

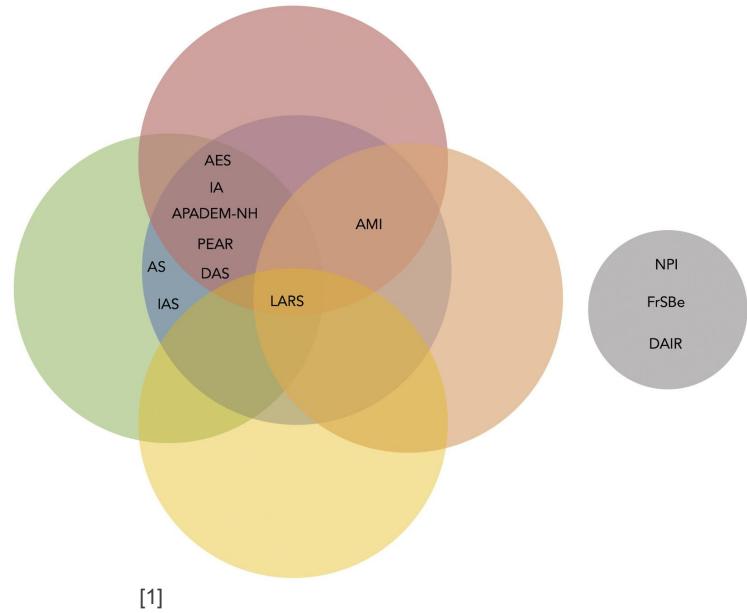
# Integrated VR-tTIS targeting apathy in stroke motor rehabilitation

Advanced Methods for  
Human Neuromodulation

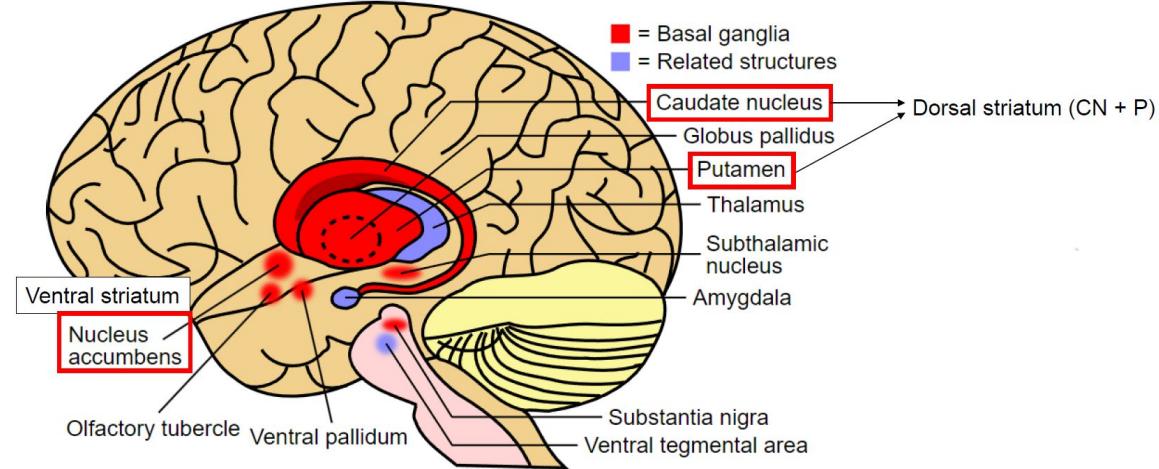
Camille Bénard  
Caroline Pilet  
Lisa van de Panne

# Apathy

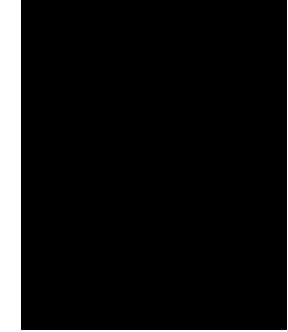
- Syndrome characterized by lack of motivation
- Different dimensions [1]
- Occurrence in various neurological disorders [2]
- Key brain region affected : striatum [3] [4] [5]



