



POLITECNICO
DI MILANO

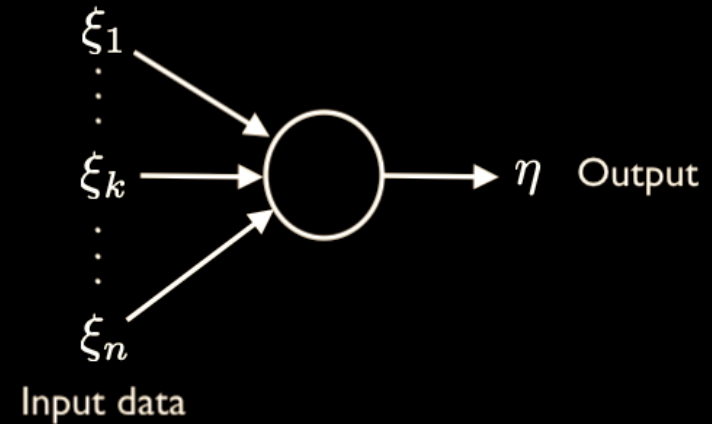
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BL  B.

ADVANCED CODING TOOLS AND
METHODOLOGIES 2021/2022

INTRODUCTION

- Idea driving the project: **Sonification of a Kohonen Network** (KN), also known as Self-Organizing Map (SOM).
- **Web frameworks** implemented: Tone.js, Canvas API, Bootstrap JS, SVG.js, Parcel API.
- **Browser compatibility**: optimised for Mozilla Firefox.



The **unsupervised learning** behavior of a KN artificial neuron has efficiency-coefficients time independent.

In KNs, forgetting rate is proportional to the weight vectors and also to a function of the **output signal (feedback)**.

KOHONEN NETWORK (KN)

- KNs are a tool for **visualize** and **convert** high-dimensional data into simple geometric relationships on a low-dimensional display [1, 2].
- A KN enables to **simulate the learning process** that allows the brain to handle sensory perception (certain cortex areas have similar properties as KNs. Examples are the processing of sound and light stimuli) [3].
- **Notice:** KNs are not a physical analogy of an expected neuronal configuration. They simply simulate the learning processing functions of certain areas of the brain cortex.

1) The learning process proceeds along **discrete time moments**: $t = 1, 2, \dots$

2) The learning process is fed with **input data** (observation vectors): $x(t)$

3) **Model vectors (nodes)** regression is made by the following process:

$$m_i(t+1) = m_i(t) + h_{c(x),i}(x(t) - m_i(t))$$

where **index “c” (winner)** is defined by the condition:

$$\|x(t) - m_c(t)\| \leq \|x(t) - m_i(t)\| \quad \forall i$$

and the **neighborhood function** (NF):

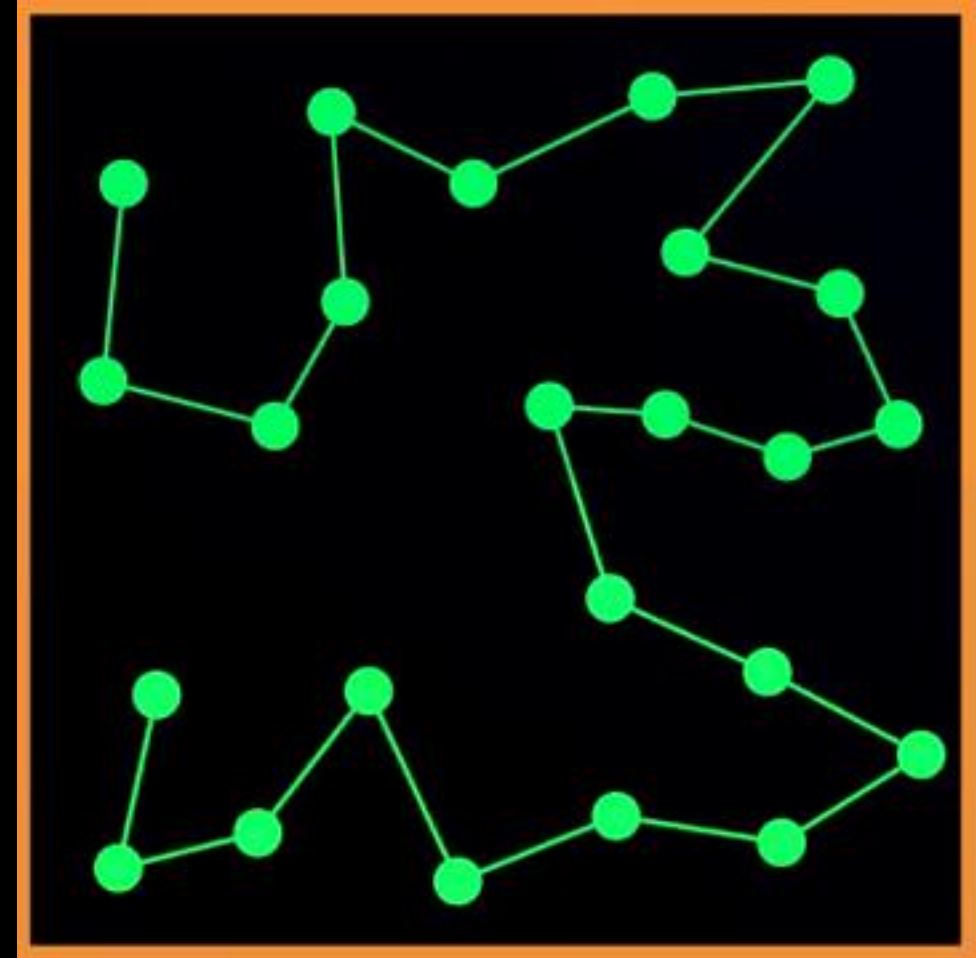
$$h_{c(x),i} = \alpha(t) \left(e^{-\frac{\|r_i - r_c\|^2}{2\sigma(t)^2}} \right)$$

$\left\{ \begin{array}{l} \alpha(t) \text{ Learning-rate factor.} \\ \sigma(t) \text{ Width of the NF.} \end{array} \right.$

They both **decrease monotonically** with the regression steps.

