CAN YOU HEAR YOUR DRAWING?

Creating synesthetic experiences through an audio-visual web interaction

by Maria Shirokova

Submitted to OCAD University in partial fulfillment of the requirements for the degree of
Design in Digital Futures
Toronto, Ontario, Canada, 2021

CAN YOU HEAR YOUR DRAWING?

creating synesthetic experiences through
an audio-visual web interaction

by Maria Shirokova

Submitted to OCAD University in partial fulfillment of the requirements
for the degree of Master of Design in Digital Futures
Toronto, Ontario, Canada, 2021

Abstract

This research focuses on creating audio-visual web interaction inspired by the synesthetic experience. Synesthesia is a neurological condition where the processing of data by one sense activates others. This project hypothesizes that interactive digital artworks enable people to touch music, hear colours and expand their creativity and senses. They evoke synesthetic associations and activate certain senses' vocabularies, and people start seeing a correlation between visual and audio experiences. This research explores the role of metaphor as a theoretical framework, conversational tool and design approach in the multimodal digital space. This project's outcome is a web application that opens an empathic dialogue between people who experience synesthesia and those who are eager to learn what it is and what it is like to have it. Users can map their audio and visual senses' associations by documenting and sharing them in the digital environment. This research applied research through design methodology by expanding the audience's role from testing and observing to participating.

Acknowledgment

I would like to express my deepest appreciation to my committee, Dr. Haru Hyunkyung Ji and Nick Puckett. I appreciate your advice, ideas and support in guiding me through this project.

Thank you to the Digital Futures community, especially to Kate Hartman, Barbara Rauch, Adam Tindale and Dr. Cindy Poremba.

I am very grateful to Sergey Prokopyev who helped me to combine my prototypes into the final version of the *Can You Hear Your Drawing?* application.

I would like to give special thanks to Elena Aleksandrovna Vyaznikova for introducing Colour Theory during my undergraduate studies.

I must thank members of the German Synaesthesia Society, the Russian Synaesthesia community and the International Synesthesia Connections Association, who agreed to collaborate and participate in this project.Thank you to Elisa Heinonen, Barbara, Donald, Paul, Noa and Becky, your contribution to this project is very valuable.

I would also like to thank my family and friends for their constant support and motivation. I am very grateful to my mom and dad for being my role models. Your research work inspired me to start this project.

Table of Contents

Table of Figures

"I see shapes and colours in response to sounds. I enjoy electronic music because it evokes such wonderful shapes and colours in my visual perception area. I feel for the first time that I am not nuts! The coloured shape is seen as if I were looking through plastic transparency that is in front of my eyes. If I shut my eyes, or if it is at night in the dark, then the shapes are the only thing in the field and are therefore more intense. However, there is a secondary path. Sometimes when I hear words, I will see shapes. This second one is the one that makes me feel silly. ... I'm not much of an artist. This the first time I've written something like this down, but it's accurate."

- MM (initials.), a synesthete

Synesthesia: A Union of the Senses by R.E. Cytowic

Introduction

As an artist and designer, I have always observed the way all senses work together. Studying colour in my undergraduate studies, I realized its massive impact on human perception of the world, from its ability to affect people's mood to the use of colour in applications, gadgets, furniture, interior and healthcare (Bosch et al., 2012). While painting and working on my previous projects, I learnt how critical it is to understand the way people perceive the world through their senses because essentially every design or painting is a combination of colours, lines, textures, sizes and shapes.

It is fascinating to see how all senses work together and how one sense can complete, expand another sense. For example, when we think of a movie scene, we can recall dialogues, faces, and certain images, sounds and feelings. We imagine that scene as one body, one organism – the one that contains sounds and visuals; sometimes, we even associate them with smells or tastes. But how often do we deconstruct those scenes into different sounds/images/tastes or odours? How often do we think about those correlations? Do we need to think about them?

Everyone may have a unique "sense language." Therefore it interests me to explore how people perceive visuals and sounds differently. This uniqueness can be affected by our cultural backgrounds, education, mood, society and many other factors. We do not explicitly keep track of our sense correlations. For instance, orange colour for me is a colour of happiness and warmth, while for another person, orange can be completely neutral and not trigger any emotions. For people with particular synesthesia forms, orange colour can cause completely different reactions: orange can be heard, smelled or tasted.

Vladimir Nabokov, a Russian American writer who experienced grapheme-colour synesthesia, documented his colour and letter associations in his autobiography *Speak, Memory*:

"I hasten to complete this list before I am interrupted. In the green group, there are alder-leaf *f*, the unripe apple of *p*, and pistachio *t*. Dull green, combined somehow with violet, is the best *I* can do for *w*. The yellows comprise various *e*'s and *i*'s, creamy *d*, bright-golden *y*, and *u*, whose alphabetical value I can express only by "brassy with an olive sheen." In the brown group, there are the rich rubbery tone of soft *g*, paler *j*, and the drab shoelace of *h*. Finally, among the reds, *b*

has the tone called burnt sienna by painters, *m* is a fold of pink flannel, and today I have at last perfectly matched *v* with “Rose Quartz” in Maerz and Paul’s Dictionary of Color. The word for rainbow, a primary but decidedly muddy, rainbow is in my private language the hardly pronounceable: *kzspygv*.”

The interconnection of the senses and documented sensations by Nabokov encouraged me to think of our senses and associations in the form of vocabulary or a diary. How else can we record our sensations or perceptions, if not in our journals? I designed a digital sense vocabulary in the form of a creative tool that people can open, change, add and compare at any time. By introducing the term “Sense Vocabulary” or “Sensation Diary” as a form of documented sense correlations or sense associations and their meanings, this research aims to help people understand better and express their sensations and perceptions via creative tools.

It is impossible to evoke a synesthetic experience among non-synesthete users (Cytowic,1996). However, there might be an opportunity of bringing a synesthetic-like experience to the broader audience. I hypothesize that interactive digital artworks enable people to touch music, hear colours and expand their creativity and senses through the sense analogy – metaphor. They evoke synesthetic associations and activate certain senses’ vocabulary, and people start seeing an understanding of the correlation between visual and audio experiences.

Can you hear your drawing? aims to allow synesthetes to explain their audiovisual perceptions to a non-synesthete user and expand the non-synesthetes’ understanding of audio-visual compositions. Each user has a chance to create their library of audiovisual pieces and share their perceptions with others – openness and the ability to share open the dialogue between synesthetes and non-synesthetes. With this research, I tend to remind people about how audio and visuals affect each other and to let them explore this connection. *Can you hear your drawing?* allows users to deconstruct their audio-visual perception. They are not given the final composition, as they are used to seeing in the real world, where sound accompanies images, but they can build their audio-visual composition based on their perceptions, associations and metaphors. _

The questions that this research focuses on are “What are the digital interface possibilities of creating an empathic dialogue between people who experience synesthesia and those who are

not familiar with this phenomenon? “, “What role does metaphor play in designing a web app about multimodality and synesthesia?” and “What are the capabilities of digital web applications in providing personalized cross-modal sensory experiences?”

This project uses Research through Design(RtD) methodology and includes iterative design methods such as rapid prototyping, sketching, user testing, peer-reviews, mind mapping, wireframing and page layouting. By creating a series of prototypes, selecting the most effective ones by evaluating them, in the result I build an app that is tested and analyzed by the audience. RtD helps to explore the capabilities of online applications in providing a multi-sensory experience to the user. To evaluate the role of metaphor in this research, I implement it at three main stages of this study and define the following terms: *Theoretical Metaphor, Design Metaphor and Conversational Metaphor*.

- Theoretical Metaphor is applied in Contextual Review, where it helps to explain synesthesia and fill the gap between subjectivity and objectivity.
- Design Metaphor is used as an RtD method in Prototyping.
- Conversational Metaphor is used for building dialogue and evaluation: it was applied for building users’ sense and association understanding between each other.

As a designer, my goal is to build a digital environment with an intuitive interface, which will inspire users to interact, play with and document their audio-visual sensations. *Can you hear your drawing?* is an application that aims to attract different creators, including visual artists, composers, writers, for their daily prompts as a tool for seeking and finding inspiration. As a researcher, I designed an interactive creative tool for exploring sensory metaphors and correlations, which can expand users’ understanding of connections between senses and enable them to see the unfamiliar in the ordinary.

Scopes and Limitations

Several limitations were considered during this research. The study followed two main directions: a multi-sensory creative tool and an exploratory tool for visualizing and sonifying synesthetic experience. The terms such as multimodality, synesthesia, interactivity are complex and may include many senses, interpretations, and, in the case of synesthesia, its crossings.

The first and the main challenge for this research is the complexity of phenomenons it explores and the goal to unite synesthesia, multimodality and interactivity in one design project.

Secondly, multimodality in this project is limited by 2.5 senses. Synesthesia implies many forms and many senses. This research is mainly focused on the auditory-visual type of synesthesia (chromesthesia) in digital space. Hearing and vision have been chosen as two primary senses for the app and touch as a secondary sense. However, this research is the beginning of my multi-modality exploration, and I am interested in considering how all human senses can work together.

Thirdly, this project is designed by a non-synesthete person to explore the app's capabilities in visualizing synesthetes' perceptions. This research applies a user-centered approach and invites synesthetes and non-synesthetes for user testing and discussions for better understanding synesthetic perceptions.

Everybody senses and perceives audio and visual information differently. With this study, I aim to explore this subjective aspect of synesthetic and synesthetic-like perceptions and use the app to investigate the way synesthetes and non-synesthetes represent their audio-visual compositions. This research is exploring how the *Can you hear your drawing?* app can fulfill everyone's sensation and if this tool can represent their intentions.

Terminology

Synesthesia – a condition in which someone experiences things through their senses in an unusual way, for example, by experiencing colour as a sound or a number as a position in space. (*Cambridge International Dictionary of English*, 1995)

Synesthete – a person affected with synesthesia. (Non-synesthete – a person who is not familiar with the synesthesia phenomenon). (*Merriam-Webster.com Dictionary*, Merriam-Webster, https://www.merriam-webster.com/dictionary/synesthete. Accessed 15 Mar. 2021)

Chromesthesia – a type of synesthesia in which a nonvisual stimulus causes the individual to perceive colour. *Colour hearing* is a form of chromesthesia. In colour hearing, a musical tone elicits a colour. (William, Shiel, 2018)

Empathy – the action of *understanding*, being aware of, *being sensitive* to, and vicariously experiencing the feelings, thoughts, and experience of another of either the past or present without having the feelings, thoughts, and experience fully communicated in an objectively explicit manner. (*Merriam-Webster.com Dictionary*, Merriam-Webster, https://www.merriam-webster.com/dictionary/empathy. Accessed 15 Mar. 2021)

Metaphor – a figure of speech in which a word or phrase literally denoting one kind of object or idea is used in place of another to suggest a likeness or analogy between them. (*Merriam-Webster.com Dictionary*, Merriam-Webster, https://www.merriam-webster.com/dictionary/metaphor. Accessed 15 Mar. 2021)

Multimodality – or, more explicitly, a modality of information representation, is a way of representing information in some medium (Bernsen & Dybkjaer, 2010). By definition, a multimodal interactive system uses at least two different modalities for input and/or output. Multimodality allows an integrated use of various forms of interaction simultaneously.

Multisensory – relating to or involving several physiological senses. (*Merriam-Webster.com Dictionary*, Merriam-Webster, https://www.merriam-webster.com/dictionary/multisensory. Accessed 15 Mar. 2021)

Sense Vocabulary or Sensation Diary – a form of documented *sense correlations* or sense associations and their meanings.

Sound Palette – a musical part of a creative audio-visual *tool*, where colours are used for navigation through sounds.

Background and Context Review

Can You Hear Your Drawing? is an online multi-sensory creative tool, thus it belongs to the realms of creative new media. Due to the interactivity and conversational output, this research studies second-order cybernetics. Because of connection to synesthesia and multi-sensory experiences, this research includes explanations and notions from psychology and neuroscience.

This chapter reviews some of the artistic, psychological and design theories and frameworks on colour-music, synesthesia, metaphor and cybernetics. Firstly, it studies colour-music and multi-sensory related art and theory projects and their methods. Secondly, it seeks to define possible connections between metaphor, nature of perception and synesthesia. Thirdly, by studying the second-order of cybernetics, this research aims to understand interactive systems' structure and how to build conversion through them. Furthermore, review of related works is applied as it helps to critically analyze existing projects and artworks in the sphere of colour music and digital multi-sensory experiences.

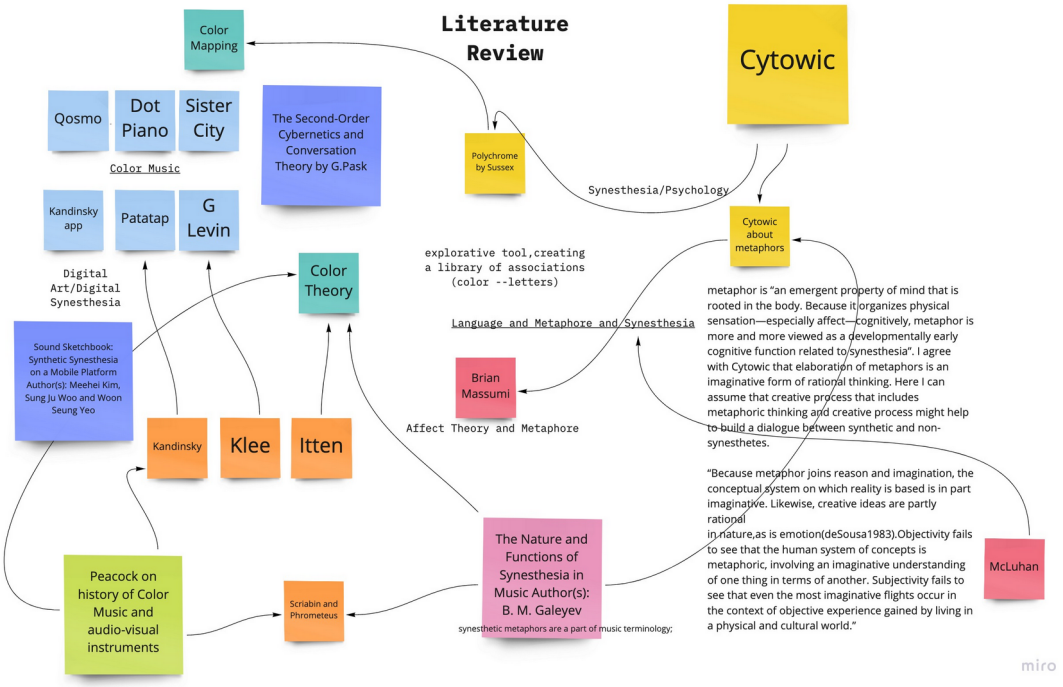


Figure 1. Mindmap "Searching and Organizing theoretical sources", image by Maria Shirokova, created via Miro (https://miro.com/), December 2020

Instrument and Apparatus: Colour Music

Music has frequently been associated with the concept of colour since before the time of Aristotle, and the ancient philosophers believed "harmony to be the union of varied coloured things" (Peacock, 2015). In the article “Instruments to Perform Color-Music: Two Centuries of Technological Experimentation,” Kenneth Peacock talks about the history of colour music instruments and how they changed throughout centuries. The correlations between music and colour have seemed a most natural human activity, and the topic has been of interest to creators and thinkers in many fields. Various theories on these connections were developed by Plato, Aristotle, Newton, a poet and philosopher – Goethe, a colour theorist – Johannes Itten, a composer – Alexander Scriabin and many others.

Multimedia artist Golan Levin created five interactive systems that allowed people to develop and perform abstract animation and synthetic sound in real-timy (Levin, 2000). Each environment was an experimental attempt to design an interface that was supple and easy to learn yet can also yield interesting, personal experiences in both the visual and audio domains. In Levin’s systems, sound and colour are affected by the user's gestures, stroke pressure. Human and machine interaction turns into a dialogue, where both roles impact the audio-visual outcome. Sonifying and visualizing processes are synced, and the user can see the patterns and then control them by different mouse pressure or location of the mouse on the screen. Levin created a set of live rendered experiences but with a fixed set of relationships. Golan Levin points out that although systems that only offer limited possibilities for manipulating or combining precomposed sounds guarantee a satisfying aesthetic output, they greatly restrict the recipients’ ability to exert their own influence on the artistic production. He raises a question about the level of limitations versus aesthetics and learning experience. By creating pre-mapped relationships he increases the learning and exploring curves and guarantees interactive aesthetic experience. However, even Levin’s systems can be explored and learnt. The notion of a learning environment implies that the exploration process turns into a skill, and the user is no longer interested in the process but the result.

Although this research focuses on providing a personalized experience, it still attempts to make this experience playful and attractive for the user. Creative tools and interactive art-making experience are crucial elements of this research. Therefore it is necessary to look at the notions of device, tool and artwork. Katya Kwastek, in her essay “Audiovisual Interactive Art: From the

Artwork to the Device and Back," defines the main characteristics of devices compared with the notion of the artwork: standardization for the result versus originality/novelty/exploration for the process. According to the definition of the Merriam-Webster Dictionary, an instrument – is " a means or implement by which something is achieved, performed, or furthered." (*Merriam-Webster.com Dictionary*, Merriam-Webster, https://www.merriam-webster.com/dictionary/instrument. Accessed 15 Mar. 2021)
Kwastek says that the increasing level of the virtuosity of the participants shifts the interactive art experience into the realm of devices and tools. The result of the experience becomes more important than the exploration process: interactive artwork mutates into a device. This system becomes an apparatus due to the complexity and programmed resistance that actuate the aesthetic experience or serves the purpose of producing an audiovisual result.

One of the questions behind the research is the level of control and customization for the user. Including more mappings and connections by the designer would prolong learning and interaction for the user, but it would decrease the level of personalized experience. *Can you hear your drawing?* is eager to combine the aesthetic experience and users' ability to visualize and sonify their sensations.

As a designer and artist, I was interested in providing the users with self-exploratory experience with possible creating interactive interfaces with unexpected mapped systems (e.g. the scale of the shape affects sound's volume or opacity effects sound complexity), but as a researcher, I followed the idea of creating a sensation diary, where user can set their own connections and meanings. It was helpful to understand the possible level of creator's control and the level of users' freedom and customization. This app can be used for both, self-exploration experience and digitizing user's audio-visual sensations. For participants of this project, both exploration process and result in the form of audio-visual composition might be important as the outcome is a tool that lets users explore their sensations and create audio-visual compositions based on these sensations. According to Kwastek, this project lies in the realm of artwork apparatus or device apparatus.

Dialogue: The Second-Order Cybernetics

Another framework that is considered while designing an interactive system as a tool for

conversation is cybernetics. Similar to synesthesia, multimodality and interactivity, cybernetics is a transdisciplinary notion and applied in many fields. The main goal behind the *Can you hear your drawing*? is designing a creative tool, conversational tool and self-exploratory tool – a learning environment, where (self)conversation and (self)understanding are significant for building a dialogue between users.

Biologist Humberto Maturana defines cybernetics as "the science and art of understanding," and it is difficult to imagine understanding without conversation. The conversation is one of the keywords on cybernetics: it can be a conversation between people, between machines and between people through a machine etc.

This research applies cybernetics as a framework for the design and interaction process. In particular, this study focuses on second-order cybernetics, in which there is an evolving and circular relationship between the observer and the observed.
For example, a few schemes can be applied for observation of the creation and sharing process in *Can you hear your drawing?:*

1. Self-exploratory/Sense diary

Users create audio-visual sketches to explore their creativity, synesthesia, multimodal associations etc. In this case, the observer creates and then observes their work.

2. Exchange/Dialogue

Users create their audio-visual compositions and exchange them for explaining, sharing or communicating their ideas via the app. In this scenario, they use the third-party tool for communicating the file or the code for inserting it into the app. They observe and are observed by the second user.

3. How many users → so many scenarios.

As this study shows later, *Can you hear your drawing?* can be applied not only for synesthetic and multimodal exploration, but every user can find their own meaning and application, as "we do not experience the same spot (twice), for although the spot may appear the same, at least in terms of location, we are not." (Glanville, 2007)

These scenarios illustrate some of the key principles of second-order cybernetics according to

Glanvill: observer included, application of understandings to self, self-reference, mutual reciprocity, improvement (not perfection) and circularity. All of the figures and schemes that illustrate cybernetics are circular, as the feedback loop is the base of conversation:

→ act→ sense→ response →

any conversation is built via this feedback loop

Glanville states that if the cybernetic interaction process is circular, the experience itself is a spiral. Because experience, “passage” is a process of change and learning that is different for the observer with every new interaction: “ On each iteration, we act, collecting the history of the iterations in an ever enrichening spiral.”

This research agrees that spiral is more exact at illustrating second-order cybernetics, as users' understanding of the app evolves with every action. Second-order cybernetics is also applied in the app structure. As the app does not include pre-mapped connections between sound and image, users must build this connection (audio-visual conversation) themself. The mapping process is the following: a person has to pick a shape and then assign it to the sound. However, there is a chance that after picking sound, the shape needs to be adjusted or changed. If in Levin’s works these adjustments and mappings are controlled by the machine, in *Can you hear the Drawing?* all the settings depend on users’ perceptions and associations.

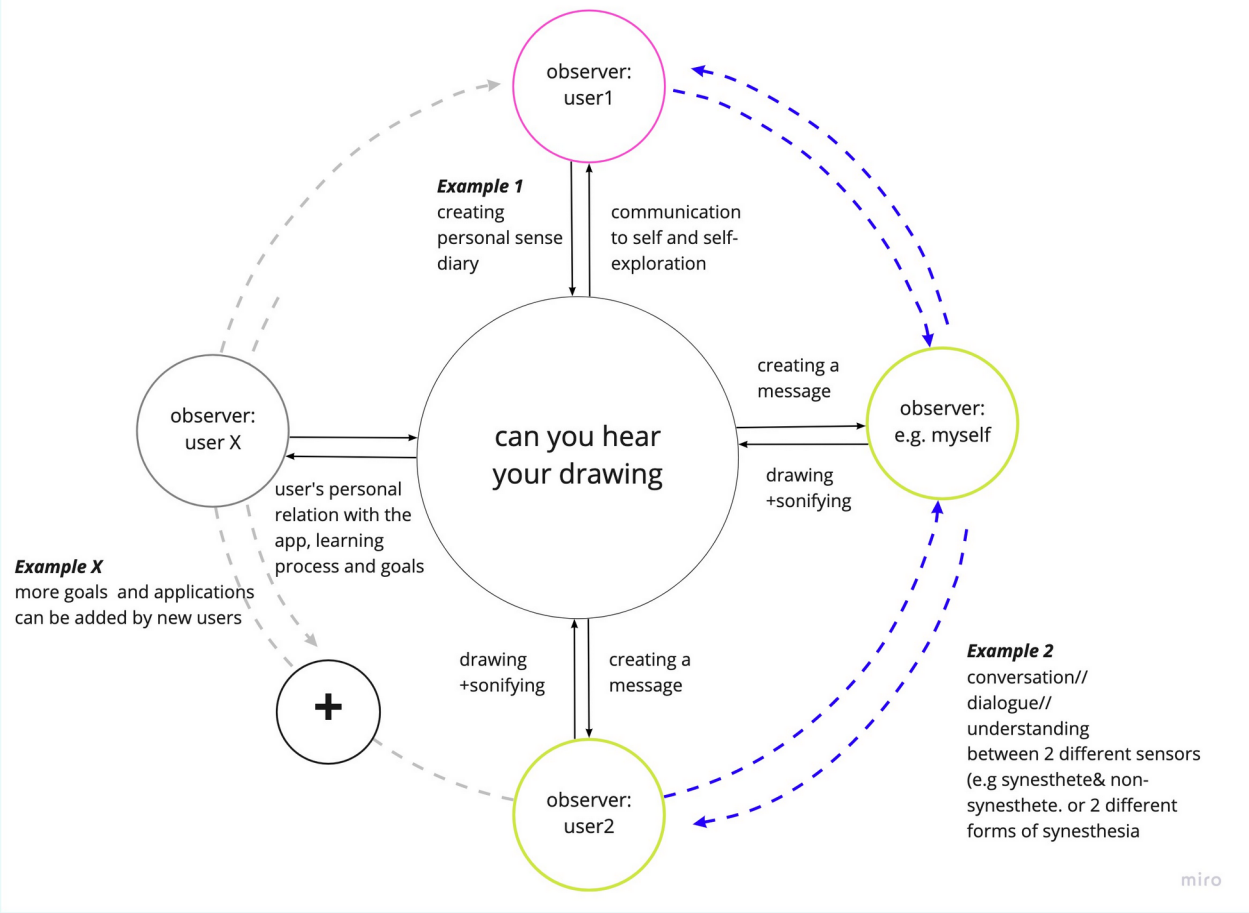


Figure 2. This scheme illustrates the Can you hear you drawing? in the context of second-order cybernetics, image by Maria Shirokova created via Miro (https://miro.com/), March 2021

Control is another critical notion of cybernetics: somebody starts the conversation, somebody monitors and moderates it. Glanville talks about control not as a restriction but as an enabling. As a designer of the system, I had to create a system of rules and limitations (even though the project's goal is to provide a personalized experience). *Can you hear your drawing*? is a system that aims to provide a personalized experience; many elements can be controlled and edited only by the creator, for example, sounds. At the same time, the user has all the freedom of mixing the sounds in any order and assigning them to any shape of any colour.

