SMART SHELF

USING CAPACITIVE TOUCH SENSORS

Problem, Prototype and Data Insights

Arko Datta, M.Tech., Department of CSE, NIT DGP

Samriddha Haldar, B.Tech., Department of CSE, NIT DGP

Dr. Ayon Chakraborty, Assistant Professor, Department of CSE, IIT Madras

Dr. Sujoy Saha, Assistant Professor, Department of CSE, NIT DGP

Systems Research Lab
NIT Durgapur

THE PROBLEM

A BUSINESS POV

We all like to browse different products in a retail store.

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We all like to browse different products in a retail store.

From a business point of view, this interaction from customer provides some valuable insights:

- Are people interacting with my product?
- Does my product have more interactions than purchases? Or are the numbers more or less similar?

THE PROBLEM

A BUSINESS POV

Using the metrics based on pre-purchase interactions, companies can understand which area to focus on (marketing, competitive pricing, packaging, etc), instead of manually performing surveys.

These metrics can be monitored using Smart Shelves.

THE PROBLEM

A BUSINESS POV

Existing Prevalent Smart Shelf Technology:

- RFID Tags

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- Computer Vision

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- Computer Vision
- Weight Sensors

THE PROBLEM

A BUSINESS POV

Existing Prevalent Smart Shelf Technology:

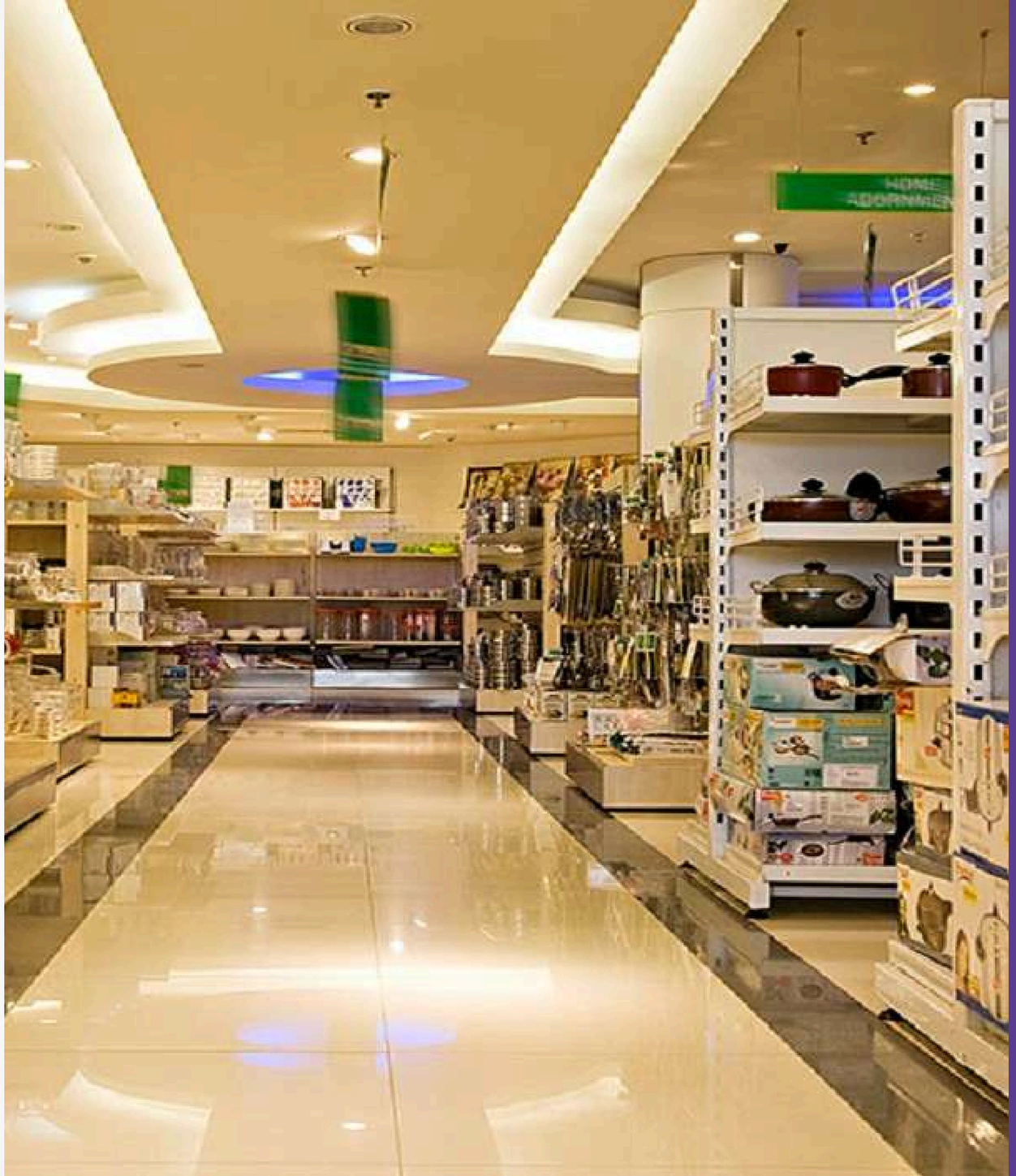
- RFID Tags
- Computer Vision
- Weight Sensors

Are quite costly, time taking, and can’t be augmented on an existing shelves. Moreover, computer vision based methods are a risk to privacy.

THE PROBLEM

A BUSINESS POV

And that’s all right for larger, bigger retail stores, that can afford high tech and high budget shelves.



THE PROBLEM

A BUSINESS POV

And that’s all right for larger, bigger retail stores, that can afford high tech and high budget shelves.

But there’s an untapped demographic: buyers in smaller retail stores:

- Which can’t afford costly smart shelf infrastructure, and
- Also don’t have much manpower and resources to maintain the shelves.

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- Is cost effective.
- Is low maintenance.

THE PROBLEM

A PRODUCT POV

From the business problem discussed, we feel there is a need of a smart shelf technology which:

- Can record and send pre-purchase item interaction analytics to businesses.
- Is cost effective.
- Is low maintenance.
- Can be used on existing shelves with low setup effort.

OUR
SOLUTION PROPOSAL

THE GRIDMAT

*A **GRID** of plate electrodes arranged on a **MAT.***

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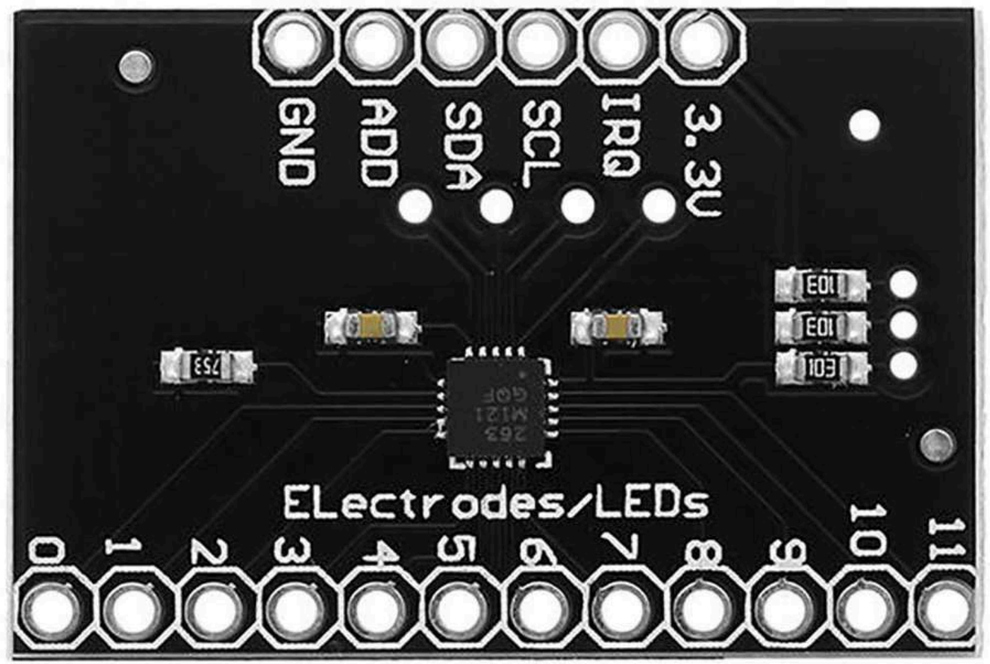
All electrodes of this GridMat is connected to a common 12 channel capacitive touch sensor: one electrode connected to one separate channel.



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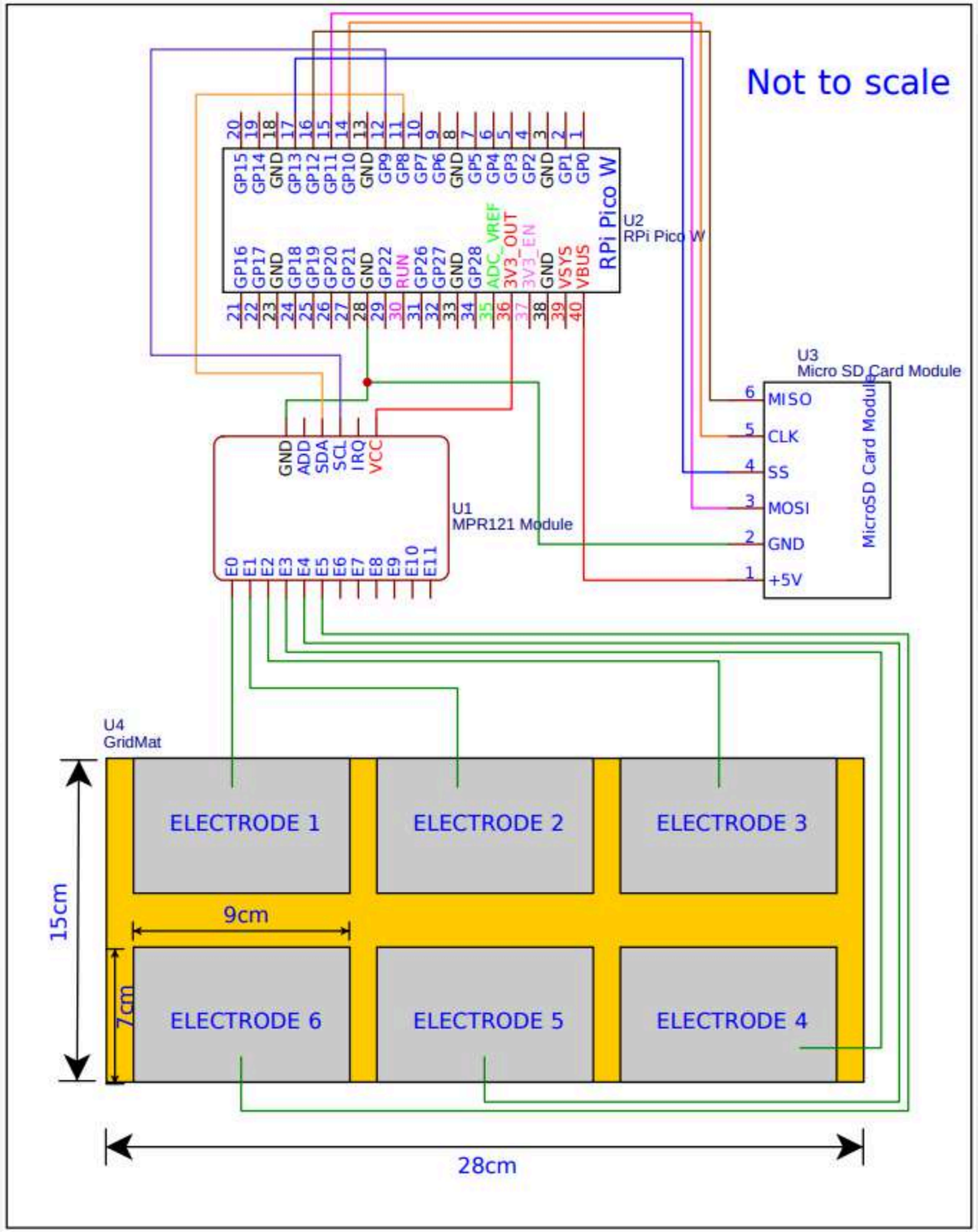
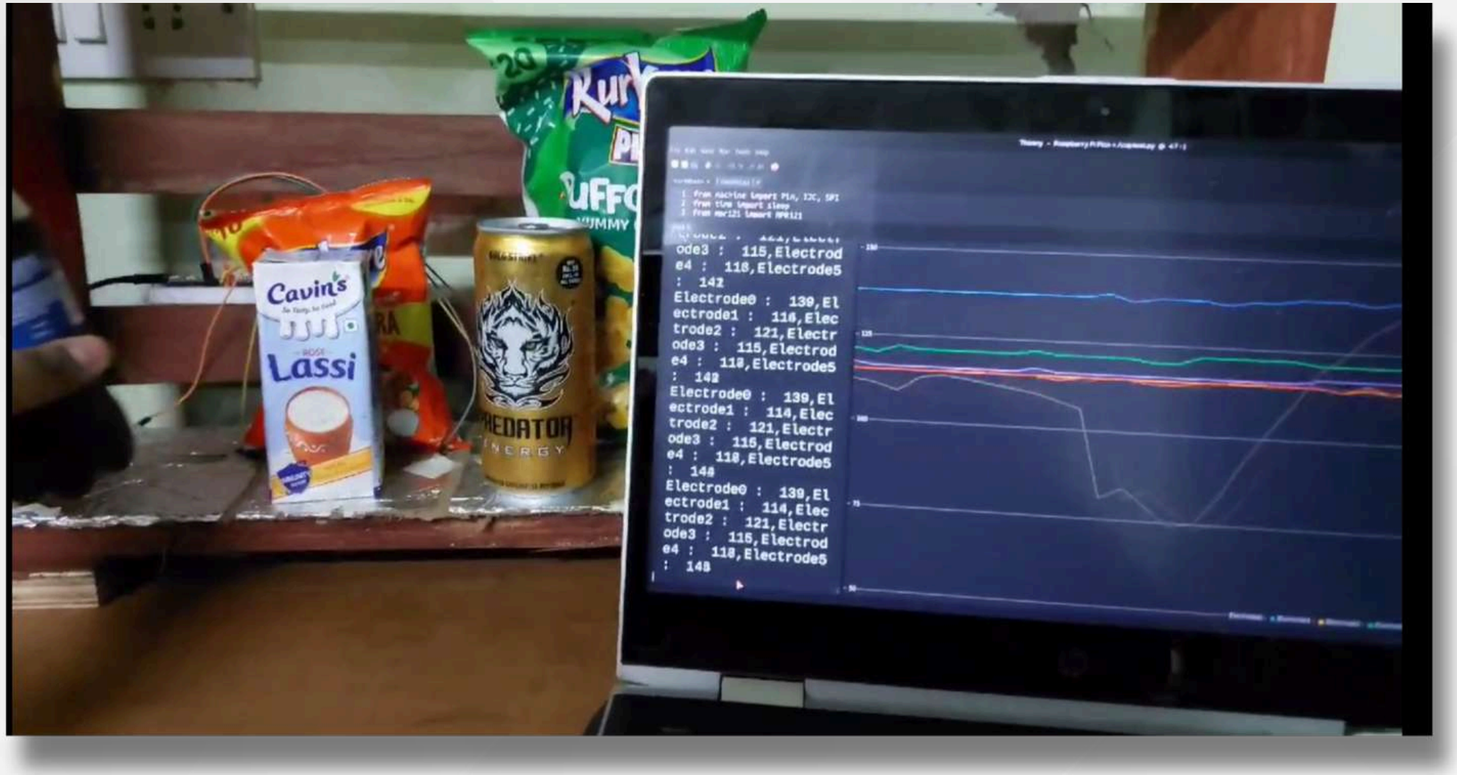
The capacitive touch sensor is connected to a microcontroller unit: Raspberry Pi Pico W.