# Striatum : brain anatomy

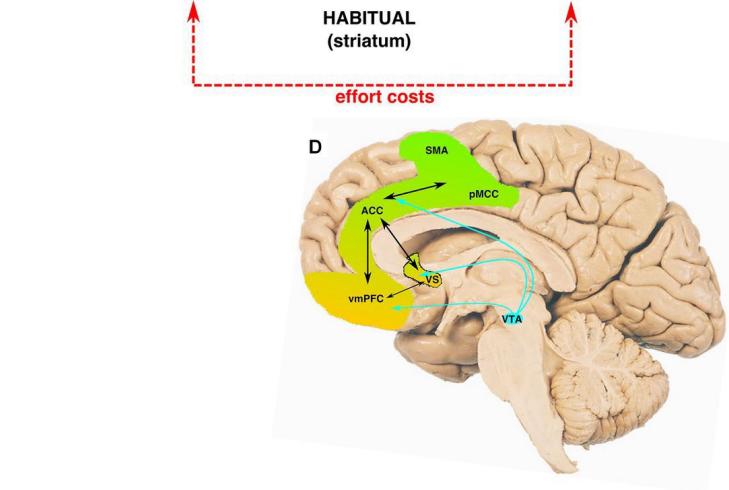
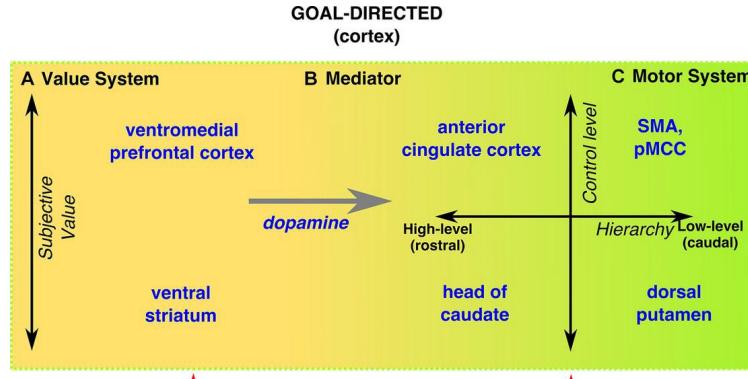


[2]

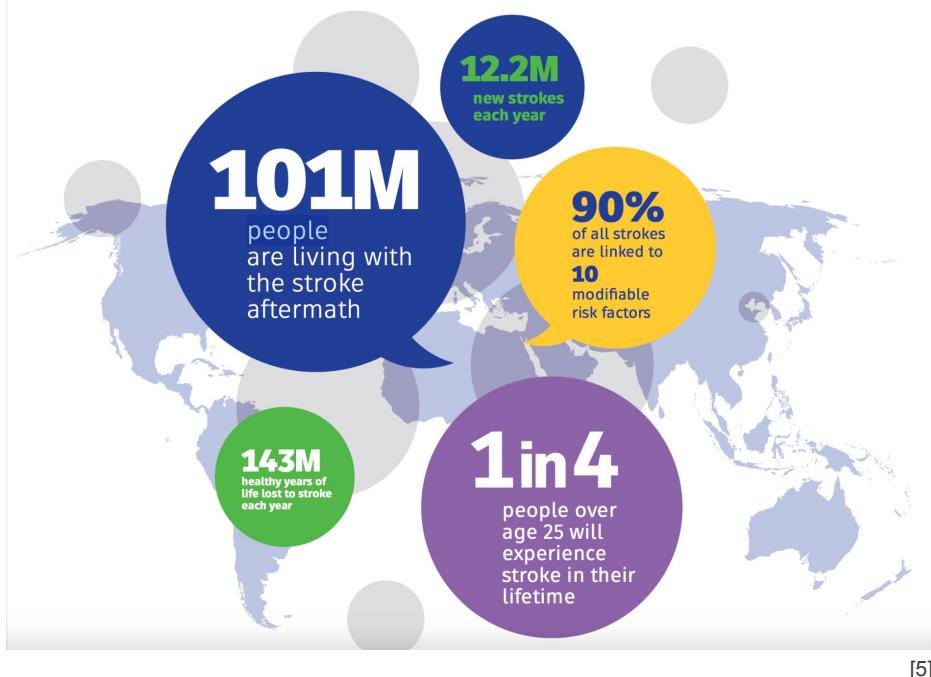


[3]

