

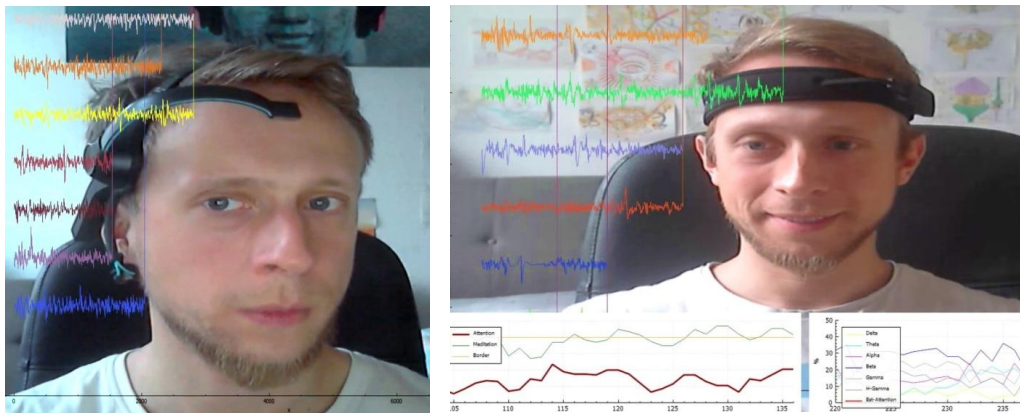
## MindDrawPlay: about

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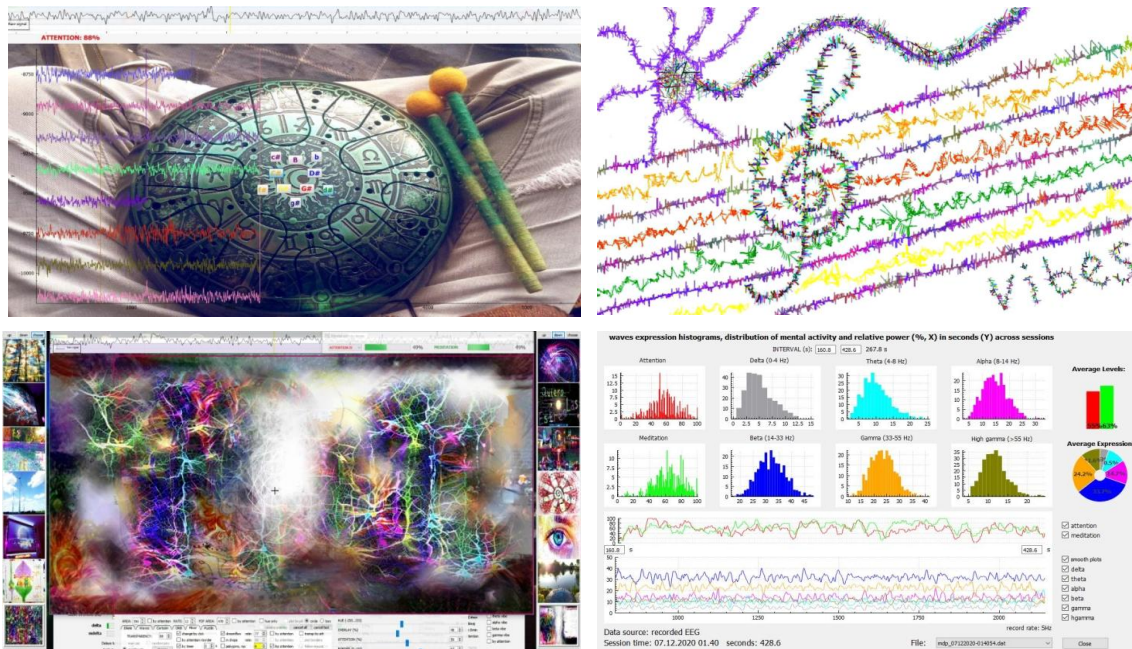
*The purpose of this file is to provide with a general overview of the project and application, explanation of underground motivation, ideas and principles. Detailed description and instructions of application user interface, all modes, options and parameters are provided in MindDrawPlay: user's manual file.*

MindDrawPlay – is a project of experimental interactive educational audio-visual art, representing translation of brain waves to drawing, visual and musical spaces, flows and controls. It has been grown on a base of research work in the direction of Brain-Computer Interfaces. Combining technology advances – such as mobile EEG devices (Pic.1) and musical knowledge – such as pentatonic scales (tones from hang and tank drums), it allows everyone to see, to hear his brain activity represented by set of sounds and to use brain waves as a brush for drawing, as parameters for image filtering, attention modulated pictures flows, in “puzzle gathering”, “find the same” and “go through” games. MindDrawPlay is much more than a neurofeedback app with sounds and visualizations, it provides with a unique experience of interactive immersion into flows of your mindspace.

The application code is written in C++/Qt, the project is tuned for MindWave™ NeuroSky or MyndPlay mobile EEG devices, but it can be adapted for other mobile or full EEG systems.



Pic.1 Mobile EEG data acquisition devices for brain waves, (left): MindWave™ NeuroSky, (right): MyndPlay.



Pic.2 Screens of the application, overview video: <https://vimeo.com/498138827>

## **System requirements**

Windows 7/8/10. For correct usage of the application interface system screen resolution should be 1920 x 1080 or higher.

Mobile EEG device: [MindWave™](#) [NeuroSky](#) or [MyndPlay](#).

*Note: the application also can be used without EEG device with Waves Generator mode, simulating EEG signal based on composition of sine waves (emulating different brain waves frequencies) and noise, all functions will be available, but the key idea – translation of brain waves will be missing.*

## **Overview**

Thanks to mobile EEG with a single dry electrode, it is simple in usage, does not require any preparation procedures (like with traditional multi-channel EEG devices) – just wear, observe and play with your mindspace. In [MindDrawPlay](#) neurofeedback is implemented in several ways, application allows user to control different parameters by changing mental activity state – becoming more focused or more relaxed. For example, in case of music – volume, duration of tones and their distribution (how often which tones play) depend on brain waves patterns. In case of drawing – different color modes of brush and amplitude of brain signals as a brush, in case of visual space flows – parameters of the flow (speed of pictures changes, transparency of overlays, size of fragments and others). In case of puzzle mode – how many pictures in a puzzle on correct places, their size and how fast they change. You can observe in a real-time dynamics of your brain waves on plots, your attention and meditation level changes, and how actions in the application or your mental activity states influence brain waves. Therefore, essentially, [MindDrawPlay](#) is form of an interactive art, neurofeedback application and a tool for exploring brain activity patterns.

