of individuals with the reference sequence and each other. Contrary to what is believed, mutations occur frequently in genomes. They have different types depending on whether they affect just a single base in the sequence or a larger segment of the sequence. Some mutations are common to a group of individuals and are passed from generation to generation and thus form heredity. In contrast, '*de novo*' mutations are changes that are unique and are seen for the first time in an individual, i.e. neither their mother nor their father had the same mutation. These may occur in two ways. In the first case, parents have mutations in germ line cells, so other cells in the body do not have the mutation. In the other case, mutation could occur immediately after fertilization while the embryo is growing and after division, all cells will have the mutation. In both cases, parents do not carry the mutation while the child carries it [7].

In this project, chromosomal positions of the '*de novo*' mutations were used. Data were taken from 5 different individuals from two different studies—one from a publicly available source of mutation data [8] and other from unpublished data. Chromosome lengths were normalized and projected onto a 'virtual' guitar string, and the positions of the mutations were found along the length of the guitar string. After that, a frequency value for each mutation was calculated depending on the positions on the string. These mutations' frequencies were converted to LED and music signals. Sound creation was done by converting data to sound through a method known as sonification [9] and an electrical circuit was prepared to combine them in an audio-visual installation. The installation was exhibited in BangPrix 2018 [10] and at Middle East Technical University (METU) Open Research Day. Subsequently, it was also displayed at the METU-Development Foundation Secondary School.

Final step of the project was testing the educational potential of the installation using questionnaires. In a previous study [11] that measures the usability of the system, SUS [12] and EGameFlow [13] questions were compiled with additional questions. Volunteers who are from different backgrounds and from different ages filled in the short survey after they experienced the installation.

Questionnaire results were analyzed in two parts. The 5-point Likert-scale type questions were analyzed for variation with respect to age and occupation to see if these factors affect comprehensibility. No statistically significant difference was found between these groups, confirming that the message of the installation was not inaccessible to any one group. Free-form questions were analyzed in and of themselves. These show highly varied levels of comprehension of the main idea from individual to

individual. Finally, suggestions for the further development of the project were collected.

Figure 1 shows the basic scheme of the project with its materials, possible audience and main steps.

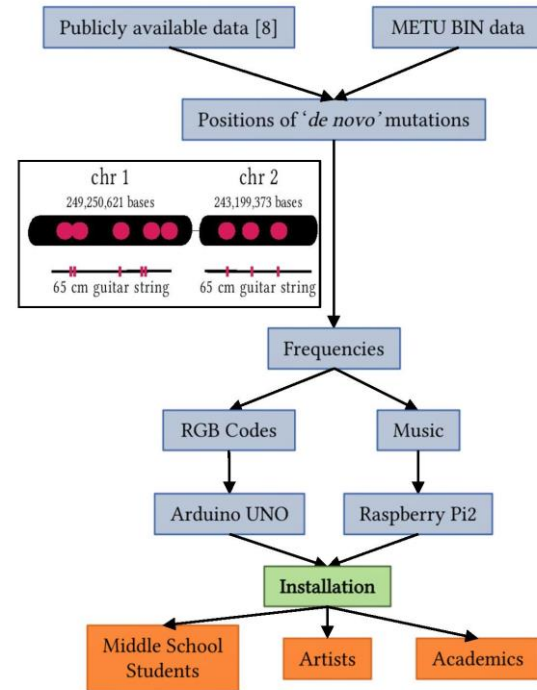


Figure 1. Basic scheme of the project.

2 Materials and Methods

2.1 Designing the Installation

'*de novo*' mutation data of 5 different individuals were used in the project. Three of them were taken from Genome of the Netherlands (GoNL) Project which includes 11,020 '*de novo*' mutations found in 250 families. This is the largest dataset that is produced from healthy individuals [8] in 2015. Data of three individuals (gonl-106c, gonl-150c and gonl-119c) were taken from the data. '*de novo*' mutations of the other two individuals were taken from an unpublished dataset from METU Bioinformatics (BIN) Program. These individuals were called METU-BIN1 and METU-BIN2 and were known to be siblings.

Chromosomal positions of the '*de novo*' mutations of each individual were converted to frequency values. Length of each chromosome that refers to number of bases on the DNA string, were equalized to the length of a guitar string which is 65cm. Positions of each '*de novo*' mutation was found on the 6th string of the guitar, which is equal to 82.41Hz. Figure 2 shows the basic idea behind mapping mutation positions on the guitar string. Fretless guitar was used as a base to retain each different frequency. Frequencies of the positions were calculated using the rate of the

string length at mutation points. A custom Python script was used to perform these calculations.