Synesthesia and Metaphor in the Context of Objectivity and Subjectivity

Being synesthetes, Wassily Kandinsky and Paul Klee, both teachers at Bauhaus, tried to represent his mapped audio-visual sensations through his paintings and explored the role of colour in music, dance and film.They gained inspiration in the ability to hear colours and shapes and explored the challenge of translating music into painting. Klee investigated similarities between auditory and visual rhythms, using the word “polyphonic.” Kandinsky was searching for a universal translation key between sight and sound. He later realized that audio and visual perceptions are unique for every individual. This research attempts not to universalize the senses but to enable individuals to translate them and to set the understanding between them.

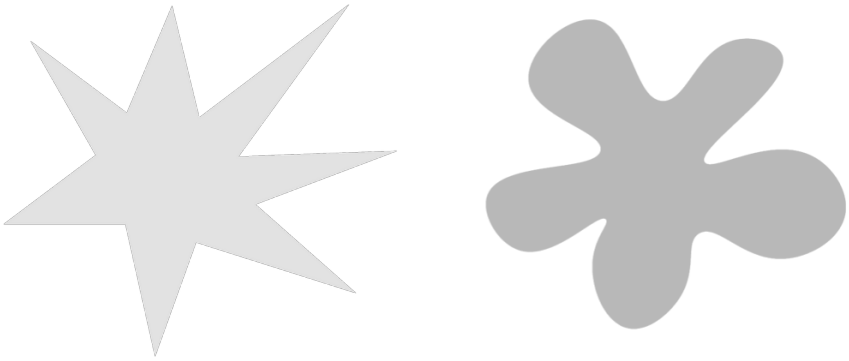
Sense understanding through metaphors and their translations are a natural part of many languages. It can be noticed how different kinds of synesthesia are fixed in the music language: baritones are heavy, “light” can be used both to describe weight, as well as colour tone and sound. Metaphor is not only an example of poetic language, as we use colour and tones to describe music and vice versa. According to Galeyev, “*similarities* in perception such as “dark is also strong” gave way to synesthetic *equivalences* such as “I know it’s ‘2’ because it’s white.” Galeyev and Cytowic agree on the connection between synesthesia and metaphor and how both of them antedate the appearance of modern language.

Although for artists, poets and musicians, the connection of vision, hearing, and scent might be pretty obvious, some people might not notice or do not think about these correlations. Cytowic states that metaphor joins reasonable and imaginary thinking. In his opinion, the conceptual system that is a core for reality is in part imaginative, as well creative ideas are in part rational in nature, as emotion. Objectivity fails to see that the human system of concepts is metaphoric (e.g. imaginative and analogical thinking and understanding), while subjectivity fails to see that imaginative thoughts occur in the context of objective experience dictated by the physical world. Our sensations often provoke our imagination and creativity. While sensation and perception are caused by affections from the objective physical world.

→ **objectivity → affect → sensation(including synesthesia) → subjectivity → imagination (including metaphor) → creativity →**

synesthesia and metaphor as connecting points between subjectivity and objectivity

There is a famous example that illustrates the connection between synesthesia, metaphor and language: test with Kiki and Bouba shapes created by Estonian psychologist Wolfgang Kohler in 1929. Test subjects are shown pictures of two objects, one spiky and star-like, the other blobby and rounded. Which nonsense name, bouba or kiki, they are asked, goes with which? Over 95 percent of subjects assign bouba to the round blob and kiki to the spiky star. (Rupp, 2021). Asked people do not have to be synesthetes to see the correlation between the shape and its name. This example is often used to explain the synesthesia phenomenon to the audience.



Figures 3-4. Kiki and Bouba from W. Kohler's test

This research aims to explore and demonstrate how to build a dialogue between synesthetes and non-synesthetes using metaphor as the primary tool. Cytowic in *Synesthesia: A Union of the Senses* supposes that metaphor is "an emergent property of the mind that is rooted in the body. Because it organizes physical sensation—especially affect—cognitively, metaphor is more and more viewed as a developmentally early cognitive function related to synesthesia". This thesis shares Cytowic's view that metaphors' elaboration is an imaginative form of rational thinking. This study attempts to prove that the creative process that includes metaphoric thinking might help to build a dialogue between synesthetes and non-synesthetes.

Synesthesia and Creativity: Synesthetic Approach

"Digital Synesthesia: A Model for the Aesthetics of Digital Art" is a research project about the synesthetic capabilities of digital art that was conducted by media artists, media and art scholars, as well as neuro- and cognitive scientists. According to Gsöllpointner et al.(2016),

synesthesia is an illustrative example of the brain's ability to cross-modally integrate two or more sensory modalities, dealing with synesthetic phenomena in which sounds are perceived as strong visual images. Digital art allows to translate and transform different forms of mediums; for instance, sonifying data, visualizing sound, the kinetics can be turned into text. Intermodality makes digital art multimodal. Artists and designers are available to map their senses digitally using various software, such as TouchDesigner, Wekinator, Cinema 4D, so interactive digital artworks can enable people to touch music, hear colours and expand their creativity and senses. They evoke synesthetic associations and activate particular sense vocabulary, and people are able to start seeing sense correlation between vision and audio experiences.

The synesthetic approach in digital media provides a broader view for the users and introduces them to new ways of world perception. Therefore, this research is eager to enable users to capture their sense of language and apply their associations in a creative tool frame. There is a study by Katrin Lunke and Beat Meier that shows that synesthetes have a significant tendency to devote more time to artistic activities related to their style of synesthesia and suggest that synesthetes may have better access to specific associations (the study conducted with 82 individuals with various types of synesthesia). A synesthetic view/approach could potentially help non-synesthetes to develop imagination and creativity. This research assumes that constant practising with mapping audio and visual for daily prompts might help people without synesthesia to discover unfamiliar sensations in the ordinary. Sevi Merter in "Synesthetic Approach in the Design Process for Enhanced Creativity and Multisensory Experiences'' suggests that the synesthetic approach can be used as a method in the design process. She assumes that this multisensory method allows intersubjectivity in the design process to associate unrelated qualities and modalities and link them with the imagination of the designer. This "thinking outside the box" method might prompt and inspire imagination, enhance interaction between the user and the product by providing users with unique sensory and emotional experiences. This research develops Merter's idea that the synesthetic way of thinking is inspiring and expands interfaces' ordinary vision. This research considers synesthete's perspective and explores synesthete communities' opinions on the connection between synesthesia, metaphor and creative practices and their view on design and interfaces.

Review of Related Works

Polychrome

The Sussex Polychrome Project endeavours to design tools for learning about synesthesia that is built by a collaboration between researchers and people with synesthesia.
The overarching purpose of this project is to investigate what synesthetic experiences are like and to develop tools for representing those experiences in collaboration with synesthetes themselves. The Polychrome Project aims to remedy this gap by developing an online colour picker that will enable synesthetes to create multi-colour words that better represent what they experience. It targets the colour-grapheme synesthesia audience and explores the patterns and correlations between users' letters and their colours. Users are free to pick the letters and assign them to the colours. There is no creative process behind the Polychrome, but it shares the same idea of a diary – a colour-letter diary (similar to Nabokov's notes about letters) that can be followed up through a certain time. Like Polychrome, this research focuses on creating a tool for synesthetes to explain their vision and perceptions. However, *Can you hear your drawing* app? explores the audio-visual type of synesthesia – chromesthesia and its influence on the non-synesthetes community. Polychrome is a research tool that collects user's data and analyzes it, while this study aims to explore the creative and metaphoric aspects of synesthesia in the form of creative tools.

Patatap

Patatap is an intuitive online application, a visual sound kit application with animations by computer programmer Jono Brandel and Japanese electronic duo Lullatone, consisting of Shawn James Seymour and Yoshimi Tomida. Patatap consists of unique palettes of colours, sounds, and shapes that are altered via the spacebar. The 26 melodic and rhythmic sounds that are in each set are triggered by pressing the A to Z keys. To develop an instrument where a user with no musical abilities could create a song, Lullatone made sure all the sounds were not "muddy if someone pressed too many buttons at once." Patatap applies the caleidoscope concept: all elements are predesigned, but users decide the outcome by selecting the keys. There is a powerful aesthetic part behind Patatap, and user interaction only affects composition partly, while it remains to look as it was designed by artists behind the scenes.

Cornelius Cardew

My interest in multimodality and further in synesthesia had started from reading an article about

Cornelius Cardew and seeing his drawn notes. He was an English experimental music composer and founder of the Scratch Orchestra, an experimental performing ensemble. He created *Treatise* – a handbook comprising 193 pages of lines, symbols, and various geometric or abstract shapes that largely eschew conventional musical notation. There are multiple repetitions, visual development of visual themes and images, certain logic, unexpected changes. Signs, situations and symbols that occur numerous times and signs that occur only once. *Treatise (Fig. 25)* can be understood, interpreted by each individual differently. The treatise was admired as a work that freed music from the constraints imposed by conventions in notation, which opened the way to completely different sounds. But at the same time, Cardew's score cannot be called absolutely free; the stretching line of images somehow calls on the musician to share his thoughts on the topic of what appears before his eyes. Here sound takes on the characteristics of a completely different language and communication tool. It is a very natural and pure instrument, isolated from concepts and laws.

Treatise, in my opinion, can be called as an anthem to subjectivity. Drawn notations by Cardew set up the tone but do not dictate the final music outcome. While developing the app, I was following the same principle: in the final prototype, users are given a limited amount of sounds, but the drawing part is very open. Users' outcomes may sound very similar, but each of them looks unique and different.

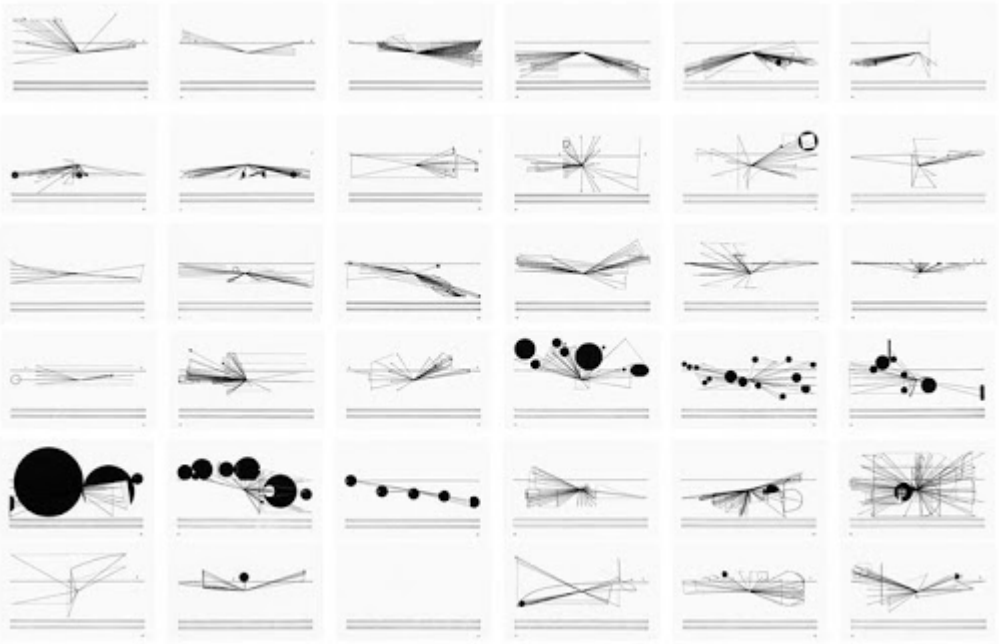


Figure 5. Pages from the Treatise by Cornelius Cardew

Iannis Xenakis

Fusing the ancient greek terms “poly” (“many”) and “topos” (“place”), Iannis Xenakis coined a neologism for his set of spatial creations that mixed sound, light, colour and architecture during live performances. (Fabrizi, 2018) The Polytopes may be considered a summa of Xenakis’s interests and skills because his formation and experiences made him a prolific composer in the realm of music and architecture.

Polytopes is the collective name of a series of multimedia installations, including sound, light and architecture, created by Iannis Xenakis during the 1960s and 1970s. (Fabrizi, 2018) In the Polytopes, Xenakis inserts-by means of loudspeakers and flashing lights-several layers of light and sound into existing architecture or a given historical site. These layers’ resolution is such that they almost allow him to draw or even construct in these superimposed, immaterial spaces. Transposing his abstract and geometrical vocabulary (based on the axiomatic entities of point and line) to the sphere of light and sound in the Polytopes, Xenakis realizes a global and parallel formalization in the spaces of architecture light and sound. He pursues in a certain way Kandinsky's theories as exposed in *Point and Line to Plane*, where he later developed the vocabulary of abstract painting as based on the elementary notions of point, line and move. (Sterken, 2001) Xenakis's aim is precisely to play with the diversity of the senses and not to create correspondences in their expression. The audience has to contribute actively to the construction of the sense of these artworks; the spectator himself has to affect the operation of synthesizing the proposed spectacle’. Therefore, instead of focusing the spectator's attention by merely playing with his reflexes or corporality or hypnotizing him with sequences of familiar images, Xenakis's abstract and multi-layered Polytopes try to open the audience's mind to diversity and simultaneity. This way, these electronic poems express the idea of intelligent interactive space. (Sterken, 2001)

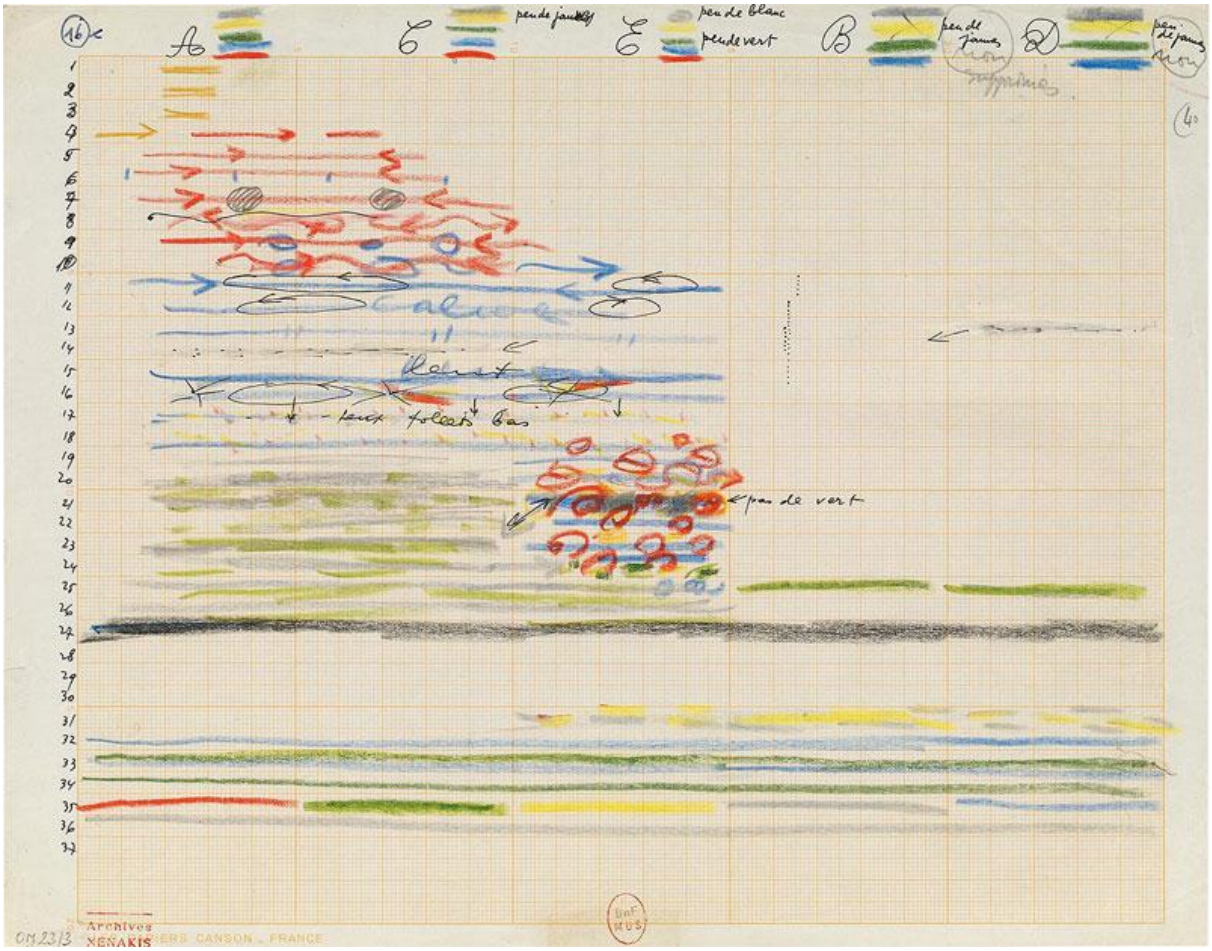


Figure 6. A study diagram from Persepolis's Polytope

video link: https://www.youtube.com/watch?v=iklDWi1-HLA

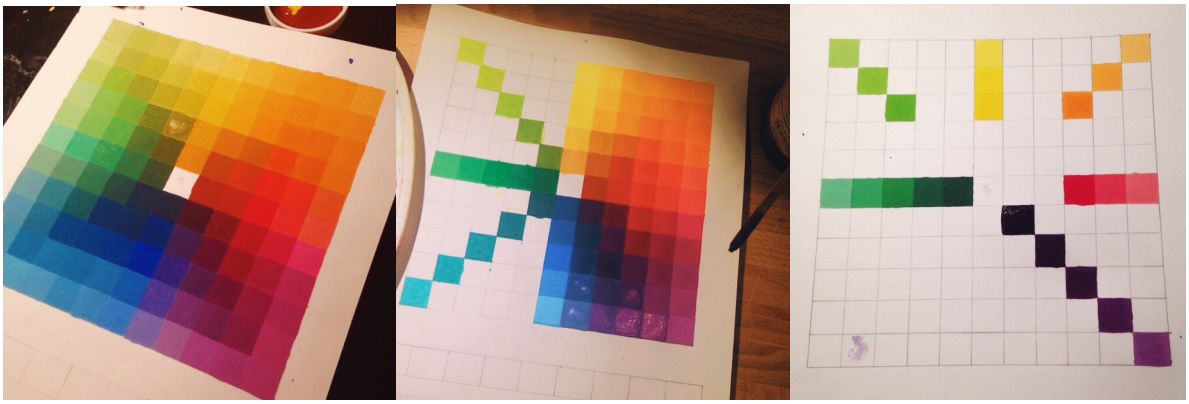
Johannes Itten

Johannes Itten is a Swiss artist, the foremost researcher of colour in art and one of the leading teachers of the famous Bauhaus. He has tried to help readers clarify a number of colour problems. He states the fundamental laws and rules of its objective nature, and he also accurately determines the area of subjective limits in the sense of the taste assessment of colour. He analyzes the patterns of colour contrasts, colour harmony and colour design.
He compares the subjective nature of colour to music: although it is perceived uniquely by everyone, both colour and music have the structure: "and you just need to see twelve colours with the same certainty with which a musician hears twelve tones of his scale." (Itten, 2002)
This research focuses on his approach of mixing colours and creative exercises that he developed as supporting material for his theories. In particular, this research explores the

colour square approach that is based on the 12-colour wheel:

Square is divided into 13 x 13 small squares (Fig.7- 9). The first square in the top row on the left must be left white. Twelve colours of the colour wheel should be placed in the upper horizontal row, starting with yellow, through yellow-orange to yellow-green. In the squares of the first vertical row, you need to consistently give a violet colour and through blue-violet and blue come to a red-violet colour. The second horizontal row squares are obtained by mixing each colour of the first horizontal row with purple. The third horizontal row squares are filled with a mixture of the colours of the first horizontal row with blue-violet. When each colour of the first vertical row is mixed with the colours of the first horizontal row, then in the general scheme, the diagonal of gray tones will be clearly visible from left to right because this is where the connection of additional tones occurs. (Itten, 2002)

According to Itten, these exercises help to understand the structure and the significance of colour. Applying this idea of colour spectrum through the concept of metaphor, this project suggests the sound palette where the main elements are coloured blocks of sounds.



Figures 7-9. Exercises based on J. Itten's Colour Wheel, Colour Theory class, image by Maria Shirokova, 2015

Method and Methodologies

This project uses Research through Design(RtD) methodology and includes iterative design methods such as rapid prototyping, sketching, user testing, peer-reviews, mind mapping, wireframing and layouting. With creating a series of prototypes, selecting the most effective ones by evaluating them, in the result I build an app that is tested and analyzed by the audience. RtD helps to explore the capabilities of online applications in providing a multi-sensory experience to the user. To evaluate the role of metaphor in this research, I implement it at three main stages of this study and define terms *Theoretical Metaphor, Design Metaphor and Conversational Metaphor*.

- Theoretical Metaphor is applied in Contextual Review, where it helps to explain synesthesia and connect the gap between subjectivity and objectivity
- Design Metaphor is used as an RtD method in Prototyping
- Conversational Metaphor is used for building dialogue and evaluation: it was applied for building users' sense and association understanding between each other.