The signals captured from each of the electrodes are proposed to be processed and provide insights using machine learning algorithms.

THE PROTOTYPE CIRCUIT





THE DATA COLLECTION EXPERIMENT

Collection of signal data from various interactions with objects

THE DATA COLLECTION EXPERIMENT
OBJECTIVE

Given:

- A GridMat based smart shelf, and
- A heterogenous collection of items each of which is assigned atmost two plate electrodes in the GridMat

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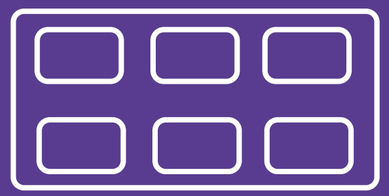

GridMat entirely empty

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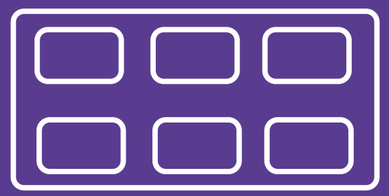

GridMat entirely empty

GridMat full

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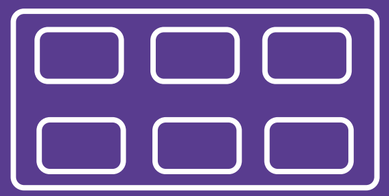

GridMat entirely empty

GridMat full

Taking an item, with others on the GridMat

THE DATA COLLECTION EXPERIMENT
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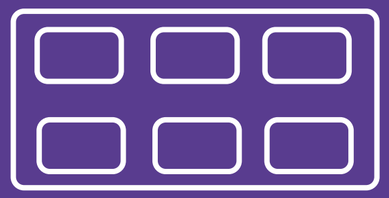

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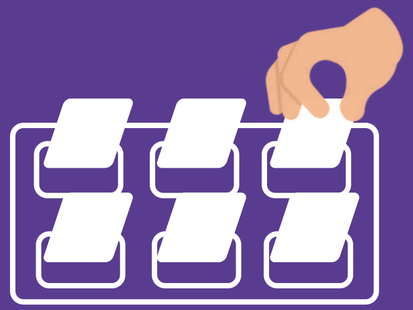
Taking an item, with others on the GridMat



Keeping back the item which was taken, while the others remain on the GridMat.

THE DATA COLLECTION EXPERIMENT
METHODOLOGY

Provision given to annotate the following before starting capture of signal:
Actions:

- zero
- all_full
- Taking
- Keeping Back

Items:

- zero
- all_full
- each item from the inventory

THE DATA COLLECTION EXPERIMENT
METHODOLOGY

Provision given to annotate the following before starting capture of signal:
Actions:

- zero
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- Keeping Back

Items:

- zero
- all_full
- each item from the inventory

Select Action

Select Item

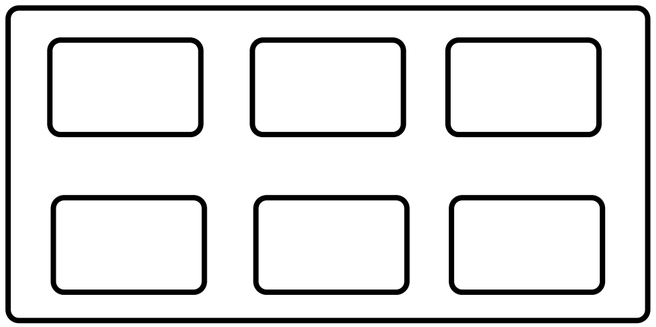
Start Recording

Perform Activity

Stop Recording

THE DATA COLLECTION EXPERIMENT
METHODOLOGY

ACTIVITIES PERFORMED IN THIS ORDER:



GridMat empty, record for 10 seconds

Select Action

Select Item

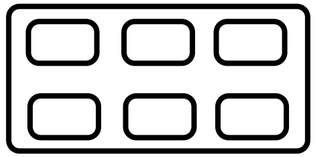
Start Recording

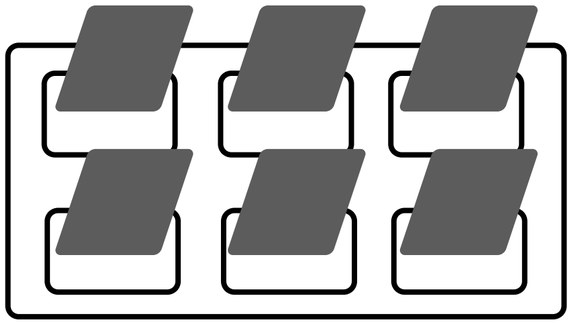
Perform Activity

Stop Recording

THE DATA COLLECTION EXPERIMENT
METHODOLOGY

ACTIVITIES PERFORMED IN THIS ORDER:





GridMat full, record for 10 seconds

Select Action

Select Item

Start Recording

Perform Activity

Stop Recording

THE DATA COLLECTION EXPERIMENT
METHODOLOGY

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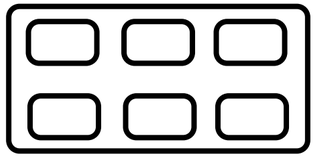
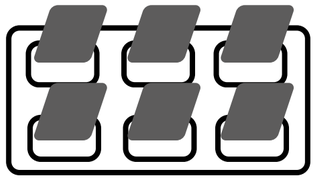
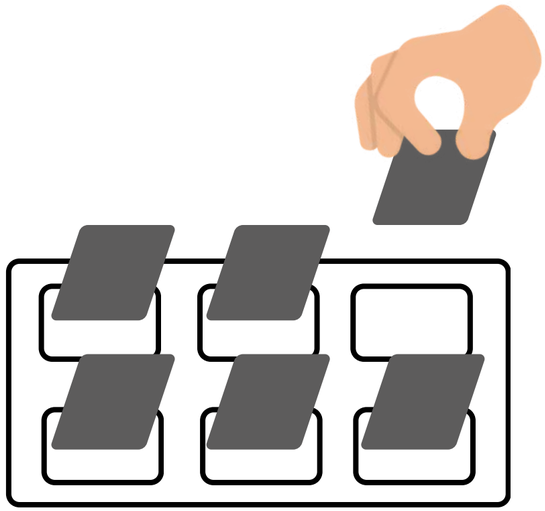






Taking an item from mat, while other items remain on mat

Select Action

Select Item

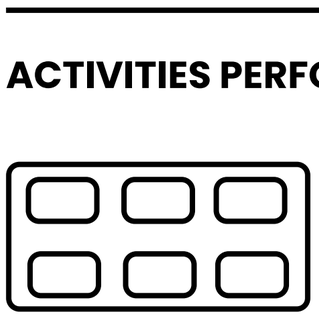
Start Recording

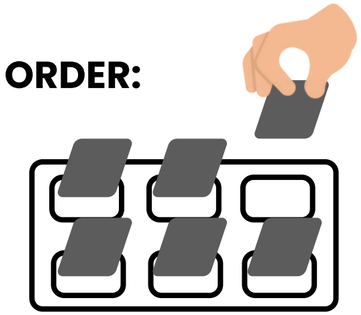
Perform Activity

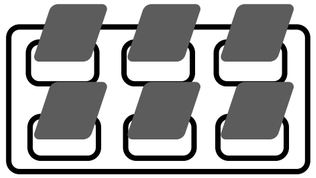
Stop Recording

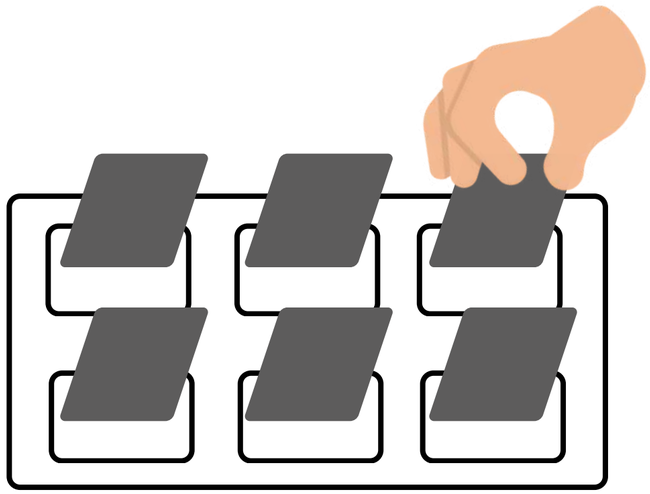
THE DATA COLLECTION EXPERIMENT
METHODOLOGY

ACTIVITIES PERFORMED IN THIS ORDER:









Keeping back the item which was taken, while the others remain on the GridMat.

Keeping back

Select Action

item_name

Select Item

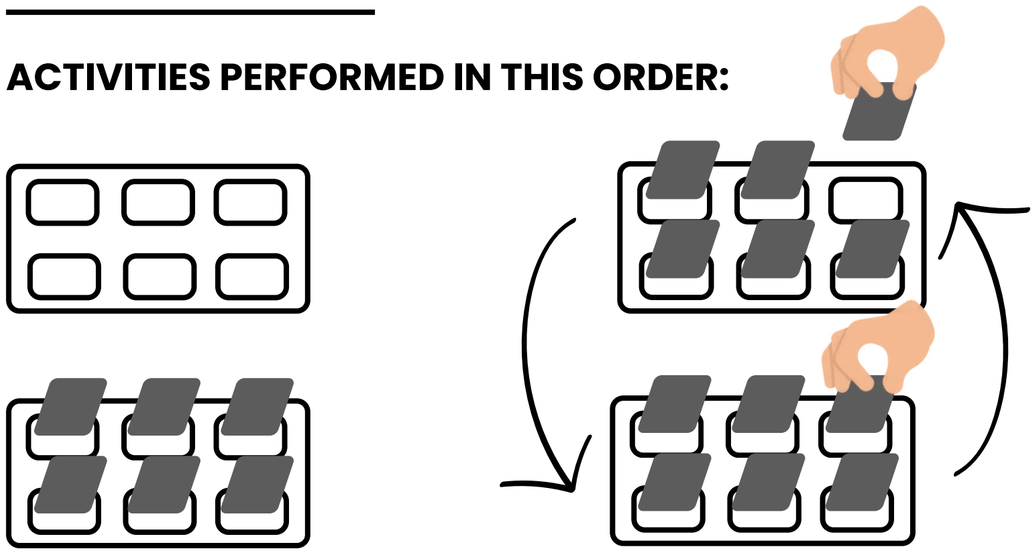
Start Recording

Perform Activity

Stop Recording

THE DATA COLLECTION EXPERIMENT
METHODOLOGY

ACTIVITIES PERFORMED IN THIS ORDER:



