

# cogniLink: A Non-Invasive Brain-Computer Interface That Enables Seamless Execution of Commands Through Thought Recognition

Project cogniLink

## Abstract

Although great strides have been achieved in making computers more accessible, its indisputable that there remains huge prospects for improvement. Given that technology is designed for the masses, it offers every individual a platform to do what is needed; this includes, but isn't limited to, support for individuals with motor, dexterity, and/or speech impairments. In this proposal, we will discuss cogniLink, a tool that assists developers in making computers more accessible for persons with afflictions. cogniLink is a brain-computer interface that allows the user to trigger the execution of a command simply by thinking of the trigger. A training data set is to be collected from n-users in order to train n-models using an ElectroEncephaloGram (EEG). Each model is programmed to recognize one or more trigger thoughts. The same model interacts with a stack of software which allows it to map positive outputs from the model and transform it into an actionable command. For the purpose of demonstration, the model will be trained to recognize commands from one user which will be mapped to a virtualHID in such a way that allows the user to play Super Mario Bros. After an extensive process of training n-models, a universal model (UM) will be trained using data from the aforementioned n-models in order to have a simpler training process for new users. cogniLink will allow disabled people to execute commands in a very seamless and orderly fashion, thus making computers more accessible to persons with digital input impairments. Two of cogniLink's long term goals are to allow an amputee to be able to effortlessly be able to control a wheelchair in real time, and for someone suffering from Locked-In Syndrome to be able to interact with the world around them with ease.

## 1 Implementation

### 1.1 Tool Chain

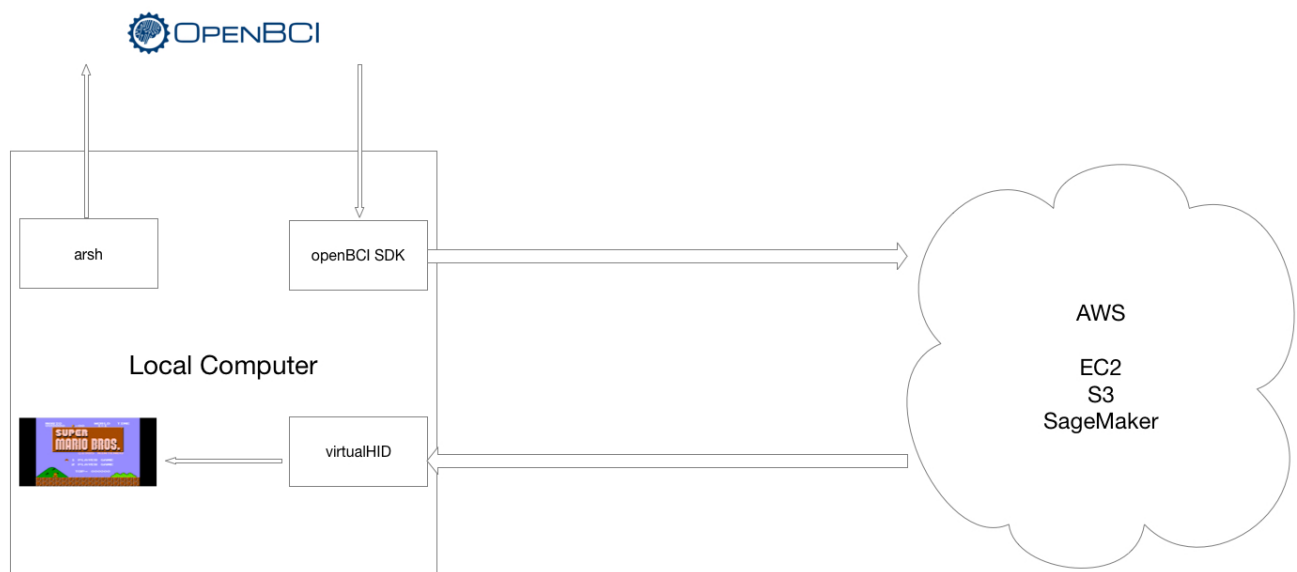


Figure 1: Tool Chain Diagram

Text about tool chain here [Figure 1](#).