Figure 2. Mutation positions on the fretless guitar string. Blue labels on the guitar neck labels the mutations.

These frequency values for each individual were converted to sound and LED signals. The frequency generator tool in Audacity¹ was used to get sounds for each position without changing the order of mutations. Then, raw frequency values were used to create music. Two different sounds from the Logic Pro X² library and its default metronome beats were used in the music. To identify chromosomes from each other, 'Triplet Tick Tock' rhythm was used for one beat when moving onto a new chromosome. If there was no 'de novo' mutation on a chromosome, an empty second was added to express it. The other sound library was the 'Blue Wave' and it was used to represent frequency values of each 'de novo' mutation. Frequency value of each 'de novo' mutation was used also as RGB codes to obtain LED color signals. The addressable LED strip WS2811 was used in the system and it was driven by an Arduino UNO³ microcontroller.

The music and LED systems were brought together in the final state of the installation. An electrical circuit, which links the Arduino UNO and a Raspberry Pi 2 Model B⁴, was created. The LED display was driven by the Arduino UNO and the music was loaded to the Raspberry Pi 2. Figure 3 shows the setup of the circuitry. With a button system in the circuit, both music and the LED light display can be activated synchronously for each of the individuals. Each individual has a different button and when pressed, the music of that person is started at the same time with its LED signals. The LED system was arranged on a 1m diameter circle made of plexiglass.

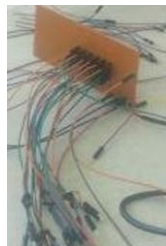


Figure 3. The electrical circuit which connects music and LED systems.

Experiencing the installation starts with a short explanation about 'de novo' mutations. After that, the participant steps into the plexiglass circle, wears the headphone and activates one of the buttons with electrical circuits on the black box. By activating one of the buttons, mutation song of the chosen individual starts. At the same time, LED at the position of the chromosome of the related mutation emits light. Since the sound and light of each mutation are synchronized in the system, the person who tries the system hears the sound of the same mutation which blinks on the plexiglass. After experiencing the system, a short questionnaire is given to the volunteers.

2.2 Analysis

The utility of the system as an educational tool was tested using the questionnaires that were applied to the volunteers after they tried the system in three different exhibition areas. First one was the Bang Prix 2018 exhibition and the project was demonstrated to artists, students and people from different backgrounds. 'Open Research Day' organized by METU Informatics Institute was the second exhibition. The opinions of academics and graduate students from different departments were collected during the event. Presentations of the project in these two exhibitions are shown in Figure 4.

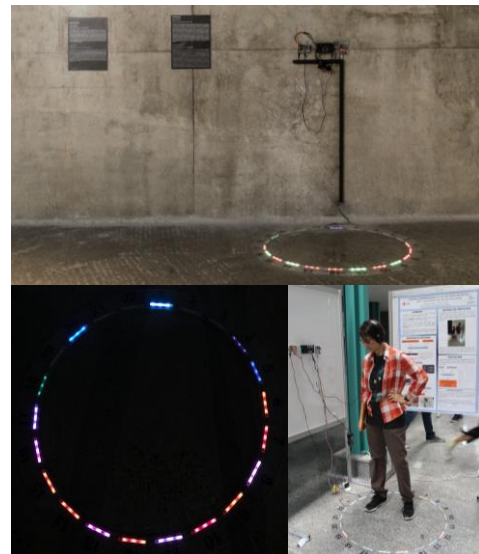


Figure 4. Demonstrations from different exhibitions. The upper image is from Bang Prix 2018 exhibition which was held in Istanbul. In the bottom left, a closer view of the plexiglass circle is presented. Finally, in the bottom right, exhibition of the system at METU is seen. A person goes into the chamber to test the system, wears the headphone and follows the changes of the LEDs on the plexiglass while listening to the music.

¹ <https://www.audacityteam.org/>

² <https://www.apple.com/tr/logic-pro/>

³ <https://store.arduino.cc/usa/arduino-uno-rev3>

⁴ <https://www.raspberrypi.org/products/raspberry-pi-2-model-b/>

The third group that evaluated the system were secondary school students from two different subgroups. While the first subgroup (Secondary School 1 = Sec. Sch. 1) did not have prior knowledge about cellular biology, the second subgroup (Secondary School 2 = Sec. Sch. 2) had.