Perform steps 3 and 4 for all items on the GridMat

Taking
Keeping back

Select Action

for all item_names

Select Item

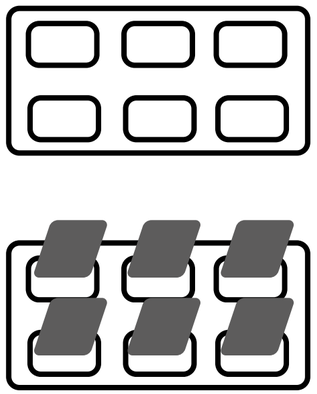
Start Recording

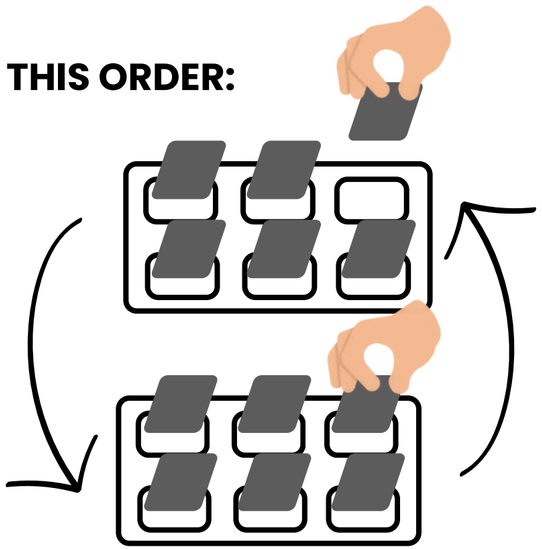
Perform Activity

Stop Recording

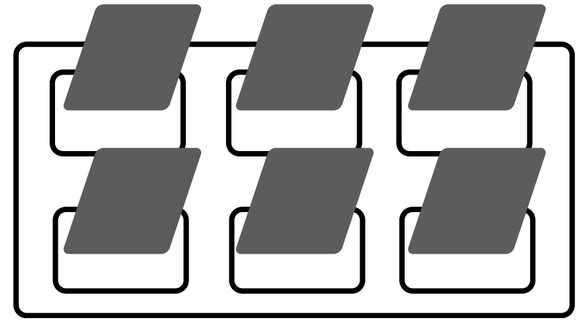
THE DATA COLLECTION EXPERIMENT
METHODOLOGY

ACTIVITIES PERFORMED IN THIS ORDER:





for all items on the GridMat



GridMat full, record for 10 seconds

Select Action

Select Item

Start Recording

Perform Activity

Stop Recording

THE DATA COLLECTION EXPERIMENT
METHODOLOGY

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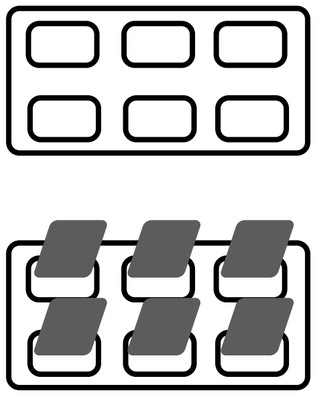
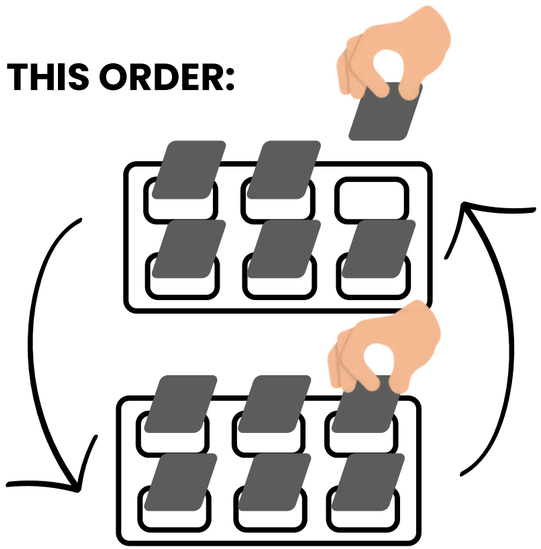
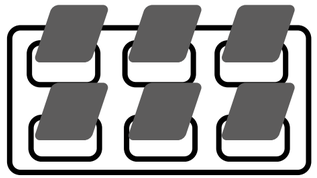
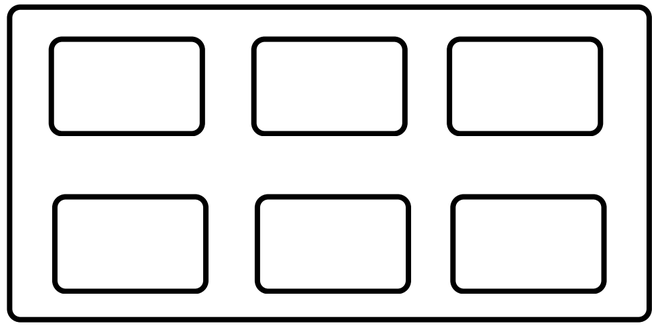




for all items on the GridMat





GridMat empty, record for 10 seconds

Select Action

Select Item

Start Recording

Perform Activity

Stop Recording

THE DATA COLLECTION EXPERIMENT
METHODOLOGY

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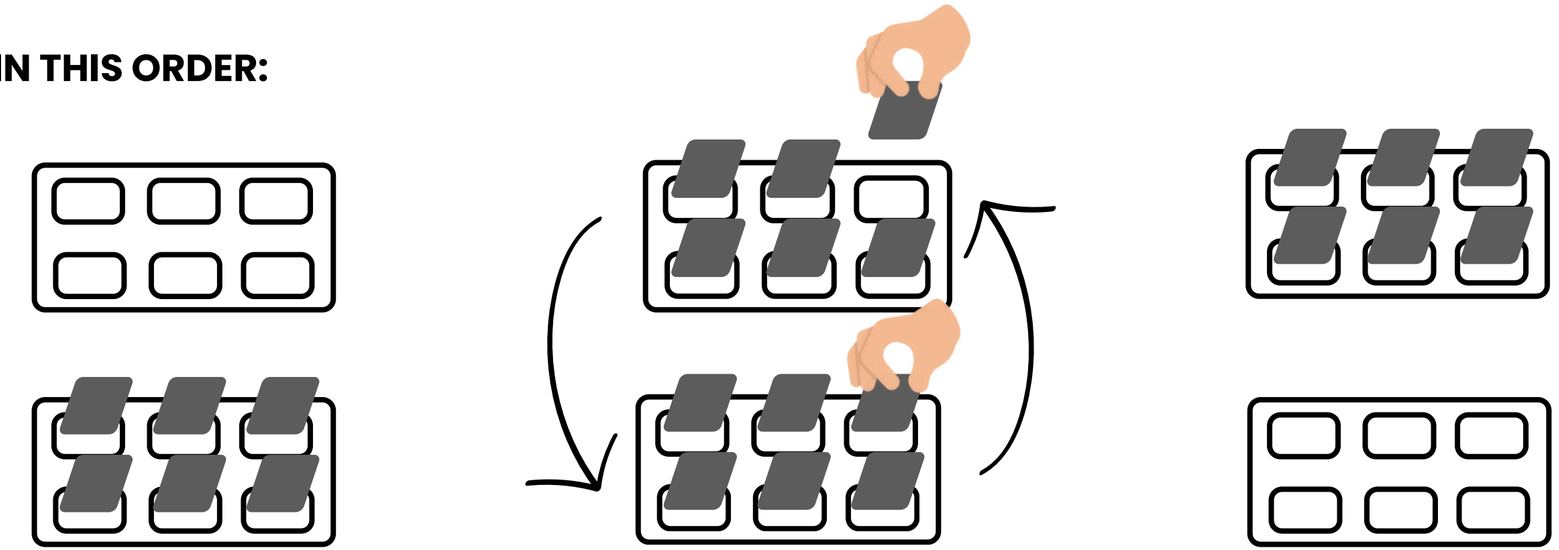


for all items on the GridMat

Set of records for each activity = 1 Experiment Iteration

Collection of all above activities, performed one after another = 1 Experiment Group

THE DATA COLLECTION EXPERIMENT

EXPERIMENT CONFIGURATION

The items and their assigned electrodes on the GridMat

THE DATA COLLECTION EXPERIMENT

DISCUSSION ON DATA COLLECTED

DATASET COLUMNS

Experiment Iteration

Iteration number of the experiment performed.

Experiment Group

Experiment group number

Item

The item being interacted with, during the iteration

Action

The action being done to the item being interacted with, during the iteration.

Electrodes 1-6

Raw values of each of the six plate electrodes, data provided by the MPR121 breakout board.

THE DATA COLLECTION EXPERIMENT

DISCUSSION ON DATA COLLECTED

DATA VOLUME

8552

RECORDS

THE DATA COLLECTION EXPERIMENT

DISCUSSION ON DATA COLLECTED

DATA VOLUME

8552

RECORDS

112

EXPERIMENT ITERATIONS

THE DATA COLLECTION EXPERIMENT

DISCUSSION ON DATA COLLECTED

DATA VOLUME

8552

RECORDS

112

EXPERIMENT ITERATIONS

8

EXPERIMENT GROUPS

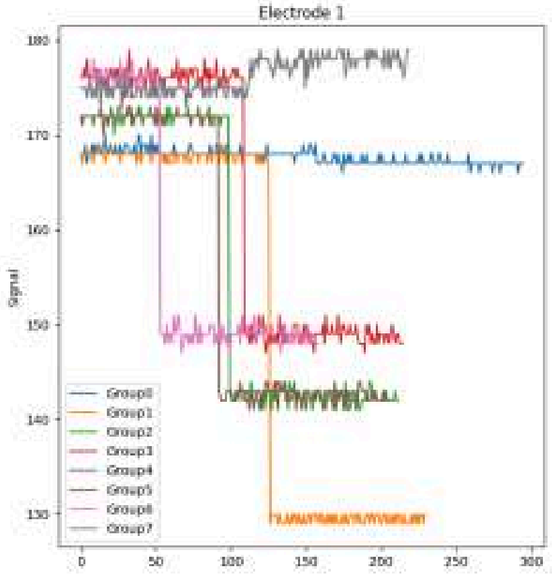
THE DATA COLLECTION EXPERIMENT

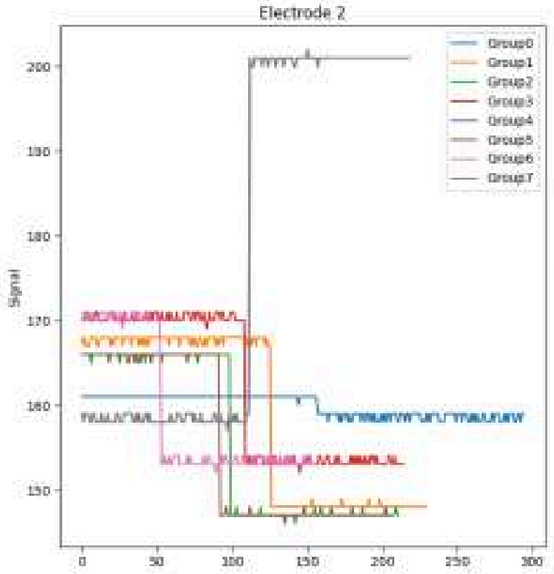
DISCUSSION ON DATA COLLECTED

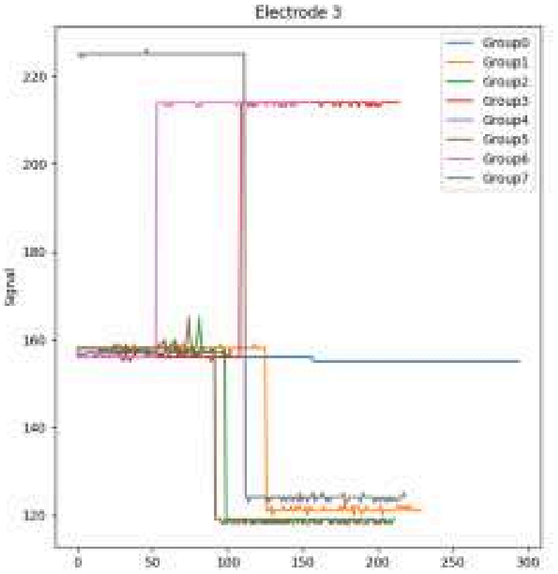
DATA PREPROCESSING - BASELINE SHIFT

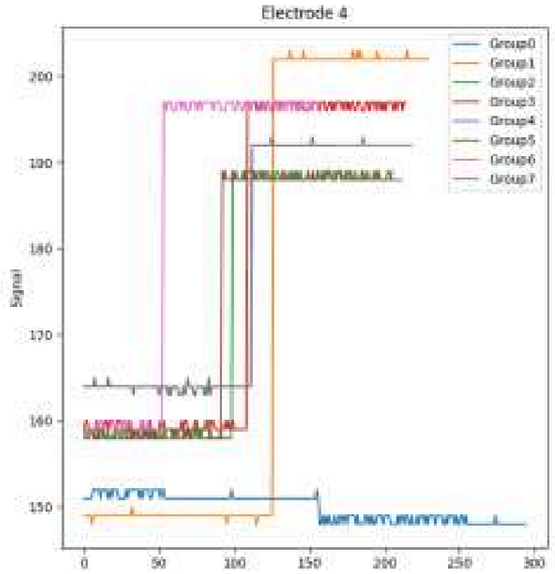
- **Variation of baseline (zero zero) values**
  - **Between groups**
  - **Within groups**

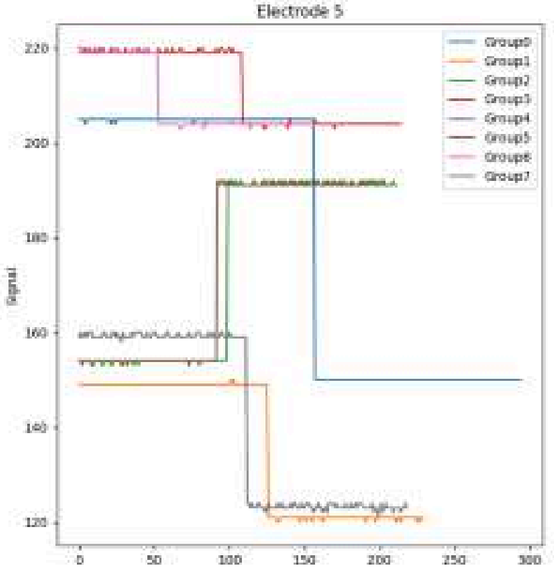
- **Causing variation between groups for other activities too.**