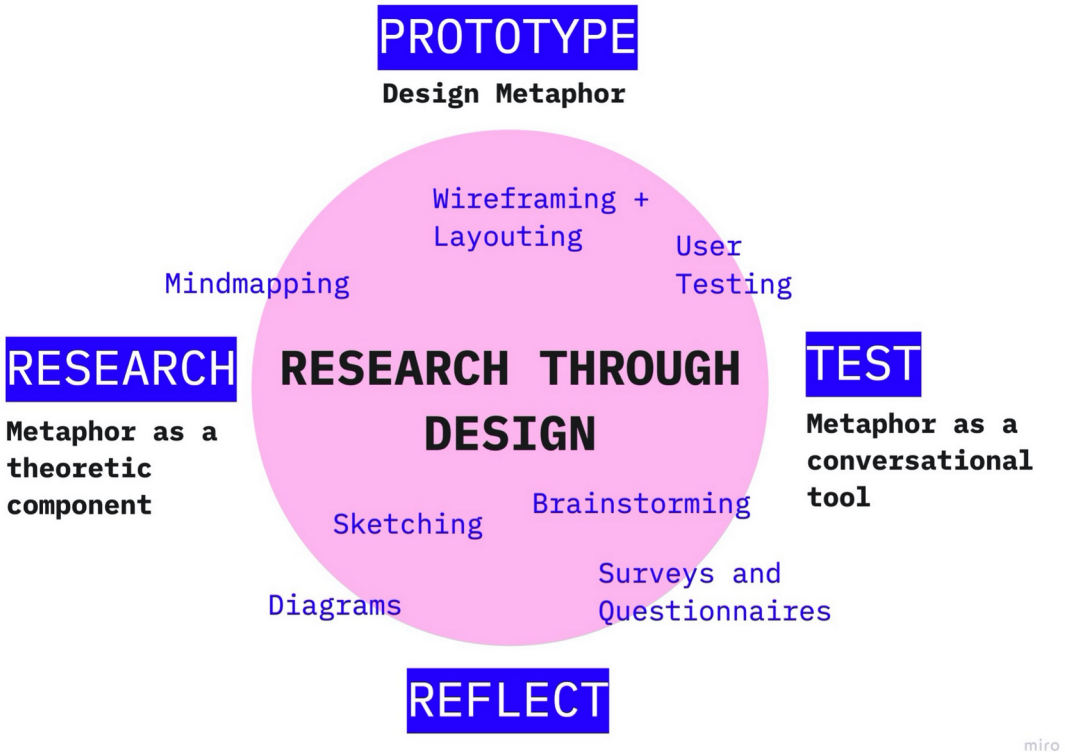


Figure 10. Methodologies and Methods, by Maria Shirokova, created via Miro (https://miro.com/), March

2021

Research Through Design

Over the years, designers have progressively integrated within the human-computer interaction (HCI) community (Gaver, 2012), and their projects take the form of research through design (Frayling, 1993; Zimmerman et al., 2007). In this methodology, the design practice is brought to perform on situations chosen for their potential, understanding legitimate means to approach the opportunities and difficulties inherent in such circumstances. Reflection on these results provides a variety of insights to be combined.
RtD is a user-centred, exploratory and learning process. RtD in this study consists of the development of prototypes (creative coding sketches) that play a central role in the knowledge-generating process and testing the concept and answering the research questions.

Behind this study, there was an intention to explore, experiment and reflect:

→ I research→I think → I prototype→ I test → I reflect→

According to the paper "Try again. Fail again. Fail better: the cybernetics in design and the design in cybernetics" by Ranulph Glanville, this research implied research-design methodology that can be compared with the notion of design as a conversation with the self (and with others).He defined central factors of design process:
(1) we look and then we draw;
(2) we see something new, not previously intended.

The research process can be divided into the following stages:

1. Research for creation ("conversation with the self and sources")

At this stage, the author explored the theoretical aspects of the research: synesthesia phenomena, metaphor, colour-music and their applications in the context of artworks and projects. Collecting all the material is very crucial for planning, structuring the prototypes and the future app. Research for creation was also used to answer the technical questions on how the tool would be built.

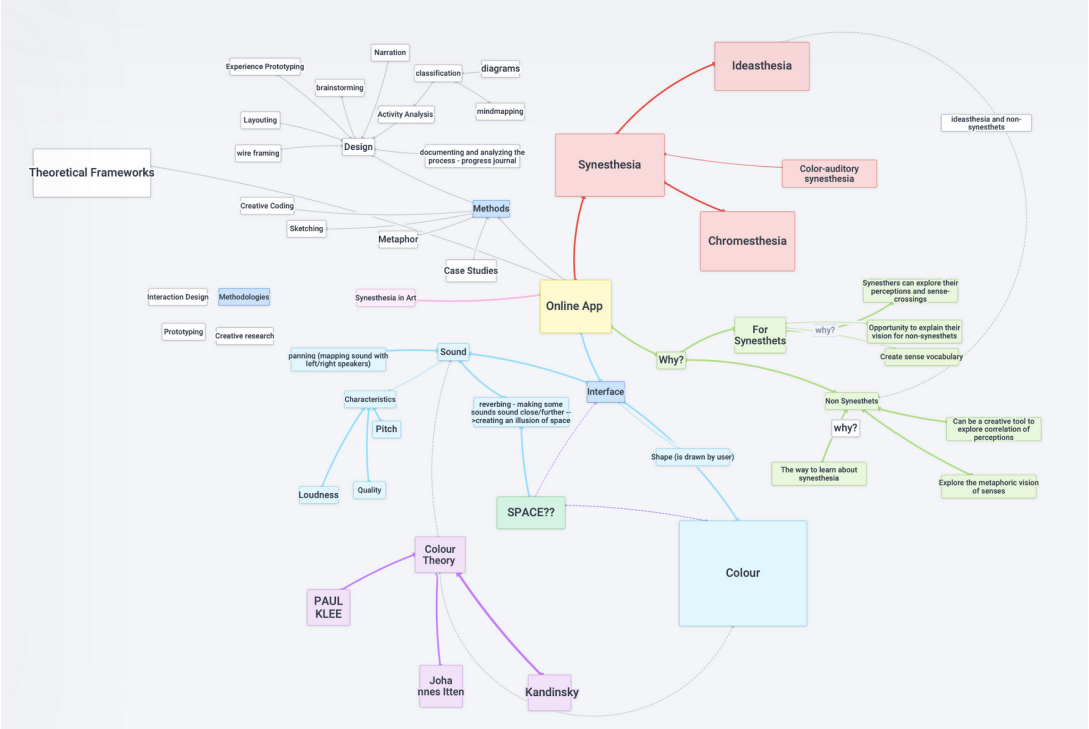


Figure 11. Mind Map illustrates psychological and artistic, and philosophical approaches used in the research. The scheme created by Maria Shirokova in Plectica (https://www.plectica.com/), July 2020

2. The “We look, and then we draw” stage is a prototyping stage after collecting information. At this stage, research was exploring the capabilities of online space in providing multi-sensory experience. By testing several software and programming languages and selecting the most effective ones, the author came up with the idea of programming in javascript and sound design via Ableton Live.

3. Research through creation (conversation with the self and the others):

This step answers one of the research questions about building an empathic dialogue between certain groups of the users. The hypothesis was being tested and evaluated, and research was being summarized. App as a tool for the study helped to explore and prove the connection and discover possible directions, new questions and application of the tool.

4. “We see something new, not previously intended” – a conversation with the others and with myself. At this stage of the research, the audience test the prototype provides feedback, and users develop their own vision of the app. At this stage, the author was able to analyze the audience feedback, its interactions with the app and define possible patterns and finally answer the last research questions about the role of metaphor.

Metaphor

The term “Metaphor” is one of the core method elements in this thesis. The term applied in 3 different ways, and one of them is a RtD method for building user interface. By applying metaphor, this research aims to create an experience that immerses users into a multisensory creative space. The project’s idea is built on a correlation and comparison of music and visual: sounds are like colours, sensations can be real or associative. The game of words and phenomenons inspired me to represent sound as a palette, and to turn geometrical shapes into musical instruments.

Casekin says that instead of reusing known design schemas and familiar solutions, the implementation of metaphors in design practice can contribute to creative thinking and, thereby, to more innovative products. The metaphor is used in creation aims to provoke metaphoric vision and to think among the app users. Using metaphors from the real world as models for the design of displays can ensure that we utilize our perceptions in the information world as we do in the real world. (Casakin, 2007)

Prototyping

Can you hear your drawing? is an app inspired by the auditory-visual form of synesthesia. I am not a synesthete but personally find this condition very fascinating. I hope some people share my interest and would like to explore synesthetic perception, and some synesthetes find this tool helpful during talking about their vision and hearing correlations. This app intends to unite non-synesthete and synesthetes and to collect their feedback in order to grow into a tool that could speak for both groups and would be interesting for everyone. This research aims to demonstrate that synesthetic vision can expand our understanding of ordinary senses and can inspire some creators on unexpected metaphors or drawings.

This app is a very simplified version of graphic editor and music software. The simplification of the familiar editors intends to create an accessible experience for users unfamiliar with such software.

The prototyping stage of this research consists of a series of sketches, that aimed to explore the ways of providing a multisensory experience in the webspace. The prototyping process started from considering different software suitable for designing an audio-visual tool: Touchdesigner +Ableton Live, p5.js. Machine learning using Runway Ml or Ml5 was also considered as a possible direction. However, having gained creative coding experience in the first year of my studies, I decided to work with Javascript libraries, which gives a variety of opportunities to work with drawing and sound. At the beginning of drafting ideas, I defined the main principles and main concepts for app development: sound palette, colour picker & gradient, mapping: sound palette, colour picker and gradient, mapping.

Sound Palette/Sound Picker (the idea of an intuitive interface)
This concept of representing sound interface as a palette/gradient grid comes from the Colour Theory methods. By using metaphor as a design method, I aimed to immerse users into space where audio and visual elements coexist in symbiotic relationships. I found the method of spectral representation of the sounds suitable for intuitive navigation.
During the prototyping process, this idea was changing, and the role of the gradient was evolving. It was inspired by colour theorists Itten, Klee, Kandinsky.

One of the design goals was to build an intuitive musical interface that attracts users without professional musical backgrounds to experiment with the app. Metaphoric comparison of sound and colour (Galeyev, 2007) and their similarity in a certain way inspired me to represent sound as a spectrum/palette of sounds, where the lightest shade represents the simplest single sound and the darkest/the brightest colour represents the most complex sound (as if the lightest colour was layered multiple times).

In colour theory, to create blending between two colours, you need to set up an equal step that determines the gradual difference between colours. Second, you mix two given colours (equal amount of each of them), and this is how you get the middle step colour. If you have more than one step in blending, you mix that middle colour with one of the given colours and get a new middle colour. Playing with different amounts of colour can give different results. I found mixing colour a playful process and wanted to experiment with the sound in a similar way.

Colour Picker and Gradient

An option to pick colours in an audio-visual composition is the key in the concept of colour music. Colour Picker is the fundamental code element that can be implemented with any Javascript Library. There were three reasons why it was crucial to include an ability to create gradients, both linear and radial, with an optional amount of steps. Firstly, users have more features to create, draw and experiment with colours. Secondly, gradient allows users to represent the complexity of the shapes, sounds, sensations based on their synesthetic or metaphoric association. Thirdly, the gradient can create 3D-like images and can add spatial-like sensations to the audio-visual experience.

Mapping

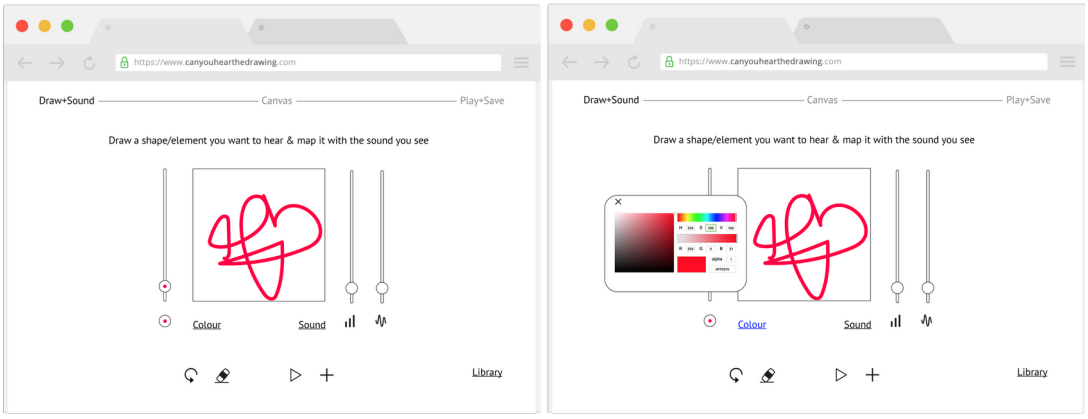
In the context of this research, mapping is used to talk about data relationships and connections. This study uses the term “mapping” to name the process of assigning/connecting audio elements with the visual aspects. For example, a green circle can be mapped to a high flute sound. The ability to map in my app provides a personalized experience and enables users to create their own audio-visual compositions. The goal was not only to map my own associations but to focus on giving users a choice and let them decide what audio-visual connection they want to build.

Prototype 1

The first prototype was an interface mock-up designed in Figma. The prototyping process started with organizing the idea into a possible interface of the future app and drafting/brainstorming its main functions and features, possible steps and the process. By using page layout and wireframing methods, I sketched possible looks and functions of the future app. Wireframing is a practice from UX design that allowed me to define and plan the information hierarchy of the future design for the app. I defined three main stages for future development:

Draw+Sound

This page was the main in the creating and mapping process: the user was supposed to create their visual image and map it with the sounds. The drawing part was planned to be simple: colour, the thickness of the lines etc. There were considered several options for the sound production part of the app: picking predesigned sounds from the sound palette; generating the sounds (in case users wanted to draft visuals depending on certain sounds); recording (the idea was to let users add their own sounds or to record the soundscapes). This feature was supposed to expand the given sounds and add more subjectivity to the app
Once users mapped the image with the sounds, they could save these mappings based on sensations/associations in the “library.”



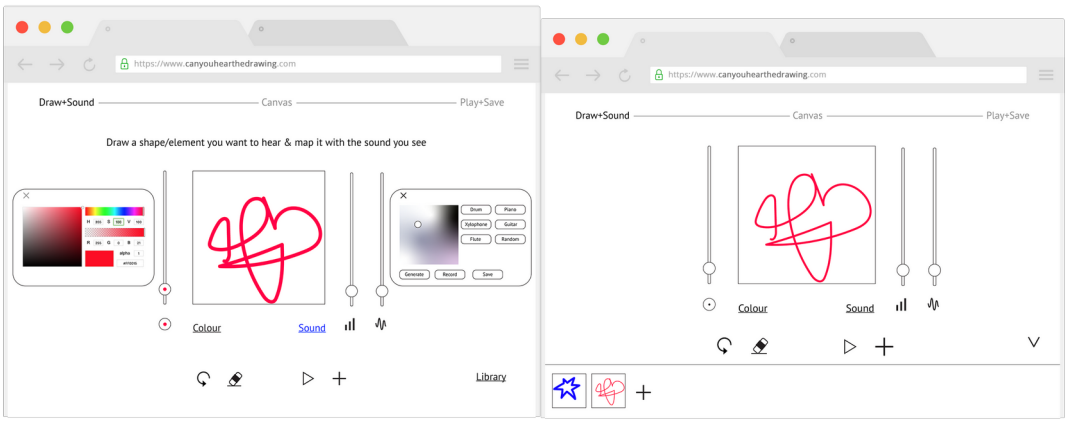


Figure 12- 15. The first UI prototype: Draw + Sound, created by Maria Shirokova, July 2020

Canvas

After creating audio-visual connections, users go to the canvas. On the canvas page, users explore and change their compositions by moving the elements around. Similar to the process of painting on the canvas, artists mix all their colours and prepare brushes in advance and then start their painting.

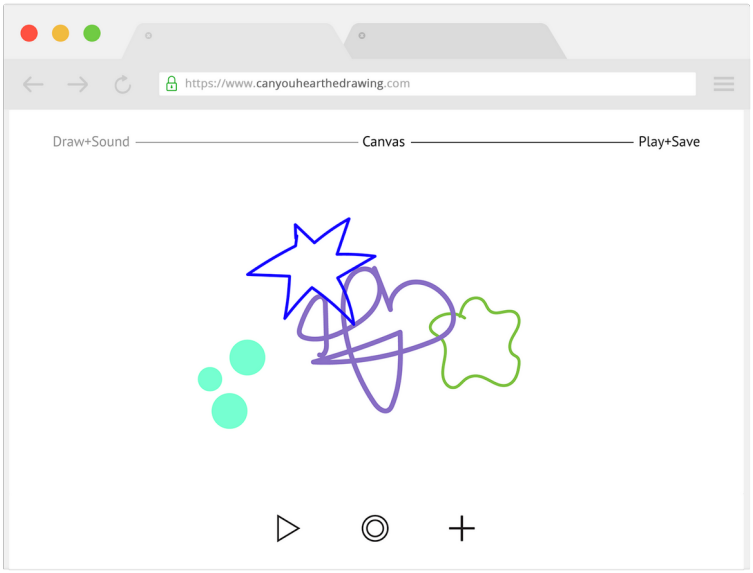


Figure 16. The first UI prototype: Play and Save, July 2020

Play & Save

The app's final page was planned to be a Play & Save page – "the playground" page, where users

could see their final composition, play and save and share with others. The goal of this prototype was to figure out the main steps and to define the following directions in developing the app: sound/visual/sharing and playing. This prototype also provided the main concept of the thesis research and played a role of a small intro. This process helped to define the main creative goals and to divide the working schedule into the main stages:

- Creating the Drawing part
- Creating the Musical Part
- Mapping audio with visual
- Putting everything together
- Additional features

Prototype 2: p5.js and sketching sounds

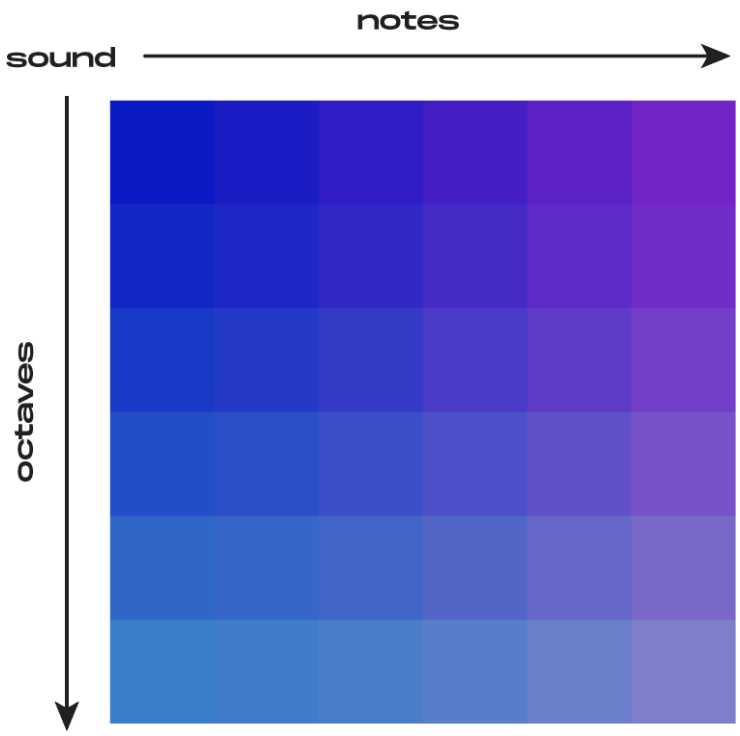


Figure 17. Audio prototype created in p5.js Web Editor, July 2020 link:
https://editor.p5js.org/MariaShirokova/present/W_pAfLekY (last time accessed in March 2021)

Once I organized the plan of future steps, I started creating a series of creative coding sketches or prototypes in p5.js. The first prototype focused on developing and testing the idea of representing a sound interface as a gradient and mapping it with the drawn image. The goal was to figure out how the sound can be divided into a spectrum: notes, octaves, pitch, volume, various musical instruments etc.

The basic knowledge of Music theory was implied. Experimenting with Tone.js allowed me to synthesize sound online with code. The first experiments aimed to understand the sound's structure and its main elements/parts: notes, octaves, harmony/intervals, rhythms etc. This is an interactive gradient – a grid 6 x 6 (Fig.17): by clicking different blocks, the user can create their own melody and then map it with the image. Horizontal gradient from blue to purple from left to right) is a gradient of notes; Vertical gradient shows the change of octaves (shades). On the one hand, the goal to experiment with sound synthesis and abilities to represent sound as a spectrum of colours was achieved during this prototyping stage. On the other hand, musical content needed to be more developed. Representing the sound menu as a 6x6 grid of notes and octaves better and more logically represented the idea of gradient and shades of sounds and colours. However, due to the simplicity of the sounds and the similarity between them, it was hard to create a melody. Therefore, later I decided to expand the complexity and variety of sounds by using Ableton Live.

Prototype 3: Paper.js + mapped sounds

At this stage, the goal was to figure out how users could visualize and draw their sensations. This project's main inspiration was abstract paintings by Wassily Kandinsky and his theory about composition, shapes and colour. In his work *Point and Line to Plane,* he defines the graphic composition's main elements: point, line, plane.

Two points together create a line, two lines create a plane. Multiple lines interact on the "basic plane" to produce a composition: "a composition is nothing other than an exact law-abiding organization of the vital forces which, in the form of tensions, are shut up within the elements." (Kandinsky, 1926). In his theory, Kandinsky wanted to design a language/system or a cohabitat of geometrical, aesthetic and spiritual concepts. He was blurring the line between "the science

of art” and “artistic science”. By referring to Kandinsky's theory, this project aims to let users create their compositions using the basic shapes that can be changed and edited according to their vision. In this context, simple geometry drawn on the screen is applied for recreating sensory visions of the users.

Another reason to use a simple shape as a drawing module was Cytowic’s research that shows that synesthetes vision is also based on “elementary: geometric configurations, lines, grids, spirals, or circular radiations.” Geometrical shapes can be the essential elements (like letters) in the “sense vocabulary”. I was considering two directions for developing the “Canvas” part of the app: the line drawing and drawing with the shapes. (Cytowic, 2002)

Prototype 3.1

Simple line drawing. The simple sketching technique was adopted for digital drawing: similar to drawing in notebooks, users were enabled to change the colour and thickness of the line. Digital linear drawing in p5.js does not allow to define where one line starts and where another line ends, which makes it impossible to divide lines into modules that can be connected to sounds.

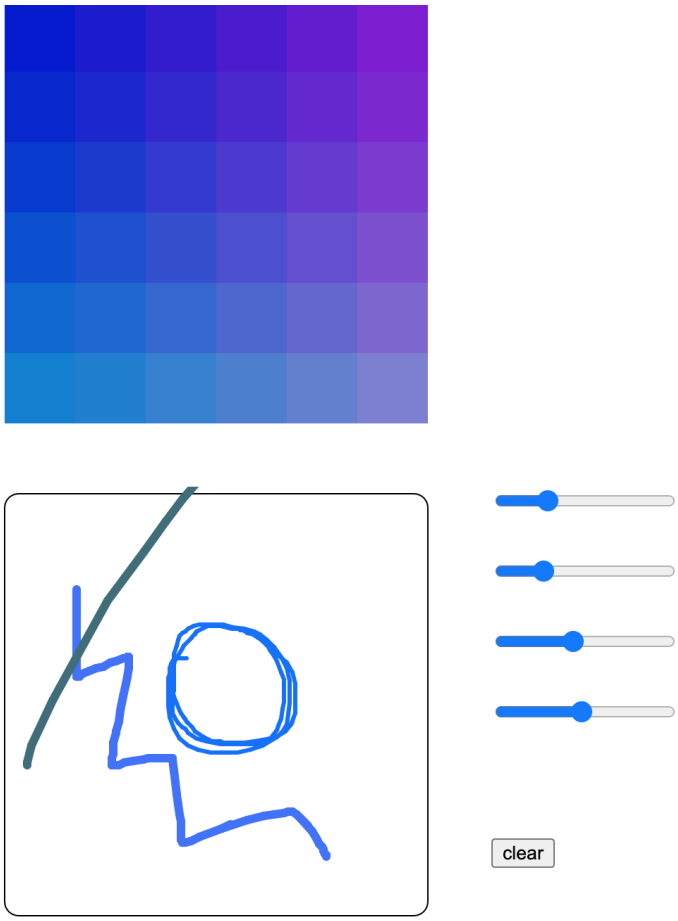


Figure 18. Audio prototype created in p5.js Web Editor, July 2021
link: https://editor.p5js.org/MariaShirokova/present/sbyil80UK (last time accessed in March 2021)

This p5.js sketch (Fig.18) illustrates the principle of drawing according to sound choice: at the top left, there is a musical grid (octaves and tones are the principle for organizing the sound spectrum) and in the bottom, there is a canvas. Users are supposed to draw a linear composition, according to the sounds they picked. First three sliders represent RGB settings: by changing them, users can pick and set up the colour. The fourth slider controls the thickness of the line.

