EXPLORING SYNESTHESIA UTILIZING SOFTWARE TECHNOLOGIES

Viktor Matanski

Abstract. Synesthesia is an involuntary neurological phenomenon in which the stimulation of one sense leads to the automatic activation of one or more others. In this paper a general overview of the current literature on the synesthetic phenomenon will be created with emphasis on chromesthesia – a sound-to-color type of synesthesia. Using the collected data specific notes and connections will be established in aid for the creation of a prototype that will virtually simulate the synesthetic experience. To truly be able to visualize, comprehend and explore synesthesia a further experience, knowledge and understanding of natural laws have to be attained.

Keywords: consciousness, perception, synesthesia, chromesthesia, computer visualisation

1. Introduction

Synesthesia (from Ancient Greek, syn = together, aisthesis = perception) is the name of the rare ability to either hear colors, see sounds, taste shapes or experience other unfamiliar to most people sensory bindings. Someone who experiences synesthesia can describe in detail the color, shape or even flavor of someone’s voice, see fireworks, shattering glass combined with geometric figures floating around when listening to music or view each symbol with a texture and color. When a synesthete sees an orange car he can also sense a smell or hear a sound that is associated by his perceptive abilities with the color orange. Synesthesia is exceptional only as not being studied throughout and current statistical data is limited. In fact, current research indicates that the synesthetic experience is a typical brain process prematurely revealed to consciousness [1].

The information received by person with synesthesia can be both experienced internally or externally. It can be projected outside of the person, in the real life scene he is currently interacting or it can also be projected inside, in his mind's eye. The inside projection can be referred to as associative synesthesia. It is estimated that 1 out of 25,000 people is born with this ability – where one sensation involuntary activates others, sometimes even more than one [1].

2. What is synesthesia

This ability is considered by most as a phenomenon. This might be because synesthesia overthrows the normal concepts of the human mind and rejects conventional laws of neuroanatomy and psychology. It is spontaneous but still induced, something that is incomparable but can be identified in great detail by the one who experiences it.

For those who are not born with the ability it can still be attained to some point. Documented cases of seizure discharges in the brain produce synesthesia. Examples such perceptions include seeing flashing lights, geometric shapes, the emergence of scent or taste, a feeling of heat rising or hearing high frequency sounds. One can also attain synesthesia by learning and training how to transfer sensations from one perception to another (artificial synesthesia).

Although there are over 20 documented forms of synesthesia the reports of people who are experiencing it are remarkably connected. The symptoms remain the same over their course of life time. Synesthetes consider their abilities as something normal and are stunned to discover other people do not perceive the world the way they do. Here comes the dialogue if we should have some or any at all limitations to perceiving the world we live in? If this structure created by society is working or is it limiting humans in their evolution? As some might note: 'Normal is an illusion. What is normal for the spider is chaos for the fly'. For the current state of development of our civilization synaesthesia appears to be impossible for science to depict, as this phenomenon is one to be understand only when experienced first hand.

Synesthesia is found to be genetically transmittable. Statistics show that it runs in families in a consistent pattern, with the chance of skipping generation. The ability predominates in women in a ratio 3:1 in the USA [2]. Another statistic fact is that synesthetes are predominately left handed. When examined using standard medical approaches, people with this ability display no difference than normal people, except for better memory results.

2.1. Mechanism of synesthesia

The human brain has specialized regions for specific functions. Increased communication between them may be accountable for the great variety of synesthetic abilities. Another possibility is the depletion in the size of inhibition along normally existing neural feedback pathways, also known as disinhibited feedback [3]. Inhibition and excitation are normally balanced, however, when feedback is not properly inhibited, signals that are fed back may influence other sensory pathways and for example activate visions when a sound is being heard. This theory grows support in specific acquired forms that are experienced by non-synesthetes in some cases. They include temporal lobe epilepsy, head trauma, stroke and brain tumors [4]. Other conditions include deep stages of meditation, concentration, sensory deprivation or the use of certain compounds.

Different theoretical approach to understanding synesthesia is held in ideasthesia. According to it, synesthesia is an ability mediated by the processing and extraction of meaning of a stimulus which leads synesthesia to be a fundamentally semantic issue. If that is so, to understand the neurological processes of synesthesia the means of semantics and extraction of meaning need to be understood better.