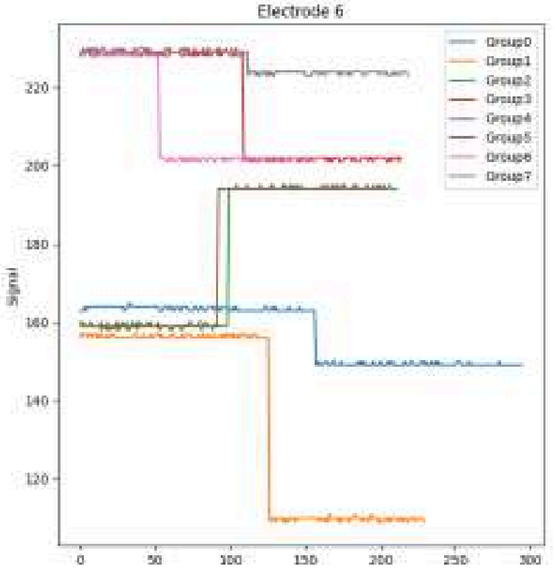








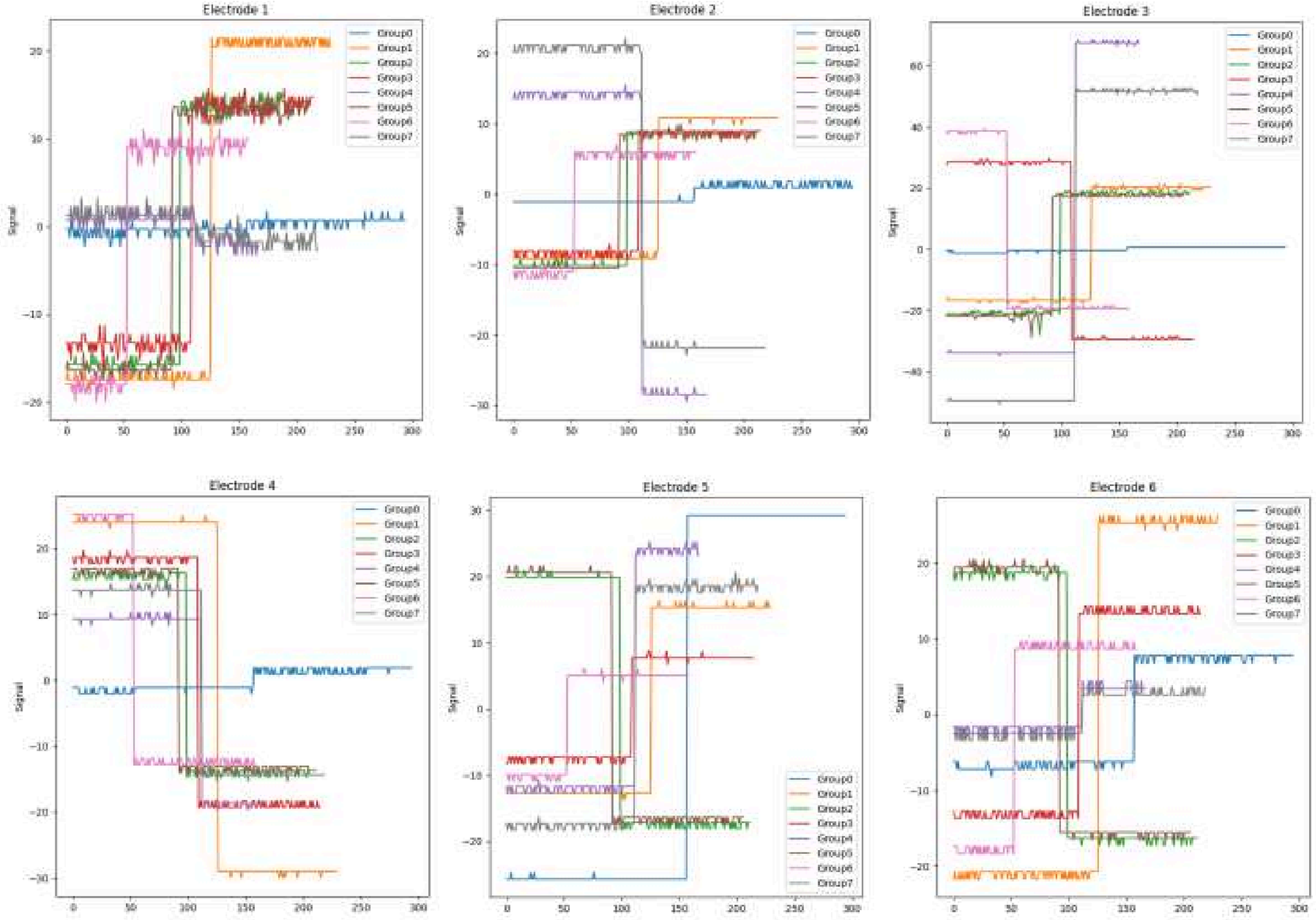




THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

DATA PREPROCESSING - BASELINE SHIFT

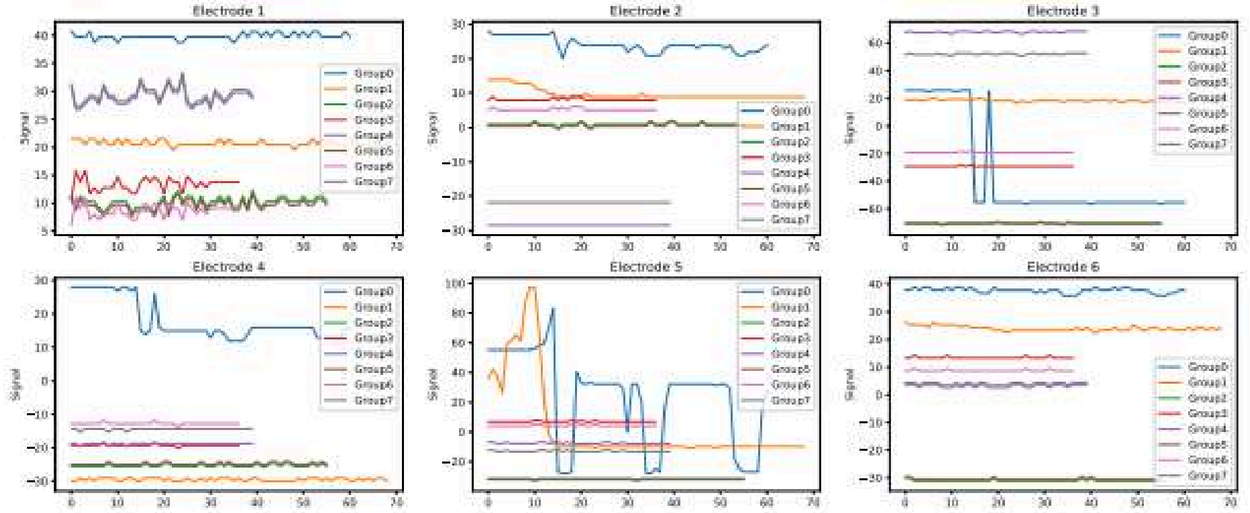
- **Solution:**
  - **For each electrode**
    - **Take the mean of baseline values of one group.**
    - **Subtract the mean from all the readings of that group for that electrode**
    - **Repeat for all groups**



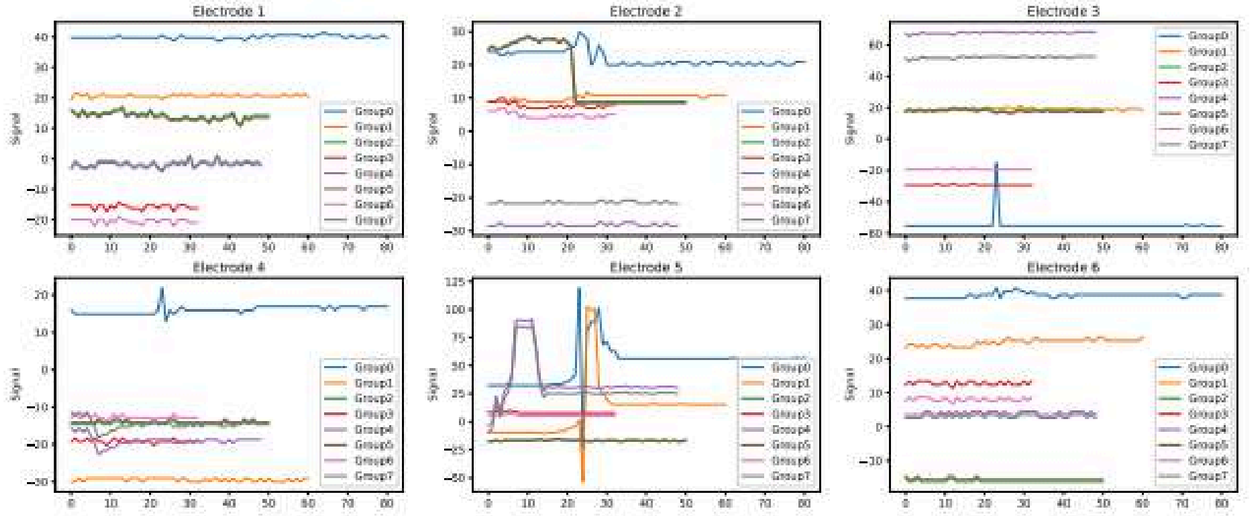
THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

DATA ANALYSIS - TIME SERIES PLOTS - ENERGY DRINK CAN

- **Energy drink can was at electrode 5**
- **More fluctuations at electrode 5 in taking as well as keeping back.**



(a) Time Series plot of taking the energy drink can from the GridMat

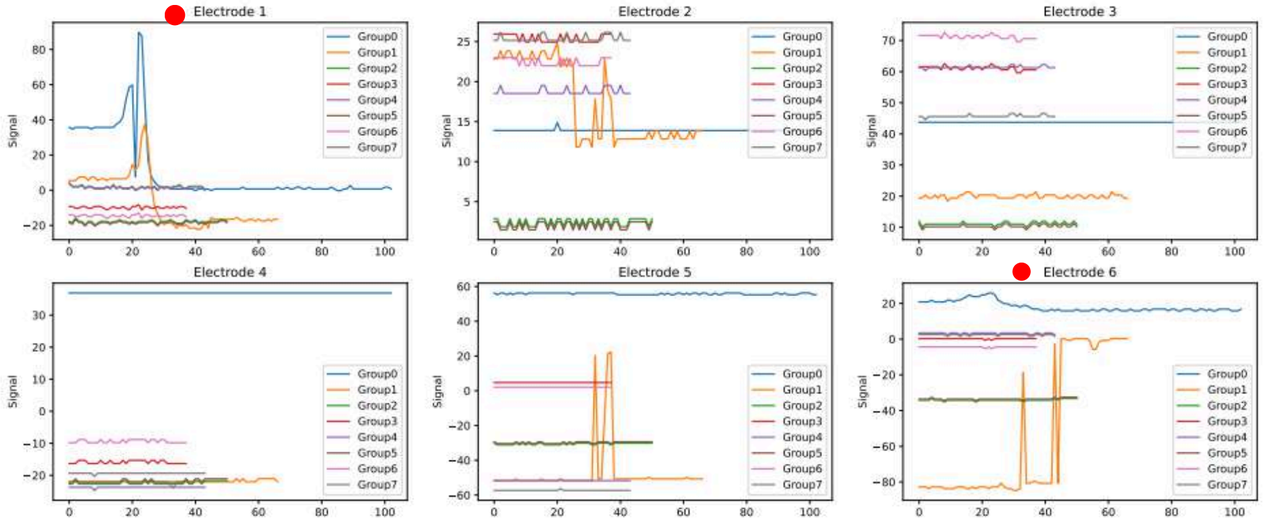


(b) Time Series plot of keeping back the energy drink can onto the GridMat

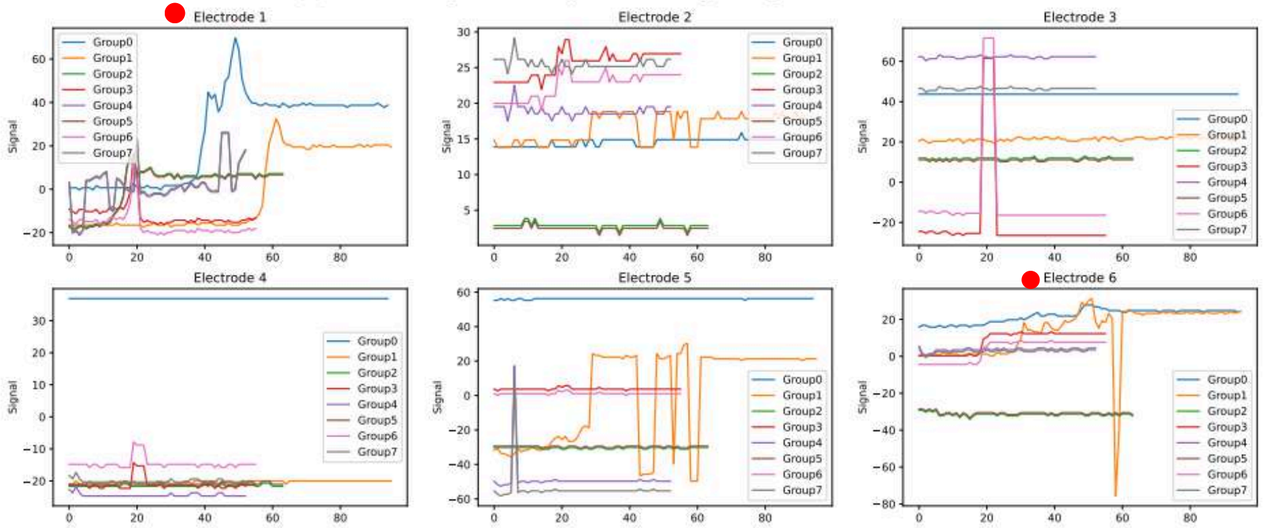
THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