Basically, there are 5 windows in the application:

**MindPlay** – responsible for translation of brain waves to music and visualization of brain waves flow.

**MindDraw** – responsible for translation of brain waves to drawing and allows to play simple games.

**MindOCV** – responsible for translation of brain waves to different visual flows, based on OpenCV library.

**MindOGL** – responsible for translation of brain waves to a simple OpenGL flow.

**Statistics** – responsible for a simple statistical analysis of data from recorded sessions.

Additionally, on the top of user's screen – there are a **plot with real-time raw brain signals** from EEG device and a small **Mental activity levels** window with 2 progress bars showing attention and meditation values. The application also allows to stream brain waves expression data and mental activity to external applications via **Open Sound Control (OSC)** protocol (see [examples of integration](#) with [TouchDesigner](#)).

## **Mental activity metrics**

Since most of the interactions and flows controls in [MindDrawPlay](#) are based on attention or meditation, it is important to explain the difference between “Attention I”, “Attention II” and “Meditation”.

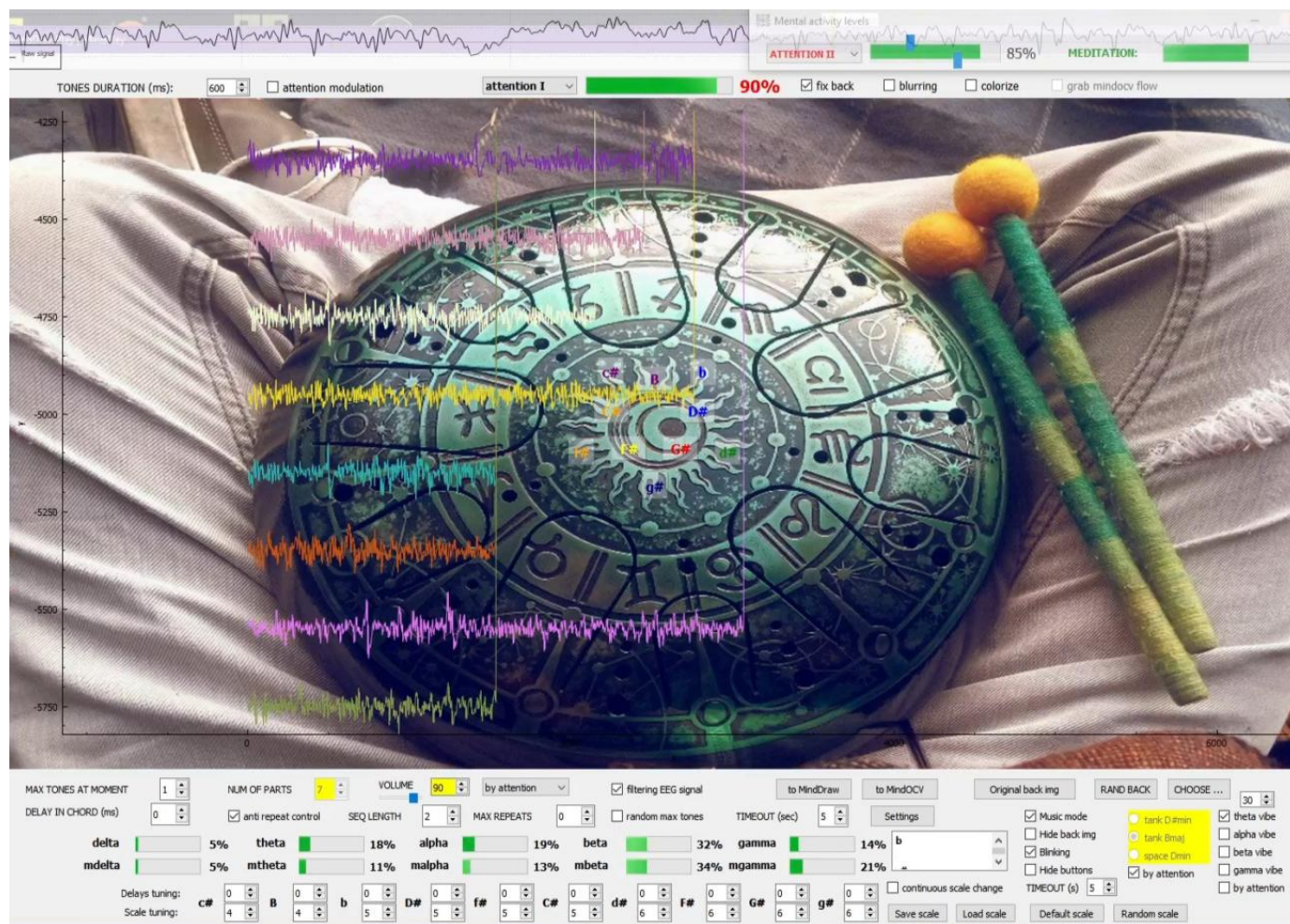
“Attention I” and “Meditation” are obtained directly from EEG device based on [eSenses](#) metric with 1 value per second. “Attention II” is based on estimation of attention level based on Fast Fourier transform (FFT) of filtered raw signal using a formula with relation of theta/beta waves expression (relative power from FFT). This metric is updated with each interval of processed signals (1/4 s, 1/2 s, 1s.. interval length can be changed in “MindPlay” and “MindDraw” windows). All metrics have values in [0..100] %.

The reason to have estimation of attention from a raw signal is that, “Attention II” provides with more fast estimation, besides having two options gives more flexibility for assessment of attention / focus / concentration states of a user. To have a smooth transition between a previous and current value for all mental activity metrics there is an interpolation, which fills all values between with 1 % step.

In Waves Generator mode “Attention I” is equal to “Attention II”, “Meditation” is estimated as a relation of alpha/beta waves expression.