KOHONEN NETWORK (KN)

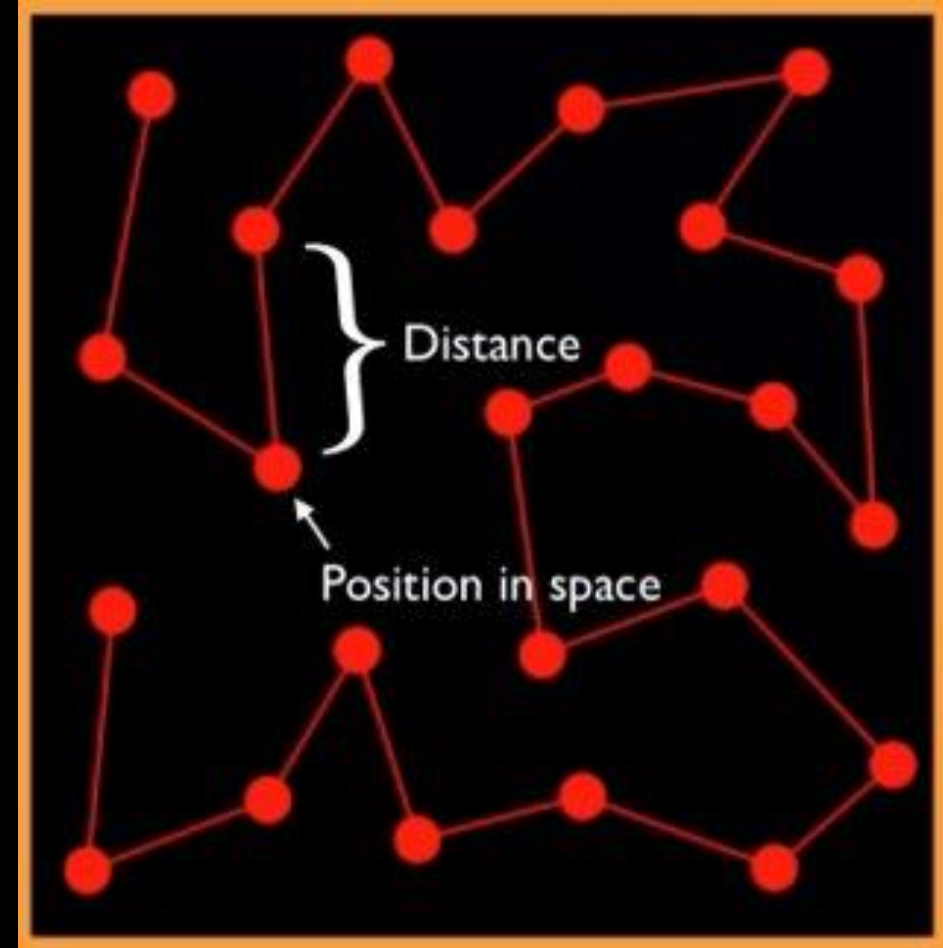
- **Weight vectors** (nodes) during the ordering process of a uniform distributed square into a curve.



Link to the video: [Self-Ordering Kohonen Network](#)

THE SONIFICATION PROCESS

- **KN Sonification** achieved extrapolating:
 1. Nodes' relative distance (Note duration)
 2. Nodes' position in space.
- By joining these features, different "pads" were developed:
 1. The **Rhythmic Pad**
 2. The **Melodic Pad**
 3. The **Harmonic Pad**

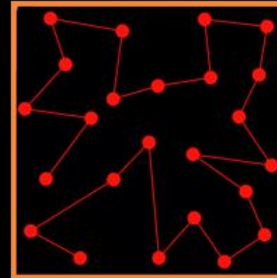


THE RHYTHMIC PAD

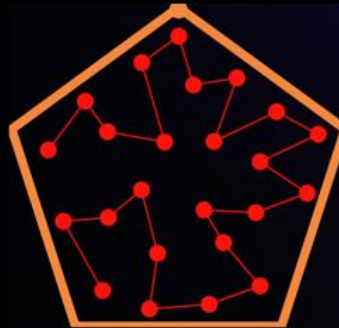
- The **Rhythmic Pad** performs solely percussive sounds:
 1. Single node associated to a single sound.
 2. Time position in the measure provided by relative nodes' distances.
 3. Metric of the measure associated to a geometric figure (see figure).
 4. Node sound is an external sample.