# Striatum in motivated behavior

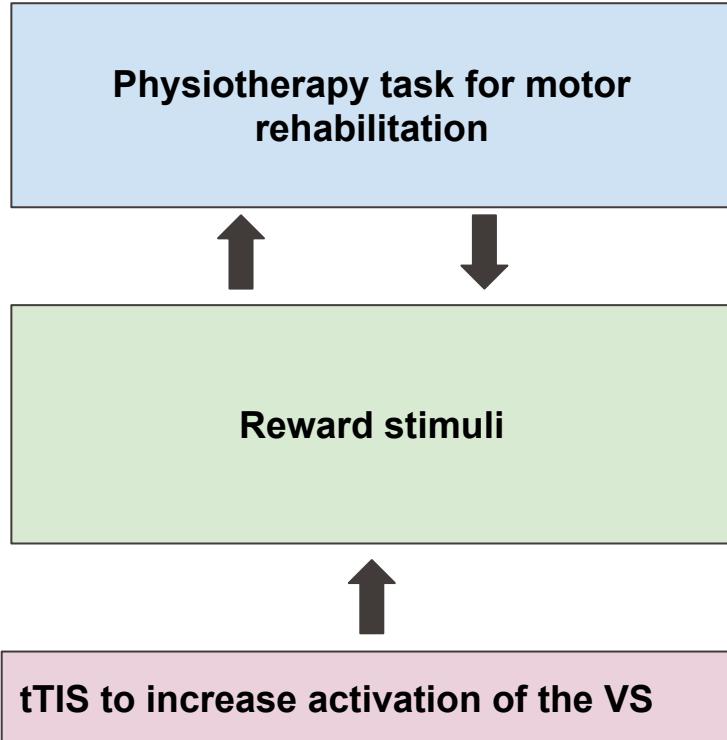


# Apathy & stroke motor rehabilitation

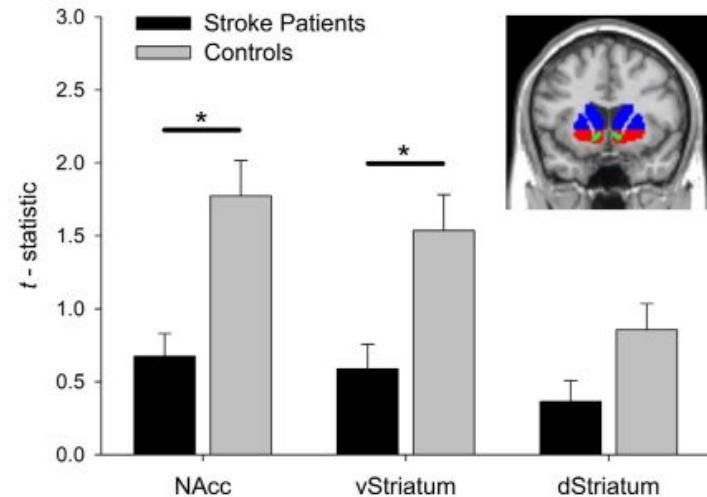


- Apathy in 36% of stroke patients [6]
- Linked to worse functional recovery and quality of life [7]
- long-term impairments of upper extremities in 50% of stroke survivors [8]

# Targeting Reward Sensitivity in Stroke Motor Rehabilitation



*NeuroImage: Clinical 24 (2019) 102036*



Stroke patients display reduced activation in the ventral striatum compared to healthy patients upon being shown performance feedback after a motor rehabilitation task [9]

# Overview of technology

## tTIS

## VR

## Pupil dilation sensors

## IMU sensors

Target reward sensitivity:  
Stimulate ventral striatum during introduction of reward stimuli