2.2. Some types of synesthesia

- Graphene-color synesthesia – one of the most frequent types where numbers and letters possess a color or a visual effect. Although synestetes do not always report the same color for specific letters, statistical studies with great number of participants find commonalities [5].
- Chromesthesia – probably the most looked after type of synesthesia. In this case sound triggers a vision of colors and shapes. The objects that are visually perceived by people with this type of ability are referred to as photisms.
- Spatial sequence synesthesia and number form – SSS type of synesthesia allows people to see number sequences as points in space while as number form synesthesia creates a mental map of numbers.
- Spatio-temporal synaesthesia – similar to number form, this type exhibits the experience of mental mapping of days, weeks or months of the year. People with this type of synesthesia report experiencing type as a construct.
- Mirror-touch synesthesia – this type refers to the synesthete experiencing the tactile sensations of others when being an observer. People with this type are reported to have great number of mirror neurons in the motor parts of the brain, which are as well linked to empathy [6].

- Lexical gustatory synesthesia – this type is very rare and corresponds to the sensation of taste when hearing specific words. There are estimations that 0.2% of the world population experiences this phenomenon [7].
- Misophonia – this type exhibits the arousal of certain feelings when hearing specific sounds [8].

2.3. Visual synesthesia, chromesthesia or sound-to-color synesthesia

Chromesthesia is a type of synesthesia in which a stimulation in the auditory system automatically and involuntarily creates an experience of color and shape [4].

Individuals with chromaesthesia possess unique color pairings. However, current studies indicate that both people with the ability and not match high pitched sounds to brighter or lighter colors and low pitches sounds to darker tones. These studies indicate the possibility of existence of a common mechanism underlining sound and color associations in normal human brains [10].

R. Cytowic describes chromesthesia in a very bright manner: it is “something like fireworks”: voice, sounds, music and plain environmental sounds such as birds, dog barking or metallic sounds can trigger firework shapes that appear, move and then fade when the sound connected with them disappears [4].

2.4. History of synesthesia

The subtle perception of synesthesia and the urge to connect our senses is well known over the centuries in our history. Sir Isaac Newton strived to device a mathematical formula to equate the vibration of sound waves to a corresponding wavelength of color. Another historical figure – Goethe discussed possible color connections in his Theory of Colors.

There was a great scientific interest in revealing the mechanisms behind synesthesia in the period between 1850 and 1930. However, there was not much success as psychology and neurology were still premature sciences at that time. This resulted in synesthesia becoming a taboo for its subjective manner and was categorized for not being proper for scientific examination.

In the 1950s synesthesia inspired a new art movement aiming to blend the human senses and submerge people in their perceptions. Multidimensional concerts and appearances were set utilizing music and light, famous with the French description – son et lumiere (French, sound and light show). Sometimes the artists pushed the boundaries and included even specific fragrances to further immerse the audience. Specialized devices were to be created for the control and synchronization of light, sound and musical notes – all of them striving to simulate the real synesthetic experience.

Today we see increased interest in deciphering the synesthetic phenomenon and understanding the mechanisms around human abilities and perception. In the last 30 years many documents with interest in synesthesia were published in different area of scientific research – from neurology, psychology and cognition to technical sciences, art and music.

2.4.1. Famous synesthetes

Alexander Scriabin (1972-1915) was a Russian composer and pianist. He was strongly influenced by synesthesia in his life and works. His ability to associate colors with different harmonic tones lead to his atonal scale. By utilizing his ability with theosophy he created a color-coded circle of fifths. In 1910 he composed the symphony “Prometheus”, The Poem of Fire. Other than orchestra, organ and choir, the composition included a mute keyboard, known at the time as “a clavier a lumieres”, to control colored light beams, artificial clouds and different geometric shapes that were included in the composition.

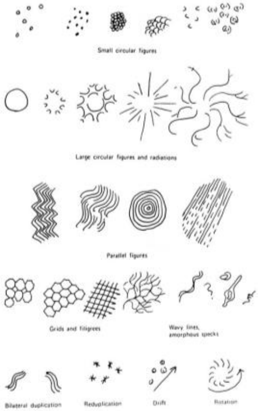
Vasilly Kandinsky (1866-1944) was born in Russia and was a very famous art theorist and painter. He is said to have created one of the first abstract works. His stage design “Pictures at an Exhibition” illustrates his synesthetic vision for a universal connection between sound, color and form. Kandinsky had a rather different approach for his describing paintings referring to them with musical terms such as “compositions” or “improvisations”. This difference was caused by his tendency to perceive a harmonious relationship between sound and color. In 1912 he created the opera “Der Gelbe Klang” (The Yellow Sound) which specified a compound mixture of sound, color, light and dance. The painters well known dictum “Stop thinking” clearly relates to the synesthetic experience.