DATA ANALYSIS - TIME SERIES PLOTS - SMALL BAG OF CHIPS

- **Small bag of chips was at electrode 1**
- **Fluctuations in electrode 1 as well as electrodes nearby. This is because**
  - **Electrode 1 is in the back row**
  - **While interacting with the small bag of chips, the hand was in proximity of electrodes near electrode 1, and several electrodes in front row.**



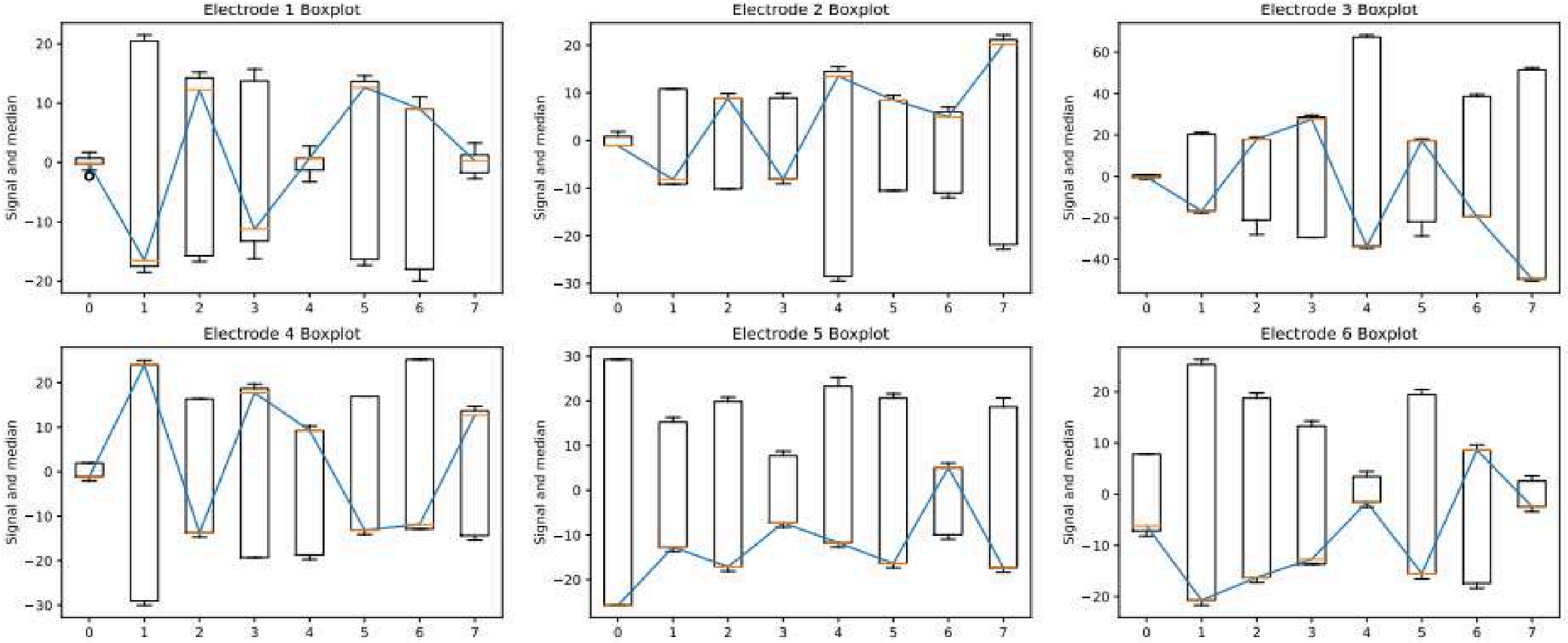
(a) Time Series plot of taking the small bag of chips from the GridMat



(b) Time Series plot of keeping back the small bag of chips onto the GridMat

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

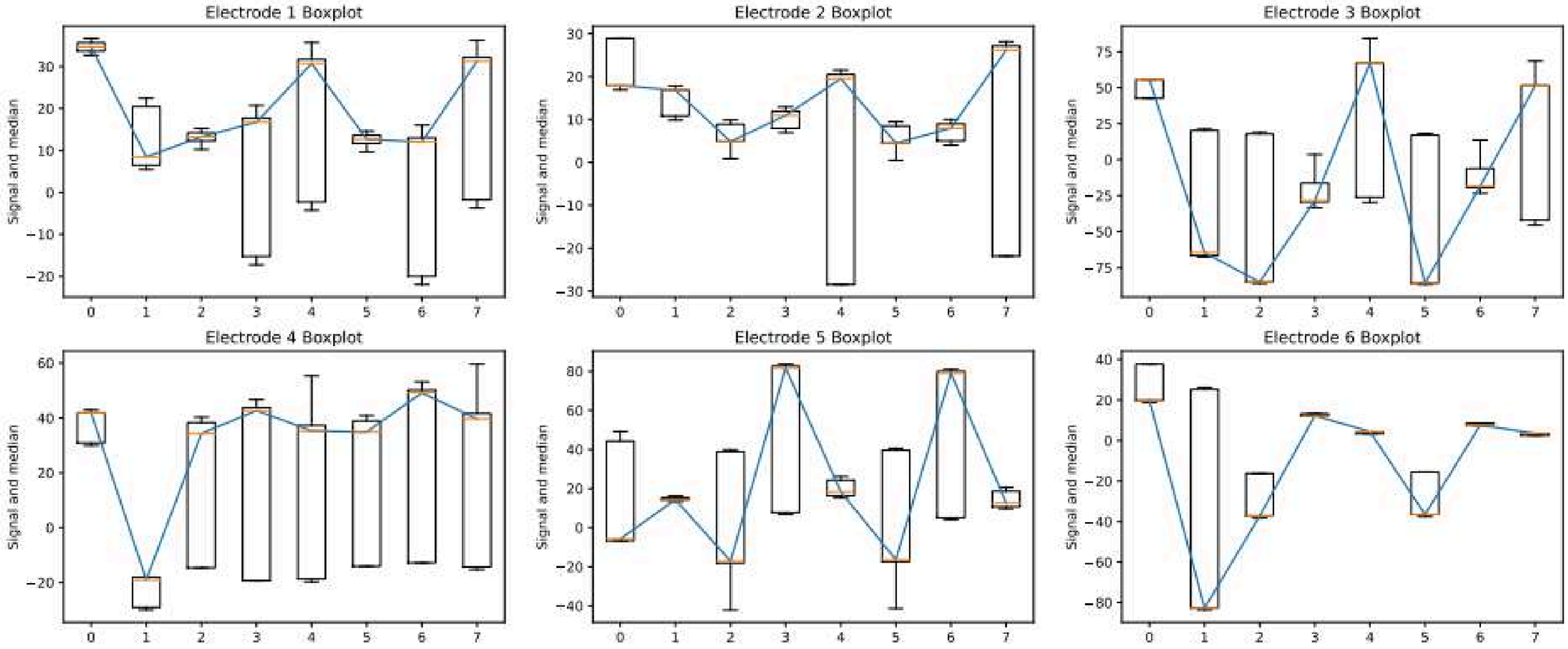
DATA ANALYSIS - BOX PLOTS - BASELINE/ZERO-ZERO CONFIG



Almost no outliers in baseline configuration readings.
Higher inter quartile range

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

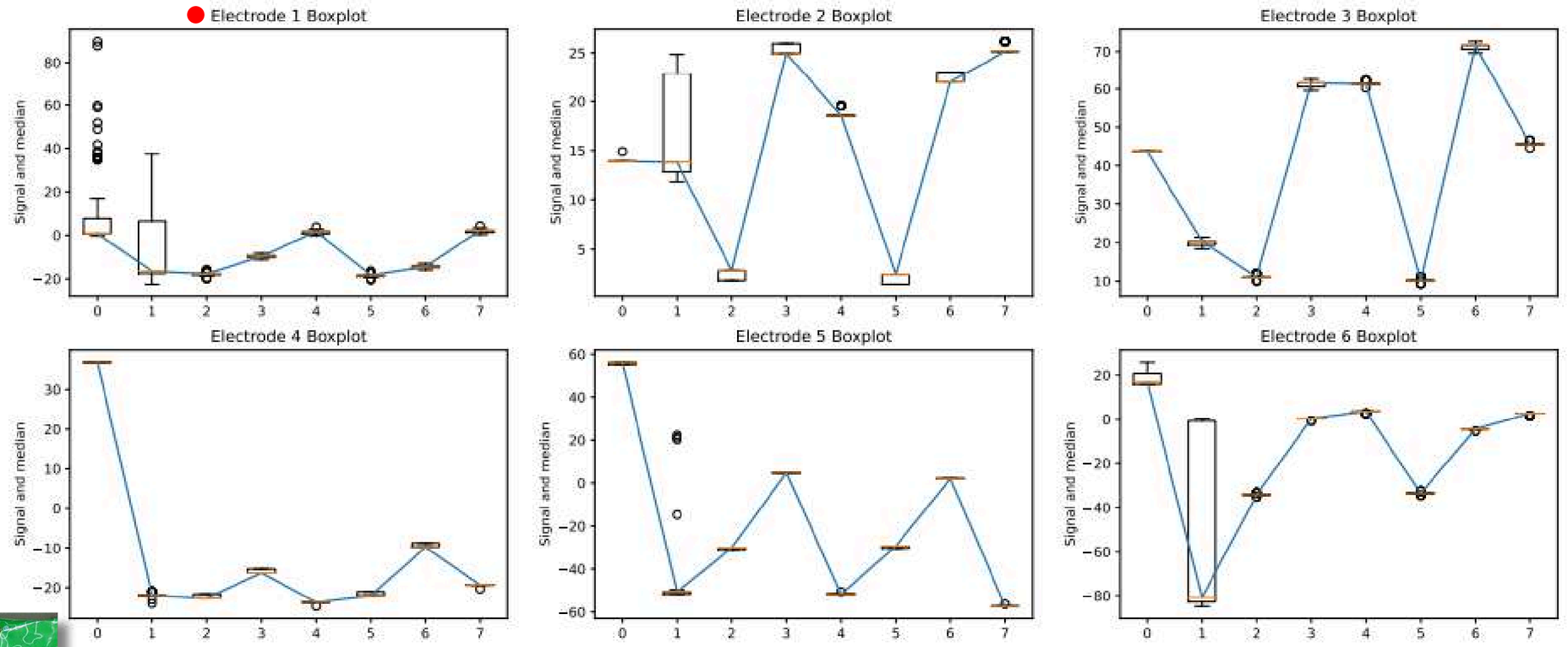
DATA ANALYSIS - BOX PLOTS - ALL FULL CONFIG