Effort stimuli:  
Gameplay involving motor rehabilitation exercises

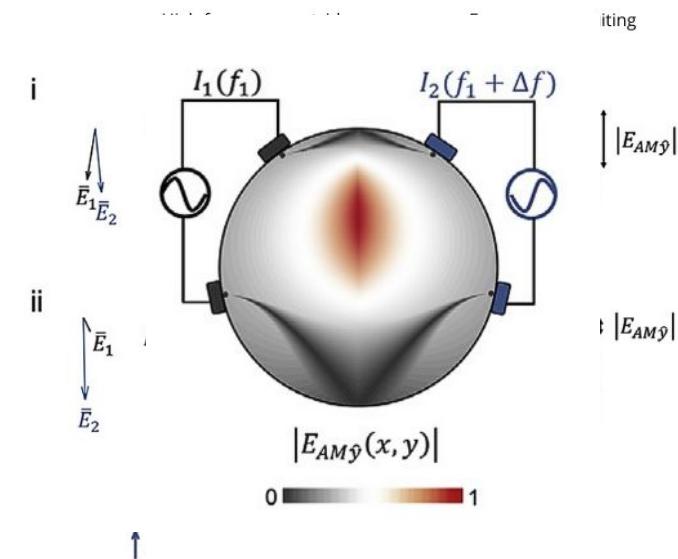
Reward stimuli:  
Point system  
Performance feedback

Primary outcome:  
Measure reward sensitivity

Secondary outcome:  
Measure motion data for motor

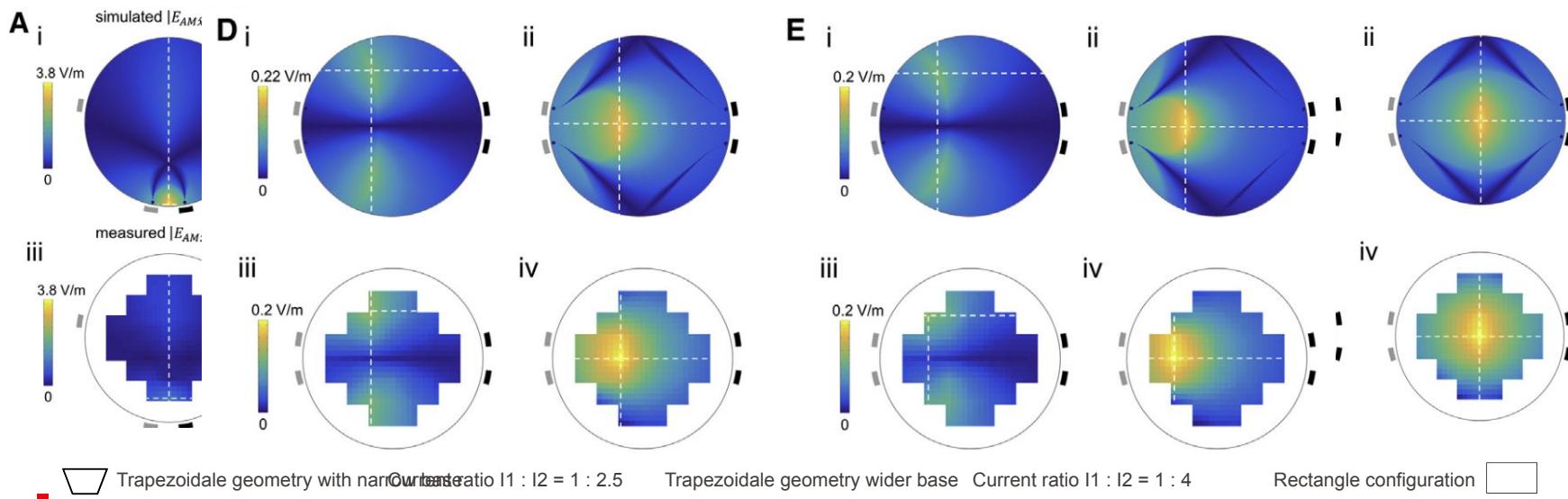
# Transcranial temporal interference stimulation

- 1) Apply high-frequency electric fields that are higher than the typical range of frequencies of normal neural operations
- 2) The difference in frequencies creates an envelope with a different frequency and amplitude
- 3) The envelope has a lower frequency, allowing neural operations



# Electrode configuration

- By alternating the locations of electrode and setting the current appropriately : can enable the interferential envelope modulation to be targeted to specific location.
- Electrode size play a minor role
- Possibility of “live steering”



# EPFL Protocol : Theta burst pattern stimulation

10

## - - Why Theta-Burst Stimulation ?

This form of stimulation has been shown to induce **long-term potentiation-like effects**

