

# Digital music interface for motor rehabilitation: a motion capture and machine learning approach

Raquel Lucena Peris

Supervisor: Rafael Ramírez Menéndez

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Sound Music & Technology - MTG



Universitat  
Pompeu Fabra  
*Barcelona*



# Introduction **STROKE**

Interruption of blood flow  
Nerve cells die  
Function may be changed



**WHO**

Annually 15M

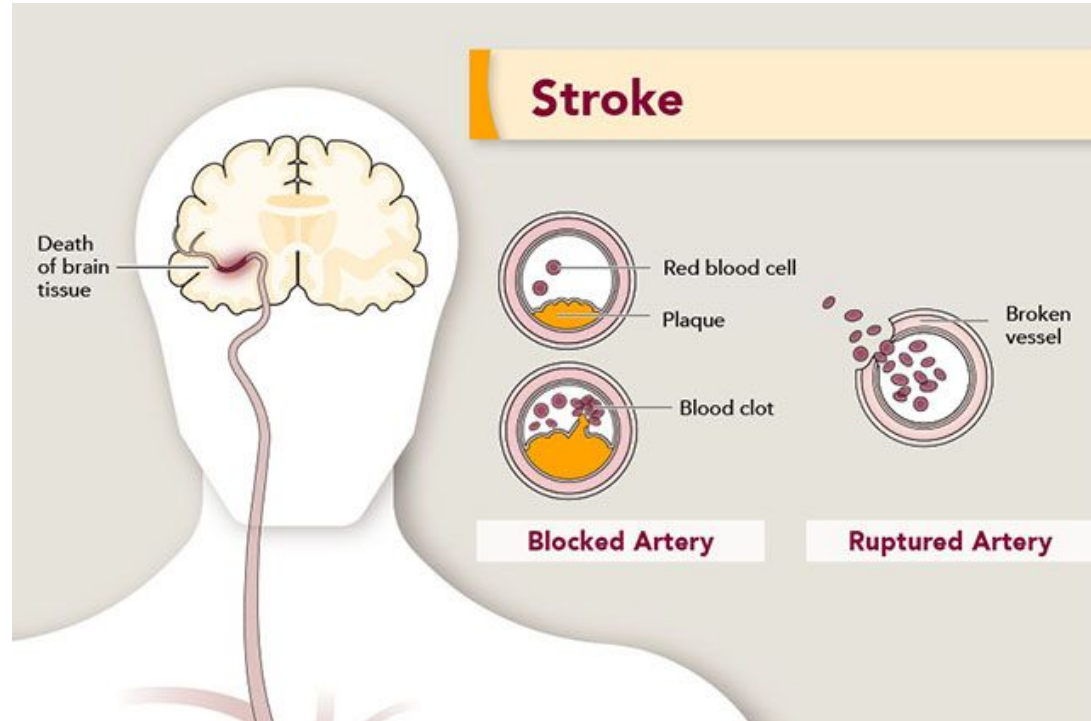
**HCB**

1/6 lifetime



Spain:

suffers every 6'  
death every 14'



Affect the quality of life and social participation



Utilizes music, rhythm, and beat to improve patient's neurological function and mood.

Singing, playing or moving (strong sense of rhythm) or listening (preferences)

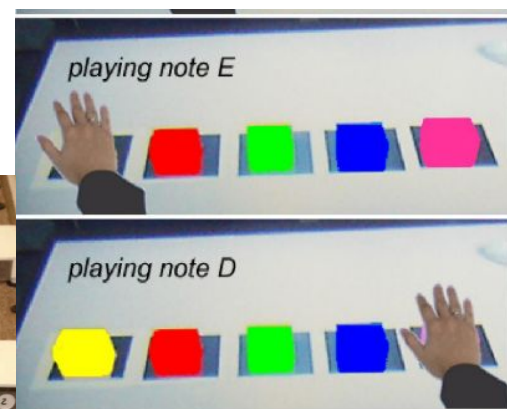
1. **Physical intervention:** physical strength, balance, movement, coordination and motor recovery
2. **Stimulate communication:** (Aphasia) speech stimulation and improve pronunciation
3. **Cognitive Stimulations:** improve attention, memory problem, depression or anxiety

- Time with a music therapist is limited
- Importance to continue with music therapy at home
- Fun and motivating way to practice repetitions of activities that stimulate muscles.
- The more you practice, the better you will get.

## Products

MusicGlove, GenVirtual and DrumsApp uses movements synchronized with music to improve one concret area function rehabilitation.