Firstly, users pick the sounds from the top palette and then visualize them with a linear drawing. For example, what if certain sequences of sounds might be visualized with blue zigzag lines and a circle. This prototype was the first attempt to combine sound interface with drawing. Due to the lack of organization in linear drawings, I later decided to work with geometrical shapes as a visual module.

Prototype 3.2: vector shapes as a creation module for drawing

This prototype stage employs Paper.js. – a javascript library is based on and largely compatible with Scriptographer, a scripting environment for Adobe Illustrator with an active community of scripters and more than ten years of development. It allowed simply to select the shapes, add points to them or move them around on the canvas.

The geometrical shape seems to be a convenient segment of graphic compositions and can also play a note or a certain audio piece. Paper.js is a flexible library, and it can be implemented together with the sound libraries. For this stage, a code sketch using paper.js was designed, where a few random shapes were assigned to certain sounds. This prototype's sounds belong to Lulatone, the composers who developed sounds for the Patatap app mentioned earlier. This prototype provides an idea of a Play and Save canvas (described in Prototype 1) stage in my UI UX sketch: users mapped their shapes to the sounds and want to play their audio-visual composition. The editable and interactive black grid was implemented as a reference to the note stand and to the line in Kandinsky's Theory (Fig. 19)

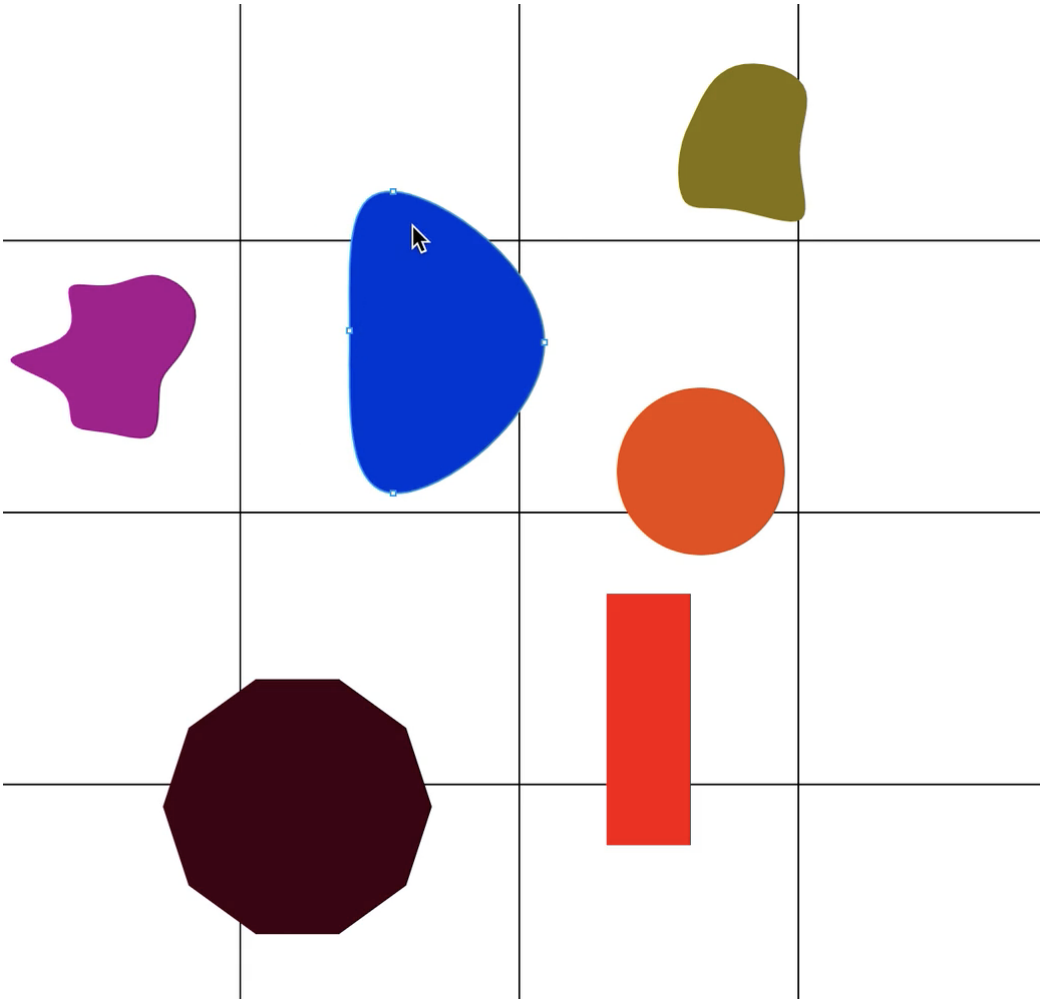


Figure 19. Prototype 3.2. October 2020. The interaction video link: https://vimeo.com/456713824 (last time accessed March 2021)

Although both prototypes were functional and could be applied for further app development, I decided to work with the paper.js and to use simple shapes as basic modules for the app. For instance, if a user needs to draw a line, they can edit the shape by deleting a few points. Paper.js is very flexible at changing and editing shapes. The feedback received from peer reviews was positive, and this prototype succeeded in representing multi-sensory space that can be customized by the user (shapes). Further, I was focused on providing a higher level of customization of audio and visual elements.

Prototype 3.3: an attempt to personalize the experience

Paper.js already makes it possible to change the shape with the mouse by dragging the points. Therefore, the goal of this prototype was to see how users can customize the shapes. Each

shape's gradient is connected to its coordinates. Each step of the gradient (every new colour in the gradient) also should be written in the code. Thus, in this sketch, it can be seen that every step of the gradient should be changed manually. This prototype was the first attempt at adding editable features. Users cannot only change the colour and gradients, but they also can add new shapes. (Fig. 20).

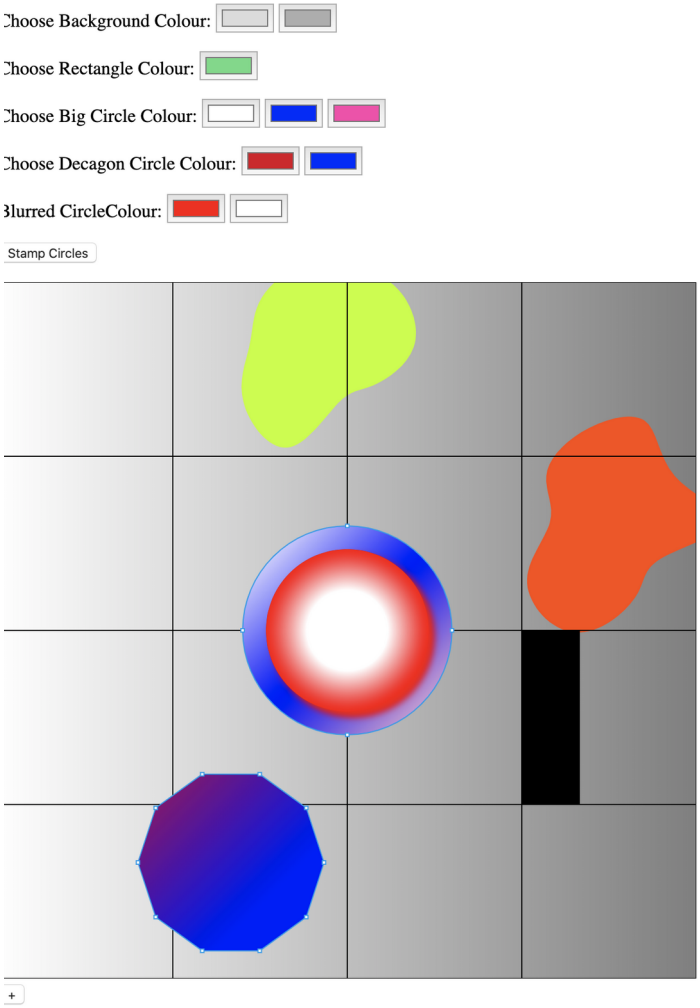


Figure 20. Prototype 3.3 October 2020

Prototype 4: sound production and sound mapping

There were a few ways of sound production considered for this app: p5.js, tone.js, flocking.js and gibber.js. Experimenting with those libraries provided more knowledge and understanding of the leading sound elements such as wave, tone, note, octave etc. However, I could not create sound palettes for the app due to the lack of knowledge in sound production and music.

The initial idea was to create an app in which audiovisual sound will be 100% dictated by users.

However, this idea appeared not to be practical as it requires the user to have professional music knowledge and some drawing skills. Therefore, this research took a path similar to Patatap: creating a series of sounds using music software mixed into one composition. Although this decision cancels the plans for a 100% personalized experience, it provides a much more pleasant and stable web experience. While the sounds are predesigned, the user still has the freedom to choose the order of the sounds and the length of the final composition and control the visual part: picking different geometrical shapes of various colours and sizes.

Prototype 4.1

Uploading the file and mapping it with the gradient:

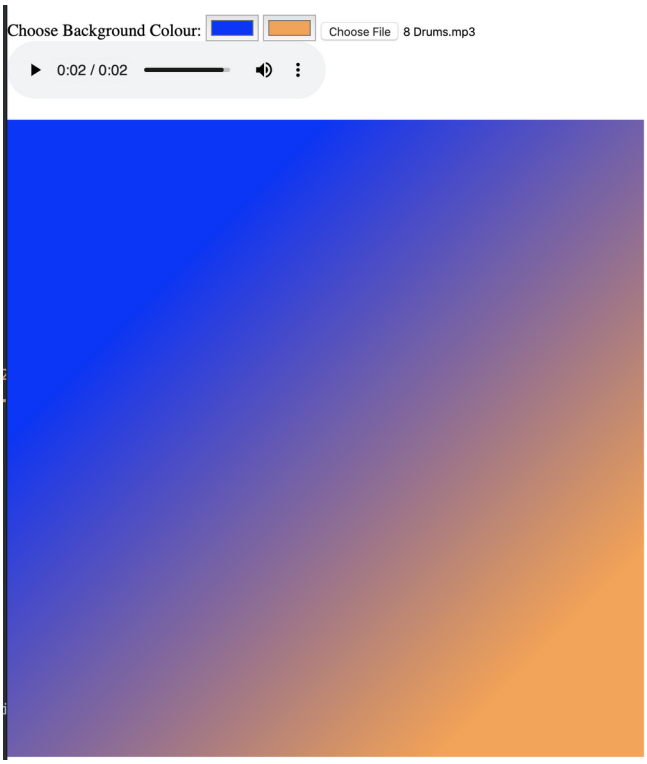


Figure 21. Prototype 4.1 November 2020 video link: https://vimeo.com/512746359 (last time accessed March 2021)

This prototype illustrates the idea of an ability to upload different files and map them with visuals. This function aims to expand the app's sound spectrum and provide a more personalized experience to the user. It is Javascript code with a two-colour-gradient and a function to upload and listen to the song. There is no technical mapping: according to the

uploaded sound, users can create a gradient-based on their sensation, association or mood. Although this feature was not used in the final prototype, it is still considered to be added in the future.

Prototype 4.2: implementing flocking.js

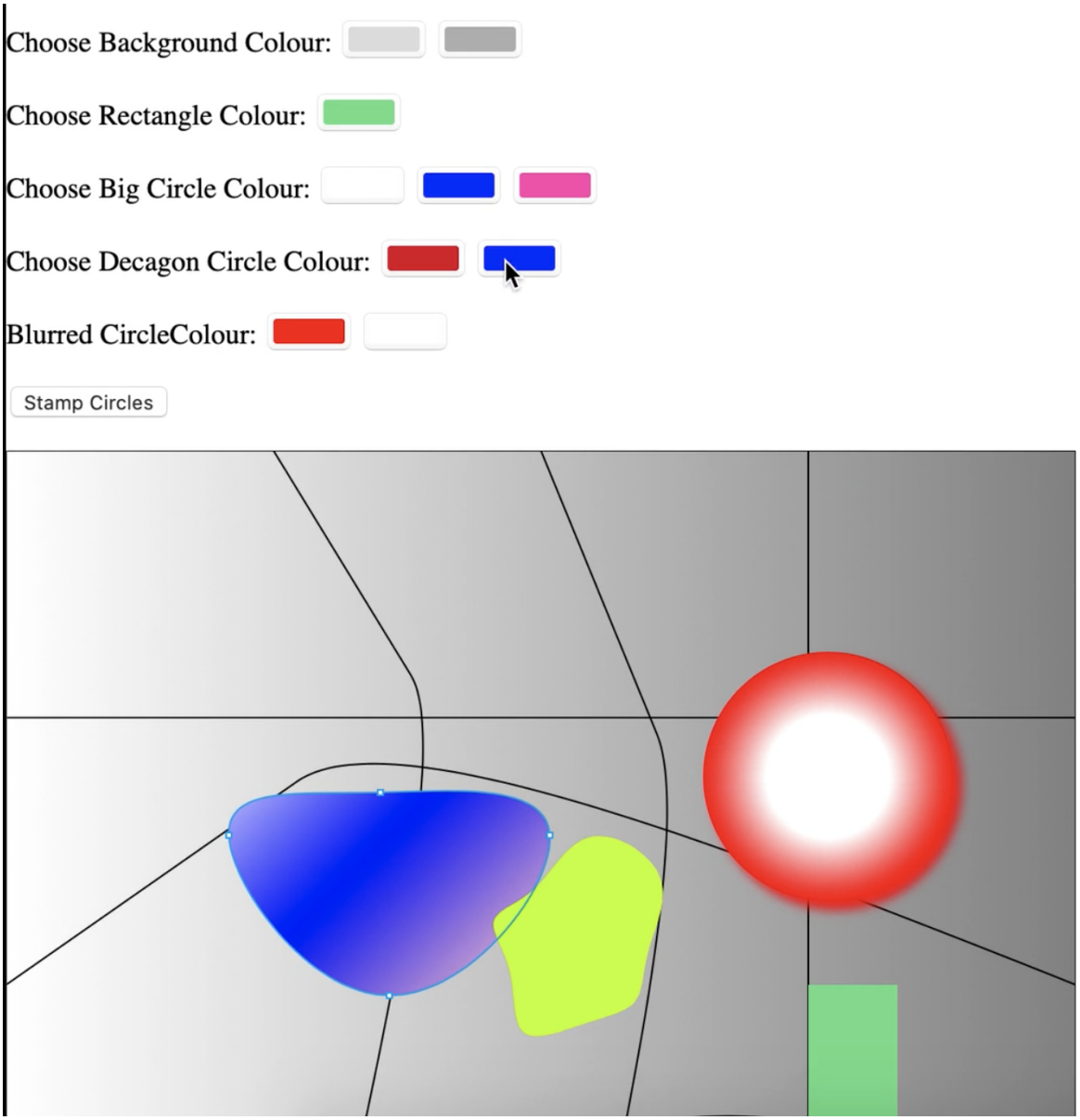


Figure 22. Prototype 4.2 Video link: https://vimeo.com/512742408 (last time accessed in March 2021)

This prototype aimed to explore flocking.js. The main question for me as a researcher and creator was if I can do online sound synthesis or I should experiment with music software such

as Ableton Live. This prototype is very similar to Prototype 3.2 – the first prototype with paper.js.

The main difference is the sound. While prototype 3.2 uses sound created by Lullatone for Patatap, prototype 4.2 shows attempts of working with flocking.js. In this prototype, sounds designed in flocking.js are assigned to the shapes. Flocking.js was introduced to me by Adam Tindale in the NIME course. It is a JavaScript audio synthesis framework designed for artists and musicians who build creative and experimental web-based sound projects. Although Flocking.js seems user-friendly and has excellent documentation, I only managed to create a few single sounds. Due to the lack of music knowledge, I could not make a spectrum of sounds – a gradient of sounds, as I wanted. Gradients of sounds mean four or nine relative sounds with different complexity but a similar character (e.g. same instrument, but different notes).

Prototype 4.3: Ableton sounds as a gradient

For this prototype, I designed a table in Javascript where each cell hosts a particular sound. One sound palette consists of nine cells – nine sounds. Gradient grid is inspired by drum pads with colourful modules: certain sounds are assigned to the buttons so that the performer can customize the pad. Drumpad's principle was combined with the idea of gradients and organizing sounds in a particular order and structure. Each block had a specific colour of the gradient: the lighter the colour – the simpler the sound, the darker the block – the more complex the sound.

The first pallets were designed by my friend, composer and musician, Jack Wictor. Then I added a palette of my sounds, designed in Ableton Live. The grid system makes it possible to add more sounds to it. While the user can not make their own sounds, the goal was to include various sounds and instruments to provide more freedom in musical choice.
The prototype helped to analyze the sound interface part of the future app. Having represented the interface in grids made it flexible for future changes, edits and expansions. This prototype was used for the final development of the app, as predesigned sounds could be easily combined into a melody.

Final Prototype: web development with react.js

The final prototype is an app that is based on my small prototypes and unites them all together:

drawing part based on Paper.js, sound gradient built-in javascript and Ableton Live.
The web development part was designed by my friend and colleague Sergei Prokopyev in React. JS. It is a JavaScript library for building user interfaces. React allows developers to create large web applications that can change data without reloading the page. The primary purpose of React is to be fast, scalable, and straightforward.

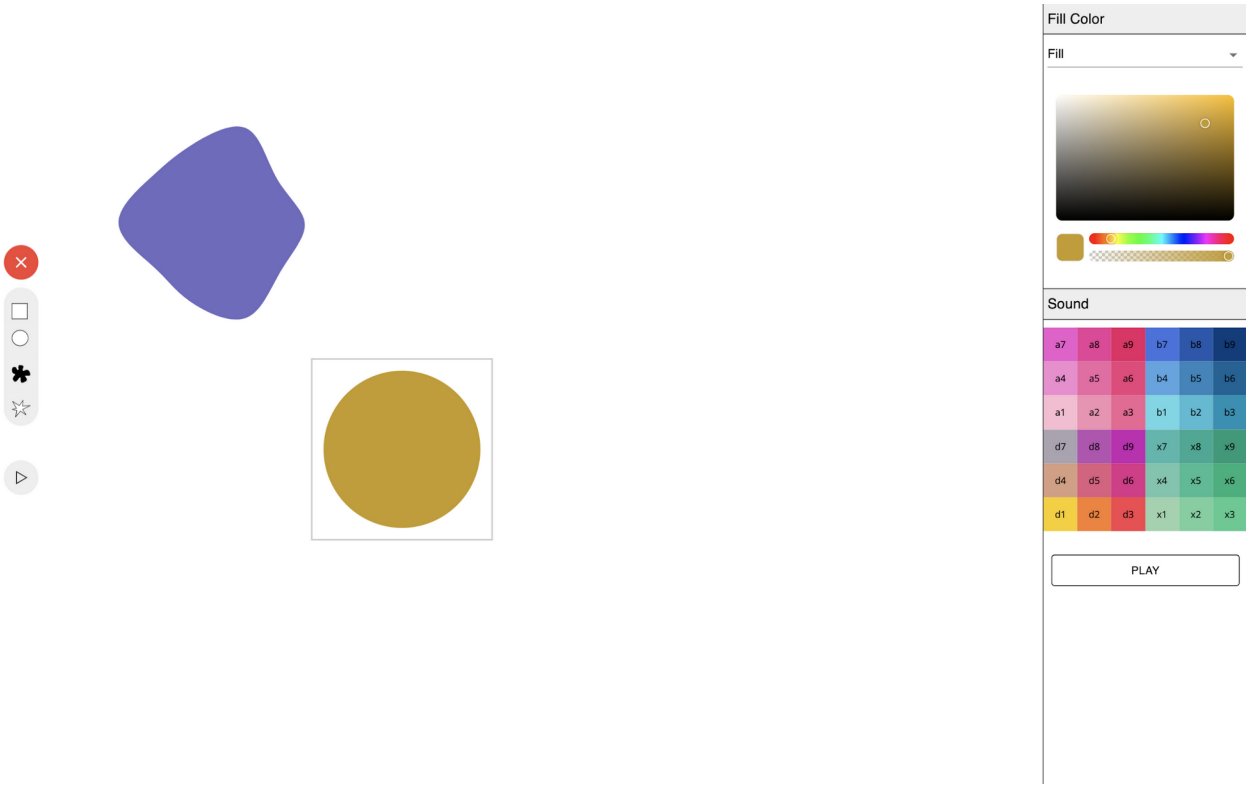


Figure 23. Prototype 5 at the User Testing stage

Video link: https://vimeo.com/507271852 (last time accessed 15 Mar. 2021)February 2021

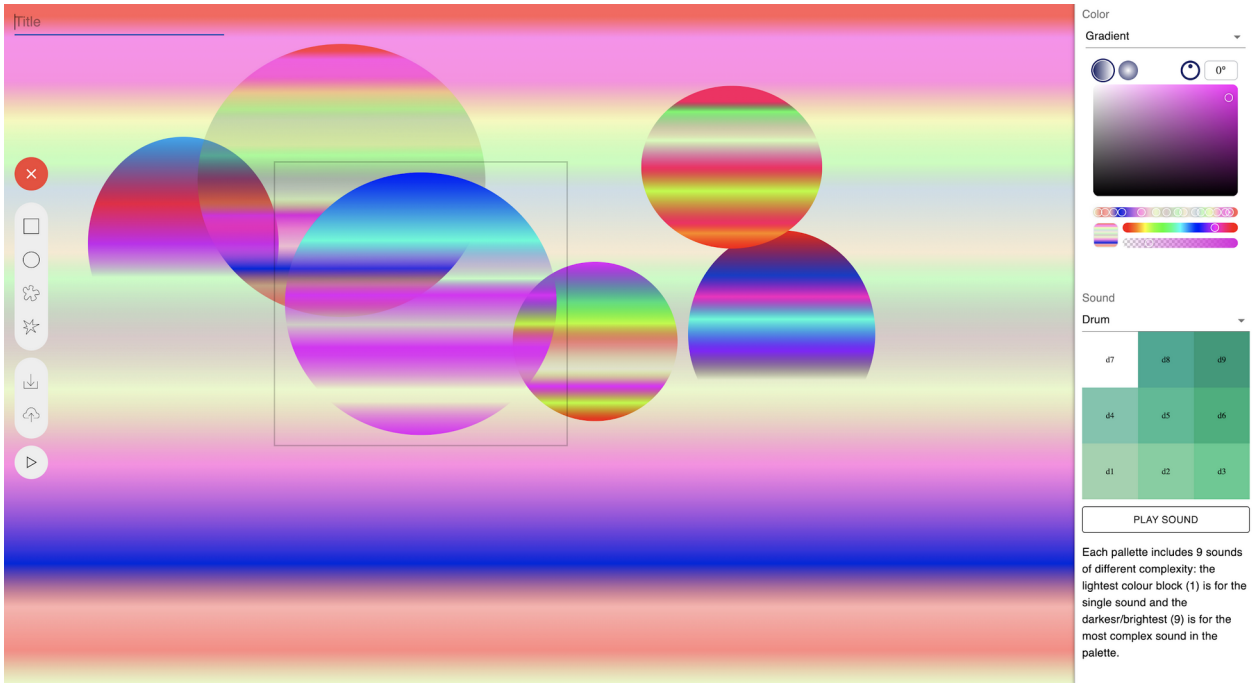


Figure 24. Final Prototype of the app, March 2021 https://canyouhearthedrawing-mariashirokova.vercel.app
Video link: https://vimeo.com/524636789 (last time accessed Mar.15, 2021)

