WORKSHOP ON PERSPECTIVES IN BIOGERONTOLOGY: ADVANCES AND ETHICAL IMPLICATIONS

Co-organised by

CUHK Centre for Bioethics

&

CUHK Jockey Club Institute of Ageing

The Ethics of using AI for Stroke Care

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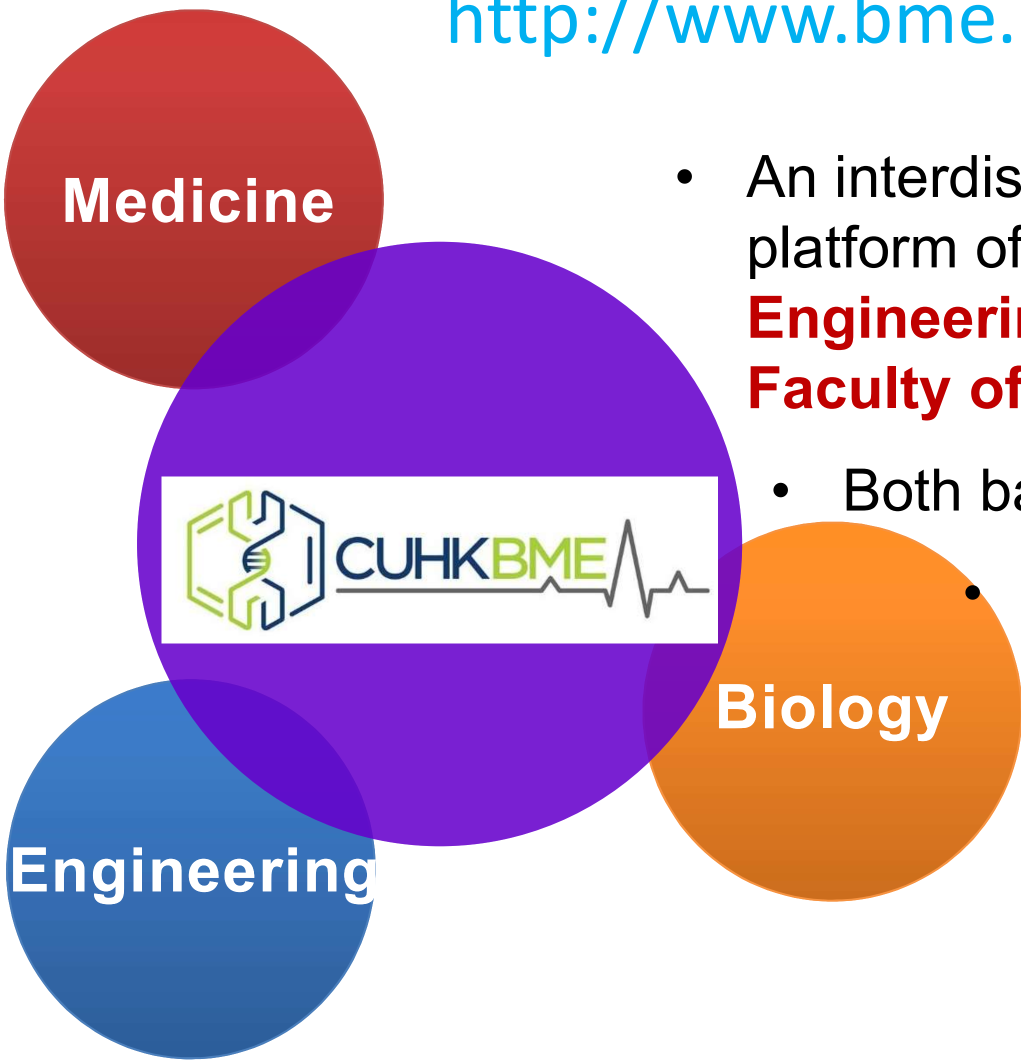

- An interdisciplinary research and education platform offered by the **Faculty of Engineering** in close collaboration with the **Faculty of Medicine**
  - Both basic and applied research
    - Wide access to courses offered by different divisions
      - Tailor-made learning programmes

Acknowledgements

- GRF grant from the Research Grants Council , HKSAR
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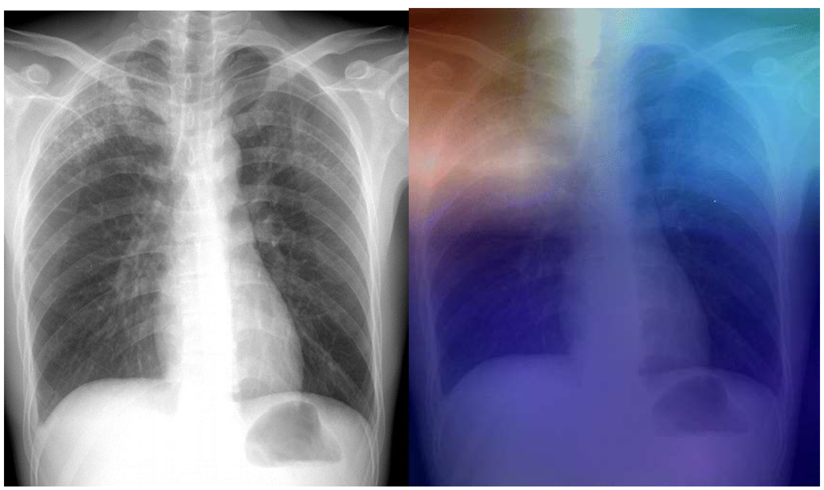
- Raymond Tong’s Research Team