Triangle → 3/4 Metric



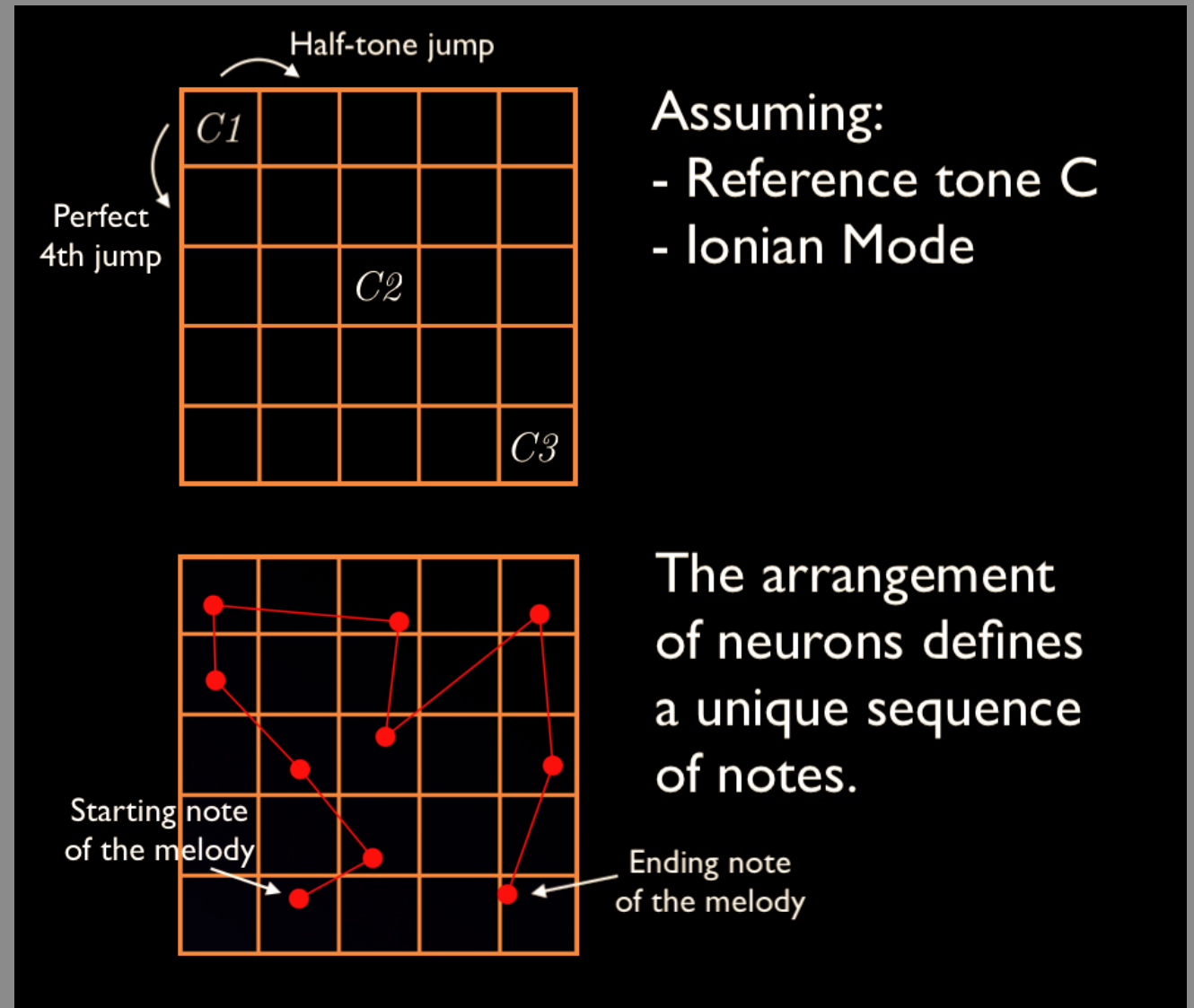
Square → 4/4 Metric



Pentagon → 5/4 Metric

THE MELODIC PAD

- The **Melodic Pad** creates a melodic line:
 1. Single node associated to a single note.
 2. Note duration and time position in the measure provided by relative nodes's distances.
 3. Scale note set by the position of the node in space (see figure).
 4. Scale Tone and Scale Mode set by the user (different and uneven nodes configurations)
 5. Note sound is played by a Tone.js Polysynth.
- **Notice:** each Scale Mode is characterized by a unique configuration in the grid.



THE MELODIC PAD: SOUND AND EFFECTS

- User can change:
 1. Metric (No geometric figure associated).
 2. PolySynth Sound (Sine wave, Square Wave, etc.).
 3. Envelope properties.
- User can add the following Tone.js effects to the melody:
 1. Delay
 2. Distortion
 3. Tremolo
 4. Phaser
- Bootstrap Modal plug-in was used for dialog box (popup window) to set effect parameters.

