Development of Smart-Phone Interfaces for Tongue Controlled Assistive Devices

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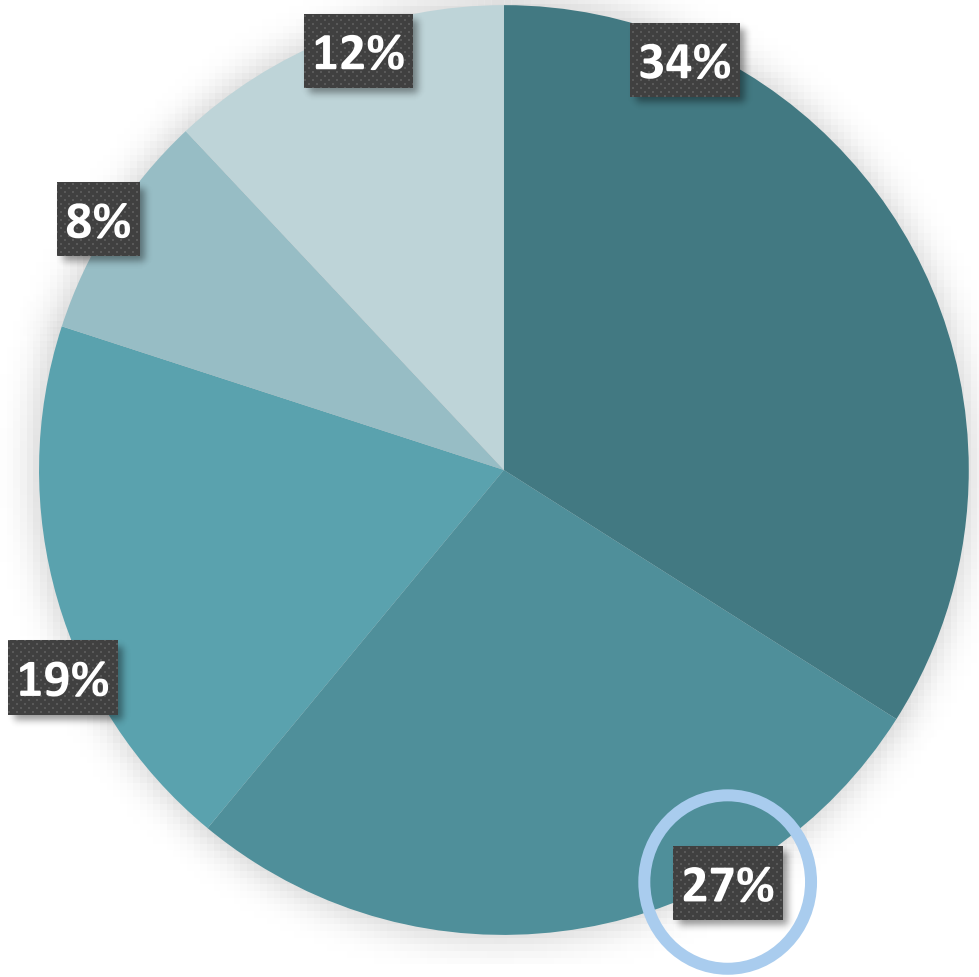
Paralysis

13.3% of the world population experiences **disability** [1]

1.7% of the USA population experiences **paralysis** [2]; [3]



[2]; [3]

Spinal Cord Injury

Partial or total **loss** of sensation and **control** of lower and **upper limbs**

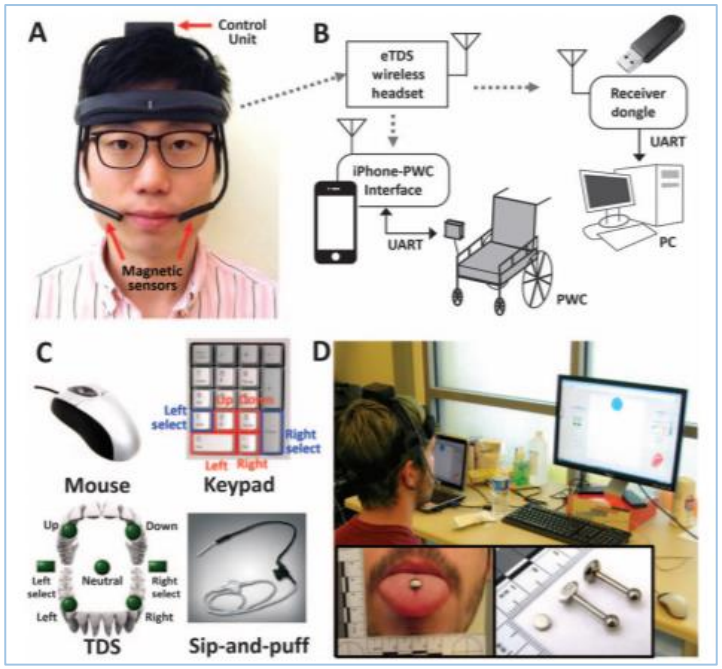
Exclusion from interacting with smartphones and computers