**MindPlay** window is responsible for translation of brain waves to music by playing samples of tones from 2 tank drums (*Bmaj*, *D#min*) and hang drum (*Dmin*), besides it allows to observe brain waves flow over background images flow or camera input flow. The background image (.jpg) can be filtered with effects – blurring and change of colors by HSV (hue) filter, blurring depends on the brain activity: higher attention or meditation levels produce less blurred image. The background image can be changed by condition: when attention or meditation > border value; the border value can be fixed (chosen by user) or adaptively tuned to previous values of mental activity. Music generated by brain waves can be combined with usual playing of tones by user.



Pic.3 Screen of “MindPlay” window with brain waves flow,

video: <https://vimeo.com/498410929>, <https://vimeo.com/490266496>, <https://vimeo.com/341203496>

### How does it work?

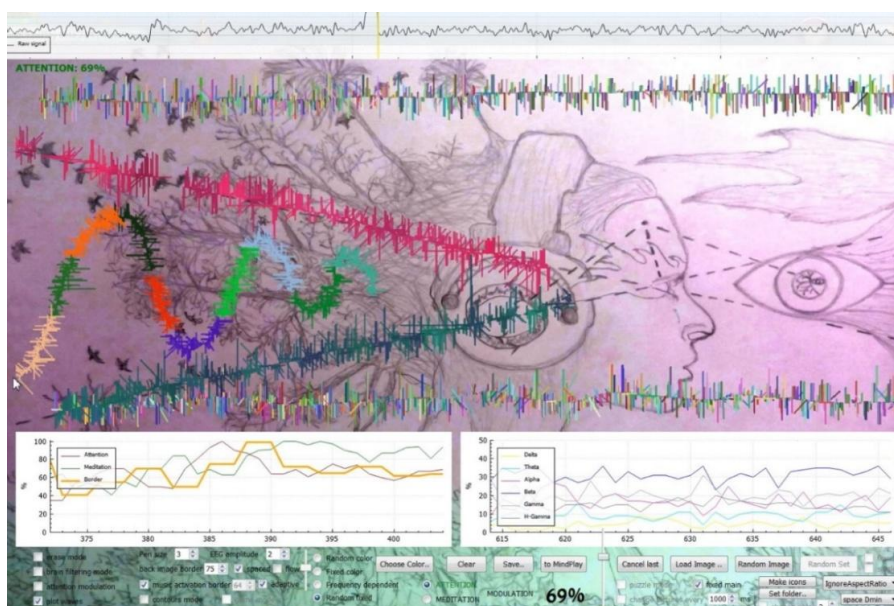
In short – it gets brain signals (electrical activity in microvolts) from 1 electrode (on frontal lobe area, Pic.1) and transmits it via bluetooth to the application, where it is processed in short intervals (1, 1/2 s or less) and frequency distribution for every interval is analyzed. Different musical tones are linked to different brain waves (*delta*, *theta*, *alpha*, *beta*, *gamma*), depending on which of them are more expressed in relation to deviations from its average values – particular corresponded tones will play. Thanks to pentatonic scale (which is used in hang or tank drums), the sounds are always in harmony. Attention or meditation levels, which are estimated by build-in algorithm in EEG device (or by Fourier transform values from raw signal) are linked with volume control: when you are more focused or more relaxed – sounds play louder, and optionally with tones duration, where with a higher level of attention or meditation – tones play longer. Brain waves are visualized by these short intervals in a flow (Pic.3), which you can scale and move.

Additionally, for each of 10 tones (or 8 for hang drum samples) there are deviation parameters, which determine how often each tone will play, this set of parameters represent an inner scale. When this set of values is fixed – you will have and hear a similar distribution of played tones (still varying depending on dynamics / deviations of brain waves expressions). Changing particular values of this scale or the whole scale will produce changes in musical patterns. Such changes can be done manually or regularly by a chosen time interval. Moreover, there are also delay parameters for each of tones (by default all = 0), which allows to make specifically some tones playing longer than the current general duration (interval length). Altogether, these modulations allow to add more variability to sound translation of brain waves.

Besides, there is an option to switch between 3 sound sample sets automatically depending on values of mental activity. In this case, the whole interval [0..100] % is divided on 3 parts by 2 borders, if mental activity < 1<sup>st</sup> border => *tank D#min* tones play, if mental activity > 1<sup>st</sup> border, but < 2<sup>nd</sup> border => *hang Dmin* plays, otherwise, *tank Bmaj* plays. When the option is checked, the borders are shown (Pic.3, right top corner) and can be changed on “Mental activity levels” window.

Moreover, there is an option to play continuously (in loops) some or all 4 background sounds: theta, alpha, beta, gamma vibes. The volume of theta is a fixed chosen value, whereas volume of other sounds depends on mental activity level: higher vibes play louder when mental activity value is more than a certain border (specific, linearly increasing for each of 3 sounds). This options allows to have a smooth sound translation independently of intervals duration and waves expression dynamics; it can be used together with interval based sound translation or separately.

**MindDraw** window with 4 different modes represents various graphical spaces and controls of them. In all modes there is an option to show brain waves expressions and attention, meditation levels on the plots. It represents your brain activity patterns, when you simply look on the application window or do something there (or wherever within limits of bluetooth). Therefore, you can see how your interactions influence your brain activity, for example, when you start drawing a line – your attention and beta waves usually increase, when you are closing eyes or relaxing – alpha waves usually get higher. Moreover, there is an option for combining drawing with music – when your attention or meditation level is higher than some value (fixed chosen or adaptively determined) – musical translation is activating and you hear sounds from “MindPlay” window.