### 1.2 Project work plan

#### Work package description

|                     |                                           |               |   |
|---------------------|-------------------------------------------|---------------|---|
| Work package number | WP1                                       | Starting week | 1 |
| Work package title  | Virtual HID, Data Collection, and ML Code |               |   |
| Participant number  | 1                                         |               |   |
| Short name          | georgio                                   |               |   |
| Person-weeks        | 2                                         |               |   |

#### Objectives

This work package has the following objectives:

1. To develop a Virtual Human Interface Device;
2. To develop an API that gathers raw data from the Cyton board and feeds it to a CSV file;

3. To write code needed to efficiently store and manage datasets;
4. To write code needed to start training Model 1 on Command A.

### Description of work

#### Task T1.1: Task1 (W1-W1)

The virtualHID will be created using macOS' IOKit Library.

#### Task T1.2: Task2 (W1-W1)

The Cyton board will be programmed using arsh.

#### Task T1.3: Task3 (W1-W1)

API to gather data from Cyton Board will be built

#### Task T1.4: Task4 (W1-W2)

Code to manage raw EEG data will be done here.

#### Task T1.5: Task5 (W2-W2)

EC2, S3, and SageMaker instances will be configured.

#### Task T1.6: Task6 (W2-W2)

Code to feed raw data to S3 bucket will be done here.

#### Task T1.7: Task7 (W2-W2)

Code to start training the model will be done here.

### Deliverables

**D1.1** WP1 W1 Progress Report. (W1)

**D1.2** Demonstration of APIs (W2)

**D1.3** WP1 Code+Tools Merged to master. (W2)

**D1.4** Main Report with full progress accomplished after the end of WP3. (W2)

## 1. Implementation

|                     |                   |               |   |
|---------------------|-------------------|---------------|---|
| Work package number | WP2               | Starting week | 2 |
| Work package title  | Model 1 Command A |               |   |
| Participant number  | 1                 |               |   |
| Short name          | georgio           |               |   |
| Person-weeks        | 4                 |               |   |

### Objectives

1. To collect training, validation, and test datasets for Model 1 Command A;
2. Training Model 1 using aforementioned data;
3. Testing/Patching Model 1.

### Description of work

#### Task T2.1: Task1 (W2-W3)

Ways to efficiently collect data with high accuracy will be looked into; validated datasets will be used (if found) as a point of reference.

#### Task T2.2: Task2 (W3-W4)

The training dataset will be collected.

#### Task T2.3: Task 3 (W4-W5)

Model 1 will be trained using the aforementioned dataset.

#### Task T2.4: Task 4 (W4-W5)

Test and Validation datasets will be collected.

#### Task T2.5: Task 5 (W4-W5)

Test and Validation datasets will be collected.

#### Task T2.6: Task 6 (W4-W5)

All collected datasets will be uploaded to an AWS S3 Bucket.

#### Task T2.7: Task 7 (W4-W5)

Accuracy of trained model will be studied.

#### Task T2.8: Task 8 (W5-W6)

Patches and optimizations will be pushed in attempt to improve model accuracy, if possible.

### Deliverables

**D2.1** Report 1 about the data collection process and initiation of the first round of training. **(W4)**

**D2.2** First iteration of the model. **(W5)**

**D2.3** Report 2 about model accuracy after inputting initial test and validation datasets. **(W5)**

- D2.4** Report 3 will include a comparative view of accuracy for each patch/iteration of the model. **(W6)**
- D2.5** Second iteration of the model. **(W6)**
- D2.6** Main Report update with full progress accomplished after the end of WP2. **(W6)**
- D2.7** Video demonstration of thought recognition process. **(W6)**

## 1. Implementation

|                     |                    |               |   |
|---------------------|--------------------|---------------|---|
| Work package number | WP3                | Starting week | 6 |
| Work package title  | Model 1 n Commands |               |   |
| Participant number  | 1                  |               |   |
| Short name          | georgio            |               |   |
| Person-weeks        | 6                  |               |   |

### Objectives

This work package has the following objectives:

1. Link the output from the Model to the virtual HID created in WP1;
2. Map trigger thoughts to button presses;
3. Play a game of 1P Super Mario Bros.