The questionnaire was prepared with questions from the SUS and EGameFlow surveys. Just related questions for the study were taken from both surveys. Questions which are easy to answer and measure general convenience of the experiencers during trial were taken from SUS survey (i.e. Questions 2, 3, 6, 7). Besides, questions that measure immersion level and knowledge improvement of the participants were taken from EGameFlow (i.e. I1, I2, K1, K2, K5) whereas other question classes that measure interactive games were eliminated. In addition to selected 5-point Likert-scaled questions of the two surveys, three free-form questions were added to the questionnaire which measure comprehensibility of the system and take suggestions from the participants. The questionnaire was given to the volunteers after they experienced the system. In total, there are 12 questions in the survey. Two of the free-form questions measure attention level of the attendees while the other one asks for the suggestions. Nine 5-point scaled survey questions were evaluated using the SUS evaluation.

3 Results

During the exhibitions, participation and attention to the installation were high. A total of 92 surveys were completed by volunteers after they tried the system. Participants were grouped depending on their backgrounds and ages, and Table 1 shows the basic statistics of different groups. While the highest mean and highest standard deviation of the survey results were found in the academics, the lowest mean was found in the secondary school students' group 2 and the lowest standard deviation was seen in the university students' group. The highest mean regarding age was calculated in the academics whereas the highest standard deviation was found in artists and other occupations equally.

The first free-form question was about measuring prior knowledge and comprehensibility of the study. Results were evaluated depending on prior knowledge and its effect on understanding the project's details. Figure 5 shows the results. Results were evaluated in three parts based on self-report of prior knowledge of the survey taker: whether they reported having prior knowledge about genetics and mutations, or they reported not having any prior knowledge, or they did not give any information either way. These were then each rated by their level of comprehension. Among 92 survey results, 61 of the participants did not have prior knowledge about the topic. From 61 answers, 45 of them were secondary school students and 20 of them understood the main idea of the study after they experienced it. 16 of the participants, other than the secondary school students, didn't have prior knowledge, and 6 of them understood the main idea. 6 people who had prior knowledge about the topic of the study were students and academics from Open Research Day at METU and they mostly understood the underlying message of the study.

Table 1. Basic statistics of the survey results. Results were examined in 6 different groups. Total number of the students from different levels is 57. Age-related data from three Secondary School students are missing.

| | No. | Age | Survey Results |
|---------------------|-----|------------|----------------|
| Sec. Sch. 1 | 31 | 11,2 ± 0,5 | 25,05 ± 7,05 |
| Sec. Sch. 2 | 11 | 13,1 ± 0,5 | 24,45 ± 4,5 |
| Academics | 6 | 37,5 ± 4 | 29 ± 7,3 |
| University Students | 14 | 26,9 ± 4,7 | 28,4 ± 2,7 |
| Artists | 3 | 28,3 ± 6,1 | 27,3 ± 4 |
| Others | 24 | 32,4 ± 6,1 | 27,2 ± 6,4 |

The second free-form question was a tricky question where we asked the user to detect the siblings to test the attention of the survey taker since the correct answer was not related to being siblings or not. Table 2 shows the details of the question. 14 of the attendees out of 92 didn't answer the question. While 34 couldn't find the answer, 38 of the volunteers provided guesses. Answers detecting individuals 2 & 3 as siblings were the most predicted one and the 3 & 5 pair was following them. Six of the volunteers didn't make any predictions.

Table 2. Answers to the tricky question – predictions to find the siblings in the data.

| Prediction | # of times it was predicted |
|---------------|-----------------------------|
| 1 & 2 | 1 |
| 1 & 3 | 4 |
| 1 & 4 | 3 |
| 2 & 3 | 9 |
| 2 & 4 | 4 |
| 2 & 5 | 3 |
| 3 & 4 | 2 |
| 3 & 5 | 8 |
| 4 & 5 | 3 |
| 9 & 12 | 1 |
| Couldn't find | 34 |
| Lack of time | 6 |
| Not answered | 14 |

User suggestions were taken into consideration with the third free-form question. Some of the attendees added their compliments

along with their suggestions. Therefore, the results were analyzed in two main groups as suggestions and compliments. Figure 6 gives the comments for the question. Suggestions were categorized according to the technical details, physical shortcomings of the system, written or verbal explanations about the system and some additional clues to develop the system in the future.

Suggestions on technical details were also sub-categorized. There were some specific suggestions on music and LED signals, so they were evaluated differently. Other two categories under technical details were aimed to increase the comprehensibility of the system.