Effects Properties ×

Delay ●

Wet: 0 FeedBack: 0

4n ▼

Distortion ●

Wet: 0 Distortion: 0.1

Tremolo ●

Wet: 0 Frequency(Hz): 1

Depth: 0 Spread: 180

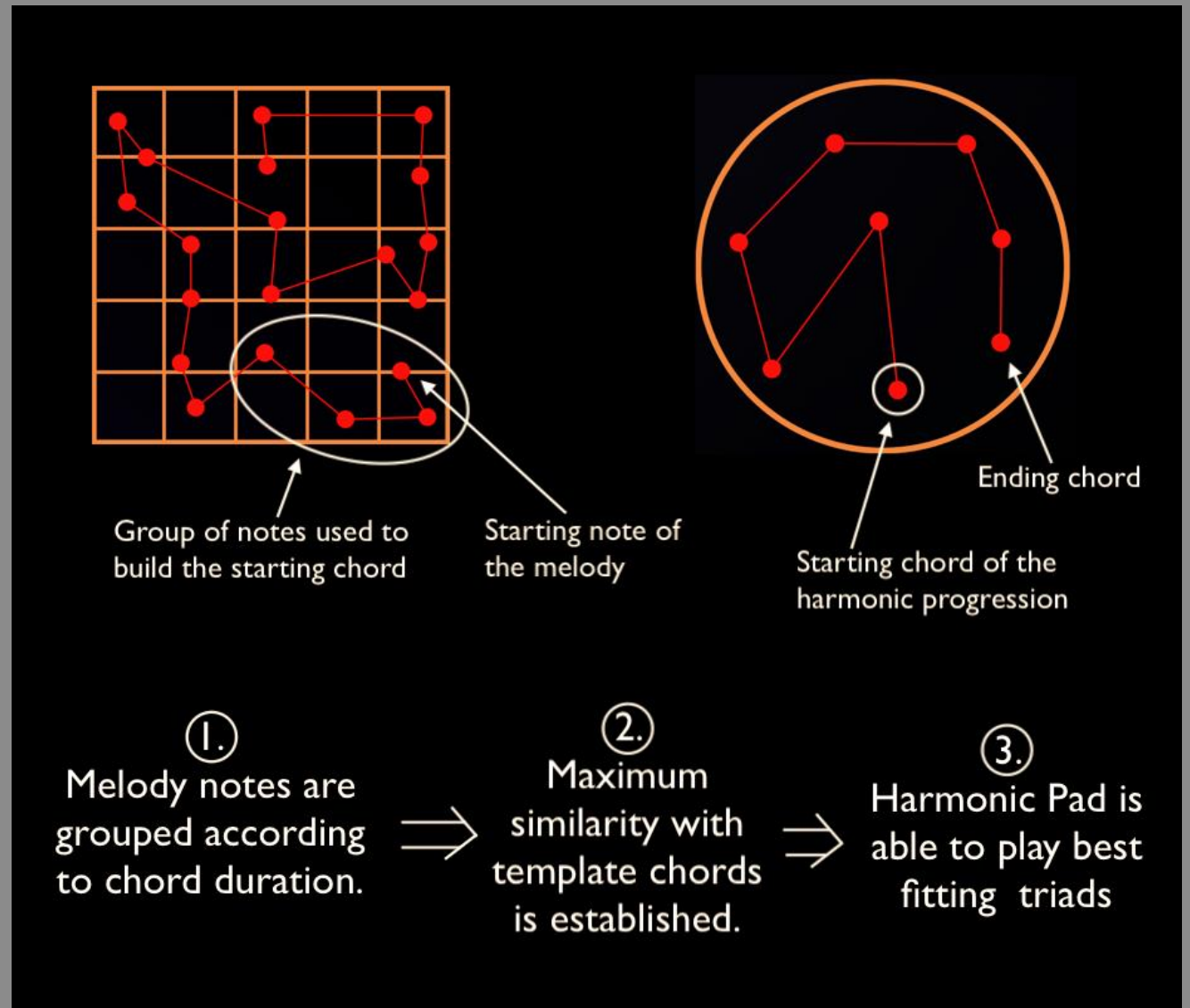
Phaser ●

Wet: 0 Frequency(Hz): 1

Octaves: 2 BaseFrequency(Hz): 150

THE HARMONIC PAD

- The **Harmonic Pad** creates an harmonic support to the melody generated by the Malodic Pad:
 1. Single node associated to a single chord.
 2. Chord duration and time position in the measure provided by relative nodes's distances.
 3. Scale Tone and Scale Mode are the same of the Melodic Pad (set by the user).
 4. Chord sound is played by a Tone.js PolySynth.
- **Notice:** Melodic Pad loop duration = Harmonic Pad loop duration.



THE HARMONIC PAD: CHORD RECOGNITION

- The **Harmonic Pad** creates an harmonic support to the melody generated by the Malodic Pad:
 1. Notes are grouped according to the chord duration.
 2. An "equal tempered" binary representation is built.
 3. The binary representation is matched with a template chord.
 4. The best fitting chord is coupled with the melody.
- **Notice:** All chords are played with the form root-3rd-5th

1) Notes are grouped according to the chord duration.



2) An "equal-tempered" binary representation is built:
[1, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0]



3) The binary representation is matched with a template chord.



4) The best fitting chord is coupled with the melody.

[1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0] (C maj.)

[0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0] (D min.)

⋮

(C major is chosen for simplicity)

THE "PRE-LEARNING" USER INTERFACE

PLAY

START SELF ORDERING

BPM:120


Rhythm Pads Sounds
Pad 1 ▾
Pad 2 ▾
Pad 3 ▾

Harmony
Key ▾
Scale ▾

Melody Wave Type
Wave Type ▾

Harmony Wave Type
Wave Type ▾

Notes Number  4-32
Metric ▾
INIT RHYTHMIC PAD 1

Notes Number  4-32
Metric ▾
INIT RHYTHMIC PAD 2

Notes Number  4-32
Metric ▾
INIT RHYTHMIC PAD 3

Notes Number  4-32
Metric ▾
INIT MELODIC PAD

Envelope (ADSR)
 A
 D
 S
 R
Effects Properties
EFFECTS

Chords Number  4-12
INIT HARMONIC PAD



Select Theme
Blob ▾

THE "PRE-LEARNING" USER INTERFACE

PLAY

START SELF ORDERING

BPM:120

Rhythm Pads Sounds

Pad 1

Pad 2

Pad 3

Harmony

Key

Scale

Melody Wave Type

Wave Type

Harmony Wave Type

Wave Type

Notes Number 4-32

Metric

INIT RHYTHMIC PAD 1

Notes Number 4-32

Metric

INIT RHYTHMIC PAD 2

Notes Number 4-32

Metric

INIT RHYTHMIC PAD 3

Notes Number 4-32

Metric

INIT MELODIC PAD

Envelope (ADSR)

A

D

S

R

Effects Properties

EFFECTS

Chords Number 4-12

INIT HARMONIC PAD

Select Theme

Blob

Rhythmic Pads and relative parameters.

THE "PRE-LEARNING" USER INTERFACE

The image shows a digital user interface for a music application. On the left is a sidebar with various controls: a 'PLAY' button, a 'START SELF ORDERING' button, a BPM slider set to 120, and dropdown menus for 'Rhythm Pads Sounds' (Pad 1, 2, 3), 'Harmony' (Key, Scale), 'Melody Wave Type' (Wave Type), and 'Harmony Wave Type' (Wave Type). The main area contains several parameter panels. Three 'Rhythmic Pad' panels (1, 2, 3) each have a 'Notes Number' (4-32), a 'Metric' dropdown, and an 'INIT RHYTHMIC PAD' button. A 'Melodic Pad' panel, highlighted with a yellow rounded rectangle, includes 'Notes Number' (4-32), 'Metric' dropdown, an 'INIT MELODIC PAD' button, an 'Envelope (ADSR)' section with four sliders for A, D, S, and R, and an 'Effects Properties' section with an 'EFFECTS' button. To the right of these is a 'Chords' panel with 'Chords Number' (4-12) and an 'INIT HARMONIC PAD' button. A 'Select Theme' dropdown at the bottom right is set to 'Blob'. A yellow arrow points from the text 'Melodic Pad and relative parameters.' to the highlighted Melodic Pad panel.