### Description of work

#### Task T3.1: Task1 (W6-W12)

Code for linking model to virtual HID will be rechecked and finalized.

#### Task T3.2: Task2 (W6-W12)

Model 1 will be trained for command B, and other commands simultaneously.

#### Task T3.3: Task3 (W12-W12)

A game of 1P Super Mario Bros will be played.

### Deliverables

**D3.1** A demonstration of the execution of alternating commands, after successful training of the second command to model 1. **(W8)**

**D3.2** Report 1 on findings made while training new commands. **(W11)**

**D3.3** Report 2 will compare the variation of latency between the model and the virtual HID for each code patch. **(W12)**

**D3.4** Code for virtual HID and updated Model 1 with multiple command recognition will be pushed to master. **(W12)**

**D3.5** A demonstration of the ability to play a game of 1P Super Mario Bros using cogniLink. **(W12)**

**D3.6** Main Report update with full progress accomplished after the end of WP3. **(W12)**

|                            |                           |                      |           |
|----------------------------|---------------------------|----------------------|-----------|
| <b>Work package number</b> | <b>WP4</b>                | <b>Starting week</b> | <b>12</b> |
| <b>Work package title</b>  | <b>Model 2 n Commands</b> |                      |           |
| <b>Participant number</b>  | <b>1</b>                  |                      |           |
| <b>Short name</b>          | <b>georgio</b>            |                      |           |
| <b>Person-weeks</b>        | <b>6</b>                  |                      |           |

### Objectives

This work package has the following objectives:

1. Replicate all steps in WP2 and WP3 so that we get a Model 2 for a different individual trained on n the same n Commands as Model 1;
2. Play a game of 2P Super Mario Bros.

### Description of work

#### Task T4.1: Task1 (W12-W18)

A new Model 2 will be created, repeting the steps from previous WPs, in such a way that it is trained using data gathered from a different individual for the same n-Commands.

#### Task T4.2: Task2 (W12-W13)

The ability to switch between models will be added to the virtual HID code, for testing purposes.

#### Task T4.3: Task3 (W18-W18)

Models 1 and 2 will be published.

#### Task T4.4: Task4 (W18-W18)

A game of 2P Super Mario Bros will be played.

### Deliverables

**D4.1** Merging model switching code to master. **(W13)**

**D4.2** Report on the ability to use 2 models simultaneously as 2 virtual HID devices. **(W13)**

**D4.3** Report on Model 2 Command 8. **(W15)**

**D4.4** Report on training Model 2 for n-Commands. **(W18)**

**D4.5** Merging code of Models 1 and 2 to master. **(W13)**

**D4.6** A demonstration of the ability to play a game of 2P Super Mario Bros using cogniLink. **(W18)**

**D4.7** Main Report update with full progress accomplished after the end of WP4. **(W18)**

## 1. Implementation

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|                     |               |               |    |
|---------------------|---------------|---------------|----|
| Work package number | WP5           | Starting week | 18 |
| Work package title  | Optimizations |               |    |
| Participant number  | 1             |               |    |
| Short name          | georgio       |               |    |
| Person-weeks        | 2             |               |    |

### Objectives

This work package has the following objectives:

1. Optimizing the code in such a way that a trigger thought is recognized in realtime.

### Description of work

#### Task T5.1: Task1 (W18-W20)

Code optimization with the main goal of reducing latency.

### Deliverables

**D5.1** Optimized code will be merged to master. (W20)

**D5.2** Main Report update with full progress accomplished after the end of WP5, emphasizing on measures taken for optimizing code. (W20)



|                     |                       |               |   |
|---------------------|-----------------------|---------------|---|
| Work package number | WP6                   | Starting week | 1 |
| Work package title  | Real Life Application |               |   |
| Participant number  | 1                     |               |   |
| Short name          | georgio               |               |   |
| Person-weeks        | 12                    |               |   |

### Objectives

This work package has the following objectives:

1. Implement cogniLink to work on a controller of a wheelchair;

### Description of work

#### Task T6.1: Task1 (W1-W12)

Here we will test the WP Task code.