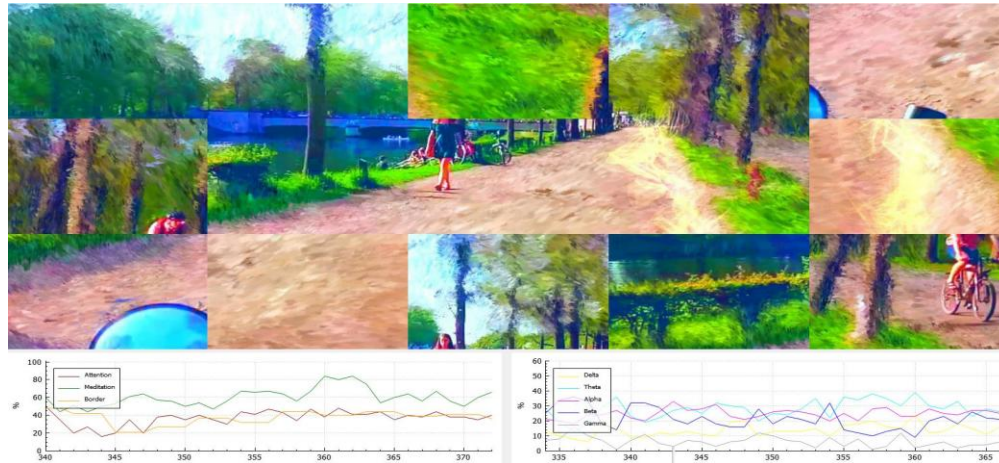
Pic.4 Screen of “MindDraw” window in “drawing mode”,

video: <https://vimeo.com/374172719>, <https://vimeo.com/331878650>, <https://vimeo.com/363152405>



1<sup>st</sup> mode – drawing with brain waves as a brush: when you press and move the mouse – signal from your brain (amplitude of brain oscillations from EEG device) is projecting on a plot with direction always orthogonal (90°) to the mouse movement. There are several options and parameters, such as color control (brain frequency dependent, random, fixed), amplitude (fixed, attention or meditation modulated), modes for instant drawing and drawing by contours. As in “MindPlay” window, any image can be used as a background layer also with a filtering flow mode. "MindDraw" and "MindPlay" windows can be switched and used with the same picture and all options available in two windows.

2<sup>nd</sup> mode – “puzzle gathering” game, where with attention or meditation level you need to complete the picture from 15 randomly shuffling fragments. The idea is that, when you are more focused or more relaxed – the puzzle is more complete, less fragments are in the wrong positions and changing slowly.



Pic.5 Screen of “MindDraw” window in “puzzle gathering” game mode,  
video: <https://vimeo.com/362443658>

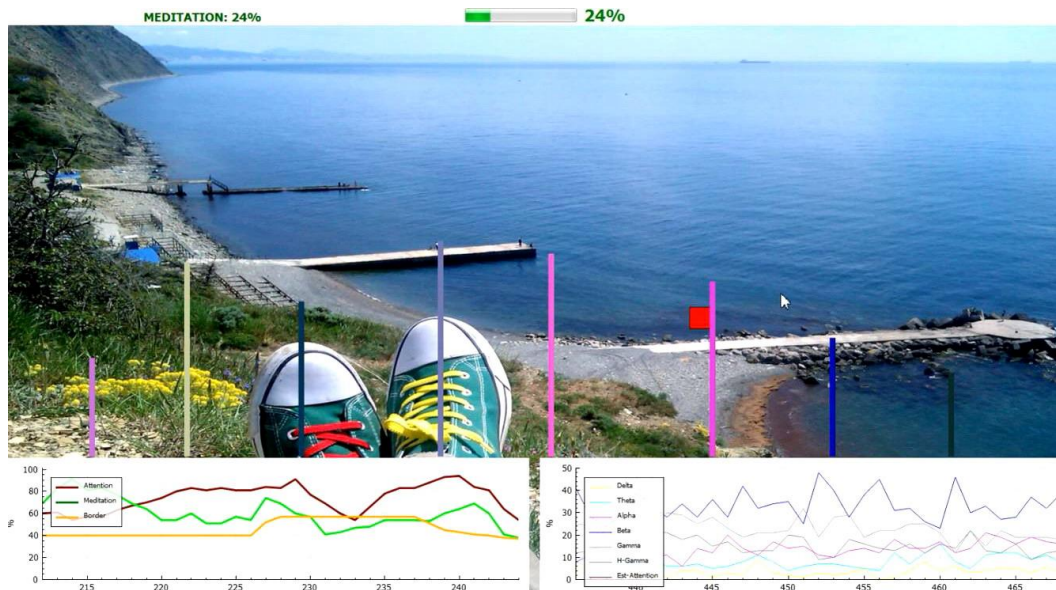
3<sup>rd</sup> mode – “find the same” game, where you need to find two the same pictures among 15, when all of them are blurring depending on attention (here “Attention II” metric is used), when you are more focused – pictures are more clean, and it is usually easy to find the same.



Pic.6 Screen of “MindDraw” window in “find the same” game mode,  
video: <https://vimeo.com/372210884>, <https://vimeo.com/404384963>

4<sup>th</sup> mode – “go through” game, where you need to pass the item through number of lines or obstacles (Pic.7) by your attention or meditation level, the item moves faster – when your mental activity level is increasing and, at the same time – the obstacles becomes lower; if your mental activity value is going down – the item moves slower and obstacles increase; if your attention or meditation level is below a certain chosen value, the item either stops or moves down (at the obstacle border). Additionally, when the item hits the obstacle or overcomes it – sound tones are played, therefore, your mental activity is also translated to music here, which will play faster or slower depending on how the item moves through the space with obstacles. When all obstacles over one space (image) are passed, then background image is changed and new game round is started.

*This mode is a prototype for 3D / VR-spaced game, where usual user controls and interactions can be combined with brain waves translations and modulations.*



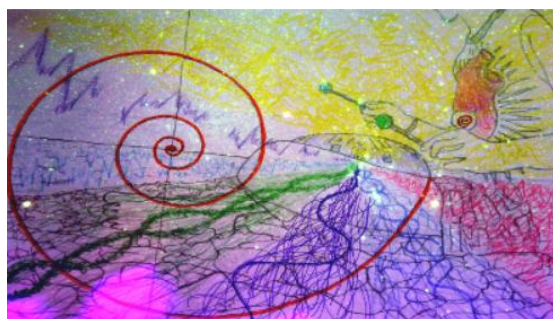
Pic.7 Screen of “MindDraw” window in “go through” game mode,  
video: <https://vimeo.com/426068418>

**MindOCV** window is based on OpenCV library and responsible for different visual flows, besides the main window this mode also opens the left and the right panels, which allow to choose the main and the overlay pictures from an image set. There are 4 modes in this window, 3 of them are flows: color-overlay flow, dreamflow, puzzle gathering flow; the last mode is a simple graphical editor / collages creator tool.