Nikolai Rimsky-Korsakov’s (1844–1908) synesthetic ability allowed him to associate different musical keys with colors. He states that the key C has a major white color and the key B major had a dark blue with a specific steel texture.

Vladimir Nabokov (1899–1977), a famous novelist, was able at a very young age to equate the number five with the color red. The interesting part in his case is that his wife and son were also synesthetic. The synesthesia experienced by their son Dimitri appeared to be a blend of his parents hues – “which is as if genes were paining in aquarelle” [11].

2.5. Other area of research connected with visual synesthesia

These subjective experiences with hard to describe nature are not only unique to synesthesia. In 1926, Henrich Kluver started a systematic study exploring the nature of hallucinations. He revised into short descriptions his test subjects various reports and concluded the predomination of bright, highly saturated colors and vivid images. There were recurring geometric patterns that persisted through the participants in the tests. These patterns were named “form constants”.



Picture 1. Heinrich Klüver’s Form Constants, pen and ink drawing on paper [9]

The following diagram displays a linear skeletal diagram of the general geometric principals of Henrich Kluvers form constants. These general representations persist both across Kluvers test subjects and natural born synesthetes.

3. Prototype development

3.1. General human perception

We, humans in our everyday life perceive the world using our two eyes. Our visual system allows us to process visual detail and further interpret it. Great part of the information that our brain receives comes directly from the visual system. Our eyes give us the ability to utilize depth and thus perceive the world in 3D. With them we can determine how tall or wide an object is, how far away is it, is it moving in a specific direction, trajectory or speed? Analyzing these observations, we can conclude several general properties of perceivable objects in space:

1. Width, height, distance (depth);
2. General Form/shape;
3. Color;
4. State – movement, transformation and interaction;
5. Duration.

The human auditory system follows after the vision system. The sounds that we hear are generally vibration of air. The human auditory system converts sound from its general form of air vibration into mechanical vibration in the outer ear and then transduces it into fluid vibration in the middle ear to the inner ear. Then there the fluid vibration is translated into nerve impulses. The auditory system processes sound and determines its pitch, loudness, direction and distance. However, when it comes to extracting valuable information from sound, such as how many instruments are playing at the same time and what instruments they are (distinguishing different instruments in a musical composition) we humans are by far superior than current available technologies.

3.2. Synesthetic perception

Current scientific data on synesthesia indicates that there are at least two ways of perceiving sound as a synaesthete, other than just hearing it. Sound can be perceived as a visual experience that can be projected either internally or externally.

The internal type of perception is being projected in the mind's eye, which can be addressed as follows: if we can see the world around us with our two physical eyes, our 'mind's eye' can 'see' a whole another reality or dimension. This vision can be in no relation to the reality that is being seen with the physical eyes or be fully related but having different principles of data or construct implementation. The simplest description of such internal synesthetic projection is like watching two sets of televisions – the first is something everyone can see with their eyes and the second channel is available only to those who experience this statistically rare ability. Because it happens in the mind's eye it is connected with imagination and can be referred to as associative synesthesia.

The external type is synesthesia being projected right on top of what a person currently sees. The union of the senses interacts directly as a part of the perceivable reality and thus augments it.

Picture 2. Black rainbow; Clouds Rise Up; G# Is Turquoise; by artist Carol Steen [20]

When investigating the artistic representation of synesthete artist Carol Steen a 2D expression of the synesthetic experience can be seen. A black background having different overlapping and merging elements on top of it.

Up to the current moment, the more documented and experienced type of sound synesthesia is the internal one. Most synesthetic report that they experience a black with various shapes in different colors and textures appearing over it. Although there are reports suggesting that the background can change its color and texture.

3.3. Collected data

Several valuable descriptive details mentioned up till now will be used to establish a foundation for the creation of the virtual synesthesia simulator.

- The type of synesthesia that is going to be simulated is the sound-to-color synesthesia phenomenon known also as chromaestesia or visual synesthesia.
- The type of projection will be internal and a black background will be used on which the visual sound elements will be displayed.
- A visual object can have the following general properties – position, size, form, color, behavior, duration.
- A sound object can have properties such as position, pitch, loudness, duration, color.