**Carrier Frequency:** Two AC currents were delivered at high frequencies:

which are essential for enhancing synaptic strength [ref]

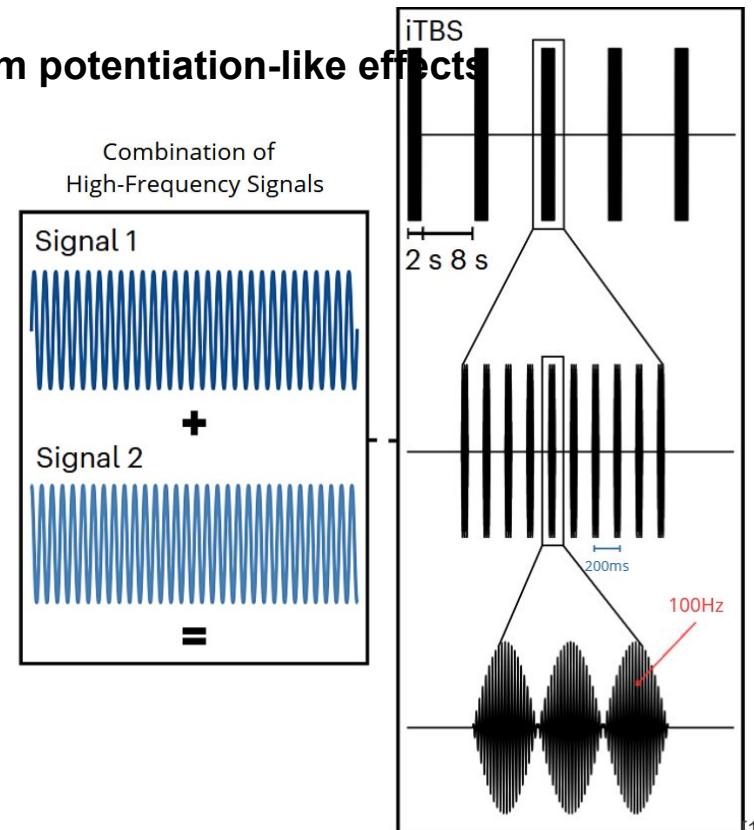
- **Signal 1:** 2.0 kHz.
- **Signal 2:** 2.1 kHz.

## Patterned Stimulation:

- **Delivery:** A train of theta-burst pulses (2 s long) was repeated every 10 s.

## Structure of Each Burst

- **Pulses:** 3 pulses of amplitude-modulated current at **100 Hz**.
- **Interval:** Bursts delivered at **5 Hz**, 200 ms interval



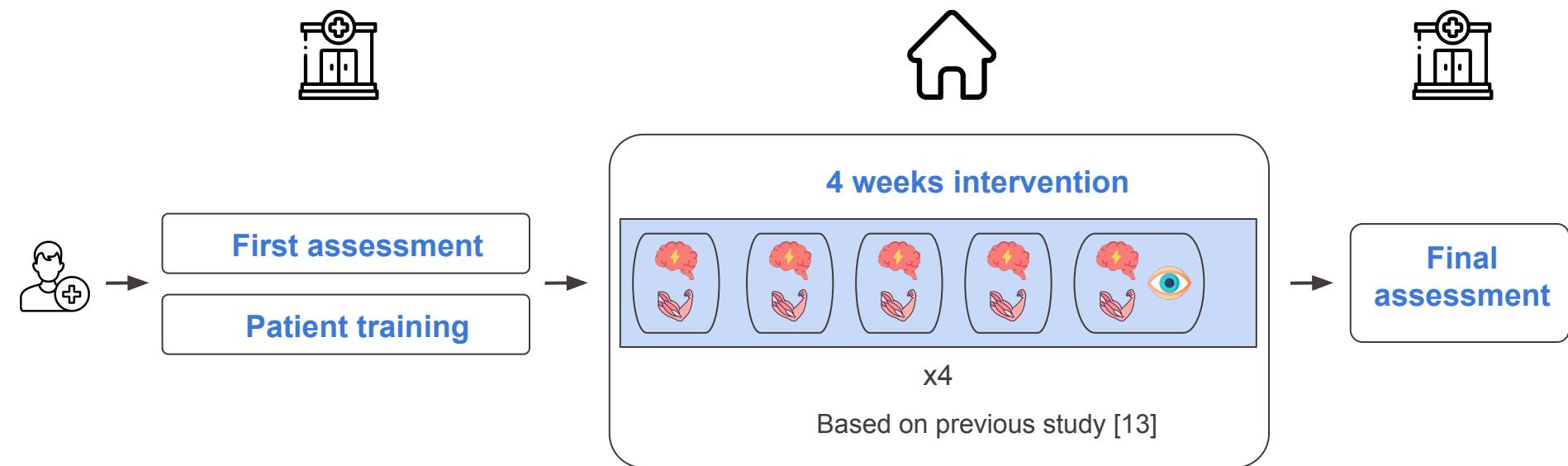
[11]