#### Task T6.2: Task2 (W6-W9)

In this task UZH will integrate the work done in ??.

#### Task T6.3: Task3 (W9-W12)

Here all the WP participants will apply the results to...

### Deliverables

**D6.1** Report on the definition of the model specifications. **(W36)**

**D6.2** Report on Feasibility study for the model implementation. **(W12)**

**D6.3** Prototype of model implementation. **(W24)**

## 1. Implementation

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|                            |                                    |                      |          |
|----------------------------|------------------------------------|----------------------|----------|
| <b>Work package number</b> | <b>WP7</b>                         | <b>Starting week</b> | <b>1</b> |
| <b>Work package title</b>  | <b>Universal Model, n Commands</b> |                      |          |
| <b>Participant number</b>  | <b>1</b>                           |                      |          |
| <b>Short name</b>          | <b>georgio</b>                     |                      |          |
| <b>Person-weeks</b>        | <b>12</b>                          |                      |          |

### Objectives

This work package has the following objectives:

1. Implement cogniLink to identify a thought and provide a way to communicate for a person suffering from Locked-In Syndrome;
2. To develop an API that gathers raw data from the Cyton board and feeds it to a CSV file;
3. To write code needed to efficiently store and manage datasets;
4. To write code needed to start training Model 1 on Command A.

### Description of work

#### Task T7.1: Task1 (W1-W12)

Here we will test the WP Task code.

#### Task T7.2: Task2 (W6-W9)

In this task UZH will integrate the work done in ??.

#### Task T7.3: Task3 (W9-W12)

Here all the WP participants will apply the results to...

### Deliverables

**D7.1** Report on the definition of the model specifications. **(W36)**

**D7.2** Report on Feasibility study for the model implementation. **(W12)**

**D7.3** Prototype of model implementation. **(W24)**

## List of work packages

Table 1.2b: List of work packages

| Work package number | Work package title                        | Lead participant no. | Lead participant name | Person-weeks | Start week | End week |
|---------------------|-------------------------------------------|----------------------|-----------------------|--------------|------------|----------|
| WP1                 | Virtual HID, Data Collection, and ML Code | 1                    | georgio               | 2            | 1          | 2        |
| WP2                 | Model 1 Command A                         | 1                    | georgio               | 4            | 2          | 6        |
| WP3                 | Model 1 n Commands                        | 1                    | georgio               | 6            | 6          | 12       |
| WP4                 | Model 2 n Commands                        | 1                    | georgio               | 6            | 12         | 18       |
| WP5                 | Optimizations                             | 1                    | georgio               | 2            | 18         | 20       |
| WP6                 | Real Life Application                     | 1                    | georgio               | 12           | 1          | 36       |
| WP7                 | Universal Model, n Commands               | 1                    | georgio               | 12           | 1          | 36       |
| <b>TOTAL</b>        |                                           |                      |                       | 44           |            |          |

## List of deliverables

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Table 1.2c: Deliverable list

| Deliverable number     | Deliverable name                                                                            | WP no. | Lead participant name | Nature | Dissemination Level | Delivery date (proj. week) |
|------------------------|---------------------------------------------------------------------------------------------|--------|-----------------------|--------|---------------------|----------------------------|
| D1.1                   | WP1 W1 Progress Report.                                                                     | WP1    | georgio               | R      | PU                  | 1                          |
| D1.2                   | Demonstration of APIs                                                                       | WP1    | georgio               | D      | PU                  | 2                          |
| D1.3                   | WP1 Code+Tools Merged to master.                                                            | WP1    | georgio               | P      | PU                  | 2                          |
| D1.4                   | Main Report with full progress accomplished after the end of WP3.                           | WP1    | georgio               | R      | PU                  | 2                          |
| D2.1                   | Report 1 about the data collection process and initiation of the first round of training.   | WP2    | georgio               | R      | PU                  | 4                          |
| D2.2                   | First iteration of the model.                                                               | WP2    | georgio               | P      | PU                  | 5                          |
| D2.3                   | Report 2 about model accuracy after inputting initial test and validation datasets.         | WP2    | georgio               | R      | PU                  | 5                          |
| D2.4                   | Report 3 will include a comparative view of accuracy for each patch/iteration of the model. | WP2    | georgio               | R      | PU                  | 6                          |
| D2.5                   | Second iteration of the model.                                                              | WP2    | georgio               | P      | PU                  | 6                          |
| D2.6                   | Main Report update with full progress accomplished after the end of WP2.                    | WP2    | georgio               | R      | PU                  | 6                          |
| D2.7                   | Video demonstration of thought recognition process.                                         | WP2    | georgio               | D      | PU                  | 6                          |
| Continued on next page |                                                                                             |        |                       |        |                     |                            |