Not adaptive to gestures or body parts





## Introduction: MOTIVATION

- Stroke affect patient's quality life.
- Limited number of professionals, computer assisted care helps
- Speed up routine procedures
- Digital music technologies:
  - low-cost and flexible approach for home practice.
  - gamification music technique to motivate and commit people with rehabilitation exercises
- Traditional instrument is difficult to play, the digital interface can be a good.
- Recovery motor function as music has a great impact in rehabilitation as auditory cortex is connected to the motor cortex



## **Introduction: OBJECTIVES**

- Works in Real-Time
- Personalized Interface
- Learns in Real-Time the user capabilities by Machine Learning
- Has a validation method

# Introduction: RESEARCH QUESTION

- **Is the combination of music and artificial intelligence useful for stroke rehabilitation?**
  - Utility, profitability and advantages
  - Engaging
- **Is the artificial intelligence digital music interface comparable to a musical instrument while doing stroke rehabilitation?**
  - Mapping between gesture and sounds
  - Autonomy and independence
  - Allow expressiveness



# Methodology: MATERIALS

## HARDWARE

- Computer and webcam
- Loudspeaker
- Mouse or touchscreen

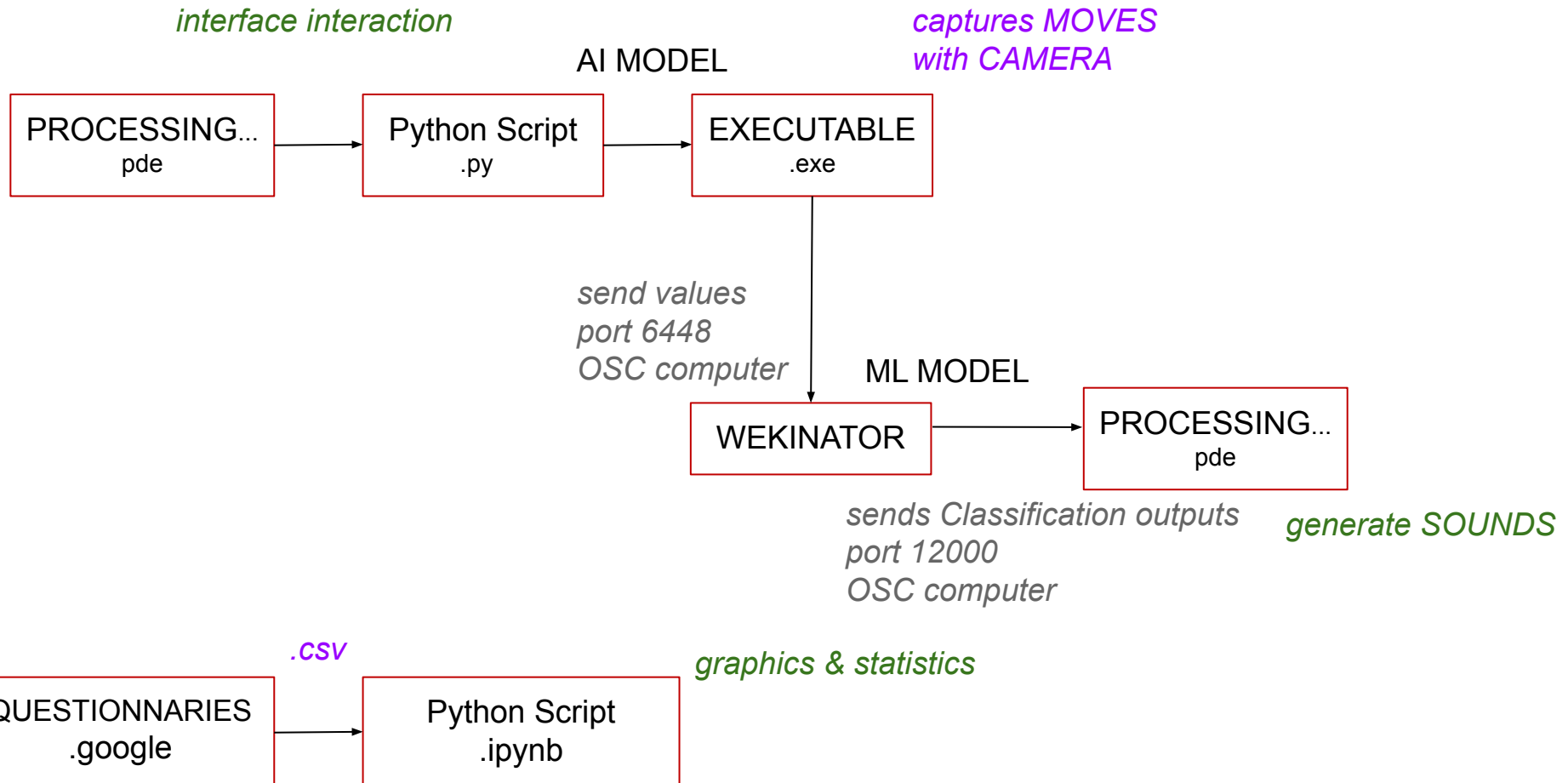
## SOFTWARE

- Python
- Processing
- Wekinator
- Sounds
- Questionnaires



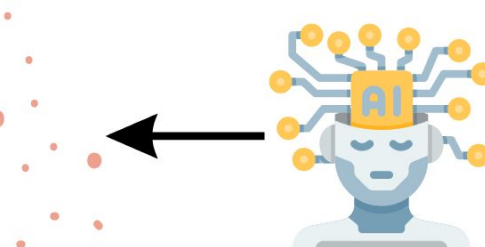
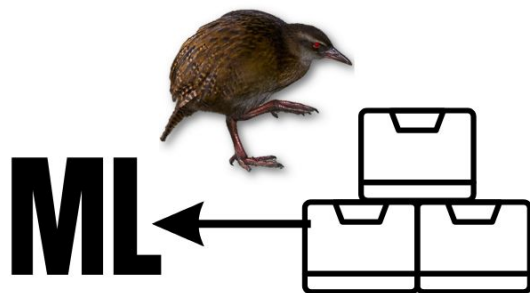
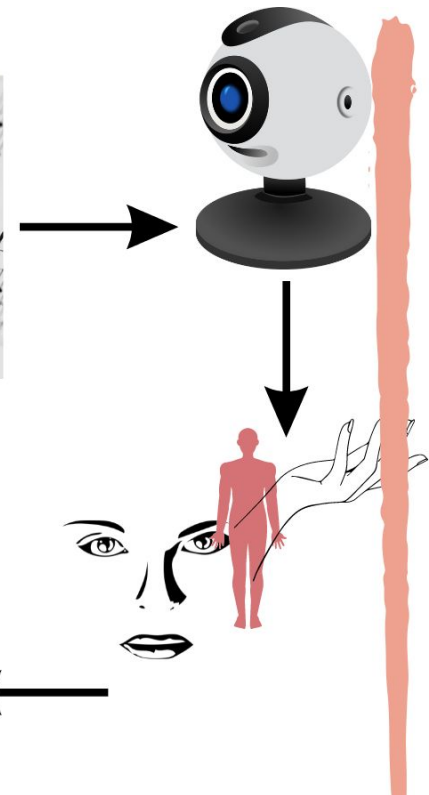
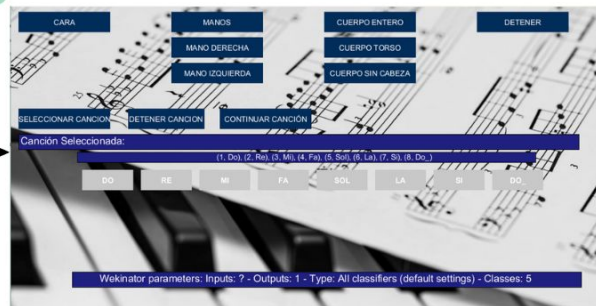