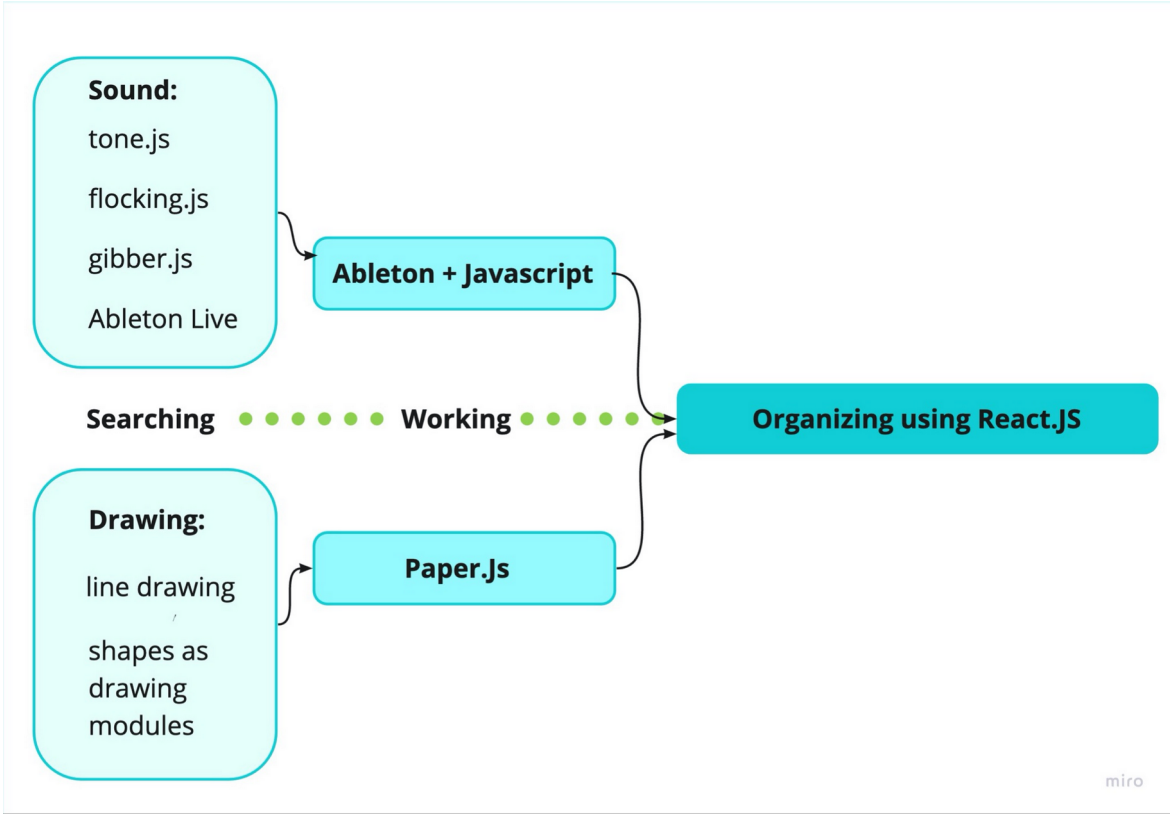


Figure 25. Prototyping stages, image by Maria Shirokova, created via Miro (https://miro.com/), February 2021

UI & UX

At this stage, the summer interface was reconsidered and adapted to the current prototypes and ideas using Page Layout and Wireframing methods. The main goal was to simplify all the steps and processes to provide an inclusive and accessible experience. This app targets not only the creative professionals but those who are interested and eager to experiment with their audio-visual mappings and do not have a background in art or music. Therefore, I defined the main options and represented them in 7 buttons on the left and sound and colour palettes on the right.

UI and UX prototype and the previous coding sketches allowed to communicate the idea for future app development. The final prototype aims to enable users to create visuals, assign them to the sounds and create a personalized audio-visual composition.

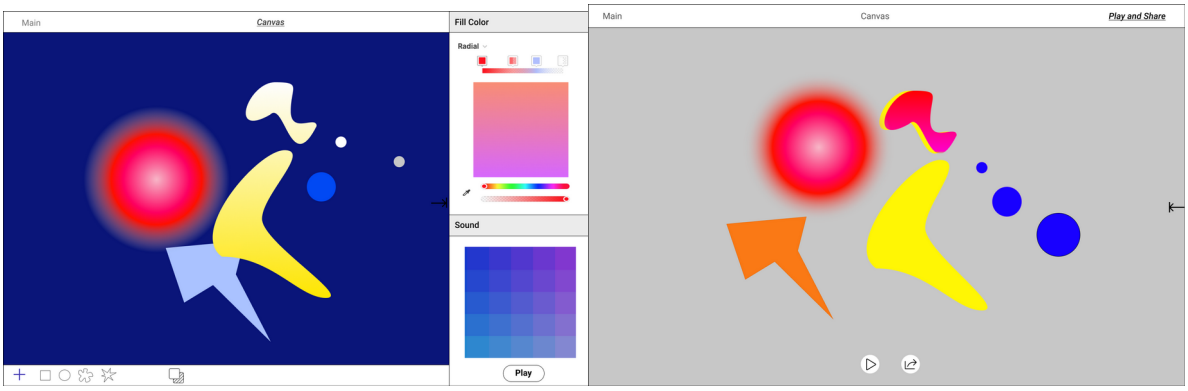


Figure 26-29. UI & UX prototype, November 2020

Drawing and mapping

The user has access to four shapes:

- Rectangle represents shapes with perpendicular angles that can be transformed into a line or a plane – one of the basic components of the compositions according to Kandinsky)
- Ellipse represents a circle or a point from Kandinsky's Theory.
- "Soft" round shape (Bouba) and "spiky" shape (Kiki) – a reference to the test by Wolfgang Kohler. Kiki and Bouba shapes are used as additional shape characters that provide more freedom in drawing. These shapes are very flexible, and the user is able to add, drag and delete points to them. The process is very similar to editing shapes in Adobe Illustrator.

Once users draw the shapes, they are able to assign sounds to them.

Play Mode

To play the created audio-visual composition, users should click on the play-mode button on the left and explore their instrument. Peer reviews and research committee meetings allowed me to get feedback while developing the app at its different stages. A very crucial comment I received from Dr. Cindy Poremba and Nick Puckett was to adopt the app for the touch screen. Firstly, tangible interaction expands my two-sensory experience from audiovisual to three senses. Secondly, having two types of devices (desktops and tablets) make the app more accessible.

Export-import JSON and 64 Base

A shareable option was very crucial for users to save and exchange their compositions. This was the key component in building dialogues and users' ability to explain their sensations. Sergey suggested 64base as an export-import format as these files are very light and collect the necessary data. Base64 is a group of similar binary-to-text encoding schemes representing binary data in an ASCII string format by translating it into a radix-64 representation. The term Base64 originates from a specific JSON (JavaScript Object Notation) is a lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate.

The sound interface concept remains open, as four palettes of sounds do not leave enough

space for creativity. The ability to upload files can lead to more variety of sounds and allow users to visualize the soundscapes they are in.

Achievements:	**Plans:**
Drawing	Record soundscapes and assign to the shapes
Sound as a spectrum/gradient	Uploading personal audio
Ability to share and store files	Online storage for compositions
	Simple animation tools

Table 2. Achievements and Plans

Exhibition

For the format of the final exhibition, there are two directions for online and offline shows.
For both variants, this project can be divided into a few parts: works made by people who took part in the user testing and would love to share their vision and experience, works created by me and works made by me but are based on the paintings and works of famous artists (Kandinsky, Matisse, Turrell, Hockney etc.). This approach would help to attract the audience to interact with already made pieces, but at the same time, they will be given all the freedom to change them, play with them, deconstruct and draw their own. Also, predesigned compositions can demonstrate the main functions and creative potential of the app.
In the gallery conditions, it could be presented with three projectors connected to 3 tablets with the headphones. A projected image on the wall is seen by all the audience in the space, while only interacting people can hear what they make or explore.

For the online show, this project was presented as a website with the gallery of the artworks, designed by synesthetes and non-synesthetes. Users were able to interact with audio-visual compositions using the app and create their own by using their tablet or desktop:

https://canyouhearyourdrawing.app/

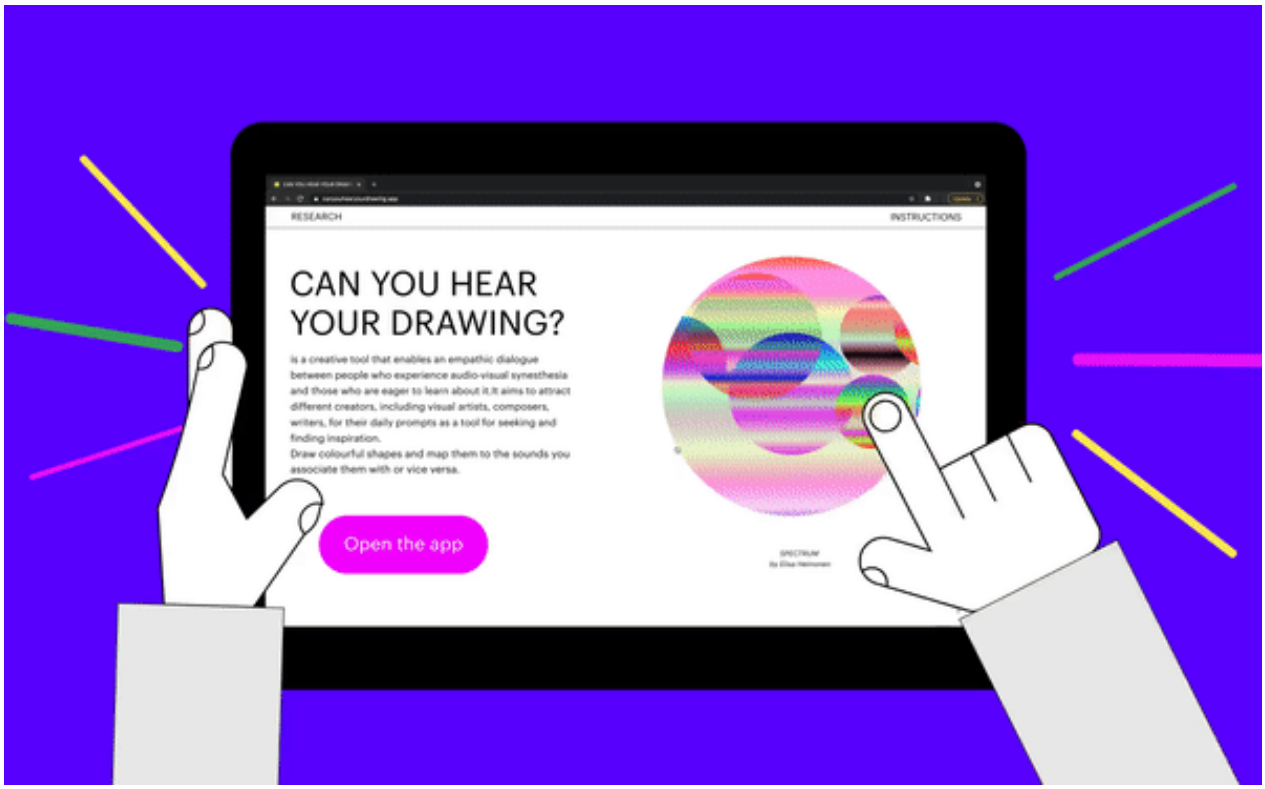


Figure 30. Online Gallery of the works made via Can you hear your drawing? app. All compositions can be experienced at https://canyouhearyourdrawing.app/ (last time accessed 23 Apr. 2021)

Building conversation: Audience and Feedback

This User Testing and the Brainstorming Session have been reviewed and received ethics clearance through the Research Ethics Board at OCAD University, file # 2021-07.

Receiving the audience's feedback and comments play an essential part in this research. I was happy to discover new research directions. For collecting data and feedback from the audience, there were two types of activities: Brainstorm Session/Discussion and User Testing Sessions. Both activities focused on the app's main aspects: design and effectiveness, main features, relationship to synesthesia, metaphor and creativity. User Testing played an important role in answering the research question about the capabilities of webspace in providing multi-sensory/synesthetic-like experience, while the Brainstorming Session aimed to explore more efficient ways of building a dialogue between synesthetes and non-synesthetes. Once the prototype was ready and functioning, its success and failures depended on the audience's

evaluation and their interest in this tool. The Brainstorming Session was held in February, when the prototyping process was almost finalized. However, this project does not end and it still can apply the knowledge learnt from this session in the future.

Brainstorming session

The purpose of the workshop was to gain insights from the synesthete community and to discuss the synesthetic point of view on digital interfaces and creativity using brainstorming and mind-mapping methods. As a part of the RtD methodology, this brainstorming session involved synesthetes who evaluated and tested the app and shared their thoughts on creating synesthesia-like experiences. All their insights were considered and applied (or going to be applied in the future) during the app further development.

Participants were asked to discuss the following questions:

1) What is Synesthetic Interface?
2) What would interfaces look like if they were designed by synesthetes?
3) How would designs look like in a world where the majority of people are synesthetes?

This session opened synesthesia and synesthetes completely from a different angle for this research. Being familiar with essays of Cytowic and Nabokov's diaries and being aware that synesthesia may cause disturbance or discomfort, I was assuming that there would be different answers and suggestions. I was prepared to hear participants' ideas on how interfaces can be improved, customized, to listen to their personal preferences in button designs, sound interfaces etc. This session involved five people, and all the participants agreed that they did not have any answers to my questions. They stated that people with synesthesia get used to living with their perceptions/sensations and learn to cope with sudden synesthesia senses in different situations. Yes, they can not turn off/on their synesthesia, but they know how to focus on the information/subject they deal with.
"We are bombarded with senses, but we know how to deal with it." This discussion also confirmed my thoughts that misunderstanding about synesthetic experience may only come from non-synesthete individuals.

Therefore, there was no need in designing something special for the synesthete community. With this session, I aimed to explore if people with synesthesia have preferences in interfaces,

websites, apps, but this conversation showed that synesthesia does not interfere with general perceptions of certain forms of information: synesthetes are able to consume and work with various sources of information. If before the session, I assumed that it could benefit my research and give more insight on building multisensory online experience. However, participants mentioned, they do try to avoid specific colours/sounds that can cause discomfort or unpleasant crossed sensations. On the other hand, there are unique senses they tend to experience by choosing certain types of music, smells, tastes etc.

"I am a huge fan of the Beach Boys because of their harmonies and the taste that I get with them is almost equivalent (depending on the song too) the piece of steak covered with some steak sauce or compared to the feeling of ice cream put on a freshly baked cupcake."
"Unfortunately, I had to avoid Bach because of my synesthesia.
It is a great thing that my mind and biological senses can tell me that this composer does not fit me".

To the question: *"How would the world look if the majority of the population were synesthetes?"* one participant answered: *"The graphic design would look different."*
Different does not mean better or worse. Subjectivity and customization I have been exploring while prototyping was completely missed and forgotten while speaking to the audience. Having two different research questions, I used the same principles of dividing the audience:
What important elements (aspects/studies/theories) should be considered while designing the interface of the multi-sensory application in order to provide users with the most effective environment for the personalized process of mapping sound with an image?
What are the digital interface possibilities of creating an empathic dialogue between people who experience synesthesia and those who are not familiar with this phenomenon?
The first question did not require dividing the audience into synesthetes and non-synesthetes as it was exploring the creative aspect of the app.

I made a mistake when I was dividing the audience into synesthetes and non-synesthetes for discussing the creative aspect of the app: synesthetes can be as different as non-synesthetes, being a synesthete can unite people as much as living in the same country (similar interests are not guaranteed at all). Dividing the audience into these two groups was not useful for researching the most effective environment for the personalized creative process and testing

the app. As the app is a creative tool, I had to change my target audience and define main characteristics as interest in creating colour music, interest in exploring creativity, metaphors and then synesthesia.

This discussion experience reminded me that I deal with different personalities and users and that I can not define the target audience by just synesthetes/non-synesthetes. As the app is a creative tool, it should target the audience who is interested in exploring creativity, in creating audio-visual compositions first, and then I can add an audio-visual form of synesthesia as a secondary direction for this project. I could not expect that every synesthete would be interested in the creative expression of their senses. Therefore I should prioritize the general user preference as creating/exploring.

Cytowic writes that synesthesia is more common among creative individuals and that synesthetes pursue arts (as a profession or as a hobby) much more often than non-synesthetes. Kandinsky was a synesthete, and this does not mean that every synesthete wants to be a painter. Study shows that most of the synesthetes who play music are very good at it and are very successful in memorizing notes, but it all depends on the personality and interests.

This session was a success and failure for the research at the same time, as this finding helped me to completely reconsider the way I target the audience-participants. Also, the participating collaborators shared their opinions on the app and described their sensations in detail.

A few participants shared their drawings during this study. They also described and explained some of the composition elements and what they discovered while using the app. With one participant, I had an online user testing meeting that evolved into a co-creation session.

This person has a colour-hearing form of synesthesia. She plays piano and paints. She describes her colour-hearing as every note has colours, and she hears songs/melodies in colourful shapes (size, kind of the shape, or its colour varies depending on the note, pitch etc.). She finds it very similar to the experience of Kandinsky. She prefers listening to classical music: Vivaldi, Mozart, Beethoven.
She described her main patterns in sensations:

- loud sounds are equal to big shapes;
- drums are seen as points or circles;

- the guitar is seen as horizontal lines;
- she never experiences “green” sounds
- the deeper the sound, the more black it gets vs., the higher the pitch, the lighter the sound (white +yellow)

During our meeting, I picked a few sounds of different complexity and instruments, and the participant drew the shapes according to the chosen sounds (Fig.30). During this session, the participant found out that she never visualized sounds into a star (Kiki) looking shapes. She said she never focused on such a sound and was surprised to “see” it: an orange star on the right was mapped to the first sound in the “Mixed palette.” Some sounds are “drawn” as a composition of shapes, for instance, the d8 sound from the “Drum Palette” is represented by three circles in the left corner (black, grey and orange)– she “sees” drums as circles. In her “vocabulary,” black is the lowest sound, and light white and yellow colours represent high pitch sounds. Volume can affect the size of the shapes: the louder – the bigger, and vice versa. The background represents the whole spectrum of sound colours “heard” by the participant.

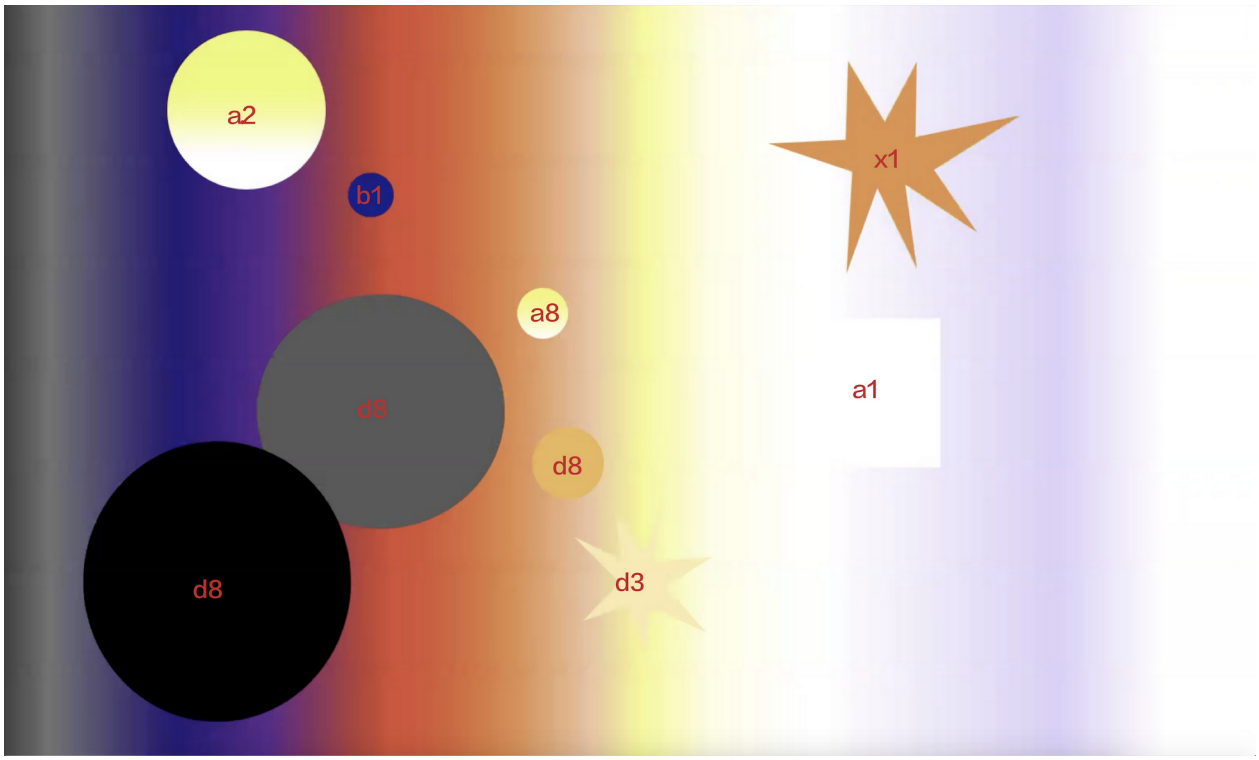


Figure 31. Audio-visual composition #1 created by the participant with colour hearing via Can you hear your drawing? the app, the shapes are signed according to the sounds from the palette. February 2021
Video link: https://vimeo.com/524388598 (last time accessed on Mar 16, 2021)

Figure 32. Audio-visual composition #2 created by the participant with colour-hearing via Can you hear your drawing? the app, February 2021

Video link: https://vimeo.com/524386516 (last time accessed on Mar 16, 2021)