**1<sup>st</sup> mode:** color-overlay flow – here attention modulates rate (how fast) overlay and color changes are applied for a chosen couple of pictures, attention also controls the transparency of the main pic (more focused – more solid), at the same time main pic is changing colors with HSV (hue) filter.

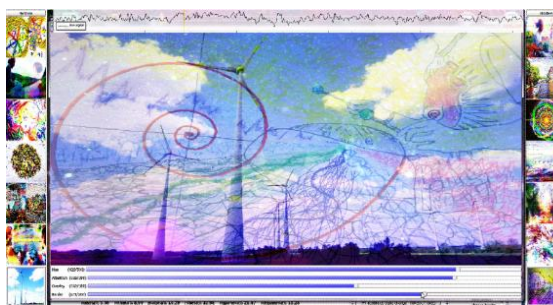
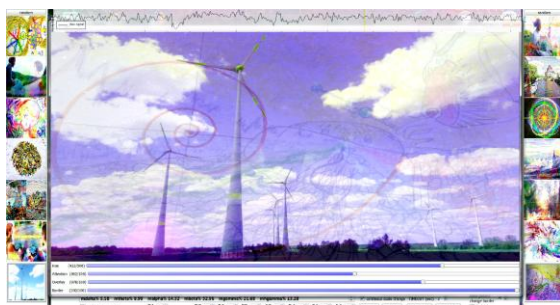


main pic



overlay pic

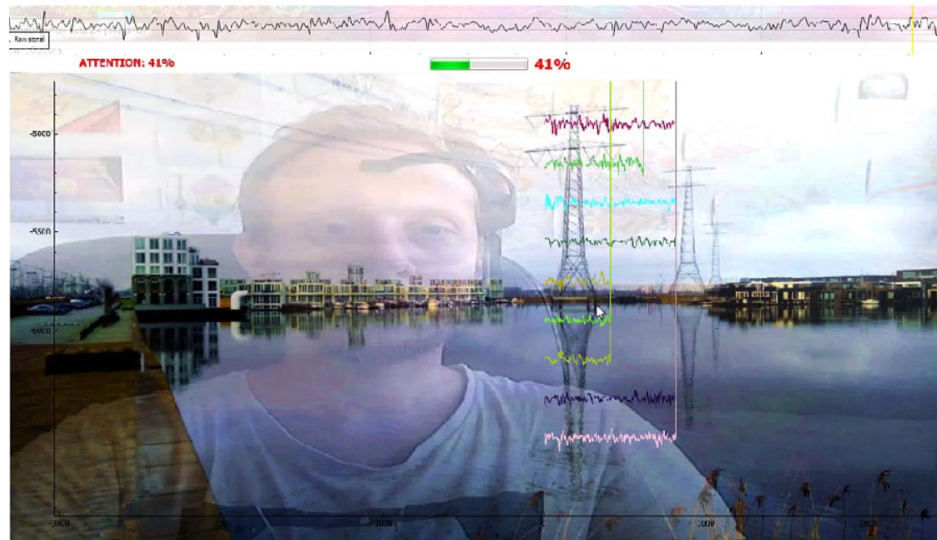
pics from resulting flow:



Pic.8 “MindOCV” window with color-overlay flow, video: <https://vimeo.com/387225095>



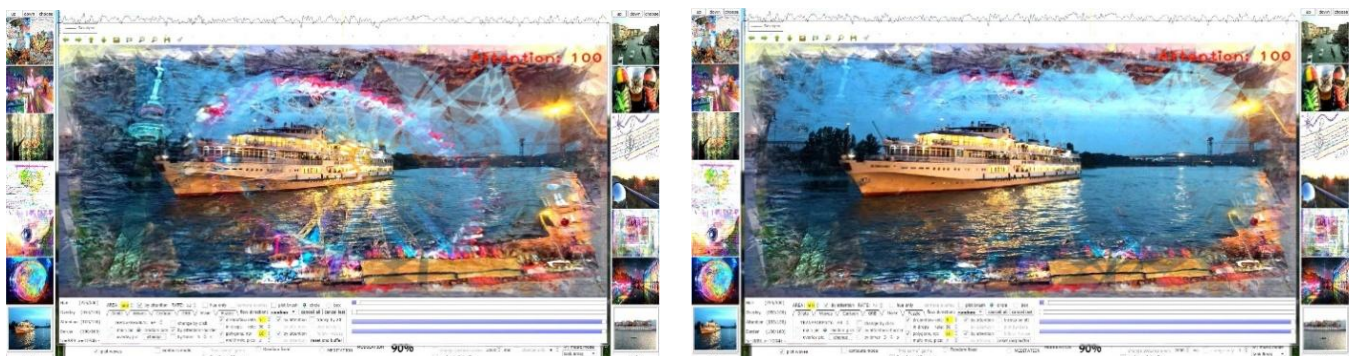
There is an option to use a camera input as a source for overlay pictures, which provides with an experience of being inside the flow, while observing and interacting with it (both by attention and usual controls). Streaming of the flow to “MindPlay” and “MindDraw” windows – allows to watch yourself or space from camera with overlay of your brain waves and mental activity levels.



Pic.9 “MindOCV” window, color-overlay flow with camera input,  
video: <https://vimeo.com/398709793>

2<sup>nd</sup> mode: dreamflow – smoothly filling visual space with parts of different pictures, either in a fully / partially user controlled way or in autonomous – when attention can modulate how fast fragments appear, their size, transparency and number of points in polygons for fragments (if polygon option is chosen, otherwise – fragments appear as circles or boxes of different sizes).

a) single mix: space is filling with random fragments of one image until change of the image