4 Discussion and Conclusions

Observations during the demonstrations and analysis results show that the main idea behind the project was mostly understood by the audience. Basic statistics in Table 1 states that there is not a significant relation between age and survey results. The free-form question results of an audience member (age 37), who has the lowest survey result, shows that he understood the underlying message of the study. Low result might be due to lack of time or a misunderstanding of the points in the scale. Two attendees from secondary school students who have the second and third last survey results seem to have not understood the project at all, as they have written in the free-form questions section. These could be an evidence that the younger age students took the process more seriously than adults. Observations by the researchers during the demonstration also support this idea.

Results of the first free-form question shows that with a little or no prior knowledge, it is possible to understand the idea of the project with a few pointers. Another piece of evidence, which shows that people mostly understood the project, is suggestions. Most of the suggestions that are shown in Figure 6 are applicable and meaningful for the project.

Second free-form question, which aimed to increase the attention of the audience, was functional because most of the users replied to this question. Although the most predicted pair as seen in the Table 2 is 2 & 3, this question did not have a correct answer because of the structures of the 'de novo' mutations.

Based on the suggestions and encouragements given in the surveys, a few improvements will be made in the future. One primary finding is that the installation definitely needs to be experienced in a sound isolated environment so that the user can perceive the details in a better way. More and varied artistic visual effects are also needed for a clear understanding and in order to increase the influence. There was also a suggestion on extending the length of the music representing each individual. However, we contend that too long a sequence becomes, the user could get distracted.

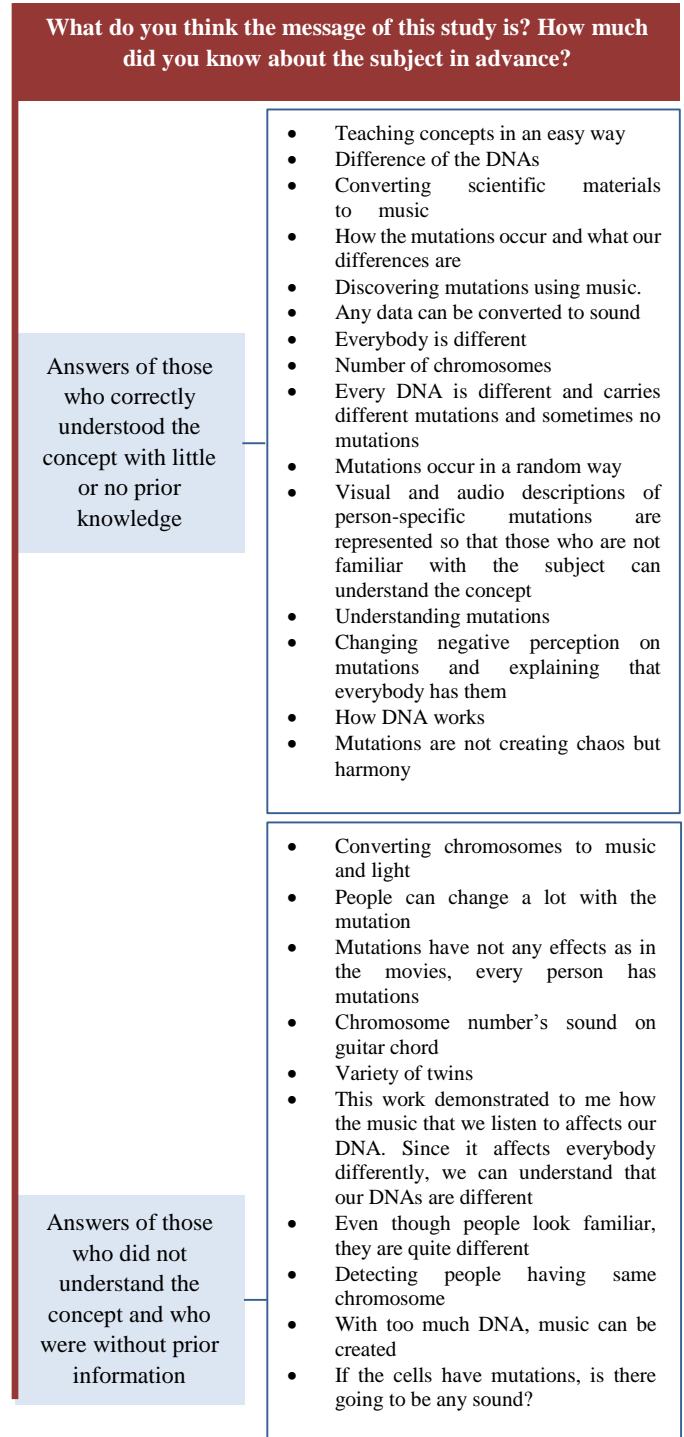


Figure 5. Comments on the first free-form question which measures the comprehensibility of the core message of the installation.