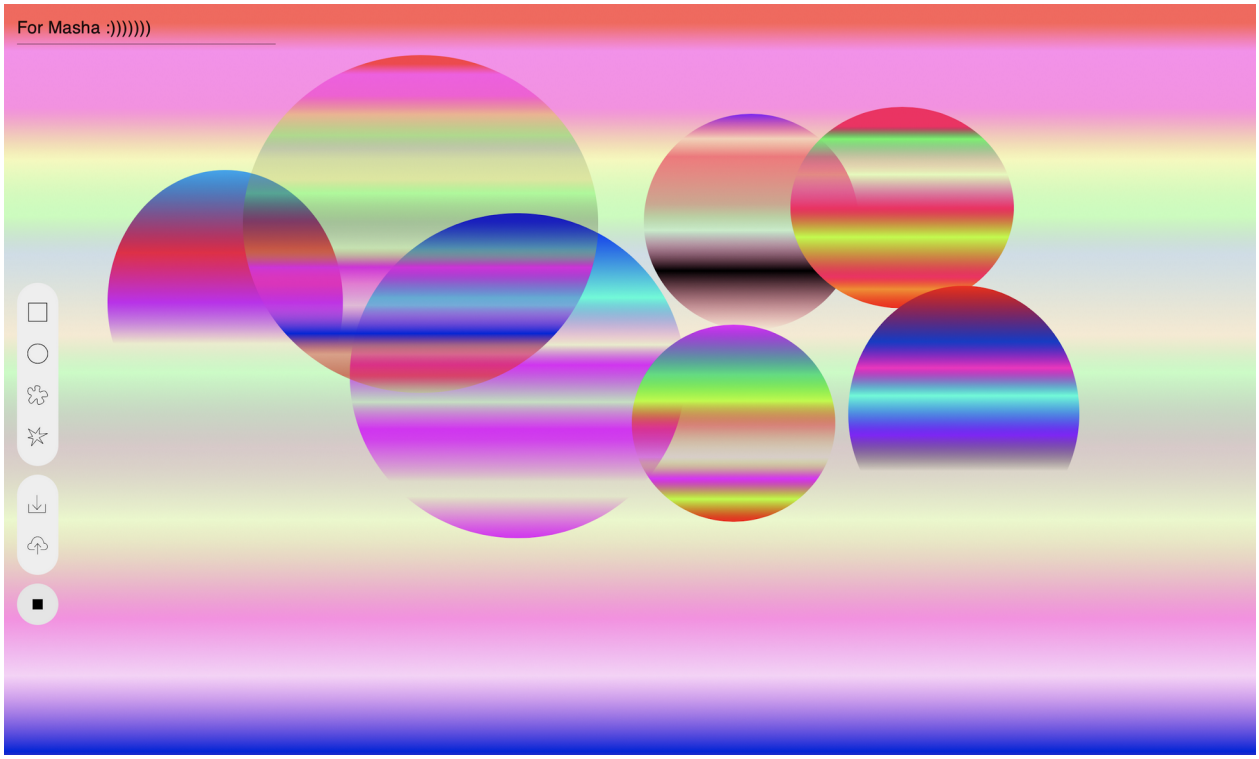


Figure 33. Audio-visual compositions created by Elisa Heinonen via Can you hear your drawing app, February 2021

Video link: https://vimeo.com/524393280 (last time accessed on Mar 16, 2021)

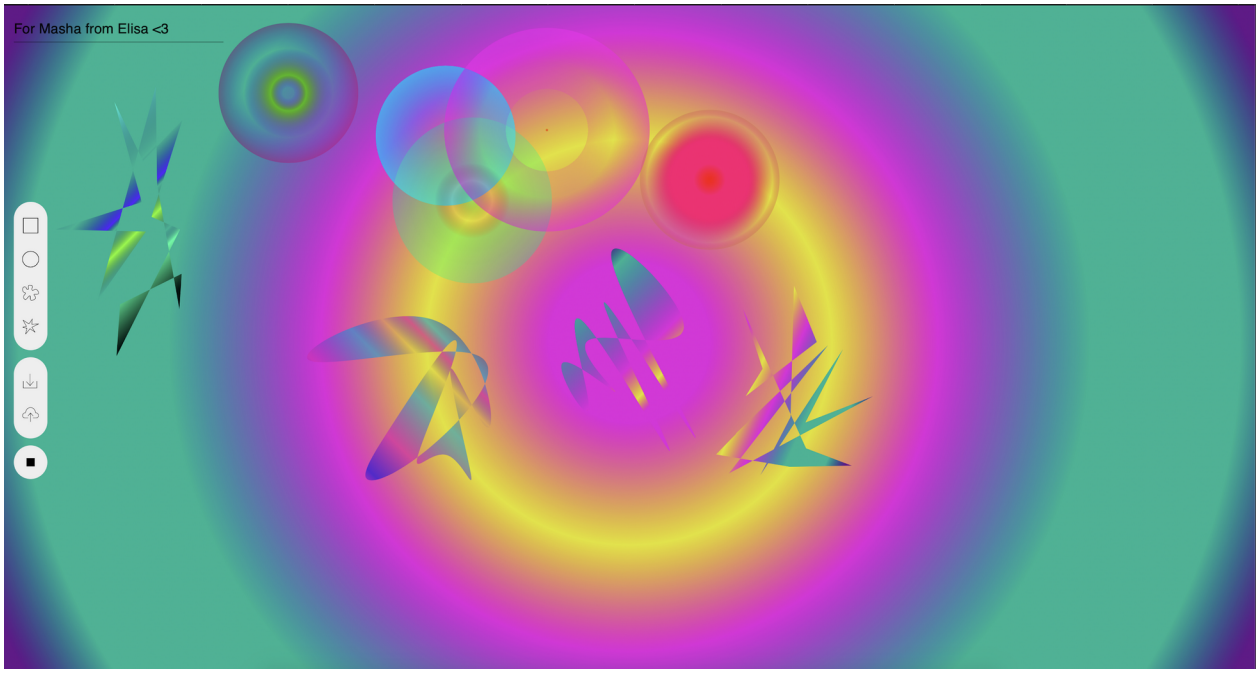


Figure 34. Audio-visual composition created by Elisa Heinonen via Can you hear your drawing app, February 2021

Video link: https://vimeo.com/52439729 (last time accessed on Mar16, 20211)

Elisa (she gave her permission to mention her and her works) drew this using the *Can you hear your drawing?* app. She experiences a few forms of synesthesia, and one of them is colour hearing. She is a very talented composer and plays violin since she was 4. In this sketch, I noticed certain patterns and structures. The circle shapes are all bass “heavy” based sounds (the Second level of complexity according to the structure of my sound palette), while the Kiki shapes with the negative space are assigned to xylophone of the third complexity (according to the structure of the sound palettes), and similar Boubas are assigned to drum sounds of the second level of complexity. From my understanding of sound, the lighter and the faster ones (xylophone, drum) are represented by more “active” shapes with more points, angles and multiple parts. The circle does not have any angles and can be interpreted as a solid single sound.

This musical drawing is very inspiring. It reminds me of light installations by James Turrell, an American artist who works with light and space, creating environments in which the visitor may experience light itself as an object rather than simply as a source of illumination.

“My work is more about your seeing than it is about my seeing, although it is a product of my seeing. I’m also interested in the sense of the presence of space; that is space where you feel a presence, almost an entity — that physical feeling and power that space can give.”
James Turrell

Figure 35-36. James Turrell'sTwilight Epiphany Skyspace at the Suzanne Deal Booth Centennial Pavilion on

the Rice University campus, Houston, TX, United States, image by Maria Shirokova, 2018)

Both these examples confirmed the capability of the app to visualize and sonify synesthetic experience. Further User Testing was aiming to receive answers from non-synesthete individuals and to see if the app could provoke synesthetic-like experiences and build understanding between the two groups.

User testing. App performance & Idea analysis

This part of the study aimed to test the effectiveness of this application, its performance, and it is eager to explore how a dialogue between synesthetes and non-synesthetes can be built. Users were invited to express their vision and preferences of creative audio-visual tools. Another purpose of user testing was to reveal bugs and non-clear elements for the user. By using the app, participants did not only test the effectiveness and functional process of it, but created audio-visual compositions, provided feedback on what should be added for a more detailed sensation experience, and discovered new possibilities of the graphic part of the project.

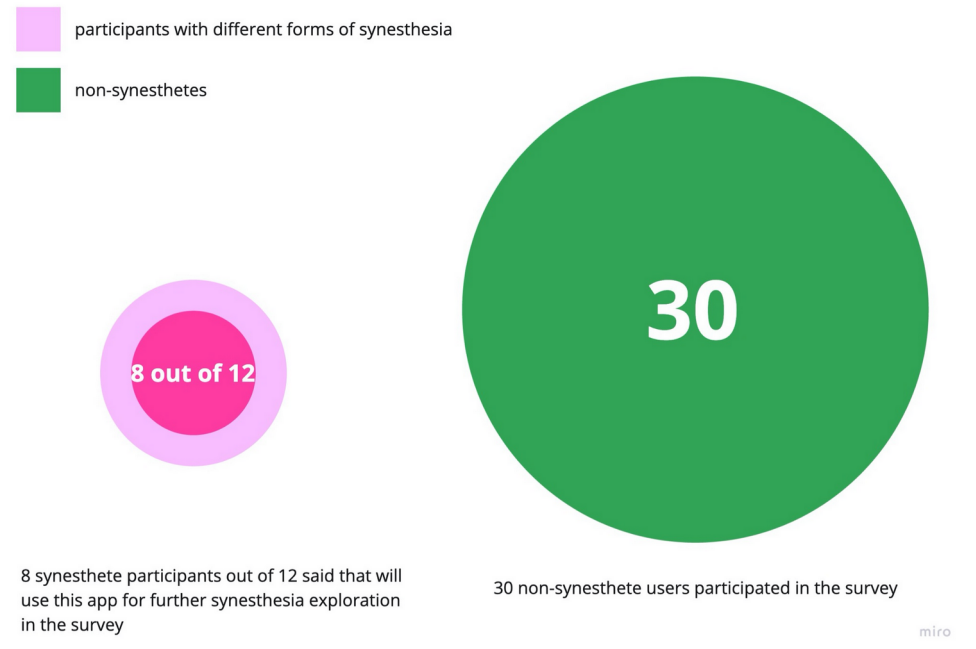


Figure 37. Data from the surveys, image by Maria Shirokova, created via Miro (https://miro.com/), March 2021

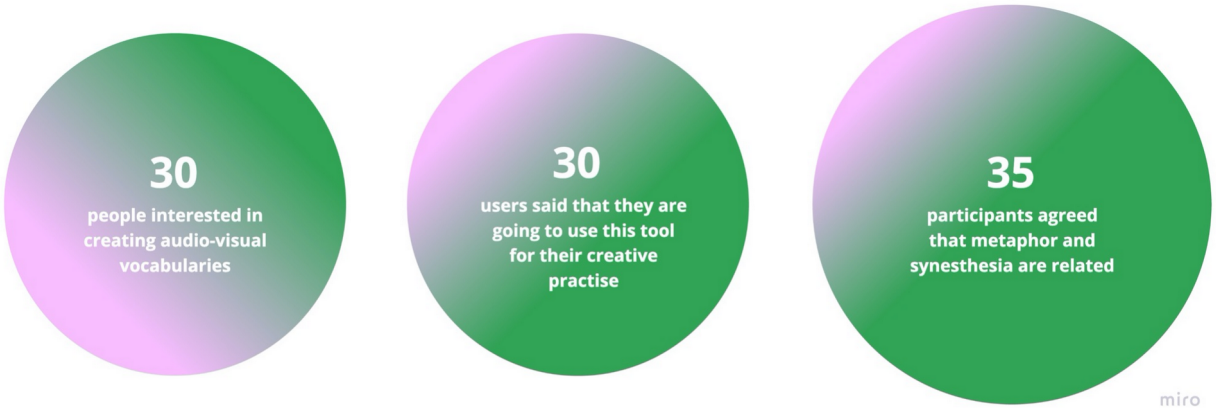


Figure 38. Data from the surveys, image by Maria Shirokova, created via Miro (https://miro.com/), March 2021

User Testing was conducted mostly asynchronously: users were given the instructions and the app link and were asked to answer the survey questions. Forty-two participants participated during three weeks (Fig. 37). Participants were invited to interact with the application by mapping their audio and visual associations and further sharing them with other participants. The first week of user testing was focused on collecting synesthete opinions and feedback. I contacted public synesthete groups and international associations.

"Our tools are in our minds"– these words belong to one of the user testing participants, who experience chromesthesia (sound to colour). He is an artist and composer. This phrase made me think if there is a need among synesthetes to have such creative tools and the ability to share their special perceptions. *What if synesthetes do not want to and do not need to share their sensations with others? The answer seems to be not in dividing people into synesthetes and non-synesthetes, it is more about the different personalities, and some individuals want to share their associations (without the context of synesthesia). There are those who prefer to keep it private.*

The study showed that individuals experiencing audio-visionary synesthesia were interested in using the app for their sense and creativity exploring more than people with other forms (Fig. 38). However, this app was not a topic of interest for people with other synesthesia forms like colour-grapheme synesthesia, mirror-touch etc. I managed "to convert" two colour-grapheme synesthetes as I showed them that letters could be drawn with the basic shapes.

In the next two weeks, more people with synesthesia participated and gave very satisfying feedback: about 70% of participants agreed that the app allows them to create compositions based on their sensation, and 80% agreed to use it for further synesthesia exploration.

Similar to the synesthete, non-synesthetes gave very diverse feedback. However, in this group, more people are interested in professional creative practice, and therefore more people agreed that they would use the app in the future. I was very glad to find out that some participants got very involved in the creative process of this app, and they later helped me to find very important bugs.

One of the survey questions asks participants to rank the cases when this app is the most suitable. They have suggested the following options:

- creative exercises
- creating colour music
- art therapy
- metaphor exploration
- synesthesia exploration

And this is the question that again brings the question about dividing people into synesthete and non-synesthetes. Some patterns illustrate the difference in perceiving the app by these two groups. None of the synesthetes ranked metaphor exploration as the first reason to use the app (but 35 people agreed that metaphor helps them understand others' perceptions and associations). Most of the users agreed that it should be used mostly for synesthesia exploration. Second place was shared between creating colour music and creative circuses. Two users also suggested art therapy. While in the non-synesthetes, the first place is divided between art therapy (7) and creative exercises(7) and creating colour music (7). Overall, most of the users agreed that this app is suitable for creative exercises and colour music, art therapy and exploring synesthesia.
It was exciting to notice that only 50% of synesthetes found synesthesia and metaphor related, while about 90% of non-synesthete answered that metaphor helps them understand synesthesia.

Another finding was that users who have skills in both visual creation and sound production are not interested in the app and do not agree with the simplified version of the sound interface.

Visual artists focus on graphic editors and ask for further development in the drawing part, while musicians require more functions to create music. However, the general audience agreed that the app could be used for daily prompts as sketches and sensory audio-visual notes, but not for the professional colour-music pieces.

This system was designed to provide an experience set and controlled by uses. The participants' most common question was if the colours of the sound palette affect the drawn shapes. While I aimed not to have any premade connections between sound and image, users searched for the already mapped relations between the shapes and sounds (e.g. bigger shapes had higher volume or more complex sounds). But in this app, these correlations should be assigned by the user. Interactive elements such as mapping scale and volume would definitely provide a more playful experience, but it would lower the subjectivity level I was aiming to achieve.
This app relies on the user's imagination and creativity and reminds more of a diary rather than software: users "write" down their sensations and share with others. Most of the non-synesthetes expressed their interest in learning more about synesthesia and applying multi-sensory thinking in their creative practise. This interest and engagement can count as first attempts of building creative conversations between these 2 groups.

App effectiveness. Technical Analysis
User testing sessions significantly helped to remove bugs and make the app more accessible. The survey asked what visual elements users would like to add. Among the main suggestions was to add animations, or at least impulse or vibration in the play mode to receive some visual feedback from clicking and expanding the sound palette. At the moment of the user testing, the impulse element in the play-mode had not been developed. Participants enjoyed drawing gradient elements, as well as draggin the shapes' pints around.

One participant said:
"These sounds are too happy. I can not say I do not like them, but currently, I am in the mood to listen to dark and sad sounds."

Critical Feedback and Suggestions	**Positive Comments**
● lack of sound variations; ● 90% of the participants suggest adding animations or impulse vibrations ● “It would be cool to see an impulse whenever a sound’s shape is triggered in ‘play’ mode; maybe a white flash inside the shape or halo around the shape?” ● ability to import images ● ability to import personal sounds or recordings	● gradients ● anxiety relief and relaxation ● playful and engaging creative tool ● ability to visualize synesthetic perceptions ● visualization possibilities

Table 2. User Testing Feedback

Engaging with the audience was the key component in evaluating the app and answering the research questions. User Testing, Brainstorming Sessions and Surveys showed that the app can be used for exploring synesthetic sensations/associations and creating sensation diaries. It successfully accomplished the main goal about providing multi-sensory experience in the web space.

Future Goals

Can You Hear Your Drawing? is an app, that enables users to create audio-visual compositions based on their sensations and associations. Although some elements require further development, this app’s achievement is a flexible framework that can be expanded or edited. App illustrates the process and idea, while the quality of its elements and steps will be improved in the future (canvas, music, shareable functions etc). The short-term goals for this project are the following:

- expanding the audio section by enabling users to record their soundscapes, generate and upload sounds;
- adding letters, lines to the visual part;

- simplifying and developing shareable functions;
- enabling online co-creation between several users;
- rethinking UI/UX;
- animations.

As long-term goals, this project aims to continue multi-disciplinary research and attract more researchers and creators for collaboration in creating synesthesia-like experiences, by applying Participatory Design Methodology. There are many directions that can be followed:

- bringing the idea into physical world by adding physical tangible controllers (personalized experience can be provided via soft materials such as mold, clay etc);
- expanding the amount of senses and adding spatial elements by experimenting with AR and VR.

Conclusion

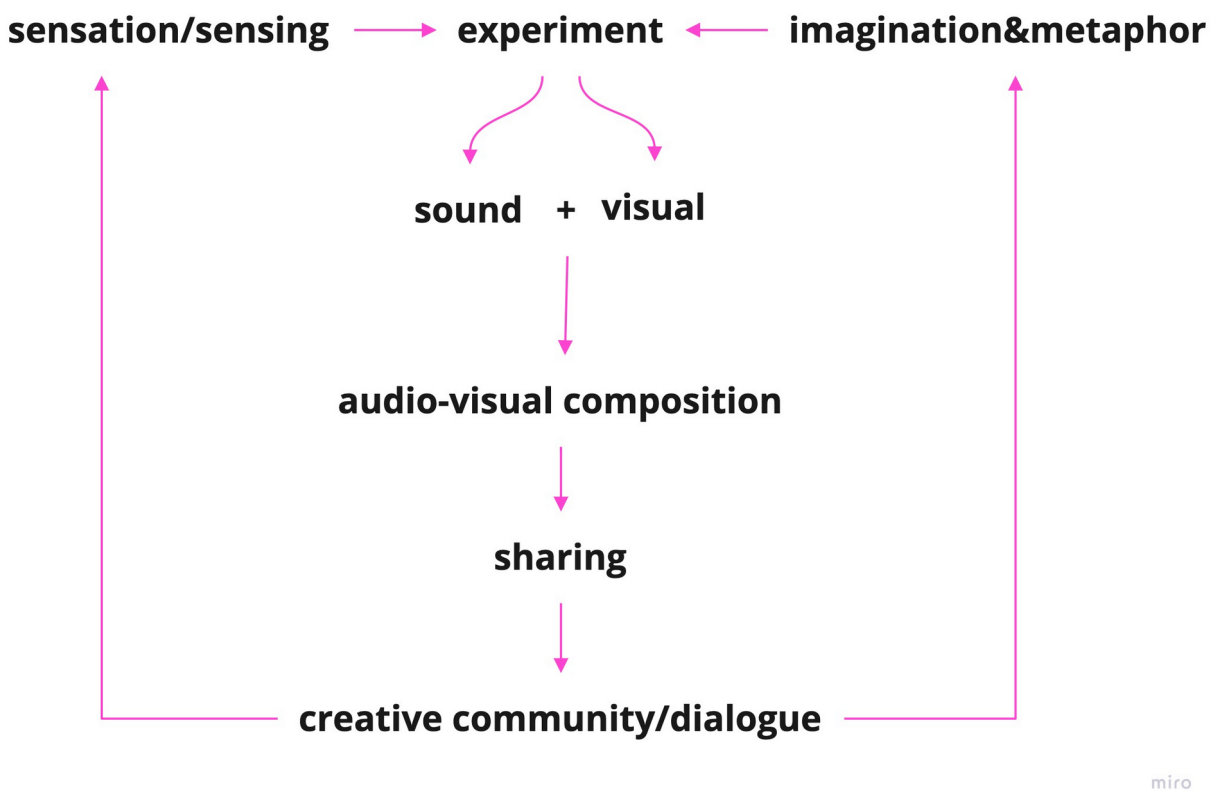


Figure 39. The main principle of "Can you hear your drawing?" App Process, image by Maria Shirokova, created with Miro miro.com, February 2021

Answering the first research question “What role does metaphor play in designing a web app about multimodality and synesthesia?”, this research concludes that metaphor played the role of conversational and design tools and theoretical framework for providing synesthetic synesthesia-like experiences. The outcome of this project illustrates that dialogue between synesthetes and non-synesthetes might be built through sense metaphors. It also evokes non-synesthete users to explore synesthesia, and in some cases (esp. with audio-visual synesthesia), users can recreate colour-music compositions based on their sensations.

Three different meanings of metaphors were applied on all main stages of the Research Through Design process: researching, making and evaluations. Non-synesthete participants agreed that metaphoric thinking helps them understand multimodal and synesthetic processes better. Furthermore, the survey shows that this app informs them how synesthesia works, and they would like to learn more about this phenomenon, while synesthetes agreed that they experience difficulties explaining what synesthesia is. This means that most of the misunderstanding was usually coming from the non-synesthetes group. Therefore it was essential to provoke empathy from the non-synesthetes. Metaphors helped me build an intuitive digital space, understandable for the user but played the main role in building an understanding process between the users.

As a researcher, I agree that (design) metaphor as an approach helped me simplify complicated notions of colour and music and break the sound into colour blocks. If cybernetics suggests that simplification leads to progress (Glanville,2007), this research might say that design metaphor can be one of the simplification steps: uniting colour and sound, combining their characteristics through the metaphor can immerse users into multi-sensory experiences and provoke them to experiment with audio-visual correlations.

According to survey answers, this app does help to build understanding between the two groups and introduce synesthesia and synesthesia-like experience to the broader audience. And according to some users, who were not familiar with drawing or composing via digital software, the app interface does allow them to create audio-visual sketches without certain experience.

However, after analyzing data, I started considering not the metaphor as the initial connecting point but the interest in creative practices. The initiative comes not from the metaphor but from

aspiration to expand creativity and imagination. Then, through metaphor, users tend to share their audio-visual pieces and maybe discuss them. Those users from both groups involved in creative practice and exploring colour music associations were keen on building mutual understanding and dialogue. To make a dialogue, both groups need to be engaged. According to the study, synesthete and non-synesthete got encouraged to share and learn new experiences. Interest in the creative process provokes users to create audio-visual experiences and communicate them through metaphor.

By answering the second research question “What are the capabilities of digital web applications in providing personalized cross-modal sensory experiences?”, this research managed to build an empathic dialogue while considering the following aspects: conversation through shareability, subjectivity, simplicity and metaphor (theoretical, design and conversational).

Shareability and conversation

Communication between humans can be built by exchanging words, texts, signs and other ways. Therefore the function to share and save files was extremely important for this app. The difference in feedback during user testing of the app without this function and the prototype with a shareable function are significant. Circulation of information about the audio-visual sensation of the users comes through the app. *The final prototype allows users to name their compositions and give short descriptions. Moreover, some users suggested implying drawings in the form of messages – similar to the concept of mail or greeting cards.*

Subjectivity

Not only is synesthesia subjective, but all the forms of perceptions and sensations are subjective. Different individuals experience colours, music, smells and tastes very(!) differently. How many people – so many perceptions and opinions. This project is led by the thought of providing a customized/personalized experience. It applies personalization over aesthetics of interaction and allows the user to create their own mappings. It is the app’s weakness and strength.