PLAY

START SELF ORDERING

BPM:120

Rhythm Pads Sounds

Pad 1

Pad 2

Pad 3

Harmony

Key

Scale

Melody Wave Type

Wave Type

Harmony Wave Type

Wave Type

Notes Number 4-32

Metric

INIT RHYTHMIC PAD 1

Notes Number 4-32

Metric

INIT RHYTHMIC PAD 2

Notes Number 4-32

Metric

INIT RHYTHMIC PAD 3

Notes Number 4-32

Metric

INIT MELODIC PAD

Envelope (ADSR)

A

D

S

R

Effects Properties

EFFECTS

Chords Number 4-12

INIT HARMONIC PAD

Select Theme

Blob

Melodic Pad and relative parameters.

THE "PRE-LEARNING" USER INTERFACE



THE "PRE-LEARNING" USER INTERFACE



THE "PRE-LEARNING" USER INTERFACE



PLAY

START SELF ORDERING

BPM:120

Rhythm Pads Sounds

Pad 1

Pad 2

Pad 3

Harmony

Key

Scale

Melody Wave Type

Wave Type

Harmony Wave Type

Wave Type

Notes Number 4-32

Metric

INIT RHYTHMIC PAD 1

Notes Number 4-32

Metric

INIT RHYTHMIC PAD 2

Notes Number 4-32

Metric

INIT RHYTHMIC PAD 3

Notes Number 4-32

Metric

Envelope (ADSR)

A

D

S

R

Effects Properties

EFFECTS

Notes Number 4-32

Metric

INIT MELODIC PAD

Chords Number 4-12

INIT HARMONIC PAD

Select Theme

Blob

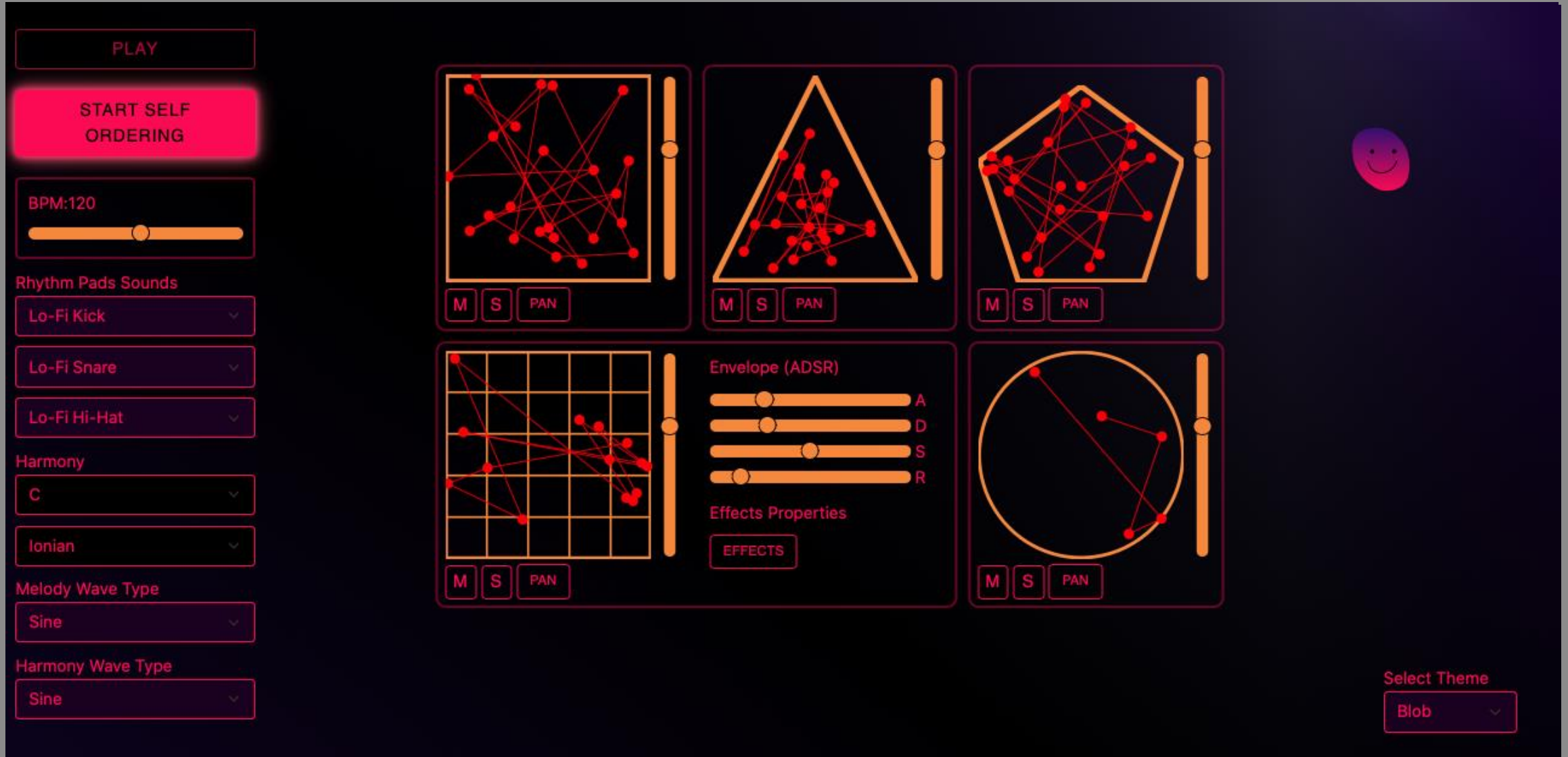
Rhythmic Pad sounds.