Assistance from family members or caretakers; this hinders independence and privacy

[4]

[5]

Intraoral Assistive Devices



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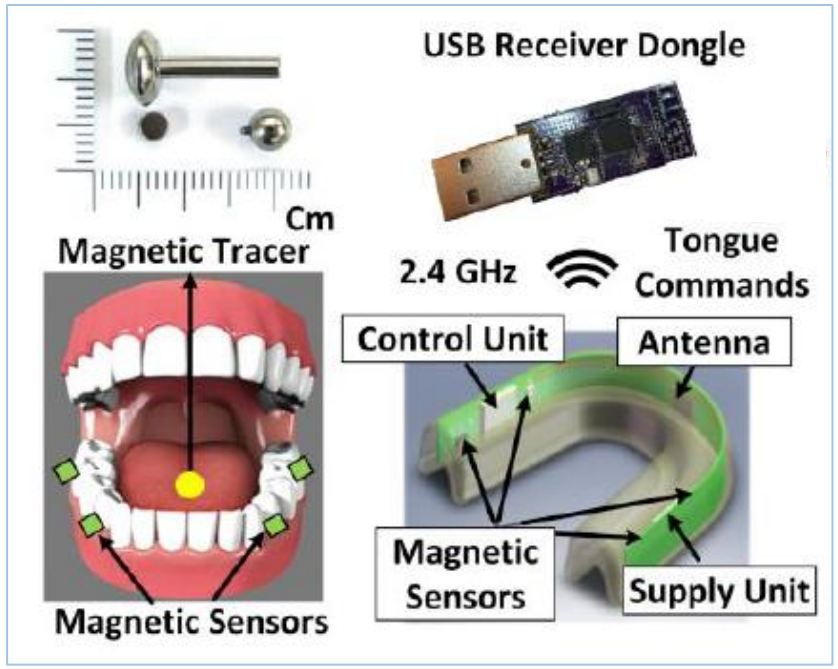

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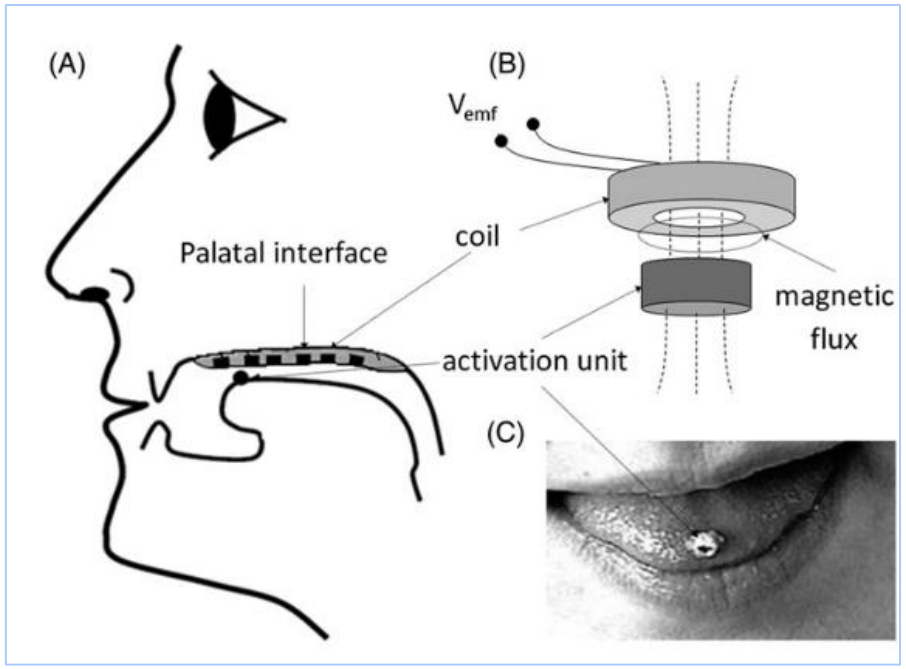