Almost no outliers and higher inter quartile range here as well

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

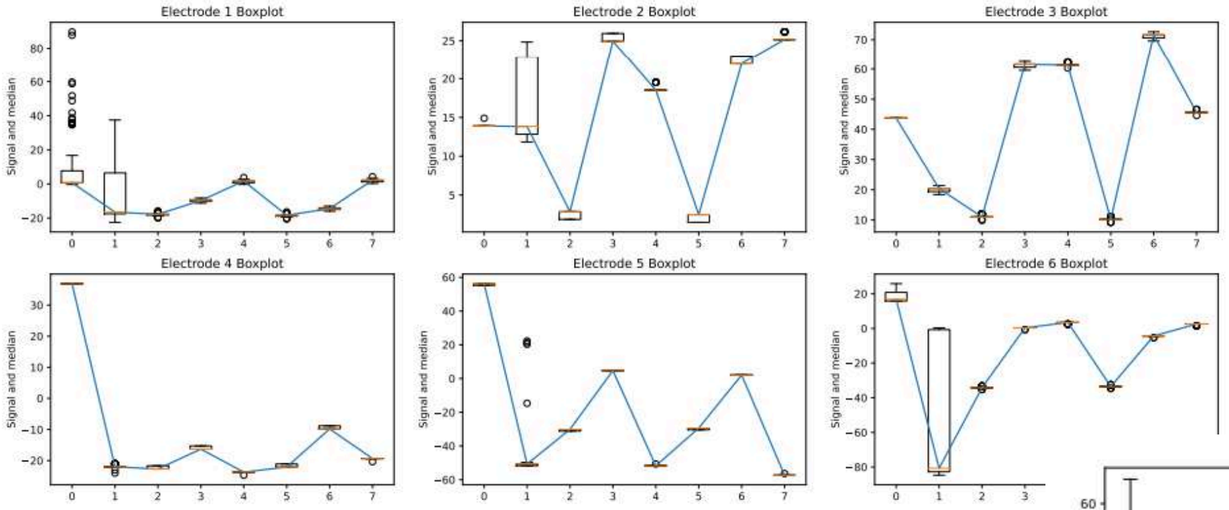
DATA ANALYSIS - BOX PLOTS - INTERACTIONS WITH SMALL BAG OF CHIPS



(a) Boxplot of taking the small bag of chips from the GridMat

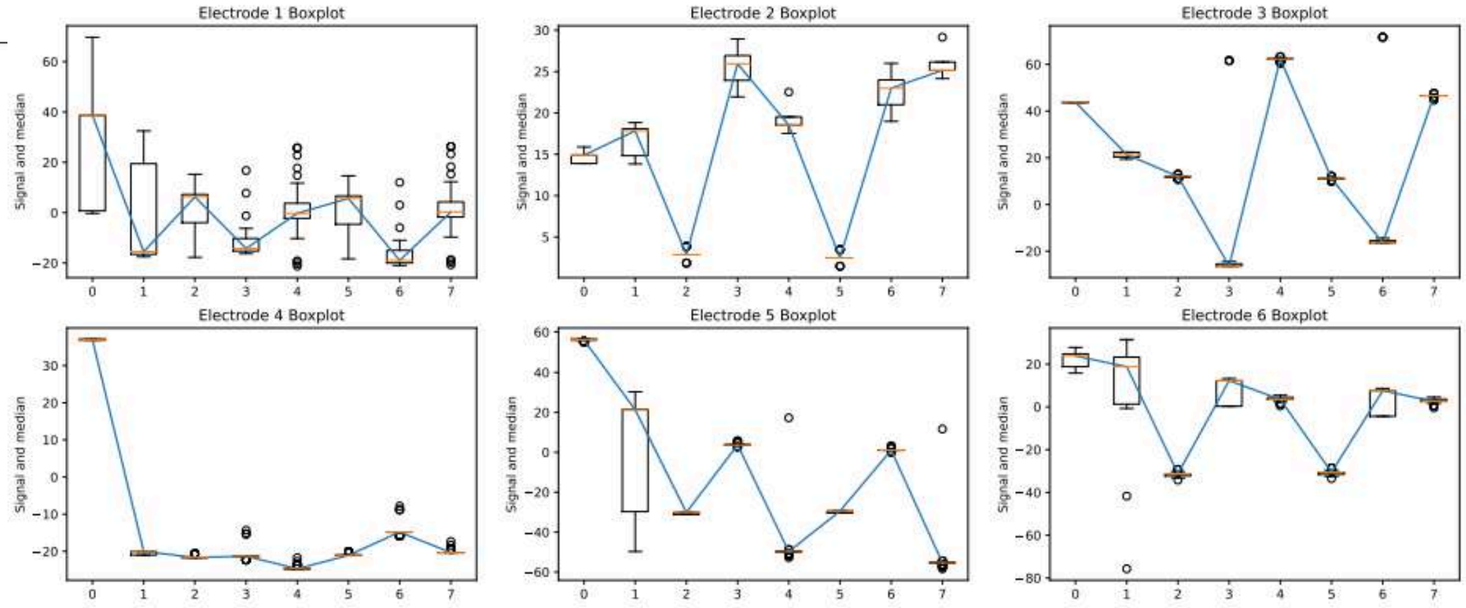
THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

DATA ANALYSIS - BOX PLOTS - INTERACTIONS WITH SMALL BAG OF CHIPS



(a) Boxplot of taking the small bag of chips from the GridMat

Outliers detected in iterations involving direct interactions from user



(b) Boxplot of keeping back the small bag of chips onto the GridMat

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

DATA ANALYSIS - CORRELATION ANALYSIS - ACROSS GROUPS

Activity	Electrode A	Electrode B	Pearson's Coefficient
Taking Small Chips	Electrode 2	Electrode 3	0.76
	Electrode 4	Electrode 5	0.92
Keeping Back Small Chips	Electrode 4	Electrode 5	0.80
	Electrode 2	Electrode 6	0.69
Taking 250 ml plastic bottle of soft drinks	Electrode 2	Electrode 3	0.62
	Electrode 4	Electrode 5	0.76
	Electrode 5	Electrode 6	0.63
Keeping Back 250 ml plastic bottle of soft drinks	Electrode 3	Electrode 5	0.85
Taking Large bag of chips	Electrode 4	Electrode 6	0.65
Keeping Back Large bag of chips	Electrode 1	Electrode 6	0.66
Taking Can of energy drink	Electrode 5	Electrode 6	0.74
	Electrode 1	Electrode 4	0.73
	Electrode 1	Electrode 6	0.71
Keeping Back Can of energy drink	Electrode 5	Electrode 6	0.66
Taking A tetrapack of juice	Electrode 5	Electrode 6	0.78
	Electrode 4	Electrode 5	0.72
	Electrode 2	Electrode 4	0.68
Keeping Back A tetrapack of juice	Electrode 1	Electrode 4	0.76
	Electrode 4	Electrode 5	0.71
	Electrode 2	Electrode 6	0.67

Correlations involving the electrodes associated with the item being interacted with, when analysis is done with data accumulated across groups - is mostly 1 or 2 across activities.

Small bag of chips, though associated to electrode 1, has no correlation of electrode 1 readings with readings of any other electrode.

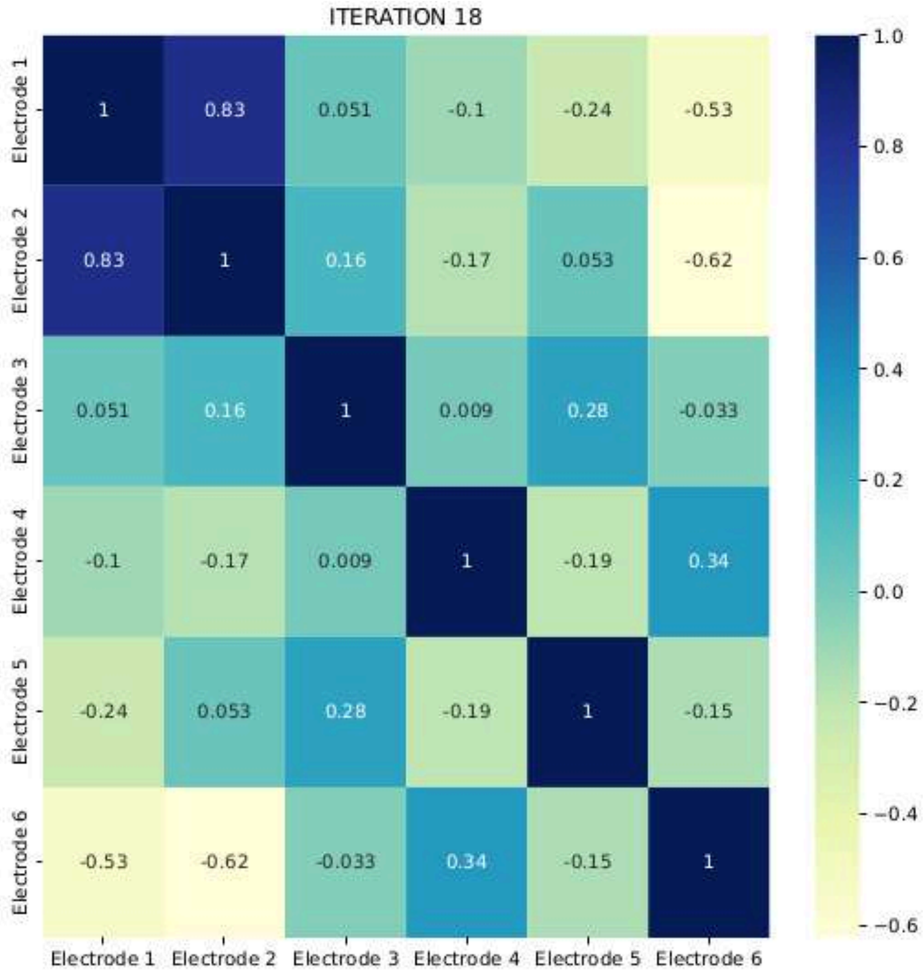
Table showing graph with electrodes having most correlations

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

DATA ANALYSIS - CORRELATION ANALYSIS - ITERATIONWISE

Small bag of chips, though associated to electrode 1, has no correlation of electrode 1 readings with readings of any other electrode.

However, if we look at the correlation matrix of specifically iteration 18 of Taking small chips, we can see a correlation between electrode 1 and electrode 2, and it is quite high.



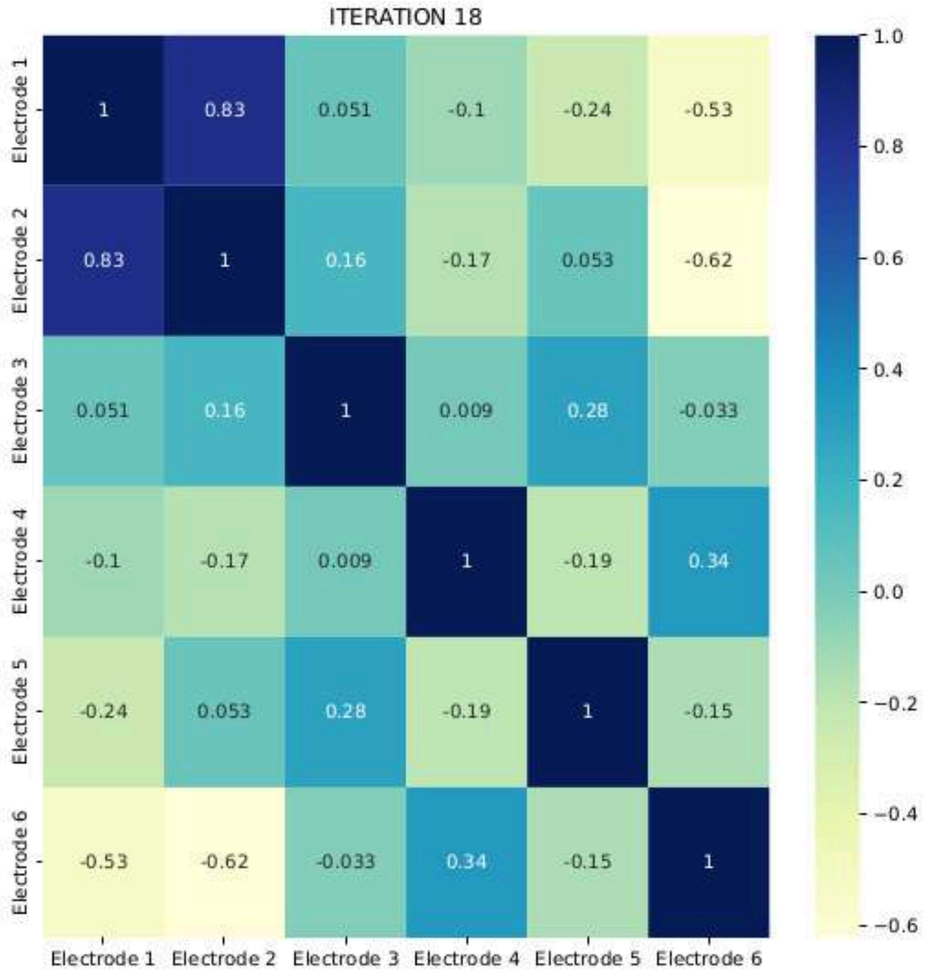
THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

DATA ANALYSIS - CORRELATION ANALYSIS - ITERATIONWISE

Small bag of chips, though associated to electrode 1, has no correlation of electrode 1 readings with readings of any other electrode.

However, if we look at the correlation matrix of specifically iteration 18 of Taking small chips, we can see a correlation between electrode 1 and electrode 2, and it is quite high.

Similarly several new correlations are discovered in individual iterations.



THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

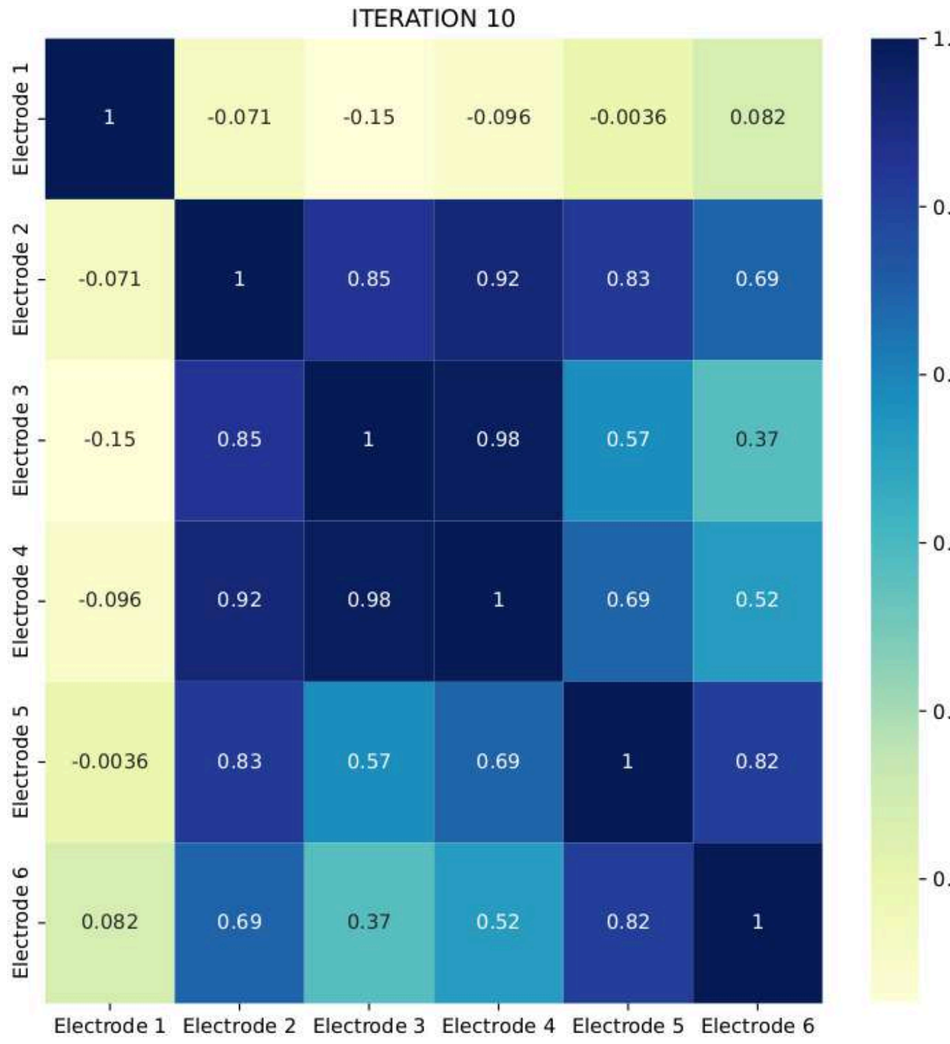
DATA ANALYSIS - CORRELATION ANALYSIS - ITERATIONWISE

Small bag of chips, though associated to electrode 1, has no correlation of electrode 1 readings with readings of any other electrode.