THE "PRE-LEARNING" USER INTERFACE

To start the self-ordering process.
Note: clickable **only after** (at least one) "INIT PAD"

The image shows a digital music creation interface with a dark blue background. On the left is a sidebar with various controls: a 'PLAY' button, a 'START SELF ORDERING' button (highlighted with a yellow rectangle and an arrow pointing to the explanatory text), a BPM slider set to 120, and dropdown menus for 'Rhythm Pads Sounds' (Pad 1, 2, 3), 'Harmony' (Key, Scale), 'Melody Wave Type' (Wave Type), and 'Harmony Wave Type' (Wave Type). The main area contains several control panels. The top row has three identical panels, each with a 'Notes Number' slider (set to 8, range 4-32), a 'Metric' dropdown, and an 'INIT RHYTHMIC PAD' button (labeled 1, 2, and 3 respectively). The bottom row has two panels. The left panel has a 'Notes Number' slider (8, 4-32), a 'Metric' dropdown, and an 'INIT MELODIC PAD' button. The right panel has an 'Envelope (ADSR)' section with four sliders for A, D, S, and R, an 'Effects Properties' section with an 'EFFECTS' button, and a 'Chords Number' slider (8, 4-12) with an 'INIT HARMONIC PAD' button. A small, colorful blob character with a smiley face is on the right. At the bottom right, there is a 'Select Theme' dropdown menu currently set to 'Blob'.

THE "PRE-LEARNING" USER INTERFACE



THE "POST-LEARNING" USER INTERFACE

PLAY

To start or reset the program

BPM:120

Rhythm Pads Sounds

Lo-Fi Kick

Lo-Fi Snare

Lo-Fi Hi-Hat

Harmony

C

Ionian

Melody Wave Type

Sine

Harmony Wave Type

Sine

M S PAN

M S PAN

M S PAN

M S PAN

Envelope (ADSR)

A

D

S

R

Effects Properties

EFFECTS

M S PAN

M S PAN

Select Theme

Blob

THE "POST-LEARNING" USER INTERFACE

The image displays a digital user interface for a music synthesizer, titled "THE 'POST-LEARNING' USER INTERFACE". The interface is set against a dark blue background with various control elements in light blue and orange.

Left Panel (Controls):

- PLAY** button
- BPM:120** slider (highlighted with a red box and an arrow pointing to it with the text "BPM is changeable in real-time")
- Rhythm Pads Sounds** section with dropdowns for:
 - Lo-Fi Kick
 - Lo-Fi Snare
 - Lo-Fi Hi-Hat
- Harmony** section with dropdowns for:
 - C
 - Ionian
- Melody Wave Type** dropdown for Sine
- Harmony Wave Type** dropdown for Sine

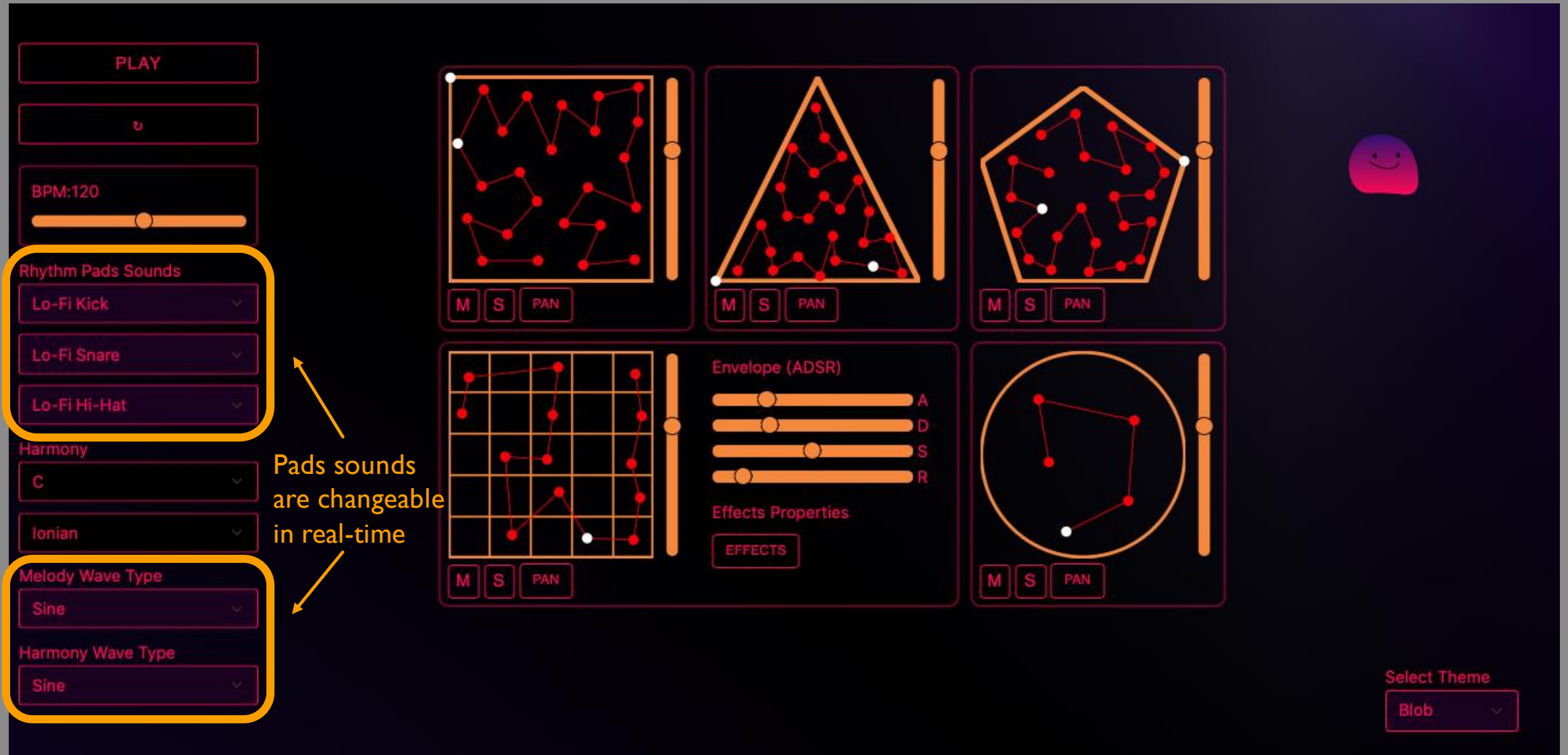
Main Area (Visualizers and Controls):