<sup>1</sup>If your action taking part in the Pilot on Open Research Data, you must include a data management plan as a distinct deliverable within the first 6 weeks of the project. This deliverable will evolve during the lifetime of the project in order to present the status of the project's reflections on data management. A template for such a plan is available on the Participant Portal (Guide on Data Management).

## 1. Implementation

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|------|-----------------------------------------------------------------------------------------------------------------------------|-----|---------|---|----|----|
| D3.1 | A demonstration of the execution of alternating commands, after successful training of the second command to model 1.       | WP3 | georgio | D | PU | 8  |
| D3.2 | Report 1 on findings made while training new commands.                                                                      | WP3 | georgio | R | PU | 11 |
| D3.3 | Report 2 will compare the variation of latency between the model and the virtual HID for each code patch.                   | WP3 | georgio | R | PU | 12 |
| D3.4 | Code for virtual HID and updated Model 1 with multiple command recognition will be pushed to master.                        | WP3 | georgio | P | PU | 12 |
| D3.5 | A demonstration of the ability to play a game of 1P Super Mario Bros using cogniLink.                                       | WP3 | georgio | D | PU | 12 |
| D3.6 | Main Report update with full progress accomplished after the end of WP3.                                                    | WP3 | georgio | R | PU | 12 |
| D6.2 | Report on Feasibility study for the model implementation.                                                                   | WP6 | georgio | R | PU | 12 |
| D7.2 | Report on Feasibility study for the model implementation.                                                                   | WP7 | georgio | R | PU | 12 |
| D4.1 | Merging model switching code to master.                                                                                     | WP4 | georgio | P | PU | 13 |
| D4.2 | Report on the ability to use 2 models simultaneously as 2 virtual HID devices.                                              | WP4 | georgio | R | PU | 13 |
| D4.5 | Merging code of Models 1 and 2 to master.                                                                                   | WP4 | georgio | P | PU | 13 |
| D4.3 | Report on Model 2 Command 8.                                                                                                | WP4 | georgio | R | PU | 15 |
| D4.4 | Report on training Model 2 for n-Commands.                                                                                  | WP4 | georgio | R | PU | 18 |
| D4.6 | A demonstration of the ability to play a game of 2P Super Mario Bros using cogniLink.                                       | WP4 | georgio | D | PU | 18 |
| D4.7 | Main Report update with full progress accomplished after the end of WP4.                                                    | WP4 | georgio | R | PU | 18 |
| D5.1 | Optimized code will be merged to master.                                                                                    | WP5 | georgio | P | PU | 20 |
| D5.2 | Main Report update with full progress accomplished after the end of WP5, emphasizing on measures taken for optimizing code. | WP5 | georgio | R | PU | 20 |
| D6.3 | Prototype of model implementation.                                                                                          | WP6 | georgio | R | PU | 24 |
| D7.3 | Prototype of model implementation.                                                                                          | WP7 | georgio | R | PU | 24 |
| D6.1 | Report on the definition of the model specifications.                                                                       | WP6 | georgio | R | PU | 36 |
| D7.1 | Report on the definition of the model specifications.                                                                       | WP7 | georgio | R | PU | 36 |