4. Prototype realization

The models are created utilizing methods [12] that allow them to be previously assessed. Pre-collected data from the models [13, 14] is used to analyze and optimize the workflow of the prototype – comparing test simulations with real visualizations [15].

4.1. Used technologies

For the development of the prototype the open source computer programming language Processing has been used. It is based on Java and has its own development environment (IDE). The language is originally created towards electronic arts and visual design with the purpose of rapid development of software in a visual context [16].

Minim is an audio library that is based mainly on JavaSound API. It is integrated into Processing and allows flexible methods for handling sound. The Minim library will be used sound processing in real time [17].

MidiBus is a MIDI library created to operate with Processing. MidiBus delivers a robust way to access and control MIDI resources on a system. This library will be used to control and trigger specific parameters connected both to sound analysis and visualization [18].

4.2. Handling sound – SoundClass

When human abilities and computer technologies are compared in relation to music information retrieval a very interesting fact can be noted. It is known that the human auditory system is limited from 20 hz up to 20 kHz but still when it comes to understanding the pattern and the content of a musical composition it is still superior to current computer technologies, as stated above. This occurrence can be because of the musicality and life of the human nature, which up to this current moment – computers lack.

In the prototype, by utilizing the Minim library, sound can be both processed from an already recorded audio file or in real time – via a microphone. In both cases the information is processed in a digital form. Utilizing Processing algorithms specific information can be extracted from this digital medium.

For each different sound an object of class Ripple is created. It has the following properties: frequency in hertz, amplitude, location and duration/length.

And in the context of synesthesia – sound has a color property. There are people with synesthesia who have created their own color-sound mappings, giving specific notes certain colors. As already reported there are studies done with both synesthetes and non-synesthetes that connect sound pitch with color tones which conclude both groups of participants experience the connection of higher pitch with brighter colors and lower pitch with darker tones. An algorithm developed from before will be used to translate the frequency of sound into wavelength of light-color [19].

4.3. Visualization – PhotismClass

To handle the visualization objects a class named Photism will be created. An instance of the class will be directly connected with RippleClass as a visual object is only created when a sound is being heard, in the visual synesthesia case that has been reviewed. PhotismClass will have the following properties:

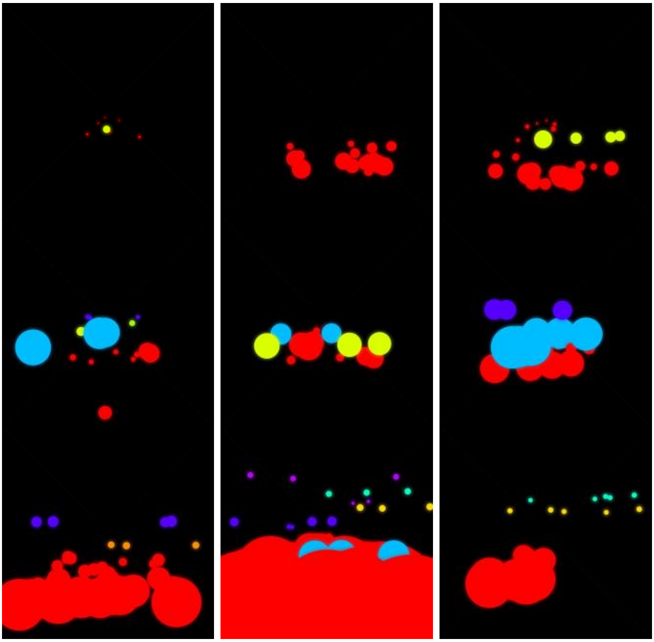
- positionX, positionY, positionZ;
- speed;
- diameter;
- duration;
- color.

The general idea is to detect every sound that is above a specific perceivable value to the human perception and turn it into a visualization. However as there are different sound sources, fine tuning of object parameters is implemented to scale the visualization and handling of sound.

5. Results

5.1. Moving circles

When a frequency onset is detected, circles are formed in the middle of the screen with specific color and size. They are further translated towards the viewer, changing their size, until they disappear. The sound used to create the visualization is piano composition by Greg Ryan called Mountain Rain.



Picture 3.