- Top Row:** Three visualizers (square, triangle, and pentagon) showing red dots connected by lines, representing a network or waveform. Each has a vertical slider on the right and buttons for **M**, **S**, and **PAN**.
- Bottom Row:** A 4x4 grid visualizer, an **Envelope (ADSR)** section with four sliders for **A**, **D**, **S**, and **R**, and an **Effects Properties** section with an **EFFECTS** button. Each of these four sections has a vertical slider on the right and buttons for **M**, **S**, and **PAN**.

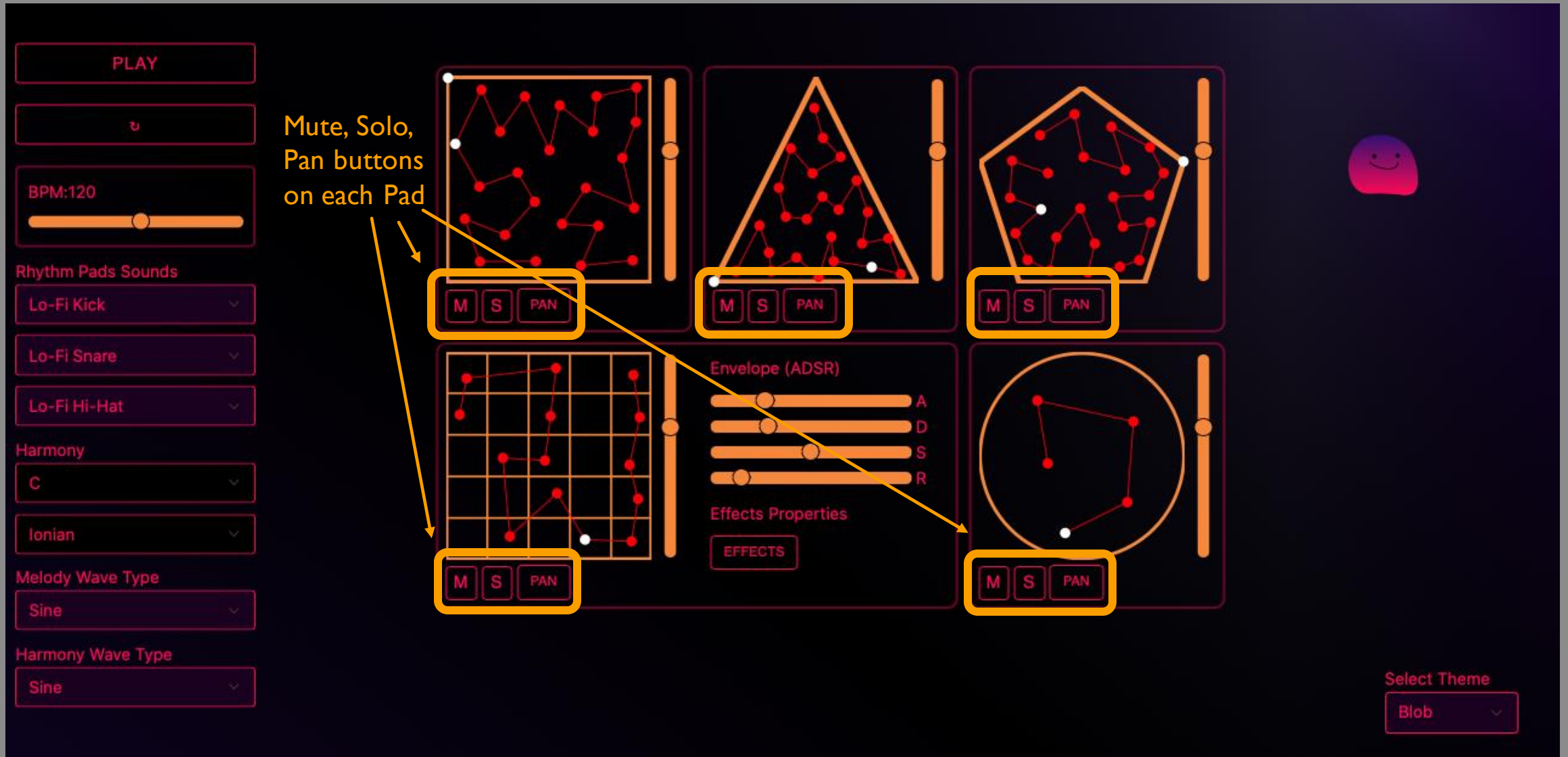
Right Panel:

- A small, colorful, blob-like character with a smiley face.
- Select Theme** dropdown menu showing **Blob**.