Deep Learning at Chest Radiography: Automated Classification of Pulmonary Tuberculosis by Using Convolutional Neural Networks (April 2017 Radiology 284(2):162326)

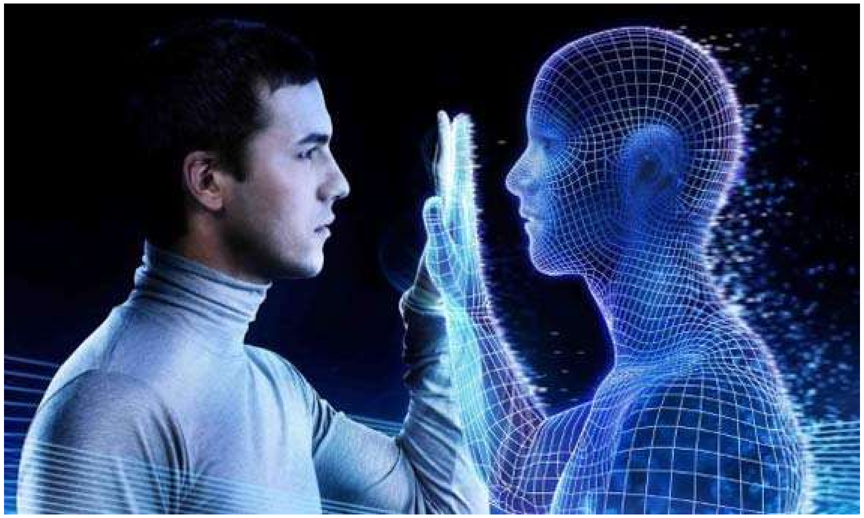
- In the medical field, taking tuberculosis as an example, the accuracy of diagnosis and treatment of senior chief physicians is usually about 70%, while a set of intelligent diagnosis system developed can reach more than 90%. By using Deep learning, the accuracy further improved Deep at chest radiography with an areas under the curve (AUC) of 0.99.



A heat map overlay of one of the strongest activations obtained from the fifth convolutional layer after it was passed through the GoogLeNet-TA classifier. The red and light blue regions in the upper lobes represent areas activated by the deep neural network. The dark purple background represents areas that are not activated. This shows that the network is focusing on parts of the image where the disease is present (both upper lobes).

AI + Human: Better accuracy

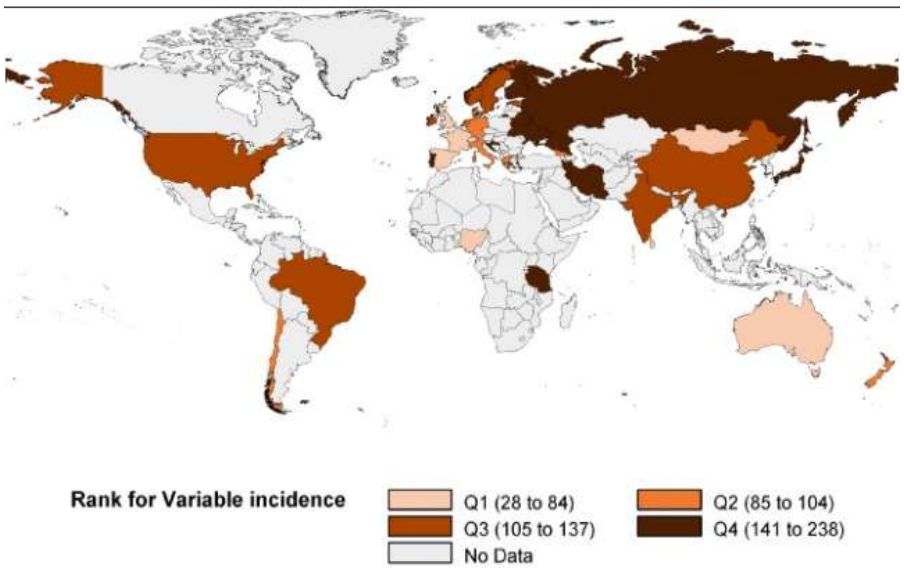
- The DCNNs had disagreement in 13 of the 150 test cases, which were blindly reviewed by a cardiothoracic radiologist, who correctly interpreted all 13 cases (100%). This radiologist-augmented approach resulted in a sensitivity of 97.3% and specificity 100%.