# Study population and control groups

Inclusion / exclusion criteria :

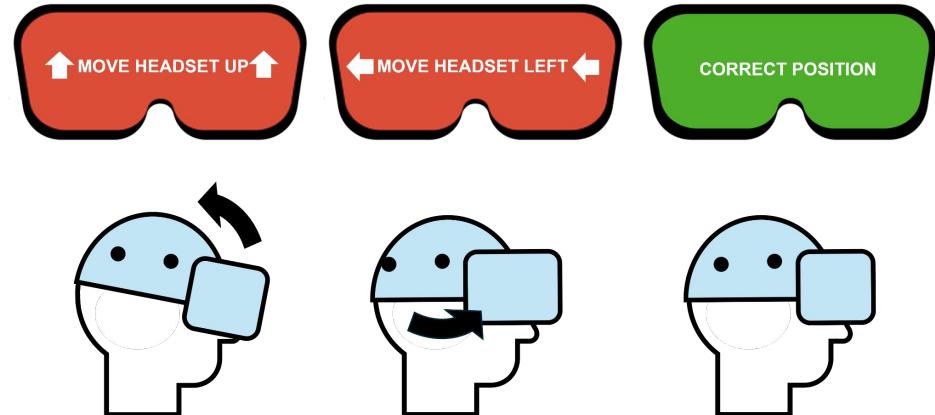
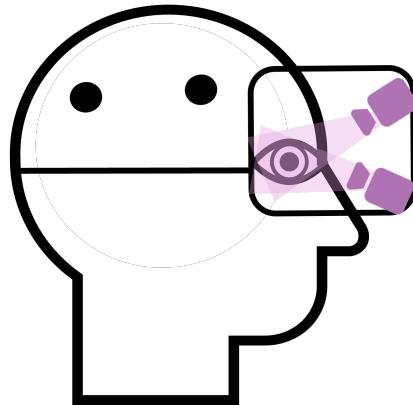
- Inclusion (based on [12]):
  - Over 18 years old
  - hemiparesis of the arm due to cerebrovascular ischemia
  - Subacute stroke (max. 100 days after stroke)
- Exclusion :
  - Drugs
  - History of seizures / epilepsy

	Group 1	Group 2	Group 3	Group 4
Apathy	✓		✓	
VR physical therapy	✓	✓	✓	✓
TI	✓	✓		

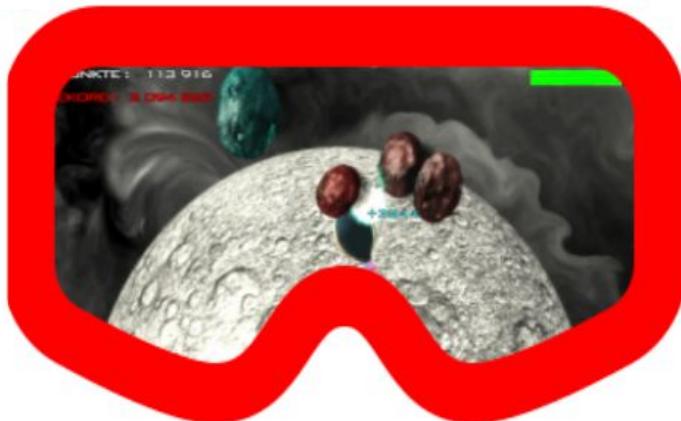


# tTIS electrode placement

- VR headpieces have integrated holes for tTIS electrode placement
- The location of the holes will be adjusted for each patient at the beginning of the study
- Sensors detect position of VR headset in relation to the anatomical position of the eye for real-time adjustment feedback