However, if we look at the correlation matrix of specifically iteration 18 of Taking small chips, we can see a correlation between electrode 1 and electrode 2, and it is quite high.

Similarly several new correlations are discovered in individual iterations.

Taking energy drink can, iteration 10 is particularly an interesting example



THE DATA COLLECTION EXPERIMENT

DISCUSSION ON DATA COLLECTED

NATURE OF NORMALITY

The data is not normal. Normality test fail:

- **Across the entire dataset**
- **Within activities**
- **Within groups**

Even after applying normal transformations such as:

- **Log transform**
- **Square root transform**
- **Cube root transform**

The normality tests fail.

THE DATA COLLECTION EXPERIMENT

DISCUSSION ON DATA COLLECTED

NATURE OF NORMALITY

The data is not normal. Normality test fail:

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Even after applying normal transformations such as:

- **Log transform**
- **Square root transform**
- **Cube root transform**

The normality tests fail.

Hence, we canot apply parametric hypothesis tests such as T-tests and F-test, since they assume normality

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY OF A SINGLE ACTIVITY ACROSS MULTIPLE EXPERIMENT ITERATIONS

Null Hypothesis: The readings of an activity A is not statistically different across iterations.
Alternate Hypothesis: The readings of an activity A is statistically different across iterations.

Test Performed: A Kruskal-Wallis test was performed, taking each iteration of an activity as a separate group

We are unable to observe any p-value for any activity and any electrode that is above the p-value threshold. Hence we can reject the null hypothesis and consider the alternate hypothesis.

Kruskal-Wallis Test *is a non-parametric statistical test that compares more than two groups or samples*

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY BETWEEN ELECTRODE READINGS FOR A SINGLE ACTIVITY

Null Hypothesis: The readings of an activity A is not statistically different between Electrode X and Electrode Y.
Alternate Hypothesis: The readings of an activity A is statistically different between Electrode X and Electrode Y.

Test Performed: Mann-Whitney U-Test was performed, taking the reading of two electrodes at a time for a single activity.

Mann-Whitney U-Test *is a non-parametric statistical test that compares two groups or samples*

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY BETWEEN ELECTRODE READINGS FOR A SINGLE ACTIVITY

Null Hypothesis: The readings of an activity A is not statistically different between Electrode X and Electrode Y.
Alternate Hypothesis: The readings of an activity A is statistically different between Electrode X and Electrode Y.

Test Performed: Mann-Whitney U-Test was performed, taking the reading of two electrodes at a time for a single activity.

Action	Item	Electrode X	Electrode Y
all_full	all_full	Electrode 3	Electrode 6
Keeping back	chips_small	Electrode 1	Electrode 6
Keeping back	chips_small	Electrode 4	Electrode 5
Keeping back	energy_drink_can	Electrode 1	Electrode 3
Keeping back	energy_drink_can	Electrode 1	Electrode 5
Keeping back	energy_drink_can	Electrode 1	Electrode 6
Keeping back	energy_drink_can	Electrode 2	Electrode 3
Keeping back	energy_drink_can	Electrode 2	Electrode 6
Keeping back	energy_drink_can	Electrode 3	Electrode 5
Keeping back	energy_drink_can	Electrode 3	Electrode 6
Keeping back	energy_drink_can	Electrode 5	Electrode 6
Keeping back	chips_big	Electrode 2	Electrode 3
Keeping back	soft_drinks_pet_bottle_250ml	Electrode 2	Electrode 5
Keeping back	soft_drinks_pet_bottle_250ml	Electrode 3	Electrode 4
Keeping back	juicebox	Electrode 2	Electrode 3

Action	Item	Electrode X	Electrode Y
zero	zero	Electrode 1	Electrode 2
zero	zero	Electrode 1	Electrode 4
zero	zero	Electrode 1	Electrode 5
zero	zero	Electrode 1	Electrode 6
zero	zero	Electrode 2	Electrode 3
zero	zero	Electrode 2	Electrode 4
zero	zero	Electrode 2	Electrode 5
zero	zero	Electrode 2	Electrode 6
zero	zero	Electrode 3	Electrode 4
zero	zero	Electrode 4	Electrode 5
zero	zero	Electrode 4	Electrode 6
zero	zero	Electrode 5	Electrode 6
Taking	chips_small	Electrode 1	Electrode 6
Taking	chips_small	Electrode 4	Electrode 6
Taking	chips_small	Electrode 5	Electrode 6

p-value for these readings were above 0.001. *This means we don't have enough evidence to reject null hypothesis.*

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY BETWEEN ELECTRODE READINGS FOR A SINGLE ACTIVITY

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Action	Item	Electrode X	Electrode Y
all_full	all_full	Electrode 3	Electrode 6
Keeping back	chips_small	Electrode 1	Electrode 6
Keeping back	chips_small	Electrode 4	Electrode 5
Keeping back	energy_drink_can	Electrode 1	Electrode 3
Keeping back	energy_drink_can	Electrode 1	Electrode 5
Keeping back	energy_drink_can	Electrode 1	Electrode 6
Keeping back	energy_drink_can	Electrode 2	Electrode 3
Keeping back	energy_drink_can	Electrode 2	Electrode 6
Keeping back	energy_drink_can	Electrode 3	Electrode 5
Keeping back	energy_drink_can	Electrode 3	Electrode 6
Keeping back	energy_drink_can	Electrode 5	Electrode 6
Keeping back	chips_big	Electrode 2	Electrode 3
Keeping back	soft_drinks_pet_bottle_250ml	Electrode 2	Electrode 5
Keeping back	soft_drinks_pet_bottle_250ml	Electrode 3	Electrode 4
Keeping back	juicebox	Electrode 2	Electrode 3

Action	Item	Electrode X	Electrode Y
zero	zero	Electrode 1	Electrode 2
zero	zero	Electrode 1	Electrode 4
zero	zero	Electrode 1	Electrode 5
zero	zero	Electrode 1	Electrode 6
zero	zero	Electrode 2	Electrode 3
zero	zero	Electrode 2	Electrode 4
zero	zero	Electrode 2	Electrode 5
zero	zero	Electrode 2	Electrode 6
zero	zero	Electrode 3	Electrode 4
zero	zero	Electrode 4	Electrode 5
zero	zero	Electrode 4	Electrode 6
zero	zero	Electrode 5	Electrode 6
Taking	chips_small	Electrode 1	Electrode 6
Taking	chips_small	Electrode 4	Electrode 6
Taking	chips_small	Electrode 5	Electrode 6
Taking	energy_drink_can	Electrode 2	Electrode 6
Taking	energy_drink_can	Electrode 3	Electrode 4
Taking	energy_drink_can	Electrode 3	Electrode 5
Taking	soft_drinks_pet_bottle_250ml	Electrode 2	Electrode 5
Taking	soft_drinks_pet_bottle_250ml	Electrode 2	Electrode 6
Taking	soft_drinks_pet_bottle_250ml	Electrode 4	Electrode 5
Taking	juicebox	Electrode 1	Electrode 3
Taking	juicebox	Electrode 2	Electrode 3

p-value for these readings were above 0.001. *This means we don't have enough evidence to reject null hypothesis.*

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY BETWEEN ELECTRODE READINGS FOR A SINGLE ACTIVITY

Null Hypothesis: The readings of an activity A is not statistically different between Electrode X and Electrode Y.
Alternate Hypothesis: The readings of an activity A is statistically different between Electrode X and Electrode Y.

Test Performed: Mann-Whitney U-Test was performed, taking the reading of two electrodes at a time for a single activity.

Action	Item	Electrode X	Electrode Y
all_full	all_full	Electrode 3	Electrode 6
Keeping back	chips_small	Electrode 1	Electrode 6
Keeping back	chips_small	Electrode 4	Electrode 5
Keeping back	energy_drink_can	Electrode 1	Electrode 3
Keeping back	energy_drink_can	Electrode 1	Electrode 5
Keeping back	energy_drink_can	Electrode 1	Electrode 6
Keeping back	energy_drink_can	Electrode 2	Electrode 3
Keeping back	energy_drink_can	Electrode 2	Electrode 6
Keeping back	energy_drink_can	Electrode 3	Electrode 5
Keeping back	energy_drink_can	Electrode 3	Electrode 6
Keeping back	energy_drink_can	Electrode 5	Electrode 6
Keeping back	chips_big	Electrode 2	Electrode 3
Keeping back	soft_drinks_pet_bottle_250ml	Electrode 2	Electrode 5
Keeping back	soft_drinks_pet_bottle_250ml	Electrode 3	Electrode 4
Keeping back	juicebox	Electrode 2	Electrode 3

Action	Item	Electrode X	Electrode Y
zero	zero	Electrode 1	Electrode 2
zero	zero	Electrode 1	Electrode 4
zero	zero	Electrode 1	Electrode 5
zero	zero	Electrode 1	Electrode 6
zero	zero	Electrode 2	Electrode 3
zero	zero	Electrode 2	Electrode 4
zero	zero	Electrode 2	Electrode 5
zero	zero	Electrode 2	Electrode 6
zero	zero	Electrode 3	Electrode 4
zero	zero	Electrode 4	Electrode 5
zero	zero	Electrode 4	Electrode 6
zero	zero	Electrode 5	Electrode 6
Taking	chips_small	Electrode 1	Electrode 6
Taking	chips_small	Electrode 4	Electrode 6
Taking	chips_small	Electrode 5	Electrode 6
Taking	energy_drink_can	Electrode 2	Electrode 6
Taking	energy_drink_can	Electrode 3	Electrode 4
Taking	energy_drink_can	Electrode 3	Electrode 5
Taking	soft_drinks_pet_bottle_250ml	Electrode 2	Electrode 5
Taking	soft_drinks_pet_bottle_250ml	Electrode 2	Electrode 6
Taking	soft_drinks_pet_bottle_250ml	Electrode 4	Electrode 5
Taking	juicebox	Electrode 1	Electrode 3
Taking	juicebox	Electrode 2	Electrode 3

p-value for these readings were above 0.001. *This means we don't have enough evidence to reject null hypothesis.*

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY OF READINGS BETWEEN DIFFERENT ACTIVITIES

Null Hypothesis: The readings between an activity A and another activity B is not statistically different for a particular Electrode E.
Alternate Hypothesis: The readings between an activity A and another activity B is statistically different for a particular Electrode E.

Test Performed: A Mann-Whitney U-Test was performed, taking the reading of an electrode for two activities at a time.

Mann-Whitney U-Test *is a non-parametric statistical test that compares two groups or samples*

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY BETWEEN ELECTRODE READINGS FOR A SINGLE ACTIVITY

Null Hypothesis: The readings between an activity A and another activity B is not statistically different for a particular Electrode E.
Alternate Hypothesis: The readings between an activity A and another activity B is statistically different for a particular Electrode E.

Test Performed: A Mann-Whitney U-Test was performed, taking the reading of an electrode for two activities at a time.

Activity 1	Activity 2	Electrode readings having p-value>0.001
all_full all_full	Keeping back chips_small	Electrode 6
all_full all_full	Keeping back energy_drink_can	Electrode 1,Electrode 2,Electrode 3
all_full all_full	Keeping back chips_big	Electrode 2
all_full all_full	Keeping back soft_drinks_pet_bottle_250ml	Electrode 1
all_full all_full	Keeping back juicebox	Electrode 6
all_full all_full	zero zero	Electrode 3
all_full all_full	Taking chips_big	Electrode 2
all_full all_full	Taking soft_drinks_pet_bottle_250ml	Electrode 1
all_full all_full	Taking juicebox	Electrode 1,Electrode 6
Keeping back chips_small	Keeping back soft_drinks_pet_bottle_250ml	Electrode 4
Keeping back chips_small	Keeping back juicebox	Electrode 2,Electrode 3,Electrode 4,Electrode 5
Keeping back chips_small	zero zero	Electrode 1,Electrode 6
Keeping back chips_small	Taking chips_small	Electrode 2,Electrode 4
Keeping back chips_small	Taking energy_drink_can	Electrode 5
Keeping back chips_small	Taking chips_big	Electrode 6

p-value for these readings were above 0.001. *This means we don't have enough evidence to reject null hypothesis.*