Simplicity and intuitive interface

By applying complex and multidisciplinary phenomenon, this project aimed to simplify them in one app, so users do not have to be professional artists or composers to use and understand this app. Although the instruction page was sometimes necessary for using the app, many user testing participants who do not have experience working with graphic editors or music software managed to create their own compositions. *"I was confused when I opened the app, but after briefly reading the instructions, I understood how to use the tool."*

Metaphor as a tool for understanding (3 in 1)

Every user was assigned a role: *Imagine every shape has a sound, every detail has a sound, and all of them create a composition.*

The app lets users feel these correlations, even though they might not make any sense to them. Users are immersed in a synesthesia-like experience that aims to evoke empathy, sympathy and understanding of synesthetes. It does not try to explain what multi-modality, multi-sensory, synesthesia, ideasthesia mean, but it just immerses users into an intuitive user face, where they map visuals to sounds. As a tip, the sound palette already reminds the user that in this space, sounds and colours need to be connected.

I would like to continue researching this question, whether it is a metaphor or creative practice that can affect and move forward the understanding between synesthetes and non-synesthetes. This research is not only about two groups of people, its survey involved 42 individuals of different age, gender, occupation, interests and cultural backgrounds. There must be many ways applied for building multi-sensory understanding between them, but I am glad that metaphors and creative practises are two of them.

My vision and understanding of the tool I designed during this research is a creative tool for creating audio-visual compositions and exploring sensory correlations. However, every new user can find personal meaning in using this tool.

Therefore, this project is open for interpretations:
Can you hear your drawing? is a creative tool for _____.

References

1. Apter, Michael J. “Cybernetics and Art.” *Leonardo*, vol. 2, no. 3, 1969, pp. 257–265. JSTOR, www.jstor.org/stable/1572155. Accessed 24 Feb. 2021.

2. Bernsen, Niels & Dybkjaer, Laila. (2010). Multimodal Usability.

3. Bosch, S. J, , Cama, R., Edelstein, E, Malkin, J (2012). "The Application of Color in Healthcare Settings."

4. *Cambridge International Dictionary of English*. Cambridge: Cambridge University Press, 1995. Print.

5. Casakin, Herman Pablo. "Metaphors in Design Problem Solving: Implications for Creativity." *International Journal of Design*. 2007. Web. 15 Mar. 2021.

6. Chrome Music Lab. (n.d.). Retrieved August 04, 2020, from https://musiclab.chromeexperiments.com/Kandinsky/

7. Cytowic, R. E. (2002). Synesthesia: A union of the senses. Cambridge, MA: MIT.

8. Cytowic, R. E., M.D. (2016). Art on the synesthetic spectrum [Scholarly project]. In Art on the Synesthetic Spectrum. Retrieved August 03, 2020, from https://static1.squarespace.com/static/55bd6bafe4b0ec7f7c03344d/t/57aeece22e69cf0f15615334/1471081722360/New+Zealand+Portrait+Gallery+2016+Richard+Cytowic+essay.pdf

9. Day, Sean & A, Sean. (1996). Synaesthesia and synaesthetic metaphors. Psyche. 2.

10. Fabrizi, Mariabruna. "Yannis Xenakis' Polytopes: Cosmogonies in Sound and Architecture." *SOCKS*. 09 Feb. 2018. Web. 18 Mar. 2021.

11. Galeyev, B.M. "The Nature and Functions of Synesthesia in Music." Leonardo. MIT Press, 01 June 2007. Web. 14 Mar. 2021.

12. Gaver, William. (2012). What Should We Expect From Research Through Design?. Conference on Human Factors in Computing Systems - Proceedings. 10.1145/2207676.2208538.

13. Glanville, Ranulph. (2007). Try again. Fail again. Fail better: The cybernetics in design and the design in cybernetics. Kybernetes.

14. Goodman, S. (2012). Sonic warfare: Sound, affect, and the ecology of fear. Cambridge, MA: The MIT Press.

15. Gregory, I.. “Ethics in research.” (2003).

16. Gsoellpointner, K. (n.d.). Digital Synesthesia. A Model for the Aesthetics of Digital Art. Edition Angewandte. Berlin/Boston: De Gruyter (2016). Retrieved August 04, 2020, from http://www.academia.edu/31698273/Digital_Synesthesia._A_Model_for_the_Aesthetics_of_Digital_Art._Edition_Angewandte._Berlin _Boston_De_Gruyter_2016

17. Hutchison, N. (n.d.). FOCUSED VISIONS. Retrieved August 04, 2020, from http://www.colourmusic.info/maistre3.htm

18. Itten, Johannes. The Art of Colour: The Subjective Experience and Objective Rationale of Color. New York: John Wiley, 2002. Print.

19. Kandinsky, Wassily, and Hilla Rebay. Point and Line to Plane. New York: Dover Publications, 2013. Print.

20. Kandinsky, Wassily, and Michael Sadleir. Concerning the Spiritual in Art. Las Vegas: IAP, 2009. Print.

21. Kwastek, Katya. Audiovisual Interactive Art: From the Artwork to the Device and Back, in

Dieter Daniels, Sandra Naumann (eds.), Audiovisuology, A Reader, Vol. 1: Compendium, Vol. 2: Essays, Verlag Walther König, Köln 2015, pp. 582-605.

22. Levin, Golan. "Painterly Interfaces for Audiovisual Performance." Web. 14 Mar. 2021

23. Lunke, B., Meier, K. "Creativity and Involvement in Art in Different Types of Synaesthesia." British Journal of Psychology (London, England: 1953). U.S. National Library of Medicine. Web. 14 Mar. 2021.

24. Madsen, R. (n.d.). A short history of colour theory. Retrieved July 28, 2020, from https://programmingdesignsystems.com/color/a-short-history-of-color-theory/index.html

25. Mankin, J., Dr. (n.d.). Polychrome. Retrieved August 04, 2020, from https://www.sussex.ac.uk/psychology/jmankin/wcp/

26. *Merriam-Webster.com Dictionary*, Merriam-Webster, https://www.merriam-webster.com/dictionary. Accessed 15 Mar. 2021)

27. Mroczko-Wąsowicz, A., & Werning, M. (2012, August 22). Synesthesia, sensory-motor contingency, and semantic emulation: How swimming style-colour synesthesia challenges the traditional view of synesthesia. Retrieved August 03, 2020, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3425383/

28. Nabokov, Vladimir Vladimirovich. *Speak, Memory: A Memoir*. London, 1951. Print.

29. Peacock, K. (2015, March 08). Instruments to Perform Color-Music: Two Centuries of Technological Experimentation[Scholarly project]. In United States Documents. Retrieved August 04, 2020, from https://documents.pub/document/instruments-to-perform-color-in-20th-century-music.html

30. Playtronica. (n.d.). Retrieved August 04, 2020, from https://playtronica.com/

31. Rupp, Rebecca. "Kiki or Bouba: What Is the Shape of Your Taste?" *Culture*. National Geographic, 10 Feb. 2021. Web. 15 Mar. 2021

32. Seubert, J. (n.d.). Subtle Multisensory Clues Reveal Other People's Emotions. Retrieved January 28, 2021, from https://www.scientificamerican.com/article/i-know-how-you-feel/

33. Seymour, S. J., & Tomida, Y. (2014, March 25). Patatap. Retrieved August 04, 2020, from https://patatap.com/

34. Sister City New York, a hotel: Now booking: From the Ace Hotel team. (n.d.). Retrieved August 04, 2020, from https://sistercitynyc.com/bjork

35. Sterken, Sven. “Towards a Space-Time Art: Iannis Xenakis’s Polytopes.” PERSPECTIVES OF NEW MUSIC 39.2 (2001): 262–273. Print.

36. Syn(es)thetic Reality: Simulating synesthesia for the non-synesthetic. (n.d.). Retrieved August 04, 2020, from http://www.iaacblog.com/programs/synesthetic-reality/.

37. Take a walk in the soundscapes "imagined" by AI. (n.d.). Retrieved August 04, 2020, from http://www.imaginarysoundscape.net/

38. Wagner, Christoph, and Johannes Itten. Johannes Itten. Munich: Hirmer, 2019. Print.

39. William C. Shiel Jr., MD. "Definition of Chromesthesia." MedicineNet. MedicineNet, 21 Dec. 2018. Web. 15 Mar. 2021.

40. Zimmerman, John & Forlizzi, Jodi & Evenson, Shelley. (2007). Research through design as a method for interaction design research in HCI. 493-502. 10.1145/1240624.1240704.

Appendices

APPENDIX A & APPENDIX B include anonymous data from the surveys that were conducted from February 1, 2021, to February 28, 2021. Survey involved synesthete and non-synesthete participants.

APPENDIX C includes the drawings of the participants that agreed to share their works with the study.

APPENDIX D is the instructions documentation that was applied at the moment of the user testing.

APPENDIX A: Survey Non-Synesthete Audience

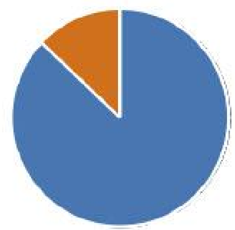
Forms(https://www.offic... Online Survey for th... auth=2) Saved ? Maria Shirokova MS

Online Survey for the User Testing participants (Non-Synesthetes)

31	04:34	Active
Responses	Average time to complete	Status

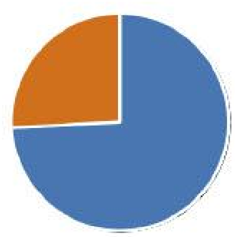
1. Do you identify as a creative practitioner?

Yes	27
No	4



2. Have you heard about synesthesia before?

Yes	23
No	8



3. Are you interested in experiencing it or would like to hear more about it?

Yes	31
No	0

4. How often do you use metaphors when you talk about your sensations, perceptions and visions? e.g. this color seems warm/sweet, cold melody etc

often	14
sometimes	17
never	0

5. Are you interested in creating vocabulary/libraries of your audio-visual metaphors? e.g. ability to map a certain geometrical shape of a certain colour with a particular sound (based on your metaphoric vision) and save it in the app, in a way you can preserve images or docs in your google drive folder

25
Responses

Latest Responses

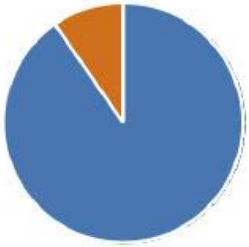
"yes!"

"Yes but needs more practicing. It's not easy to create a perfectl..."

"no"

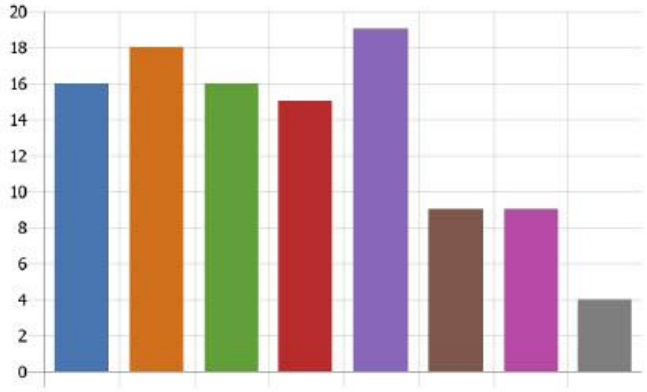
6. Do you find synesthesia and metaphors related?

Yes	28
No	3



7. What elements would you like to see when you explore your audio-visual perceptions and associations?

solid colours	16
transparency	18
gradients	16
aura	15
animated elements	19
static image	9
stroke	9
other	4



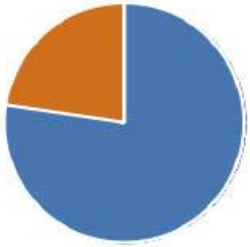
8. If you chose other in the previous, please type in your answer

5
Responses

Latest Responses

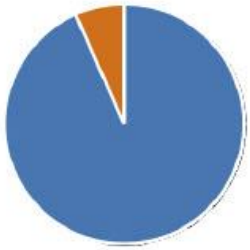
9. Does the app allow you to visualize sounds according to your associations and metaphors?

Yes	24
No	7



10. Did you find interface of this app user-friendly?

Yes	28
No	2



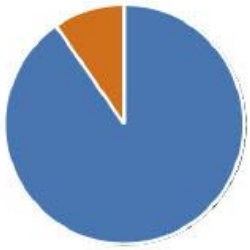
11. If you answered no, please name what you do not like about the interface and what you wish to be improved.

15
Responses

Latest Responses
"I like the simplicity of the app"

12. Does this app provide you with more insight into how synesthesia works?

Yes	28
No	3

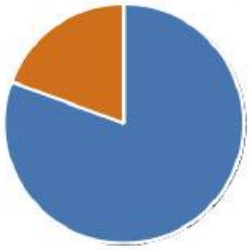


13. Would you use this app for further synesthesia/metaphor exploration?

Yes	30
No	1

14. Would you use this app as a creative tool for daily prompts and searching for inspiration?

Yes	25
No	6



APPENDIX B: Survey Synesthete Audience

Forms (https://www.office.com/launch/forms?auth=2) Online Survey for th... Saved Maria Shirokova MS

Online Survey for the User Testing participants (Synesthetes)

12	14:26	Active
Responses	Average time to complete	Status

1. Do you identify as a creative practitioner? If yes, please provide what creative practice you are interested in

12 Responses

Latest Responses

"Musician "

"yes, guitar, composing songs"

"Yes, painting and music (piano)"

2. What type of synesthesia do you experience? You may provide an example

12 Responses

Latest Responses

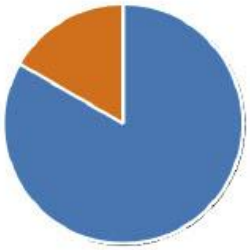
"Visual-audio, or more precisely movement-audio "

"Music, influencing the mood, changes the color preferences, i.e....

"colour-hearing, mirror-touch, ticker tape, mirror-emotion, OLP, t...

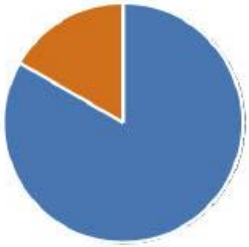
3. Does synesthesia contribute to your creative process?

Yes	10
No	2



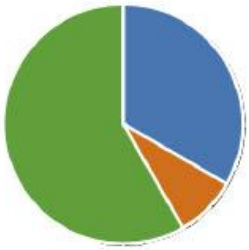
4. Does it inspire you or motivate you?

Yes	10
No	2



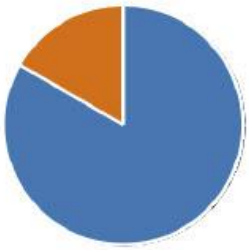
5. Do you experience difficulties in explaining your synesthetic experience to others?

Yes	4
No	1
Sometimes	7



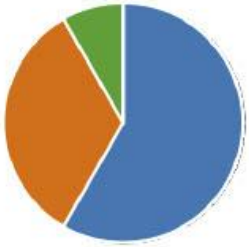
6. Are you interested in capturing your synesthetic associations and mapped sensations in a digital/ webspace? e.g. ability to map a certain geometrical shape of a certain colour with a particular sound (based on your synesthetic sensation) and save it in the app in a way you can preserve images or docs in your google drive folder

Yes	10
No	2



7. Do you find synesthesia and metaphors related?

Yes	7
No	4
Other	1



8. If your synesthesia includes colour mappings: Do your colour perceptions depend on digital or analog space? (e.g are associations different in REB (digital: web, phones, tablets, LED screens etc) and CMYK (prints: books, magazines brochures, bill boards etc, photos etc) ?Yes/No

12
Responses

Latest Responses

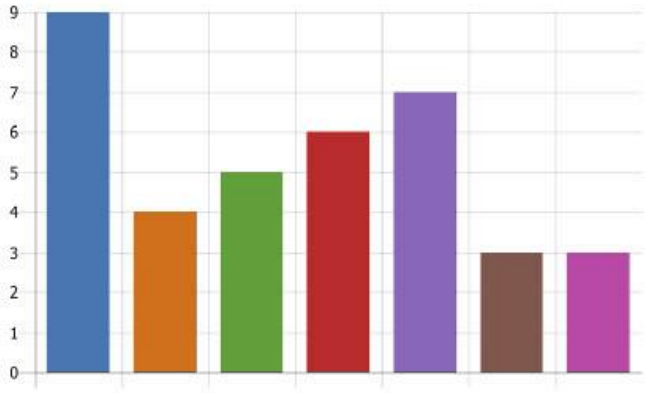
"My synesthesia seems to be primarily one way. Sounds do not i..."

"no"

"the most colours are different, most colours are mixed from ma..."

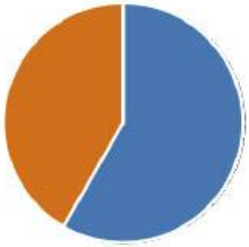
9. How would you describe your synesthetic vision?

solid colours	9
transparency	4
gradients	5
aura	6
animated elements	7
static image	3
stroke	3



10. Does the app allow you to visualize sounds according to your synesthetic experience?

Yes	7
No	5



11. Did you find interface of this app user-friendly?If no, please name what you do not like about the interface and what you wish to be improved.

12 Responses

Latest Responses

"I tried the app without reading the instructions at all deliberatel...

"Yes. Requires simpler reproduction of music samples without re...

"yes, it is user-friendly"

12. What do you think could be added to this app in order to provide a synesthetic experience?

12 Responses

Latest Responses

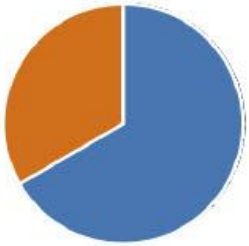
"From my standpoint of long-time musicianship, I found the lack ...

""A very important point: each figure must have several states, f...

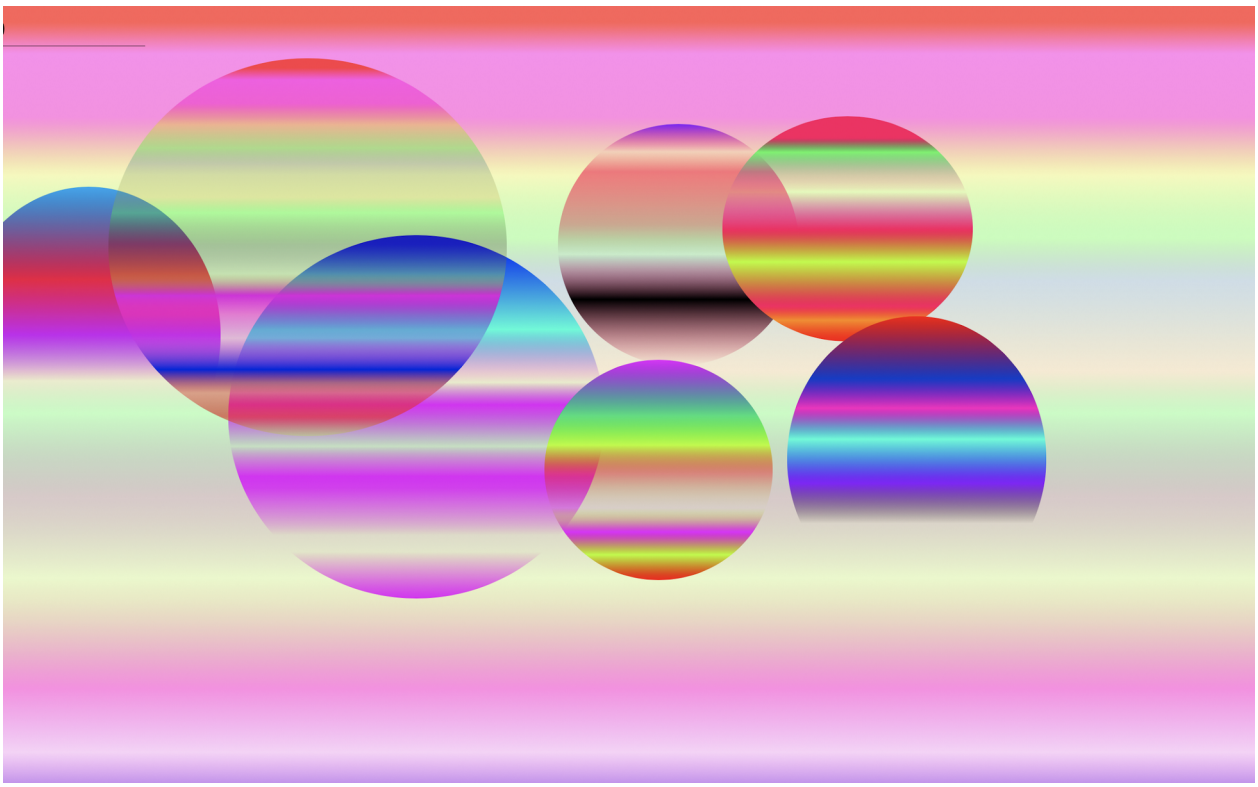
"movements from the points and strings, getting louder - the big...

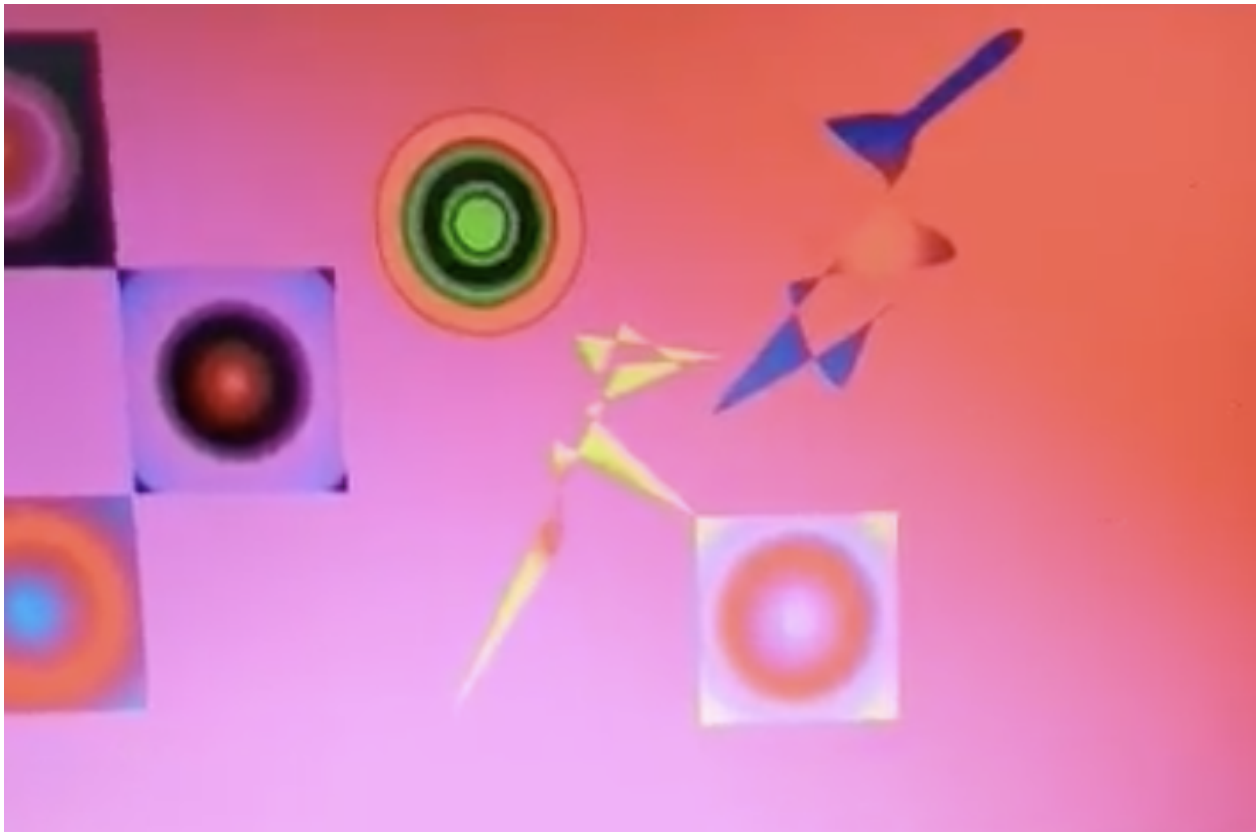
13. Would you use this app for further synesthesia exploration?