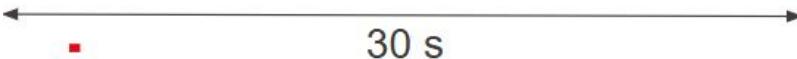


## Exercise Time - Gameplay



**Exercise Time (Effort Stimuli)**

- Patient performs the rehabilitation exercise as instructed by the VR video game protocol



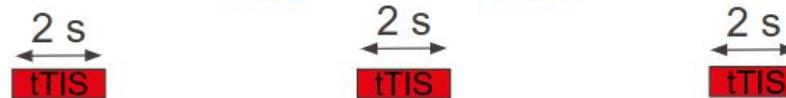
## Rest Time - Reward Information

8

Points Earned: 94873 pts  
Exercises Completed: 14  
Next Exercise: 547093 pts

WOW

:) good job



### Rest Time (Reward Stimuli)

#### Performance feedback:

- Show # of exercises completed
- Show # of points earned from last exercise
- Show motor rehabilitation progress using IMU data

#### Reward offer:

- Show # of points available for next exercise

x10

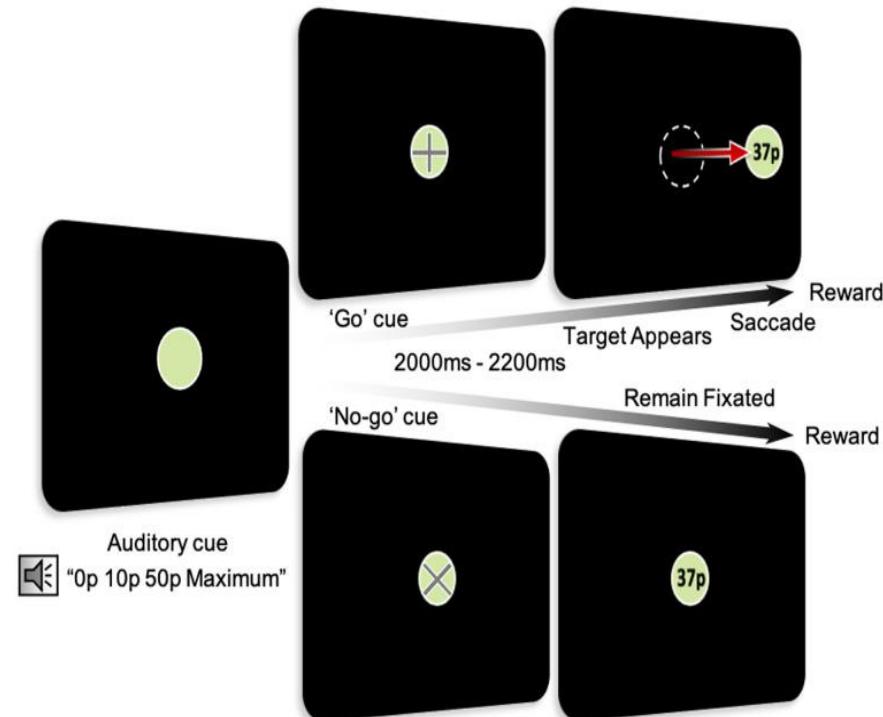


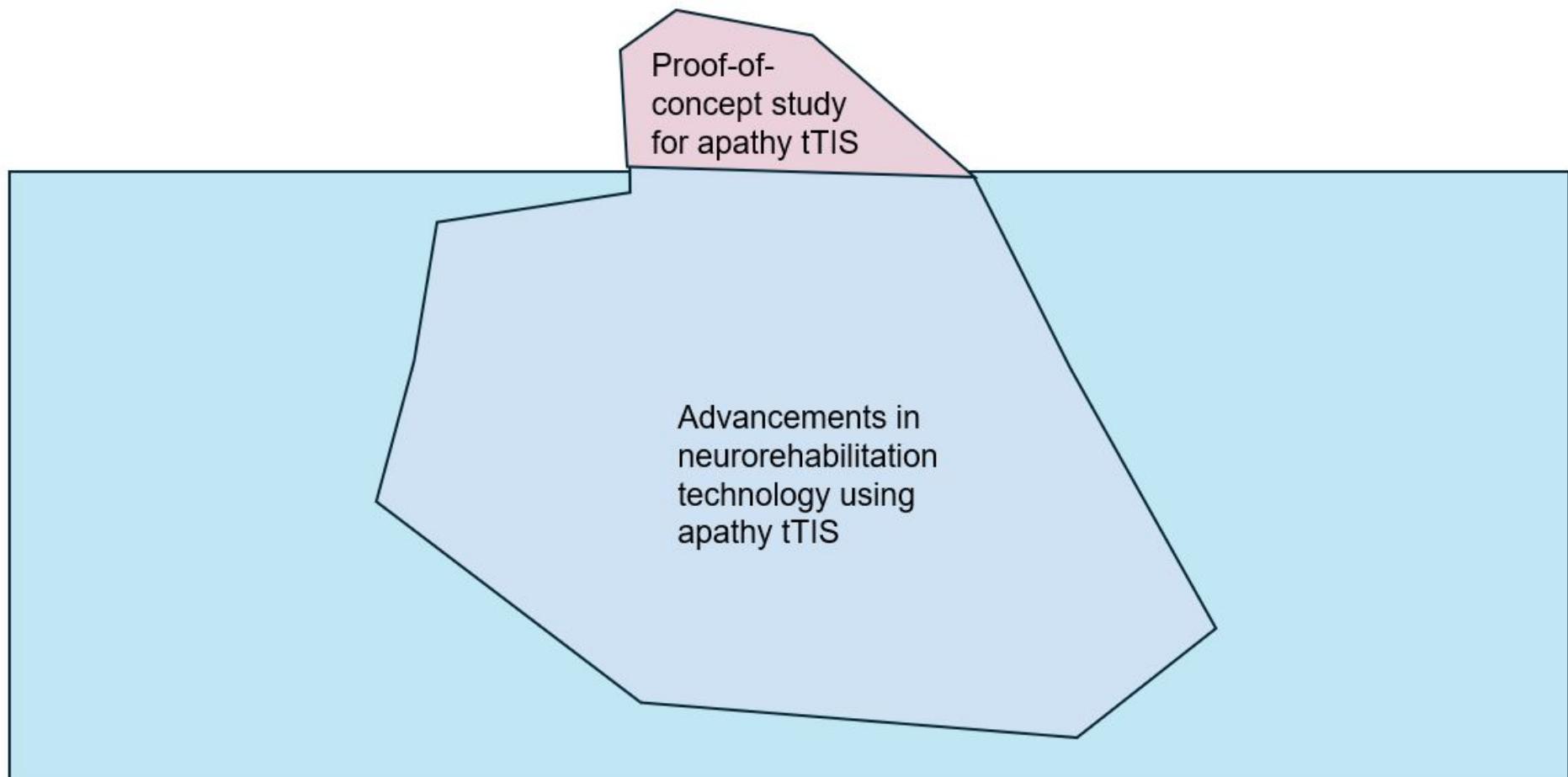
### Primary measurement : reward sensitivity

- Once a week at the beginning of the session
- Protocol based on previous studies [15] [16]
- Measurement : pupil dilation when receiving reward feedback after task

### Secondary measurement : motor function

- IMUs
- Fugl-Meyer Assessment and Wolf Motor Function Test





Proof-of-concept study  
for apathy tTIS

Advancements in  
neurorehabilitation  
technology using  
apathy tTIS

**Proof-of-concept study:**  
Does tTIS of the reward system for apathy improve motor rehabilitation in stroke patients?

### Follow-Up Work

Can tTIS of apathy be combined with tTIS for motor learning to further improve motor rehabilitation outcomes?

### Follow-Up Work

Expansion for use outside of VR, implementation of tTIS into smart headband for use with IMUs in smart clothing, and reward stimuli from a smartphone app

### Follow-Up Work

Personalization of VR protocols to individual patient preferences to improve patient engagement during VR stroke rehabilitation

# Personalization of VR protocol



**Thank you.**

**Do you have any questions ?**

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