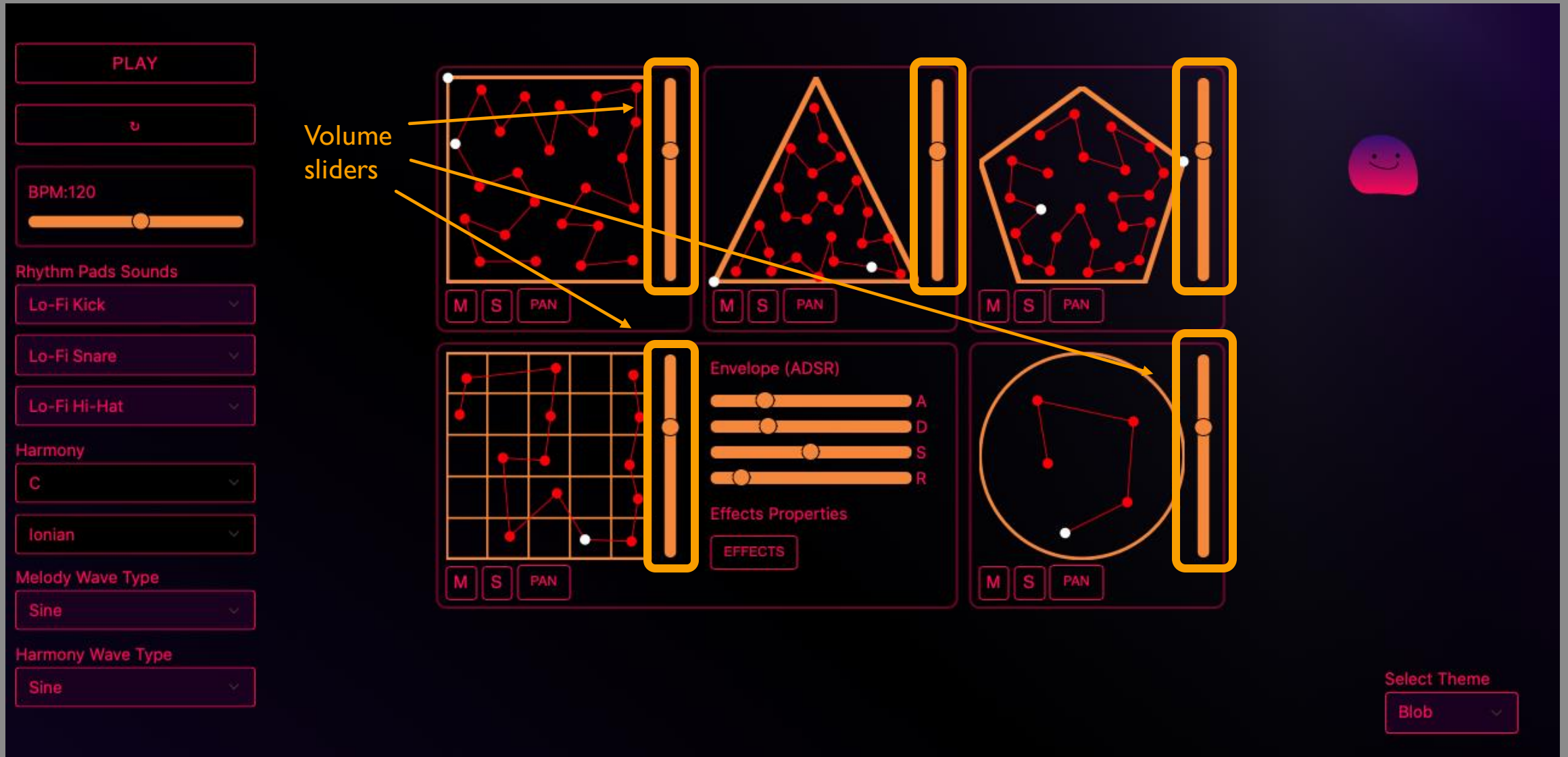
THE "POST-LEARNING" USER INTERFACE



THE "POST-LEARNING" USER INTERFACE



THE "POST-LEARNING" USER INTERFACE



THE "POST-LEARNING" USER INTERFACE

The playing nodes glow white.

PLAY

BPM:120

Rhythm Pads Sounds

Lo-Fi Kick

Lo-Fi Snare

Lo-Fi Hi-Hat

Harmony

C

Ionian

Melody Wave Type

Sine

Harmony Wave Type

Sine

Envelope (ADSR)

Effects Properties

EFFECTS

Select Theme

Blob

THE "POST-LEARNING" USER INTERFACE

The beat of each Rhythmic Pad can be easily followed.

PLAY

BPM:120

Rhythm Pads Sounds

Lo-Fi Kick

Lo-Fi Snare

Lo-Fi Hi-Hat

Harmony

C

Ionian

Melody Wave Type

Sine

Harmony Wave Type

Sine

Envelope (ADSR)

A

D

S

R

Effects Properties

EFFECTS

M S PAN

M S PAN

M S PAN

M S PAN

Select Theme

Blob

I'M HERE TO HELP YOU :)

- **Bloppity Blop** is clickable:
It will help you to use correctly the program.

... Thank you for your attention.

Hi! My name is Bloppity Blob :)
Click on me for instructions!



REFERENCES

- [1] Kohonen, T. Self-organized formation of topologically correct feature maps. *Biol. Cybern.* **43**, 59–69 (1982). <https://doi.org/10.1007/BF00337288>
- [2] Kohonen T. (2013). Essentials of the self-organizing map. *Neural networks : the official journal of the International Neural Network Society*, 37, 52–65. <https://doi.org/10.1016/j.neunet.2012.09.018>
- [3] Vrieze O.J. (1995) Kohonen network. In: Braspenning P.J., Thuijsman F., Weijters A.J.M.M. (eds) *Artificial Neural Networks. Lecture Notes in Computer Science*, vol 931. Springer, Berlin, Heidelberg. <https://doi.org/10.1007/BFb0027024>