[8]

WTSE Laboratory Solution

Oral User Interface Controller

O-UIC

[9]

Tongue Trackpad User Interface Controller

TT-UIC

[10]

WTSE Laboratory Solution

Discreet design that completely fits in the oral cavity

Bluetooth Low Energy communication with phones and computers

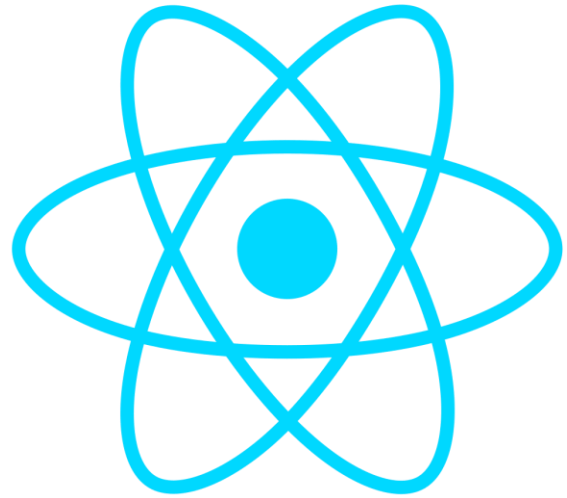
Capacitive Sensing to detect tongue touches against the palate

Goals

Allow the **O-UIC** device to interact with an application that **decodes** the communicated information

Simplify the interaction for the **cursor** based **TT-UIC**

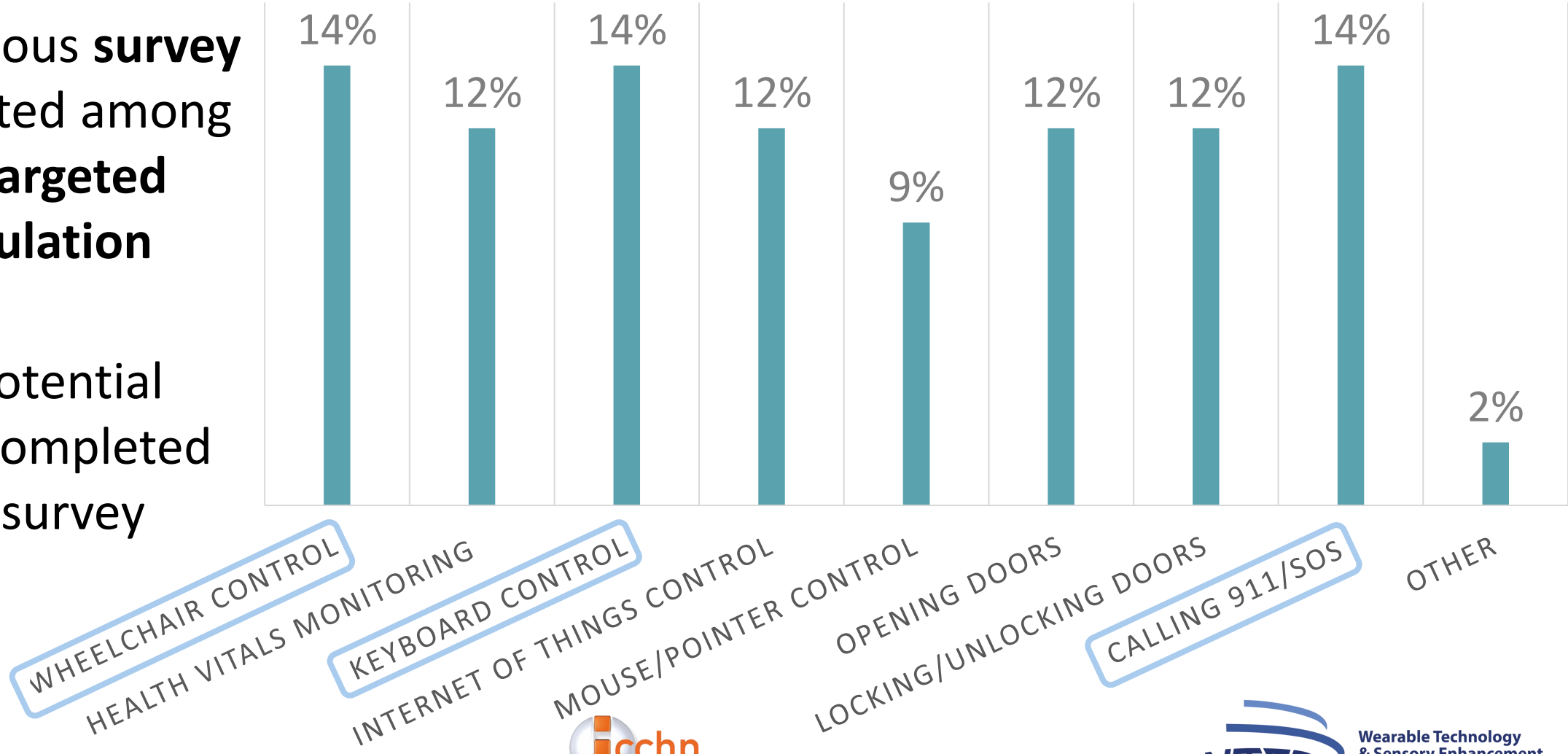
Create a **Tongue Training** enviroment for the necessary **movements**