# Methodology: PIPELINE



# Methodology: TRAINING DATA

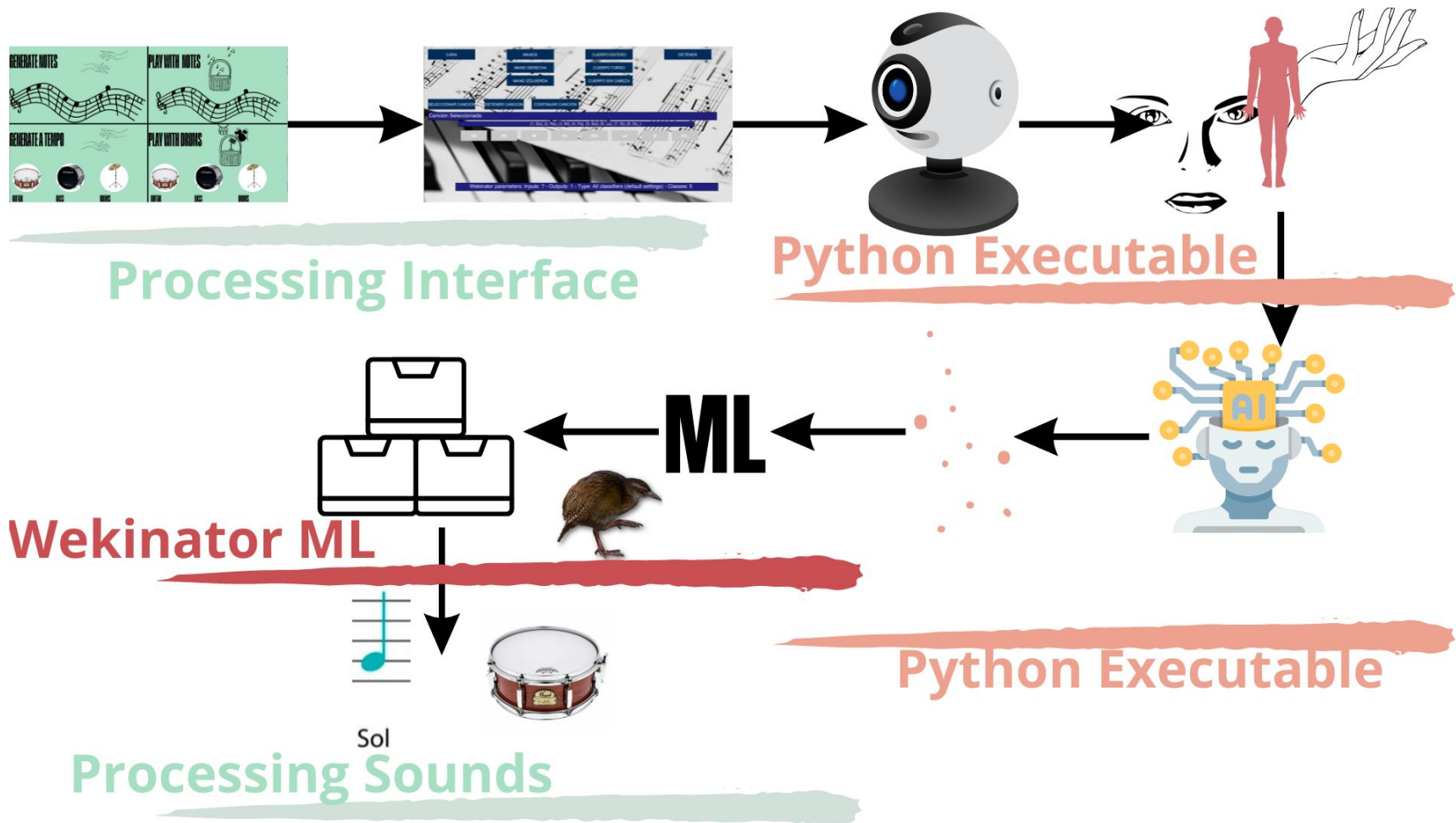
## Processing Interface



Wekinator ML Algorithm

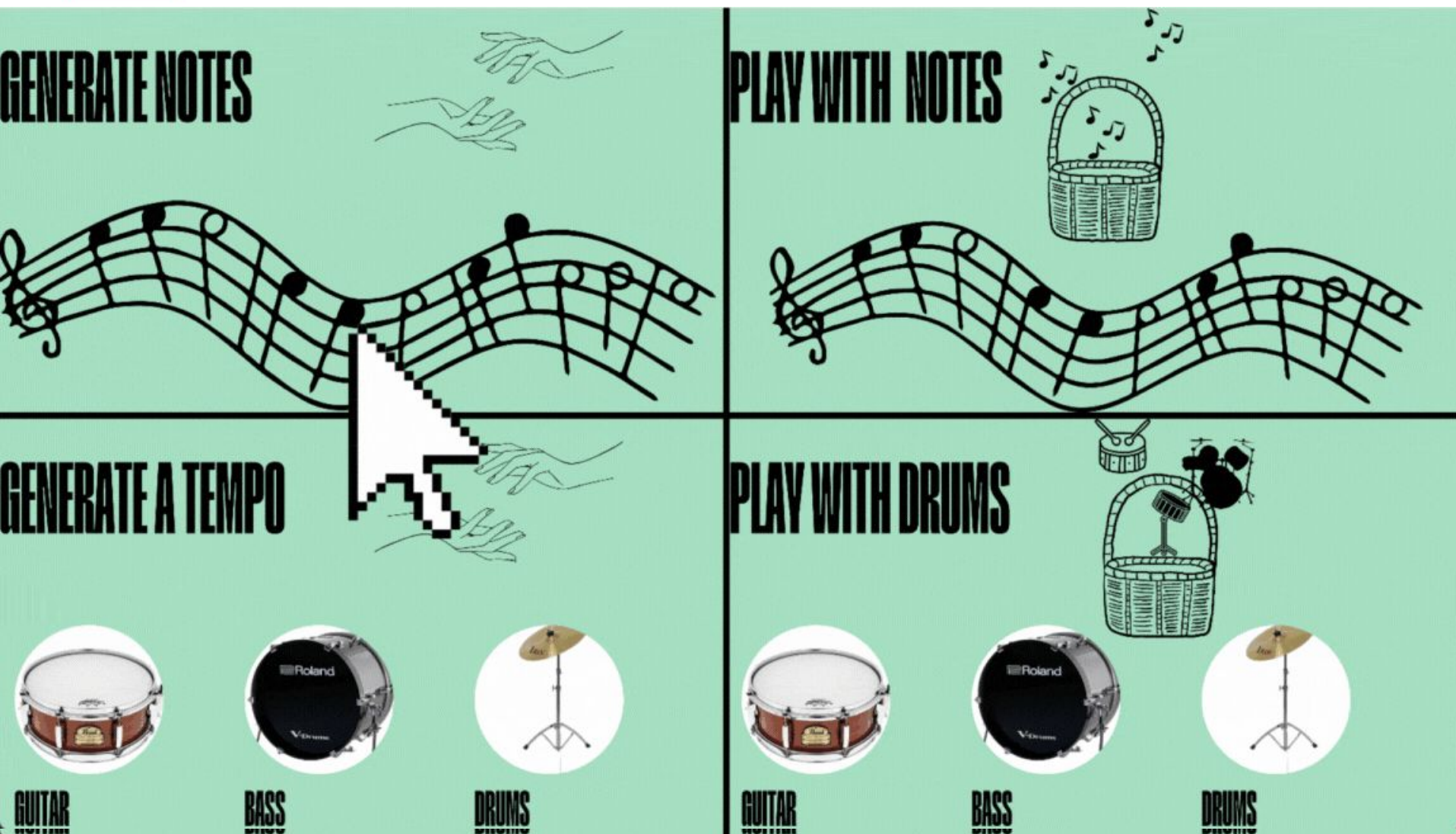
Python Executable

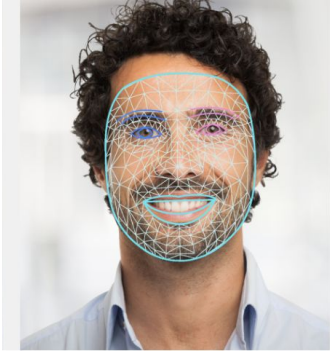
## Methodology: REAL-TIME TEST





# Methodology: PROCESSING INTERFACE



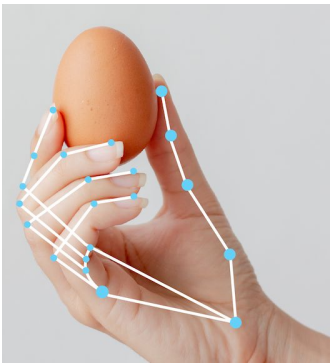


## MediaPipe:

Google

Hands (42) and Face (468) Landmark detection

3D landmarks in Real-Time



## Movenet:

TensorFlow

17 keypoints (x, y, p)



## Python order

- Download and import the packages
- Initialize Models
- Set the port where keypoints are sent as OSC messages
- Open Camera
- Processing frame videos
- Extract keypoints
- Send to Wekinator



## Methodology: WEKINATOR and ML

- **Set project parameters**
- **Record each class**
- **Train:** KNN
- **Run** (Real Time Output)





# Methodology: PROCESSING and SOUNDS

## Library of sounds

- 3 Audio Drums

## Sounds created

- Using Sine Signal and Changing Frequency

Not two consecutive sounds of the same class

To avoid sound misclassified gestures, a time difference between sounds is set



# Methodology: SESSIONS

## Healthy-Participants

- 5' explain system and train classes
- 3' 2-classes test
- 3' 3-classes test
- 2' User's form

## Stroke Patients: Centre Fòrum - Parc de Salut Mar

### First session

- 10-15' explain system and train classes
- 10-15' real - time rehabilitation
- 2' Music Therapist and PhysioTherapist form

### Other Sessions

- 5' open all the system
- 5' training more data if needed
- 20' Exercises and pause
- 2' PhysioTherapist form