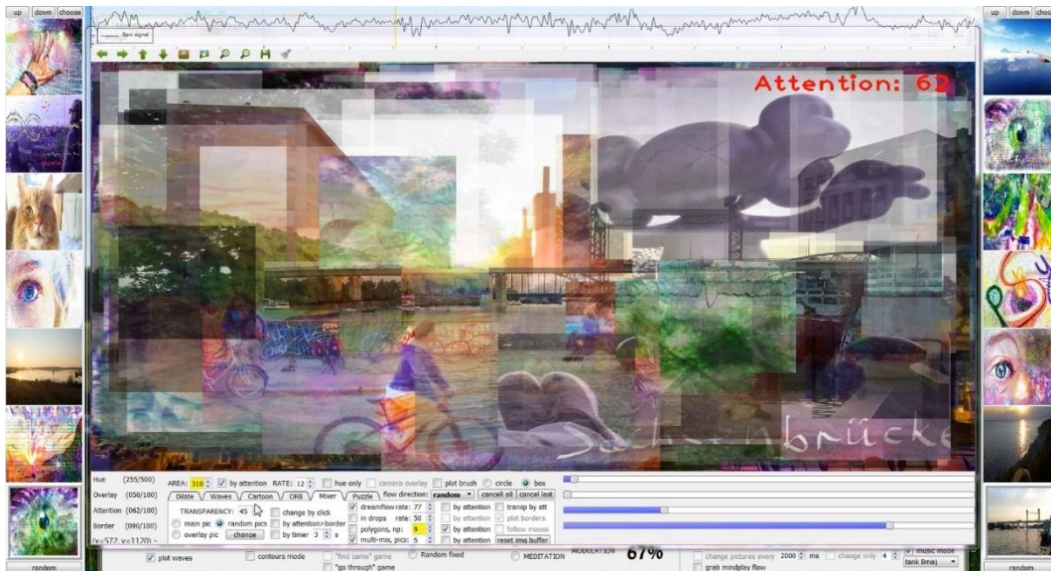


Pic.10 “MindOCV” window, dreamflow, single-mix

video: <https://vimeo.com/396094596>, <https://vimeo.com/396226013>, <https://vimeo.com/396294651>

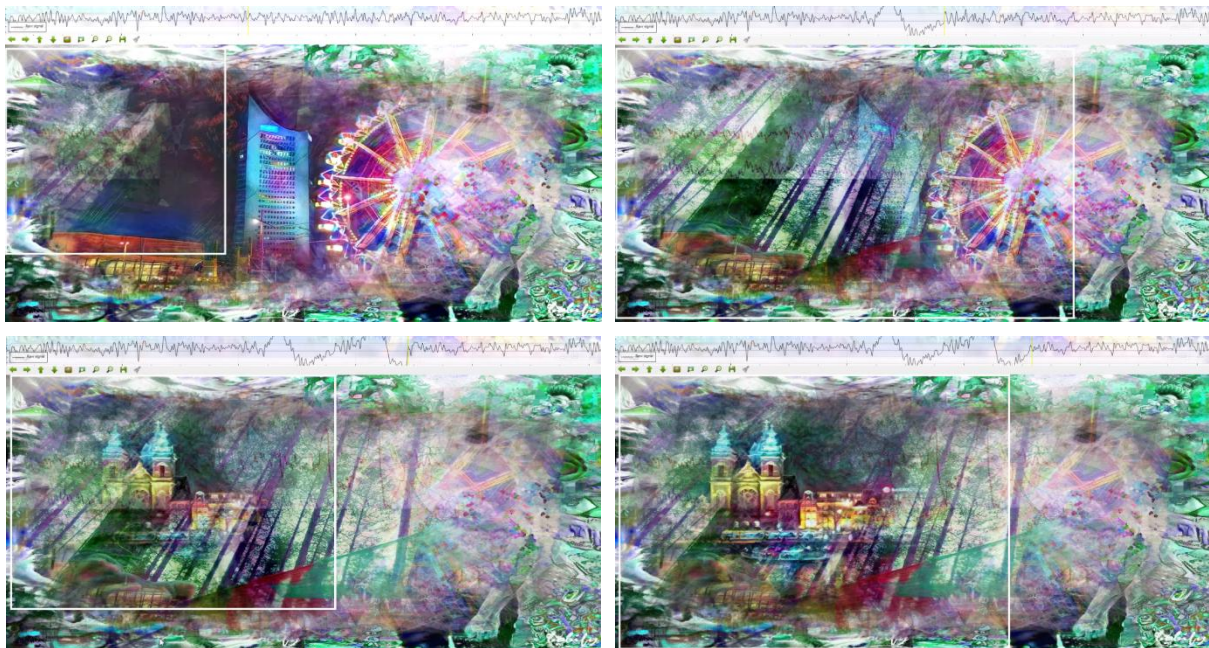
b) multi-mix: with each new fragment space is filling with parts of different images from a small set, where 1<sup>st</sup> image – main pic, 2<sup>nd</sup> – overlay pic, next N in the set are random; number of images in the current flow-moment can be controlled by user or by attention, when with a higher concentration – less number of pics are used, for example: with attention > 80% - only 2 pics (main and overlay) will be manifested, and with attention > 90% - only the main pic.





Pic.11 “MindOCV” dreamflow, multi-mix, video: <https://vimeo.com/419927090>, <https://vimeo.com/491870772>

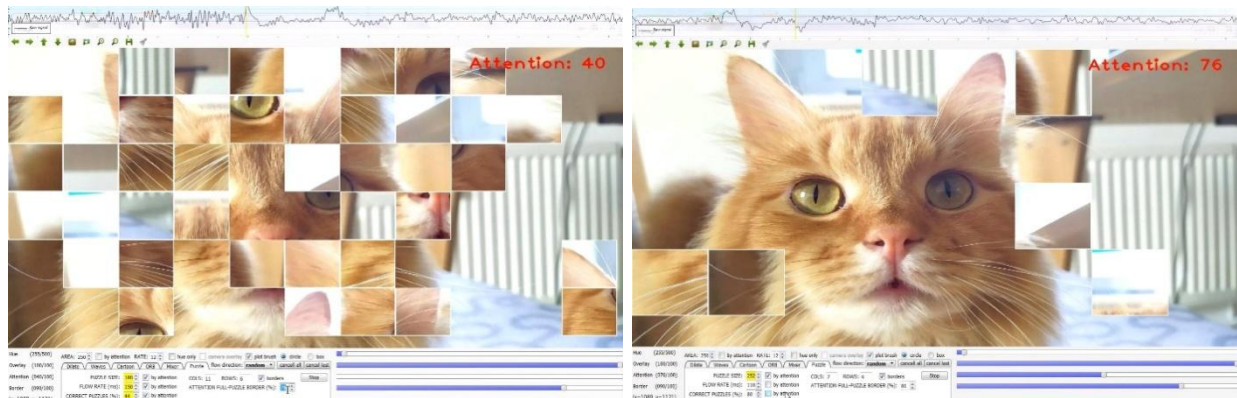
Additionally, both “single” and “multi-mix” dreamflows can be used with “drops” mode – where fragments of pictures appear in growing windows (drops), the rate of drops area increase can be modulated by attention, such as with a higher focusing – drops grow faster, new drops appear either at random position or at a current mouse position.