User Needs Assessment

Anonymous **survey** distributed among the **targeted population**

18 potential users completed the survey

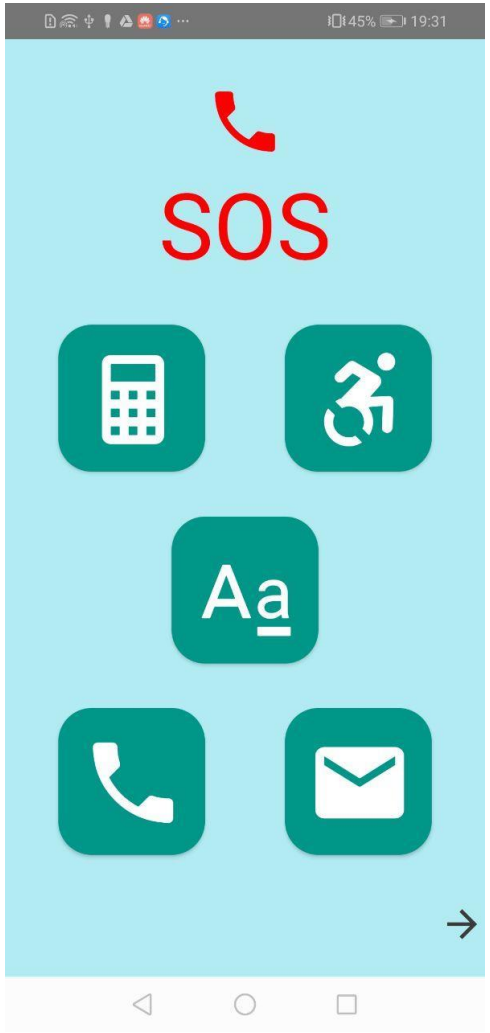


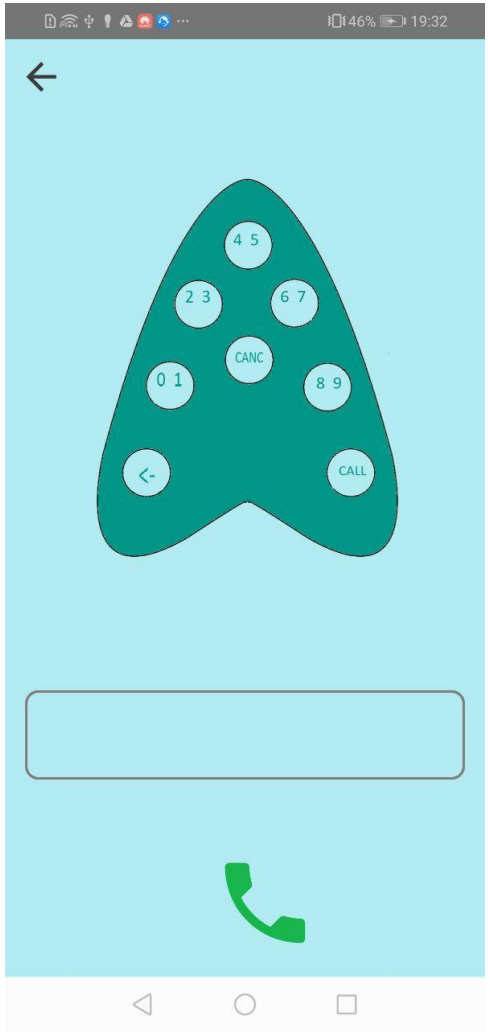
Functionalities

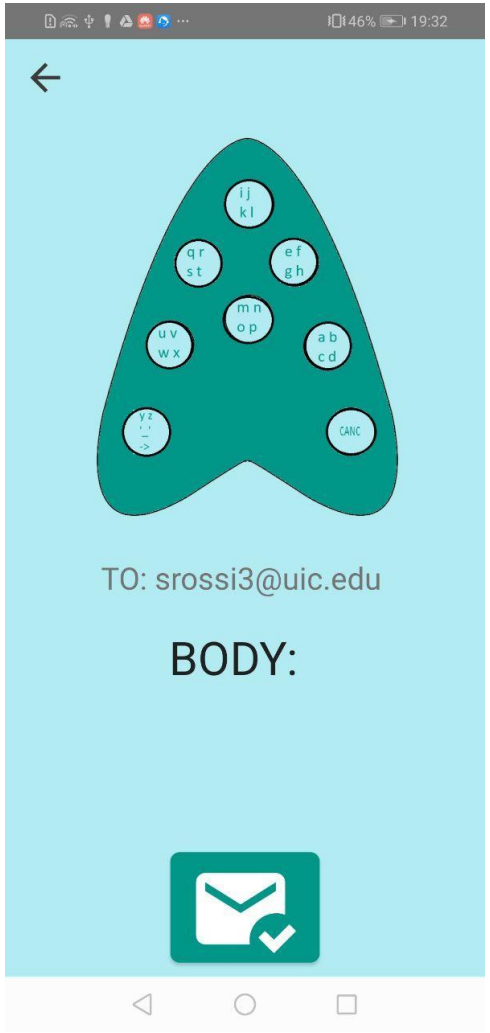
Three **core functionalities** developed

- SOS phone call for emergencies
- Phone calls to all phone numbers
- Typing of text (for SMS and Email)