### 1.3 Management and risk assessment

#### List of milestones

Table 1.5a: Summary of staff effort

| Partic. no.  | Partic. short name | WP1 | WP2 | WP3 | WP4 | WP5 | WP6 | WP7 | Total person weeks |
|--------------|--------------------|-----|-----|-----|-----|-----|-----|-----|--------------------|
| 1            | georgio            | 2   | 4   | 6   | 6   | 2   | 12  | 12  | 44                 |
| <b>Total</b> |                    | 2   | 4   | 6   | 6   | 2   | 12  | 12  | 44                 |

Table 1.3a: List of milestones

| Milestone number | Milestone name                                                            | Related WPs | Estimated date               | Means of verification                                       |
|------------------|---------------------------------------------------------------------------|-------------|------------------------------|-------------------------------------------------------------|
| <b>M1</b>        | Completed Development of Model 1 for Command A                            | WP 2        | End of WP2 (add week number) | Execution of command using trigger thought                  |
| <b>M2</b>        | Completed Development of Model 1 for Commands A and B                     | WP 3        | mid WP3 (add week number)    | Execution of alternating commands using trigger thoughts    |
| <b>M3</b>        | Completed Development of Model 1 for n-Commmands                          | WP 3        | End WP3 (add week number)    | Playing a game of 1P Super Mario Bros                       |
| <b>M4</b>        | Completed Development of Model 2 for n-Commmands                          | WP 4        | End WP4 (add week number)    | Playing a game of 2P Super Mario Bros                       |
| <b>M5</b>        | Transitioning from using virtual-HID on OpenEmu to Wheelchair in Realtime | WP 6        | mid WP7 (add week number)    | Driving a wheelchair with no hands                          |
| <b>M6</b>        | Integration with Locked-In Patient                                        | WP 6        | End of WP7 (add week number) | Enabling a Locked-in patient to communicate using cogniLink |
| <b>M7</b>        | Training Universal Model for n-Commands                                   | WP 7        | End of WP8 (add week number) | Ease of training models for new users                       |

### Critical risks for implementation

Table 1.3b: Critical risks for implementation

| Description of Risk                                       | WPs involved | Proposed risk-mitigation measures |
|-----------------------------------------------------------|--------------|-----------------------------------|
| The dedicated chip sent to fabrication is not functional. | WP ??        | Resort to Software simulations    |

## 1. Implementation

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### 1.4 Consortium as a whole

### 1.5 Resources to be committed

#### Summary of staff efforts

**Other direct cost items (travel, equipment, other goods and services, large research infrastructure)**

| <b>Participant no. 1 (georgio)</b> | <b>Cost (EUR)</b> | <b>Justification</b>                                                                                   |
|------------------------------------|-------------------|--------------------------------------------------------------------------------------------------------|
| <b>Travel</b>                      | 2500              | 3 pairwise meetings for 2 people, 2 conferences for 3 people, 3 internal project meetings for 3 people |
| <b>Equipment</b>                   | 3000              | CAD workstation for chip design                                                                        |
| <b>Other goods and services</b>    | 60000             | Fabrication of 2 VLSI chips                                                                            |
| <b>Total</b>                       | 65500             |                                                                                                        |

| <b>Participant no. 1 (georgio)</b>   | <b>Cost (EUR)</b> | <b>Justification</b> |
|--------------------------------------|-------------------|----------------------|
| <b>Large research infrastructure</b> | 400000            | Synchrotron          |

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## 2 Ethics and Security

### 2.1 Ethics

### 2.2 Security

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<sup>2</sup>Article 37.1 of the Model Grant Agreement: Before disclosing results of activities raising security issues to a third party (including affiliated entities), a beneficiary must inform the coordinator – which must request written approval from the Commission/Agency. Article 37.2: Activities related to “classified deliverables” must comply with the “security requirements” until they are declassified. Action tasks related to classified deliverables may not be subcontracted without prior explicit written approval from the Commission/Agency. The beneficiaries must inform the coordinator – which must immediately inform the Commission/Agency – of any changes in the security context and –if necessary – request for Annex 1 to be amended (see Article 55).