Pic.12 “MindOCV” dreamflow, drops mode,  
video: <https://vimeo.com/397576948>, <https://vimeo.com/397859469>, <https://vimeo.com/399557745>



3<sup>rd</sup> mode: puzzle gathering flow: similar to puzzle gathering game in “MindDraw” window, but allows to use more options, such as change of puzzles size, percentage of correctly placed puzzles and how fast wrongly placed puzzles change their positions; it is possible to choose control between attention and meditation levels, and set a border value (%) for completing the puzzle.



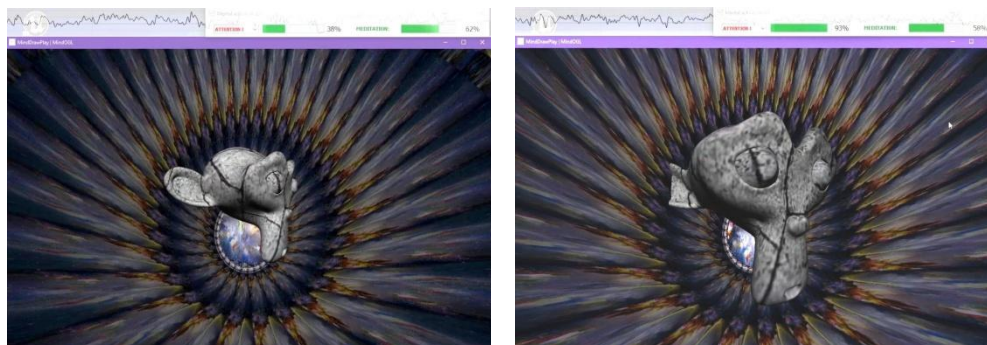
Pic.13 “MindOCV” puzzle-gathering flow,  
video: <https://vimeo.com/434909901>, <https://vimeo.com/437115484>

In all “MindOCV” flows pictures can be changed by user action, time interval or condition: when attention > border value (for example, 80%) in color-overlay flow – the overlay pic becomes main pic and a new overlay pic is randomly chosen; in a single mix dreamflow – new picture for filling space is randomly chosen, in multi-mix dreamflow – the main pic is updated; with “drops” mode – new picture is also chosen, when the current drop area fills full screen.

4<sup>th</sup> mode: a simple graphical editor / collage creator tool – currently with 5 filters (Dilate, Waves, Cartoon, ORB features, Mixer), this mode is more for exploring OpenCV filters and other image transforms, but also can be used during dreamflow mode or when one of the flows is stopped. The brush size and other filter-specific parameter can be attention modulated.

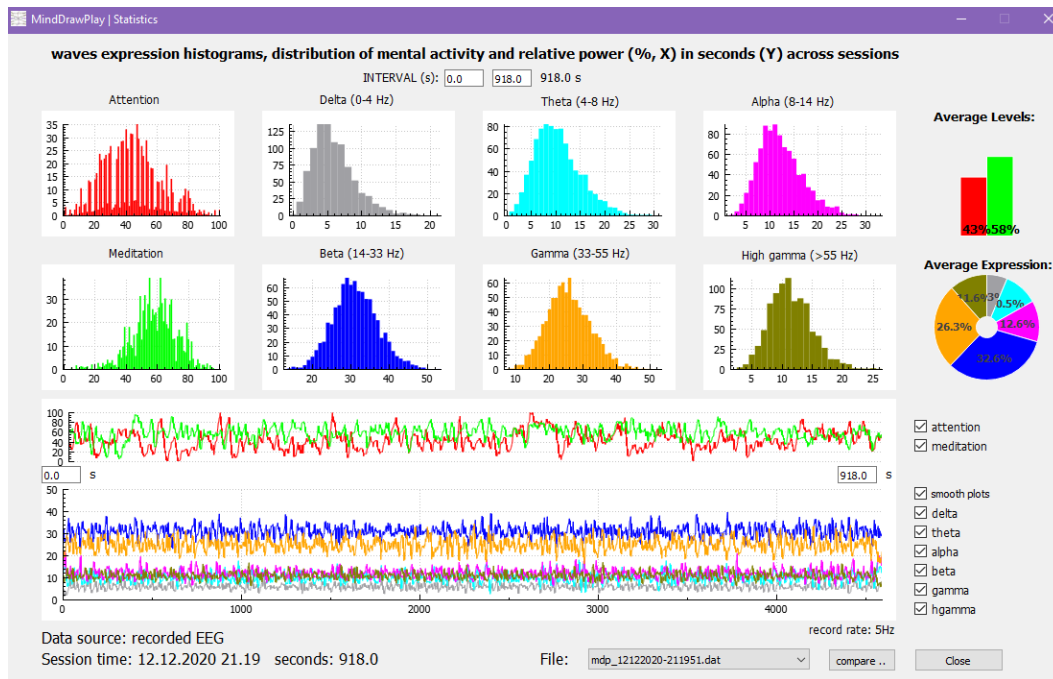
All “MindOCV” flows and pictures can be streamed to “MindPlay” and “MindDraw” windows and used there as a background layer, the images from those windows can also be send to “MindOCV”. Such transfers allow to observe and create various combinations of flows, drawing and filtering with pictures, sounds and brain waves.

**MindOGL** window is responsible for translation of brain waves to a simple OpenGL (GLU based) flow. 3D visual space is represented by a space object (torus) and inside of it – by an item object (monkey head – by default). There are 3 parameters of the flow, which are controlled by attention: rotation speed of the space ( *glRotatef()* ), change of texture and scale of the item ( *glScalef()* ). When attention level is higher – rotation is slower and the item is bigger (closer to camera view point), when attention > border value => space texture is changed. Additionally, transparency of the window can be controlled by user or by attention, this option allows to overlay with other flows from “MindPlay” and “MindOCV” windows.