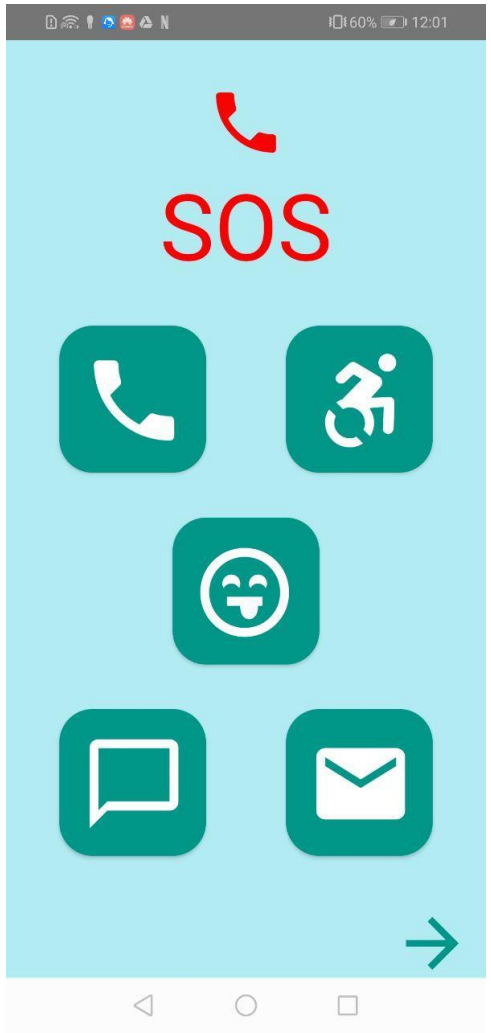
Developed Functionalities – O-UIC

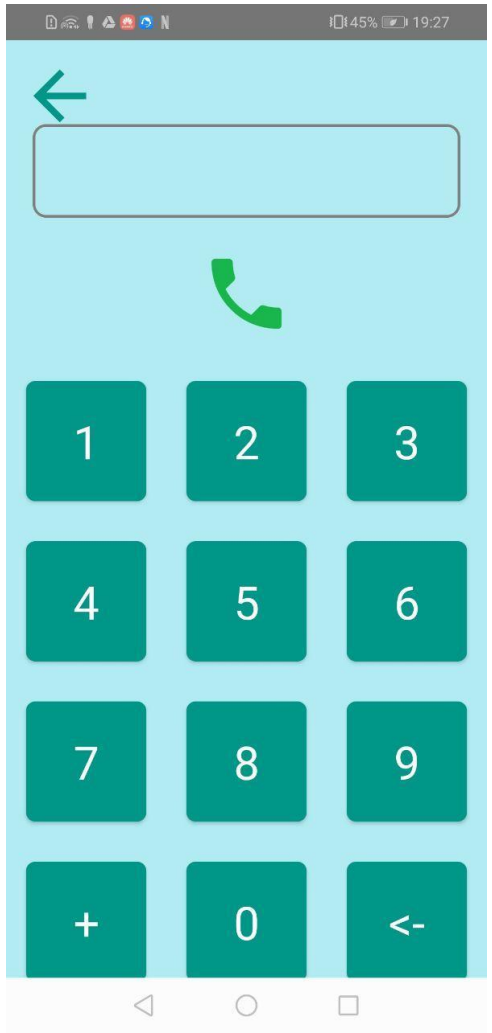


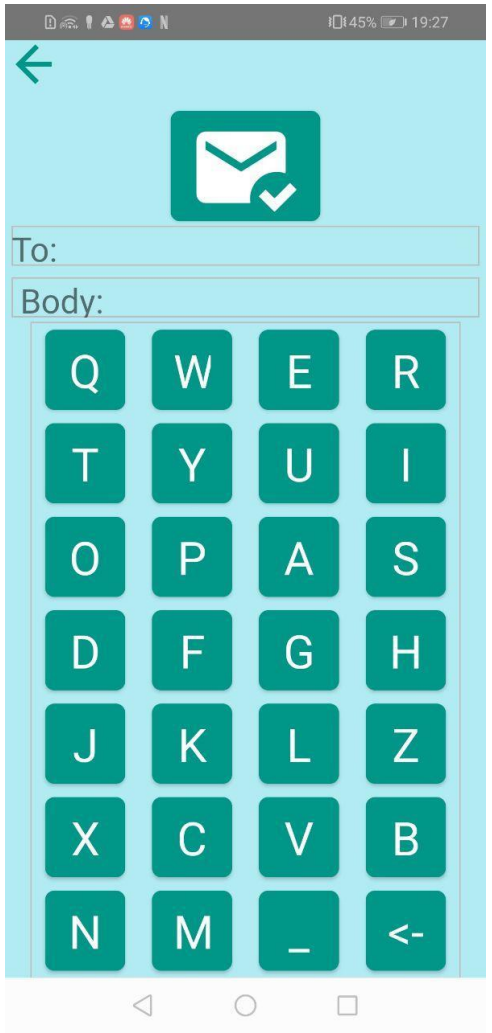




Developed Functionalities – TT-UIC







Tongue Trackpad – Fitts Law

Theoretical analysis of **pointing actions** → Difficulty Index: ratio between **target distance** (A) and **width** (W)

$$MT = a + b \log_2 \left(\frac{A}{W} + c \right)$$ [11]

MT = movement time
a,b,c = constants
A = distance
W = width

	Default Keyboard	Custom Keyboard
Width (dpi)	35.14	60
Difficulty index (1/dpi)	0.028	0.016

→ **43% decrease** in difficulty

Theoretical Evaluation

Keystroke Level Model (**KLM**) analysis of the developed screens

Breakdown of core tasks in **finite elements** to identify the theoretical **time** of execution

Action	Operator	Duration [s]
Key or button press	K	0.20
Pointing	P	1.10
Drawing	D	varies
Mental preparation	M	1.35
Homing	H	0.4
Representation of the response	R	depends on system