# Methodology: QUESTIONNAIRES

## Healthy participants

- Compare traditional music instrument with digital music interface

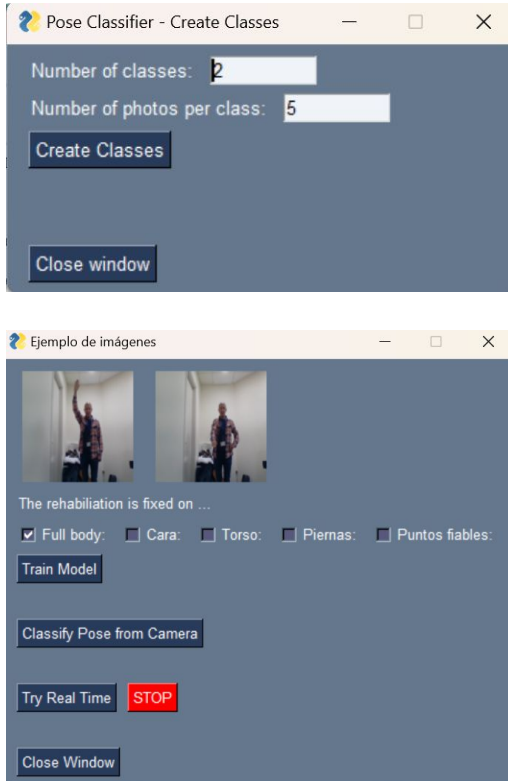
## Physiotherapist

- Fugl-Meyer Assessment (FMA) to assess motor functioning.
- Free answers to other exercises

## Music Therapist

- Study the understability and the utility of the interface

# Methodology: Python vs. Processing



PYTHON	PROCESSING
Only 1 program language ✓	2 program language ✗ Wekinator
Easier to train for users ✓	More tricky to train ✗
Difficult to add new training data ✗	Easier to add new training data ✓
Difficult to code ✗	Easier to code ✓
Simple interface ✗	Better visual designed interface ✓
<b>Huge Delay 0.3s</b> ✗	<b>Slight Delay 0.05s</b> ✓
More space needed (all images are saved) ✗	Less data saved ✓



## Results: ML ALGORITHMS PYTHON TESTING

### MoveNet

Classes considered	SVM	KNN	Decision Tree	AdaBoost	Naive Bayes
2	0.68	0.98	0.9	0.92	0.96
8	0.125	1	0.75	0.625	0.94

### Hand MediaPipe

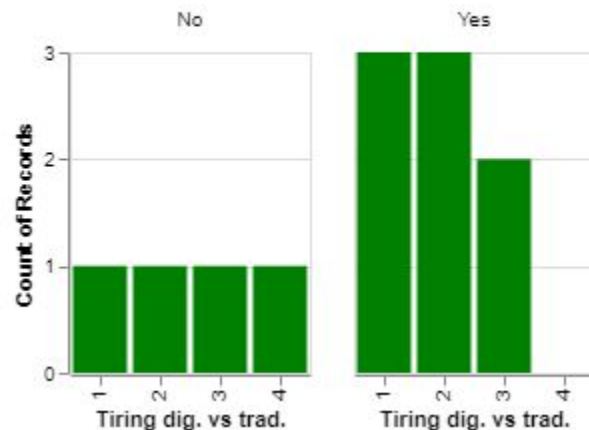
2	0.77	1	0.9	0.92	1
10	0.36	1	0.92	0.68	1

## Results: HEALTHY PARTICIPANTS (12)

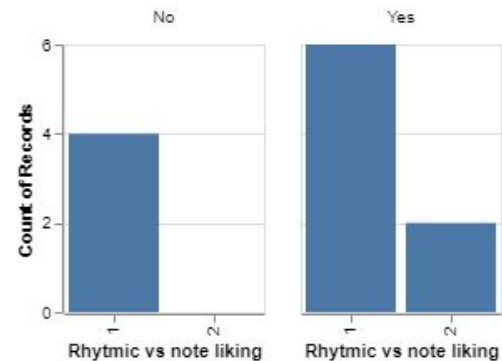
Practice needed in comparison of traditional instruments  
Music education received



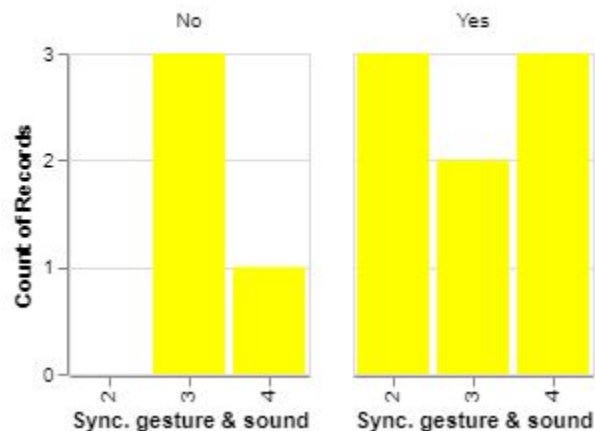
Comparison of tiredness in digital vs traditional instruments  
Music education received