Pic.14 “MindOGL” flow, video: <https://vimeo.com/498418710>

**Statistics** window provides with a simple statistical analysis of data from recorded sessions. The analysis is based on data recorded every 200 ms and includes 9 values: relative expressions of delta, theta, alpha, beta, gamma, high gamma bands, attention level estimated from FFT, attention and meditation levels from EEG device. The window shows histograms and average values for mental activity and brain waves expression for chosen time interval of the session; it also has plot representing data from the session, which can be zoomed and shifted for a particular time interval. There is an option to open a second window and compare data from different sessions or between specific time intervals of the same session.



Pic. 15 "Statistics" window

## Streaming to external applications

The brain waves data (9 values for each interval: relative expressions of delta, theta, alpha, beta, gamma, high gamma bands, attention level estimated from FFT, attention and meditation levels from EEG device) can be streamed via Open Sound Control (OSC) protocol to external applications (example of streaming to [TouchDesigner](https://www.touchdesigner.com/): osc\_mdp.toe).

*Author is interested and opened for any potential collaborations, especially, with sound and visual artists, mobile, 3D and VR applications developers.*

## Presentations:

27.12.2020 Zoom, discussion club Salon  
 18.03.2020 Berlin, TOP Project Space, Brain Awareness Week  
 31.01.2020 Leipzig, Basislager Coworking  
 04.12.2019 Berlin, Wild Code School  
 04.10.2019 Leipzig, Halle 14  
 20.06.2019 Leipzig, Krudebude  
 24.03.2018 Leipzig, Pilotenkueche  
 17.03.2018 Leipzig, Kunstraum Ping-Pong

Examples of drawings and pictures made with the app:

<https://www.artstation.com/neur0forest/albums/1338653>

Screen recordings demonstrating work of the app:

<https://www.artstation.com/neur0forest/albums/1425498>



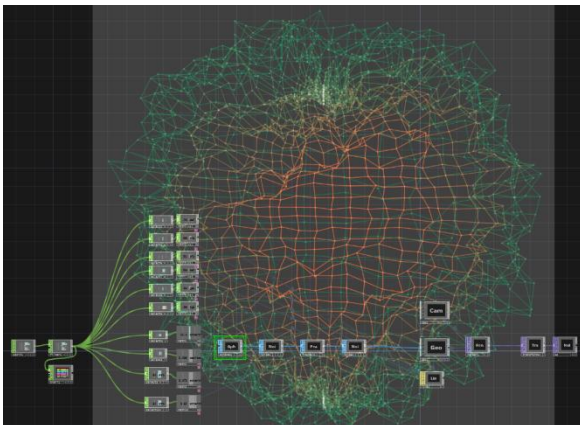
## Integration with TouchDesigner

Below is provided examples of streaming data via OSC protocol from [MindDrawPlay](#) to [TouchDesigner](#) (TD) and using brain waves data there for interactive visualizations. OSC parameters include address and port and can be changed in application (by default – address: 127.0.0.1, port: 9023). The data is streamed with each processed interval of EEG signals in bundles with 9 *int* values: *attention1*, *attention2*, *meditation*, *delta*, *theta*, *alpha*, *beta*, *gamma*, *hgamma*.

In general, any project in TD is a network of different operators nodes. Common for both examples are usage of CHOP operator *OSC in* ([https://docs.derivative.ca/OSC\\_in\\_CHOP](https://docs.derivative.ca/OSC_in_CHOP)) and preprocessing steps. Firstly, *OSC in* is used to receive data from MindDrawPlay, then Gaussian filter is applied to smooth transitions between obtained values, next *Select* operator is used to choose a specific value from all 9 values, then Math operator is applied to transform range of obtained values from [0..100] % to required range for modulated parameter of network's node. Overall, the main part of the integration is to find appropriate parameters in network for modulation by brain waves and corresponded scaling transformations. Below only short description of visualizations and parameters used for modulation are provided, the whole networks can be find in TD project files, examples are demonstrated in videos.

Example 1. MindWaveSphere (mindsphere.toe) <https://vimeo.com/468769144>

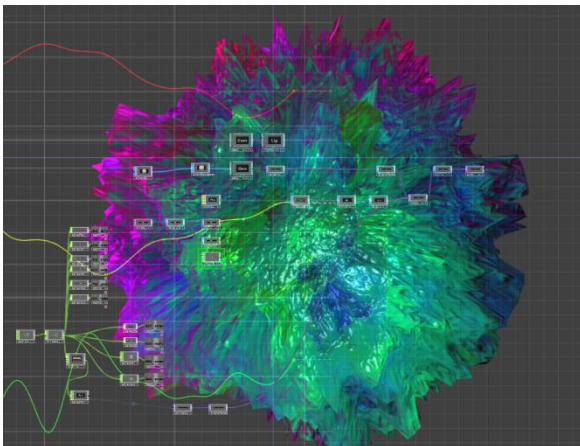
Attention and meditation values modulate complexity of the sphere and its dynamics through parameters of Sphere, Noise and Fractal nodes; brain waves expressions determine colors of sphere lines.



attention1 \* 0.2: number of rows & cols in Sphere node  
attention1 \* 0.006: exponent in Noise1 node  
attention1 \* 0.01: scale in Fractal node  
meditation \* 0.004: period and amp in Noise2 node  
delta \* 15/255: linenearcolorR in Line node  
theta \* 10/255: linenearcolorG in Line node  
alpha \* 8/255: linenearcolorB in Line node  
beta \* 6/255: linefarcolorR in Line node  
gamma \* 6/255: linefarcolorG in Line node  
hgamma \* 8/255: linefarcolorB in Line node

Example 2. MindWaveGlobe (mindglobe.toe) <https://vimeo.com/469577668>

Attention and meditation values modulate dynamics of the globe surface waves through displacement scale parameter of Phong node. With a higher attention values surface waves have less amplitude, and with a higher meditation values – slower frequency of appearance on the surface.



(1 – attention1 \* 0.01) \* 2:  
amplitude in LFO node for displacement scale in Phong node  
0.1 + (1 – meditation \* 0.01) \* 0.6:  
frequency in LFO node for displacement scale in Phong node