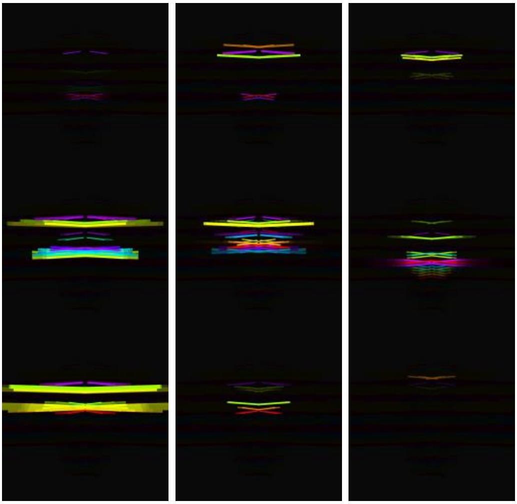
In the figure 3 the following can be observed:

- Different notes are displayed in different color and are positioned on different parts on the screen.
- Each object has size directly connected to the note amplitude.
- Objects can merge creating new shapes with different colors.
- When a great number of notes are being played simultaneously the sound amplitudes start to exceed the differentiation range and flood the screen or hide other objects.

5.2. Noted lines

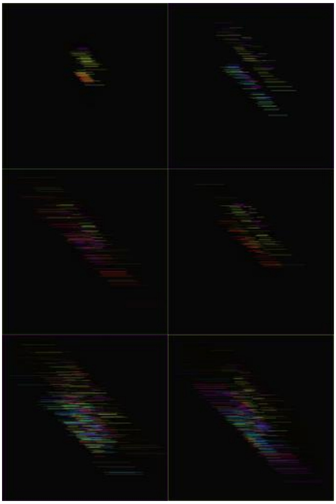
For each frequency onset a line is drawn. The properties of the line (color, size, curvature) depend on the frequency that it corresponds to. The music used to create the visualization is Mozart – The Piano Sonata No 16 in C major.

5.2.1. Rotating lines



Picture 4.

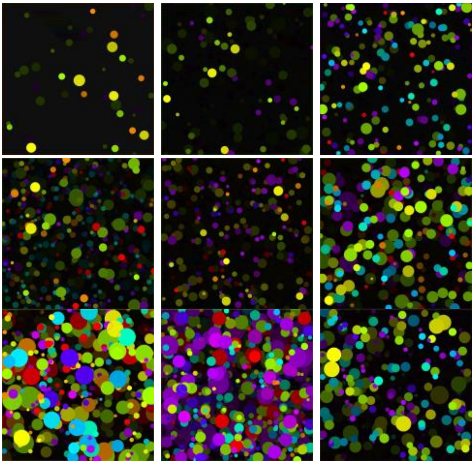
5.2.2. Randomized lines



Picture 5.

5.4. Randomized circles

Unlike the above examples based mainly on logic, in this case only the color and size correspond to the amplitude and frequency of different sounds. The location of each visualization is fully randomized across the screen. The abstract visualization comes close to what most visual synesthetes describe.



Picture 6.

6. Conclusion

The current paper has presented general information about the synesthetic phenomenon. However, up to the current moment synesthesia is not being fully explored by science. Additional knowledge of the mechanisms behind the condition can lead to further understanding of how the human brain works. The results from the simulation display a possible way of how chromesthesia can experienced. Further experiments have to be conducted to determine the relevance and accuracy of the established connections between sound and color, implemented in the visualizations. Data collected from these experiments can be applied to develop the prototype.

Acknowledgements

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Faculty of Mathematics and Informatics
Plovdiv University
236 Bulgaria Blvd,
Plovdiv 4003, Bulgaria
E-mail:

ПРОУЧВАНЕ НА ФЕНОМЕНА СИНЕСТЕЗИЯ ЧРЕЗ ИЗПОЛЗВАНЕТО НА СОФТУЕРНИ ТЕХНОЛОГИИ

Виктор Матански

Резюме. Синестезията е неволен неврологичен феномен, в който стимулацията на едно сетиво води до автоматичната активация на едно или повече други сетива. В тази статия се създава частичен преглед на досегашната литература, свързана с неврологичното състояние, като се набляга на хромоестезията – специфична форма на синестезията, изразяваща се в обвързаност между звук и цвят. Събраната информация се използва за изграждането на прототип, който има за цел да представи виртуална среда за симулация на неврологичната способност. За да се проектира реална интерпретация на феномена синестезия, по-нататъшно разбиране на същността на преживяването трябва да бъде постигнато.

Ключови думи: съзнание, възприятие, синестезия, хроместезия, компютърна визуализация