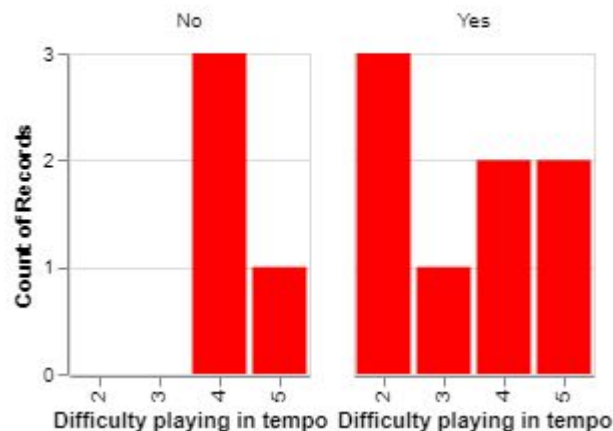
Comparison of rhythmic vs note accompaniment preferences  
Music education received



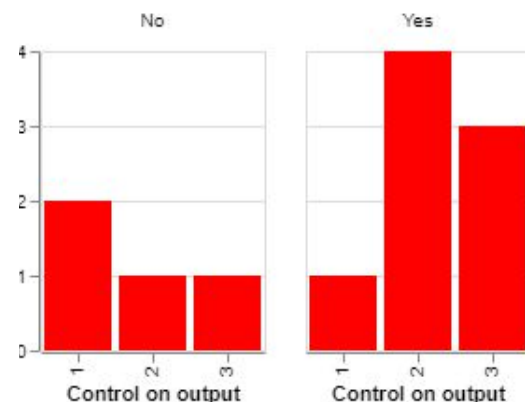
Degree of synchronization between gesture and sound  
Music education received



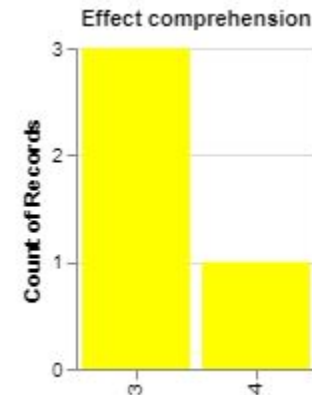
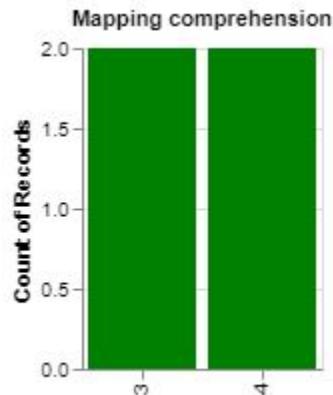
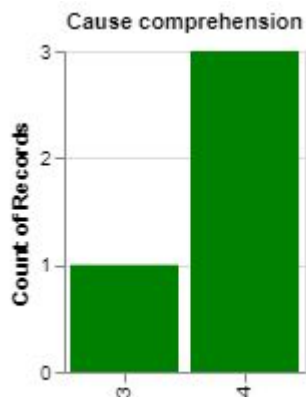
Comparison of keeping tempo in digital vs traditional instruments  
Music education received



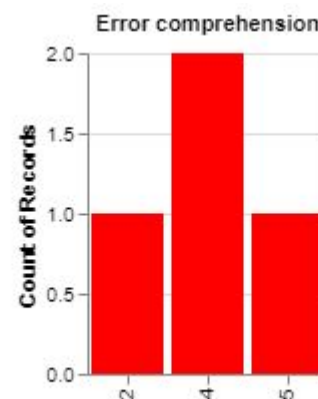
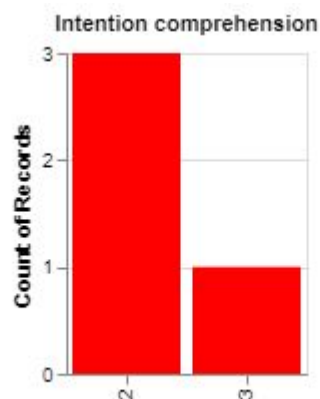
Expressiveness controlled by the music output  
Music education received