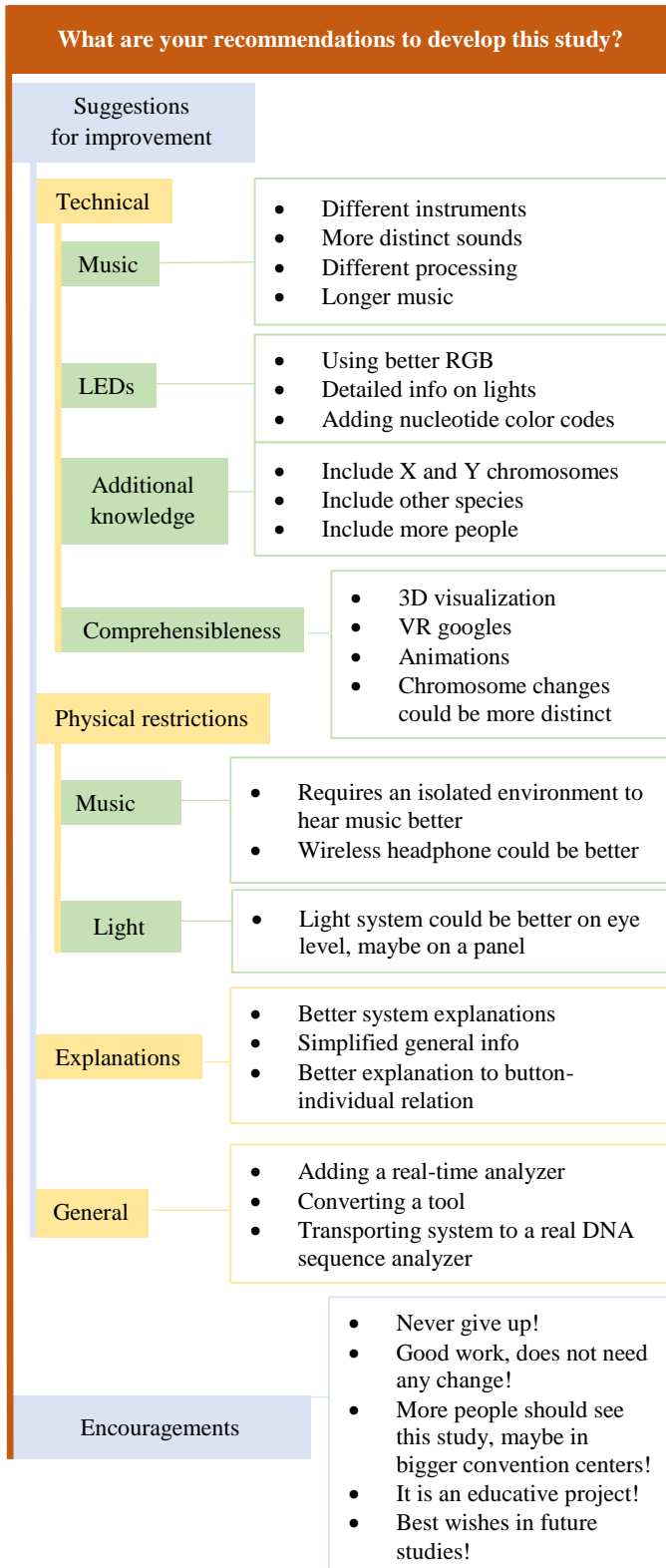


Figure 6. Suggestions to develop the installation.

In conclusion, the project was found to be apprehensible by the users and we are encouraged to develop it further in the future. The project was also found to be enjoyable in both preparation and demonstration steps. In the end, this project can be considered as an encouragement for those who would like to merge science and art—when they come together, the impact of the message is even more powerful.

ACKNOWLEDGMENTS

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SUPPLEMENTARY MATERIALS

Music excerpts from the project:

<https://soundcloud.com/elif-bozlak>

Leaflets and Photographs from the demonstrations:

<https://www.flickr.com/photos/165795698@N08/>

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