Yes	8
No	4

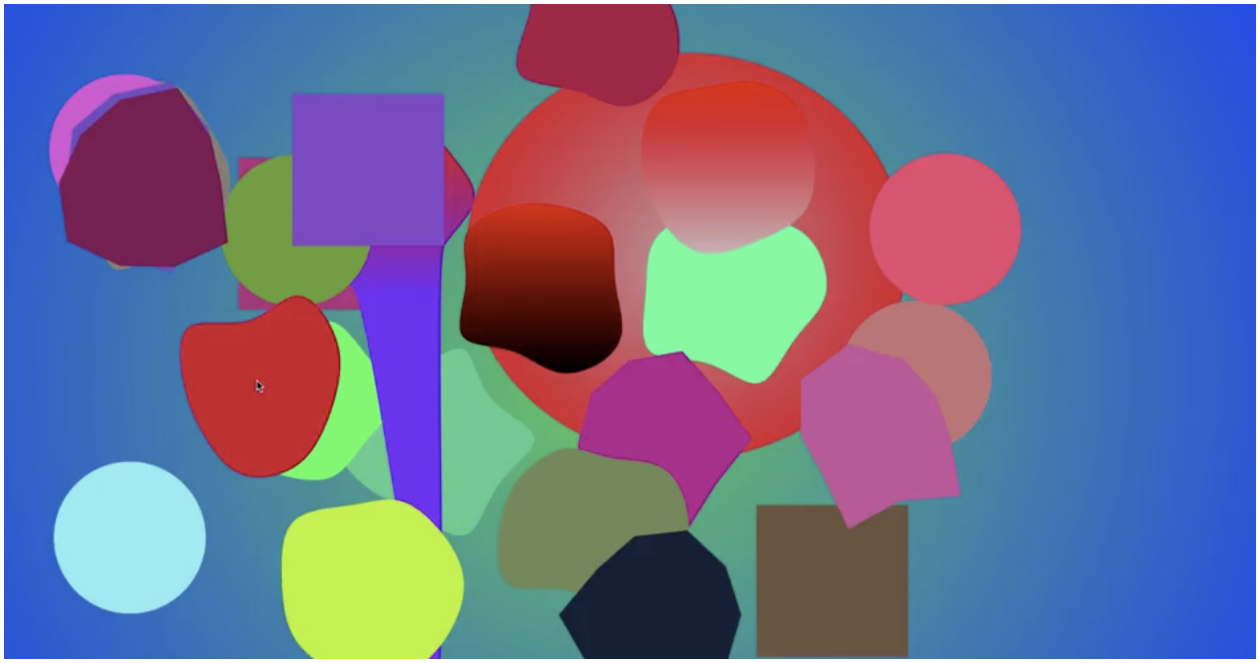


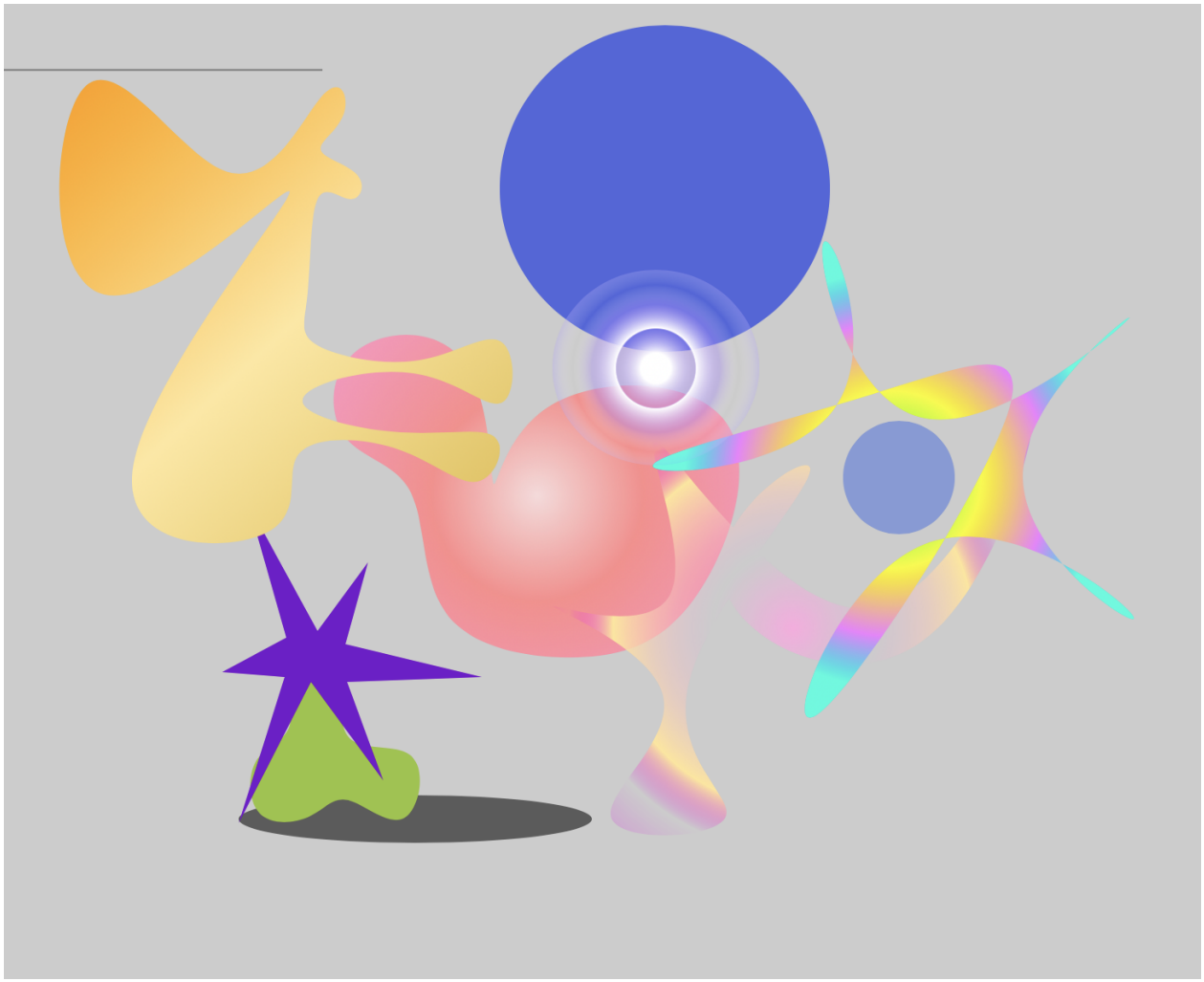
APPENDIX C: Participants' Drawings and Compositions

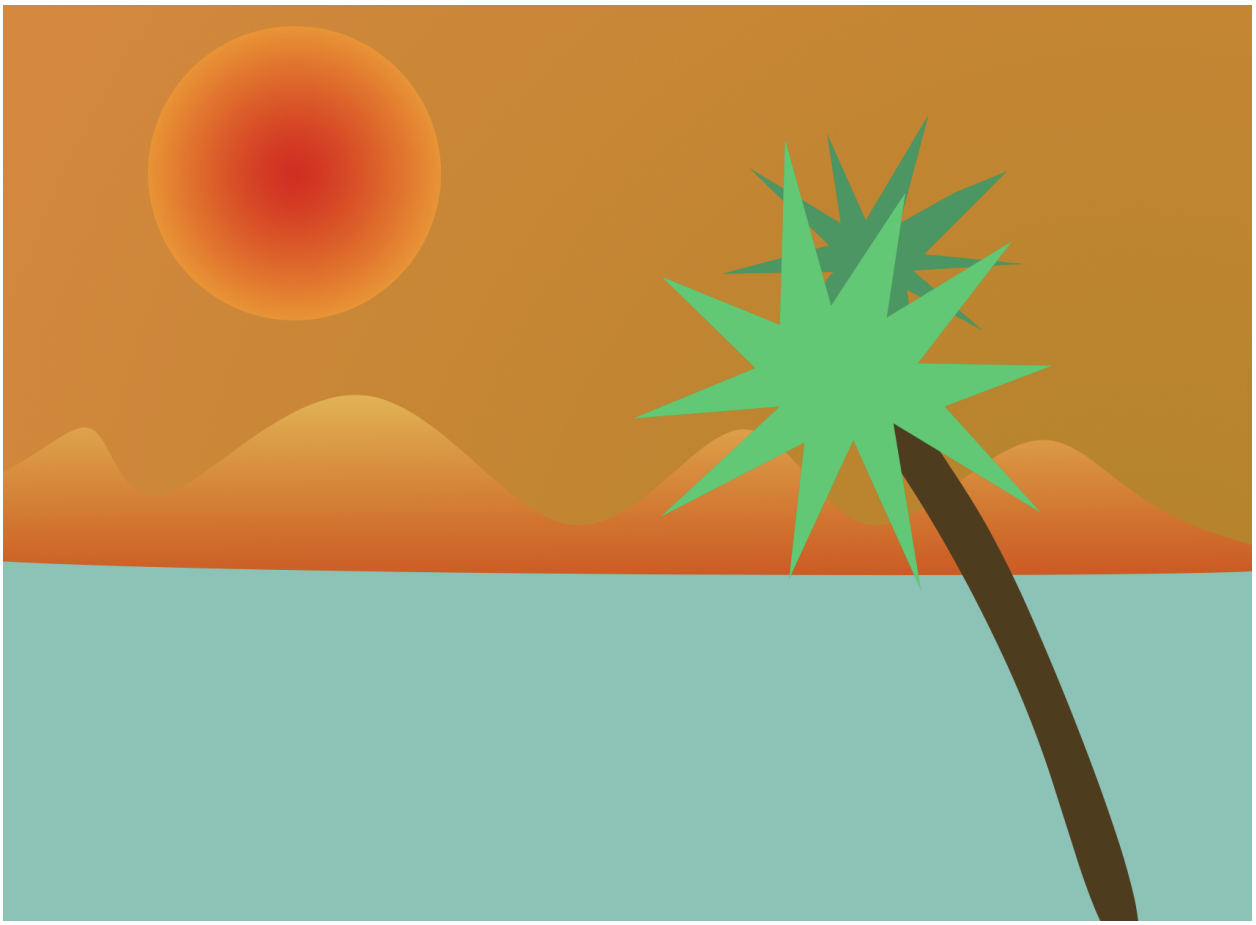




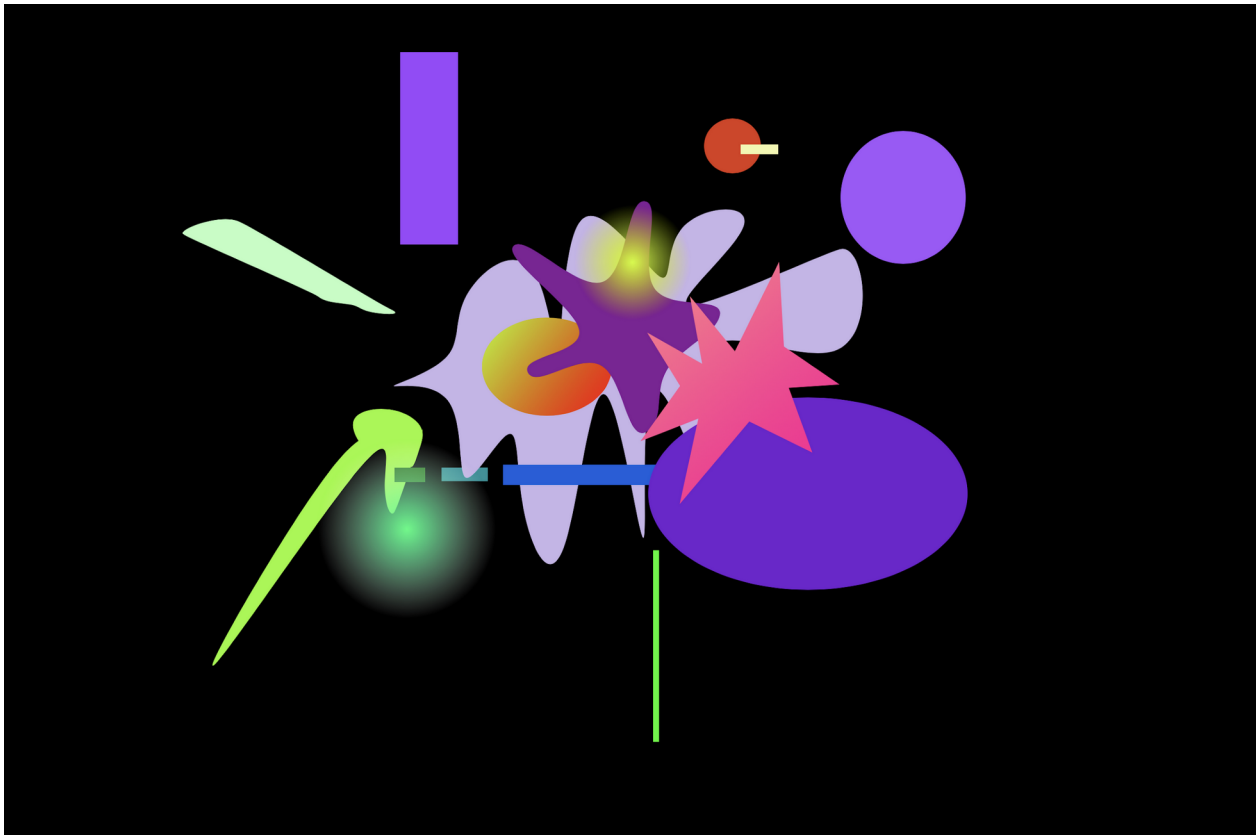

ROOROO

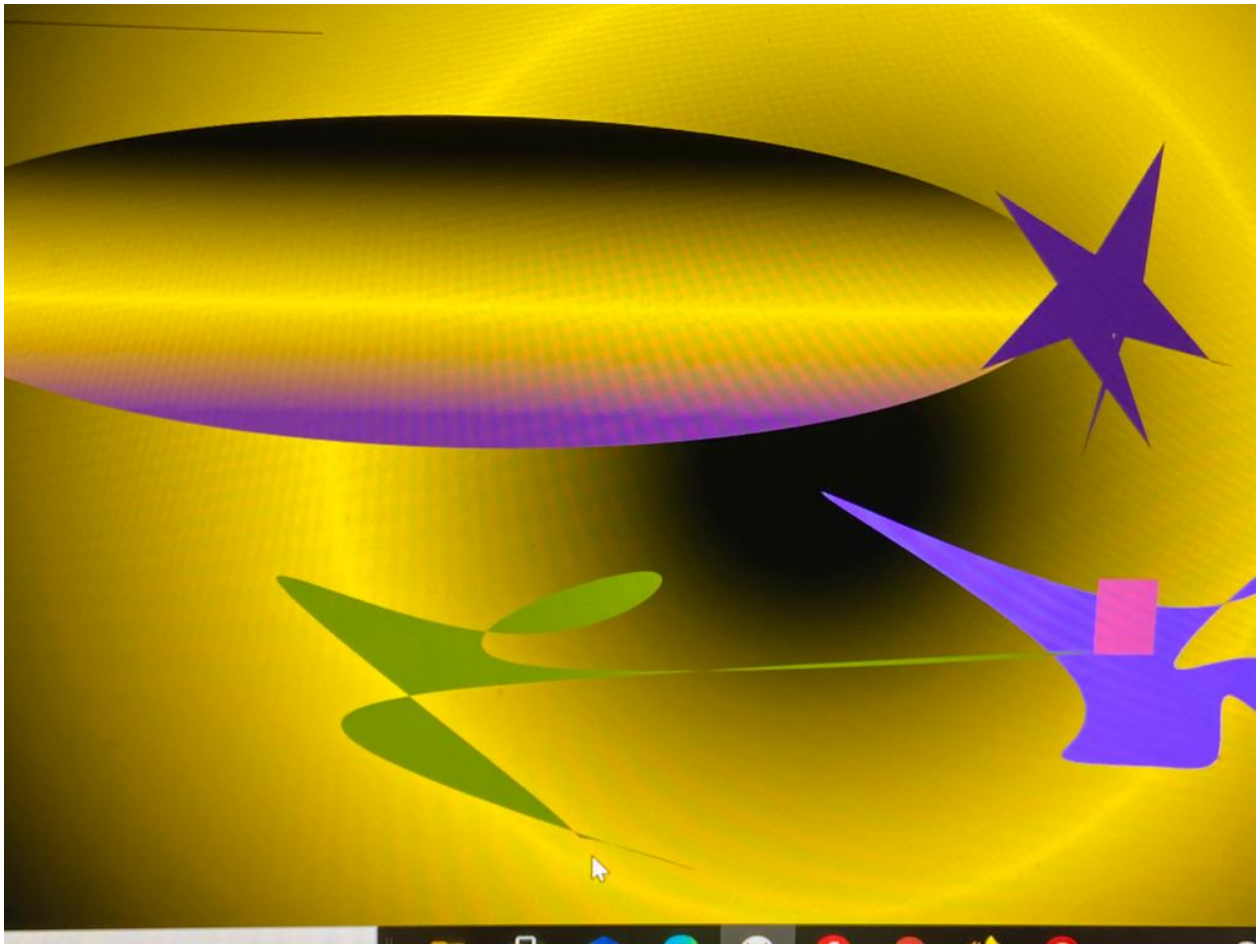


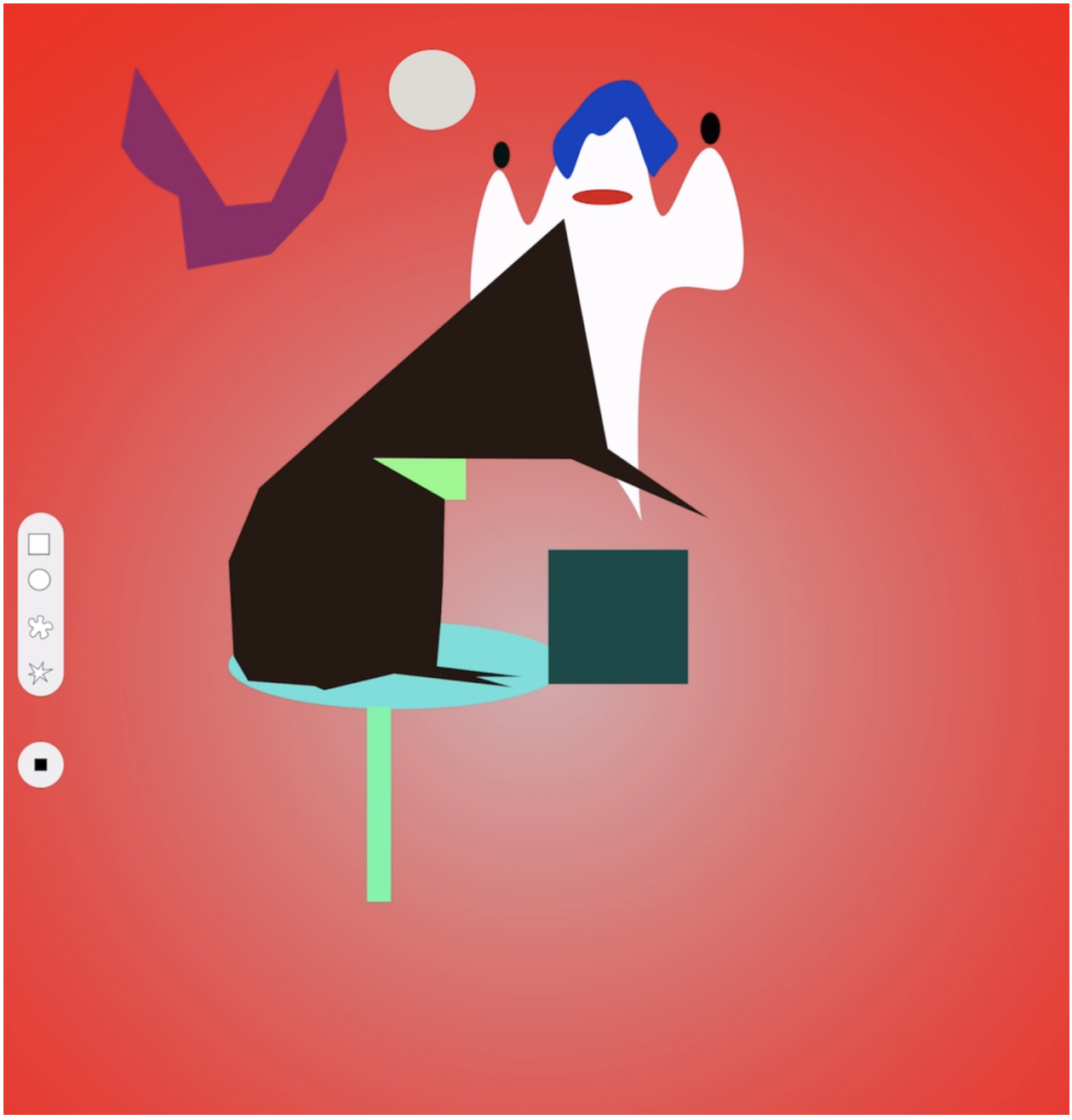


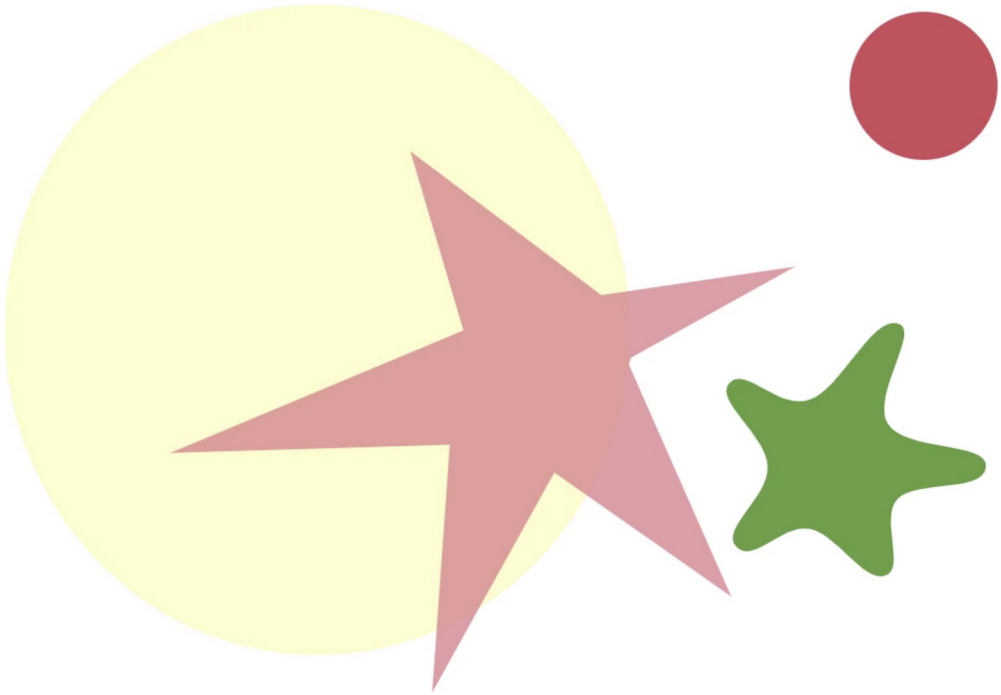



For Masha from Elisa <3









APPENDIX D: Instructions & Guidance

https://sites.google.com/view/canyouhearthedrawing-guide/english