## Results: MUSIC THERAPISTS (4)



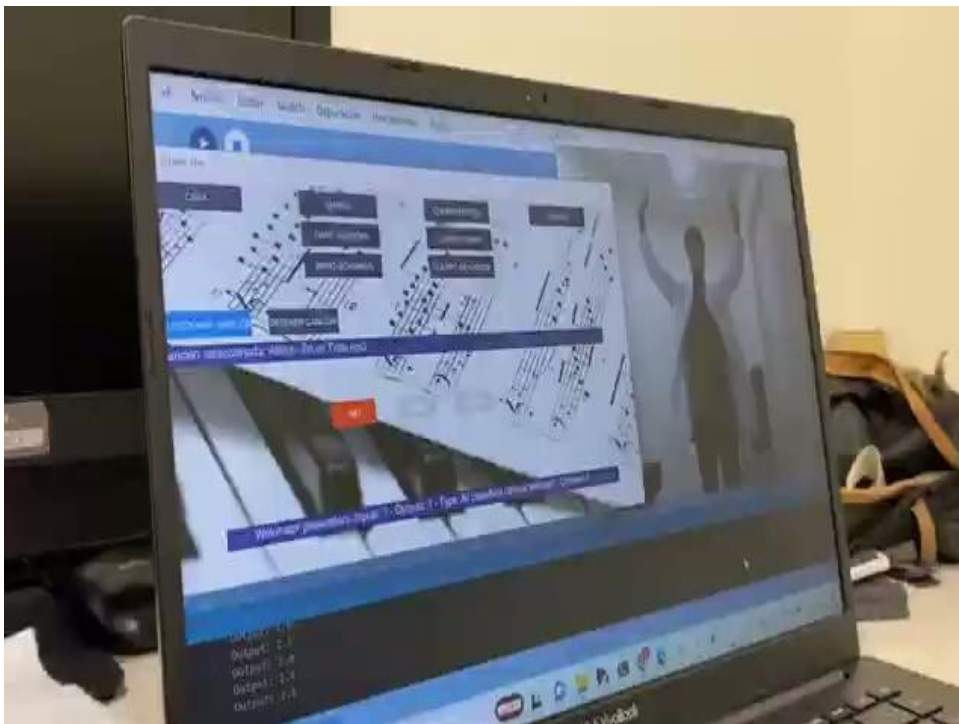
Were the available input gestures clear? Was the connection between the input gestures and the control parameters clear? Were the available control parameters clear?



How well did the system allow the user to express his musical intentions? If there had been errors in the performance, would they have been noticeable?

# Results: DEMO

## Centre Fòrum - Parc de Salut Mar



## Results: PATIENTS (2)

	PATIENT 1	PATIENT 2
<b>Session 1</b>	<p>Extension of arms &amp; shoulders: from center to back of the head.</p> <p>Pain when goes down to the neck.</p> <p>Rod of 200g of weight</p> <p>Exercise well and with repetition</p>	<p>Raise the arm from the rest position to above the head, keeping it straight at all times.</p> <p>Performs exercise well.</p> <p>Gets tired in each turn</p> <p>Stop few seconds and control breathing</p>
<b>Session 2</b>		<p>Same exercise</p> <p>Improvement in resistance on the movement</p> <p>Better synchronization with piano</p>

## Discussion: INTERFACE



Less tiring

Less practice needed

Clear available inputs

Clarity bt parameters and gestures

Rhythmic accompaniment



Difficult keeping tempo

Less expressiveness

Noticeable errors



## Discussion: LIMITATIONS



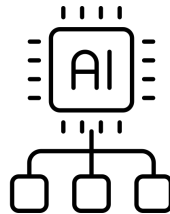
Lack of another PC

Very few patients



No professional aid

Wekinator accuracy



## Discussion: FUTURE WORK

### Complete the study

- Large-Scale clinical trials are needed:
  - 3 more sessions expected
- Control vs. experimental group

### Improving cognitive and rehabilitation game

- Not random sequence
- Known melodies sequences

### Avoid delay.

- Frame Camera
- Explore other language programs
  - C++





### Improve sync. and accuracy

- Change Wekinator for Python
- Train, Validation & Test





## Conclusion: OBJECTS REVIEW

- Works in Real-Time 
- Personalized Interface 
- Learns in Real-Time the user capabilities by Machine Learning 
- Has a validation method 

## **Conclusion: RESEARCH QUESTION**

- **Is the combination of music and artificial intelligence useful for stroke rehabilitation?**

YES: autonomy and learns how to structure the movements

But: Longer period of time, delay, misclassification

- **Is the artificial intelligence digital music interface comparable to a musical instrument while doing stroke rehabilitation?**
  - More or less.
    - + Less tired and easy to play.
    - No expressiveness and difficult tempo