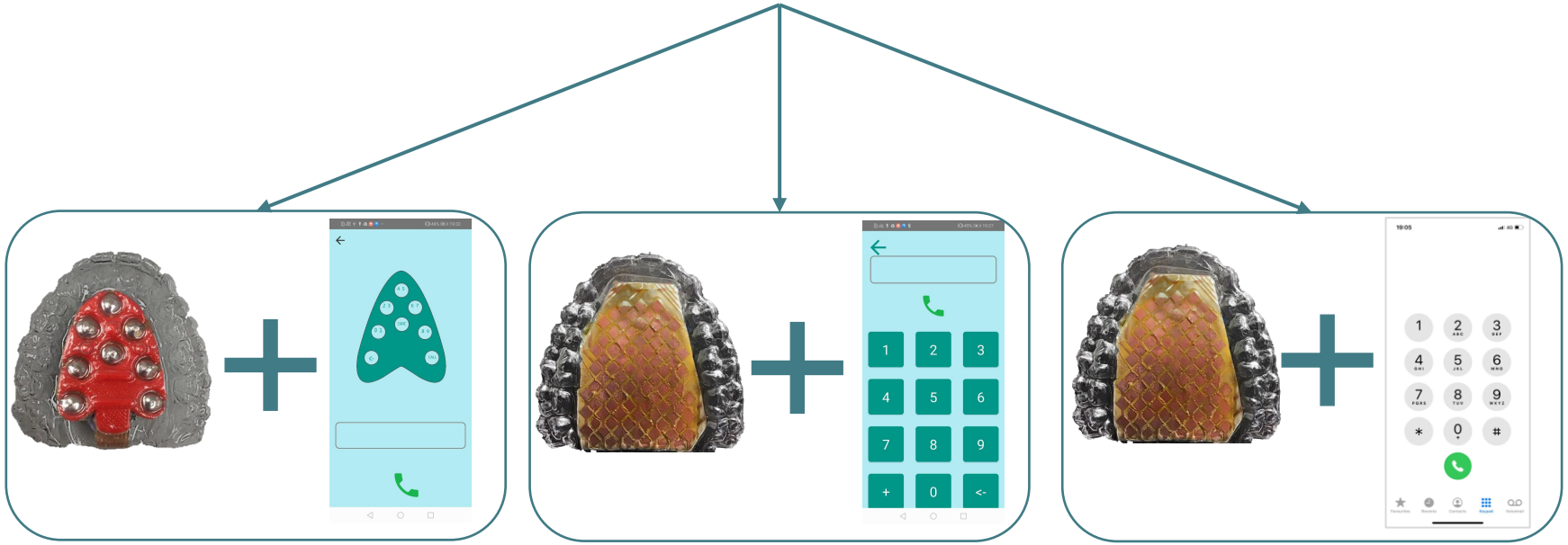
KLM Analysis - Results

	911 Call	Phone Call	Email
Estimated time using O-UIC [s] 	2.65	22.85	30.2
Estimated time using Tongue Trackpad [s] 	2.65	29.15	34.45

Functioning Evaluation

The **same core tasks** that were theoretically evaluated were proposed to a **user**

Comparison between environments



O-UIC Evaluation - Results

		Inexperienced Users	Experienced Users
O-UIC [pangram testing]	Characters per minute [CPM]	16.72	32.67

		SOS Call	Phone Call	Email
O-UIC [with custom application]	Time needed [s]	2	36	53
	Errors made	0	4	5

TT-UIC Testing - Results

		SOS Call	Phone Call	Email	SMS
Tongue Trackpad [with custom application] 	Time needed [s]	2.53 ± 0.35	50.25 ± 1.48	68.75 ± 2.86	71 ± 4.74
	Errors made	0	0.75 ± 0.43	0	1 ± 1
Tongue Trackpad [with default environment] 	Time needed [s]	21.9 ± 2.57	65.18 ± 13	76.75 ± 5.8	109.5 ± 20.2
	Errors made	0	1.25 ± 0.8	2.25 ± 0.43	2 ± 0.7

39.6% decrease in time

63.3% decrease in errors

Feedback Survey- Results

	I think that I would be able to use this system independently after it is placed inside the oral cavity.	I think this system would assist me in my interaction with my smartphone and computer.	Overall interest in the wearable device and the associated application.
O-UIC 	4.6 ± 0.49	3.4 ± 1.02	2.8± 0.97
TT-UIC 	4.4 ± 0.8	3.2 ± 1.32	3.2 ± 1.32

Future Developments

Extensive **user testing** to evaluate the effective time needed for the different tasks

Implementation of further **functionalities** to expand the possibilities

Inclusion of the target population in both the testing and the identification of additional functionalities

Conclusions

Two interfaces developed for easy user interaction with intraoral assistive devices

Preliminary testing and feedback survey demonstrated the functioning of the application and the interest of the target population

The interfaces and devices are a possible option for paralysed users to easily interact with technology

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Thank you

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