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY BETWEEN ELECTRODE READINGS FOR A SINGLE ACTIVITY

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all_full all_full	Keeping back energy_drink_can	Electrode 1,Electrode 2,Electrode 3
all_full all_full	Keeping back chips_big	Electrode 2
all_full all_full	Keeping back soft_drinks_pet_bottle_250ml	Electrode 1
all_full all_full	Keeping back juicebox	Electrode 6
all_full all_full	zero zero	Electrode 3
all_full all_full	Taking chips_big	Electrode 2
all_full all_full	Taking soft_drinks_pet_bottle_250ml	Electrode 1
all_full all_full	Taking juicebox	Electrode 1,Electrode 6
Keeping back chips_small	Keeping back soft_drinks_pet_bottle_250ml	Electrode 4
Keeping back chips_small	Keeping back juicebox	Electrode 2,Electrode 3,Electrode 4,Electrode 5
Keeping back chips_small	zero zero	Electrode 1,Electrode 6
Keeping back chips_small	Taking chips_small	Electrode 2,Electrode 4
Keeping back chips_small	Taking energy_drink_can	Electrode 5
Keeping back chips_small	Taking chips_big	Electrode 6
Keeping back chips_small	Taking juicebox	Electrode 3,Electrode 4,Electrode 6
Keeping back energy_drink_can	Keeping back chips_big	Electrode 2,Electrode 3
Keeping back energy_drink_can	Keeping back soft_drinks_pet_bottle_250ml	Electrode 1,Electrode 6
Keeping back energy_drink_can	Keeping back juicebox	Electrode 3
Keeping back energy_drink_can	Taking energy_drink_can	Electrode 6
Keeping back energy_drink_can	Taking soft_drinks_pet_bottle_250ml	Electrode 1
Keeping back energy_drink_can	Taking juicebox	Electrode 1,Electrode 3
Keeping back chips_big	Keeping back juicebox	Electrode 6
Keeping back chips_big	zero zero	Electrode 6
Keeping back chips_big	Taking energy_drink_can	Electrode 1,Electrode 4
Keeping back chips_big	Taking chips_big	Electrode 1,Electrode 2,Electrode 5
Keeping back chips_big	Taking soft_drinks_pet_bottle_250ml	Electrode 6
Keeping back chips_big	Taking juicebox	Electrode 6
Keeping back soft_drinks_pet_bottle_250ml	Keeping back juicebox	Electrode 4,Electrode 5
Keeping back soft_drinks_pet_bottle_250ml	Taking chips_small	Electrode 4
Keeping back soft_drinks_pet_bottle_250ml	Taking energy_drink_can	Electrode 2,Electrode 3,Electrode 4,Electrode 6

p-value for these readings were above 0.001. *This means we don't have enough evidence to reject null hypothesis.*

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY BETWEEN ELECTRODE READINGS FOR A SINGLE ACTIVITY

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Activity 1	Activity 2	Electrode readings having p-value>0.001
all_full all_full	Keeping back chips_small	Electrode 6
all_full all_full	Keeping back energy_drink_can	Electrode 1,Electrode 2,Electrode 3
all_full all_full	Keeping back chips_big	Electrode 2
all_full all_full	Keeping back soft_drinks_pet_bottle_250ml	Electrode 1
all_full all_full	Keeping back juicebox	Electrode 6
all_full all_full	zero zero	Electrode 3
all_full all_full	Taking chips_big	Electrode 2
all_full all_full	Taking soft_drinks_pet_bottle_250ml	Electrode 1
all_full all_full	Taking juicebox	Electrode 1,Electrode 6
Keeping back chips_small	Keeping back soft_drinks_pet_bottle_250ml	Electrode 4
Keeping back chips_small	Keeping back juicebox	Electrode 2,Electrode 3,Electrode 4,Electrode 5
Keeping back chips_small	zero zero	Electrode 1,Electrode 6
Keeping back chips_small	Taking chips_small	Electrode 2,Electrode 4
Keeping back chips_small	Taking energy_drink_can	Electrode 5
Keeping back chips_small	Taking chips_big	Electrode 6
Keeping back chips_small	Taking juicebox	Electrode 3,Electrode 4,Electrode 6
Keeping back energy_drink_can	Keeping back chips_big	Electrode 2,Electrode 3
Keeping back energy_drink_can	Keeping back soft_drinks_pet_bottle_250ml	Electrode 1,Electrode 6
Keeping back energy_drink_can	Keeping back juicebox	Electrode 3
Keeping back energy_drink_can	Taking energy_drink_can	Electrode 6
Keeping back energy_drink_can	Taking soft_drinks_pet_bottle_250ml	Electrode 1
Keeping back energy_drink_can	Taking juicebox	Electrode 1,Electrode 3
Keeping back chips_big	Keeping back juicebox	Electrode 6
Keeping back chips_big	zero zero	Electrode 6
Keeping back chips_big	Taking energy_drink_can	Electrode 1,Electrode 4
Keeping back chips_big	Taking chips_big	Electrode 1,Electrode 2,Electrode 5
Keeping back chips_big	Taking soft_drinks_pet_bottle_250ml	Electrode 6
Keeping back chips_big	Taking juicebox	Electrode 6
Keeping back soft_drinks_pet_bottle_250ml	Keeping back juicebox	Electrode 4,Electrode 5
Keeping back soft_drinks_pet_bottle_250ml	Taking chips_small	Electrode 4
Keeping back soft_drinks_pet_bottle_250ml	Taking energy_drink_can	Electrode 2,Electrode 3,Electrode 4,Electrode 6
Keeping back soft_drinks_pet_bottle_250ml	Taking soft_drinks_pet_bottle_250ml	Electrode 1,Electrode 5
Keeping back soft_drinks_pet_bottle_250ml	Taking juicebox	Electrode 1,Electrode 4
Keeping back juicebox	zero zero	Electrode 6
Keeping back juicebox	Taking chips_small	Electrode 2,Electrode 4
Keeping back juicebox	Taking energy_drink_can	Electrode 4,Electrode 5
Keeping back juicebox	Taking chips_big	Electrode 6
Keeping back juicebox	Taking soft_drinks_pet_bottle_250ml	Electrode 1
Keeping back juicebox	Taking juicebox	Electrode 2,Electrode 3,Electrode 4,Electrode 6
zero zero	Taking energy_drink_can	Electrode 2
zero zero	Taking soft_drinks_pet_bottle_250ml	Electrode 2,Electrode 5,Electrode 6
zero zero	Taking juicebox	Electrode 6
Taking chips_small	Taking chips_big	Electrode 2
Taking chips_small	Taking soft_drinks_pet_bottle_250ml	Electrode 3,Electrode 6
Taking chips_small	Taking juicebox	Electrode 4
Taking energy_drink_can	Taking chips_big	Electrode 1
Taking chips_big	Taking juicebox	Electrode 6
Taking soft_drinks_pet_bottle_250ml	Taking juicebox	Electrode 1,Electrode 5

p-value for these readings were above 0.001. *This means we don't have enough evidence to reject null hypothesis.*

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

HYPOTHESIS TESTS - SIMILARITY BETWEEN ELECTRODE READINGS FOR A SINGLE ACTIVITY

Null Hypothesis: The readings between an activity A and another activity B is not statistically different for a particular Electrode E.
Alternate Hypothesis: The readings between an activity A and another activity B is statistically different for a particular Electrode E.

Test Performed: A Mann-Whitney U-Test was performed, taking the reading of an electrode for two activities at a time.

Activity 1	Activity 2	Electrode readings having p-value>0.001
all_full all_full	Keeping back chips_small	Electrode 6
all_full all_full	Keeping back energy_drink_can	Electrode 1,Electrode 2,Electrode 3
all_full all_full	Keeping back chips_big	Electrode 2
all_full all_full	Keeping back soft_drinks_pet_bottle_250ml	Electrode 1
all_full all_full	Keeping back juicebox	Electrode 6
all_full all_full	zero zero	Electrode 3
all_full all_full	Taking chips_big	Electrode 2
all_full all_full	Taking soft_drinks_pet_bottle_250ml	Electrode 1
all_full all_full	Taking juicebox	Electrode 1,Electrode 6
Keeping back chips_small	Keeping back soft_drinks_pet_bottle_250ml	Electrode 4
Keeping back chips_small	Keeping back juicebox	Electrode 2,Electrode 3,Electrode 4,Electrode 5
Keeping back chips_small	zero zero	Electrode 1,Electrode 6
Keeping back chips_small	Taking chips_small	Electrode 2,Electrode 4
Keeping back chips_small	Taking energy_drink_can	Electrode 5
Keeping back chips_small	Taking chips_big	Electrode 6
Keeping back chips_small	Taking juicebox	Electrode 3,Electrode 4,Electrode 6
Keeping back energy_drink_can	Keeping back chips_big	Electrode 2,Electrode 3
Keeping back energy_drink_can	Keeping back soft_drinks_pet_bottle_250ml	Electrode 1,Electrode 6
Keeping back energy_drink_can	Keeping back juicebox	Electrode 3
Keeping back energy_drink_can	Taking energy_drink_can	Electrode 6
Keeping back energy_drink_can	Taking soft_drinks_pet_bottle_250ml	Electrode 1
Keeping back energy_drink_can	Taking juicebox	Electrode 1,Electrode 3
Keeping back chips_big	Keeping back juicebox	Electrode 6
Keeping back chips_big	zero zero	Electrode 6
Keeping back chips_big	Taking energy_drink_can	Electrode 1,Electrode 4
Keeping back chips_big	Taking chips_big	Electrode 1,Electrode 2,Electrode 5
Keeping back chips_big	Taking soft_drinks_pet_bottle_250ml	Electrode 6
Keeping back chips_big	Taking juicebox	Electrode 6
Keeping back soft_drinks_pet_bottle_250ml	Keeping back juicebox	Electrode 4,Electrode 5
Keeping back soft_drinks_pet_bottle_250ml	Taking chips_small	Electrode 4
Keeping back soft_drinks_pet_bottle_250ml	Taking energy_drink_can	Electrode 2,Electrode 3,Electrode 4,Electrode 6
Keeping back soft_drinks_pet_bottle_250ml	Taking soft_drinks_pet_bottle_250ml	Electrode 1,Electrode 5
Keeping back soft_drinks_pet_bottle_250ml	Taking juicebox	Electrode 1,Electrode 4
Keeping back juicebox	zero zero	Electrode 6
Keeping back juicebox	Taking chips_small	Electrode 2,Electrode 4
Keeping back juicebox	Taking energy_drink_can	Electrode 4,Electrode 5
Keeping back juicebox	Taking chips_big	Electrode 6
Keeping back juicebox	Taking soft_drinks_pet_bottle_250ml	Electrode 1
Keeping back juicebox	Taking juicebox	Electrode 2,Electrode 3,Electrode 4,Electrode 6
zero zero	Taking energy_drink_can	Electrode 2
zero zero	Taking soft_drinks_pet_bottle_250ml	Electrode 2,Electrode 5,Electrode 6
zero zero	Taking juicebox	Electrode 6
Taking chips_small	Taking chips_big	Electrode 2
Taking chips_small	Taking soft_drinks_pet_bottle_250ml	Electrode 3,Electrode 6
Taking chips_small	Taking juicebox	Electrode 4
Taking energy_drink_can	Taking chips_big	Electrode 1
Taking chips_big	Taking juicebox	Electrode 6
Taking soft_drinks_pet_bottle_250ml	Taking juicebox	Electrode 1,Electrode 5

Upon repeating the Mann-Whitney U-Test within each experiment group (instead of across all groups), we still observe several statistical similar records.

THE DATA COLLECTION EXPERIMENT
DISCUSSION ON DATA COLLECTED

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all_full all_full	Keeping back chips_big	Electrode 2
all_full all_full	Keeping back soft_drinks_pet_bottle_250ml	Electrode 1
all_full all_full	Keeping back juicebox	Electrode 6
all_full all_full	zero zero	Electrode 3
all_full all_full	Taking chips_big	Electrode 2
all_full all_full	Taking soft_drinks_pet_bottle_250ml	Electrode 1
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Keeping back chips_small	Keeping back soft_drinks_pet_bottle_250ml	Electrode 4
Keeping back chips_small	Keeping back juicebox	Electrode 2,Electrode 3,Electrode 4,Electrode 5
Keeping back chips_small	zero zero	Electrode 1,Electrode 6
Keeping back chips_small	Taking chips_small	Electrode 2,Electrode 4
Keeping back chips_small	Taking energy_drink_can	Electrode 5
Keeping back chips_small	Taking chips_big	Electrode 6
Keeping back chips_small	Taking juicebox	Electrode 3,Electrode 4,Electrode 6
Keeping back energy_drink_can	Keeping back chips_big	Electrode 2,Electrode 3
Keeping back energy_drink_can	Keeping back soft_drinks_pet_bottle_250ml	Electrode 1,Electrode 6
Keeping back energy_drink_can	Keeping back juicebox	Electrode 3
Keeping back energy_drink_can	Taking energy_drink_can	Electrode 6
Keeping back energy_drink_can	Taking soft_drinks_pet_bottle_250ml	Electrode 1
Keeping back energy_drink_can	Taking juicebox	Electrode 1,Electrode 3
Keeping back chips_big	Keeping back juicebox	Electrode 6
Keeping back chips_big	zero zero	Electrode 6
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Keeping back chips_big	Taking soft_drinks_pet_bottle_250ml	Electrode 6
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Keeping back soft_drinks_pet_bottle_250ml	Taking soft_drinks_pet_bottle_250ml	Electrode 1,Electrode 5
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zero zero	Taking juicebox	Electrode 6
Taking chips_small	Taking chips_big	Electrode 2
Taking chips_small	Taking soft_drinks_pet_bottle_250ml	Electrode 3,Electrode 6
Taking chips_small	Taking juicebox	Electrode 4
Taking energy_drink_can	Taking chips_big	Electrode 1
Taking chips_big	Taking juicebox	Electrode 6
Taking soft_drinks_pet_bottle_250ml	Taking juicebox	Electrode 1,Electrode 5

Upon repeating the Mann-Whitney U-Test within each experiment group (instead of across all groups), we still observe several statistical similar records.

Conclusion

1

- We discussed the development of a smart shelf by using the principle of capacitance, using a mechanism called GridMat.

Conclusion

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2

- Analysis of the data and several clues to proceed forward as well as several shortcomings of the GridMat mechanism

Conclusion

1

- We discussed the development of a smart shelf by using the principle of capacitance, using a mechanism called GridMat.

2

- Analysis of the data and several clues to proceed forward as well as several shortcomings of the GridMat mechanism

3

- In the future it is aimed to develop a more robust solution by developing on the findings from this experiment, in order to provide a cost effective retail analytics solution

THANK YOU!