Stroke Rehabilitation Market

- Stroke is the **Leading Disability** in the world, among the U.S, Europe and Asia
- **Golden Period** **(within 3 months after stroke)** for better motor recovery is in Early Stroke Period

→ Clinical + Home-based Training will be ideal

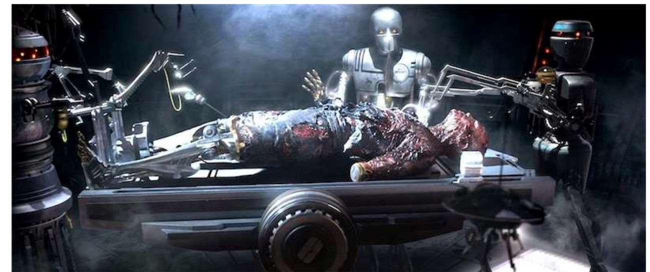


Amanda G Thrift, Dominique Cadilhac, Tharshanah Thayabaranathan, Geoffrey A Donnan, (2014) Global stroke statistics, International Journal of Stroke 9(1):6-18

- Only In US in 2006,
  - 6.4 millions people have had stroke
  - 795,000 new and recurrent stroke attacks
  - 137,119 people died of stroke
- In Hong Kong ,
  - Increasing prevalence per year : 11,062 (1981) → 25,053 (2007)
  - Relatively stable mortality rate of about 3,000
  - More people living with disability due to Stroke

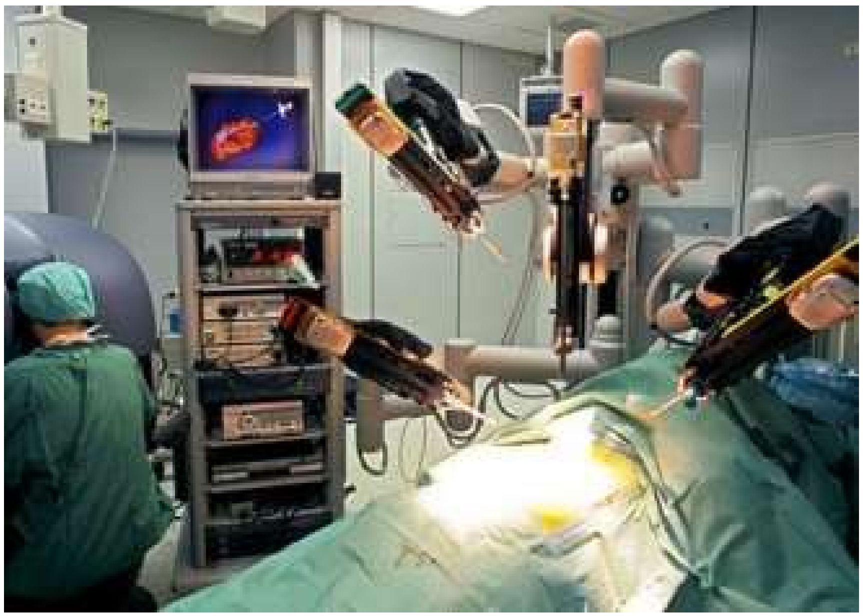
AI + robot

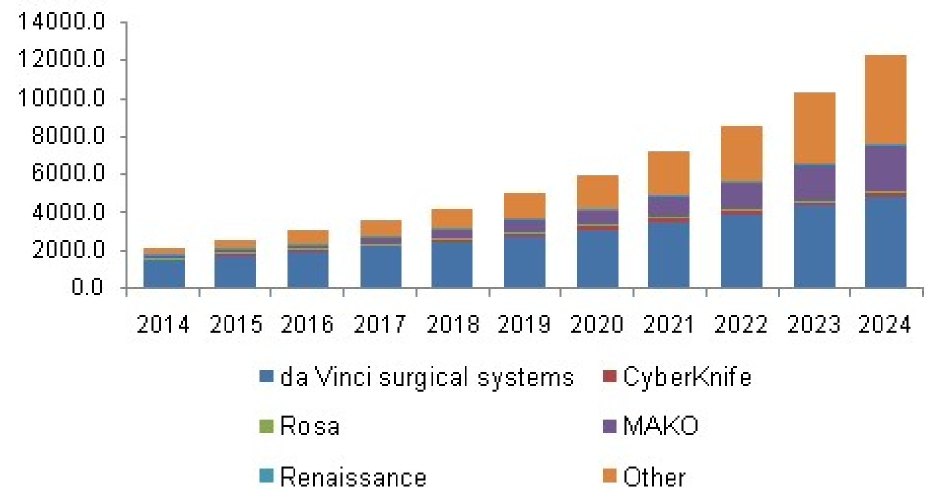
"*[Star Wars Episode III: Revenge of the Sith]*"(2005)



"*Prometheus*" is called the "*Medical Pod 720i*."

North America surgical robot market share, by product, 2014 - 2024

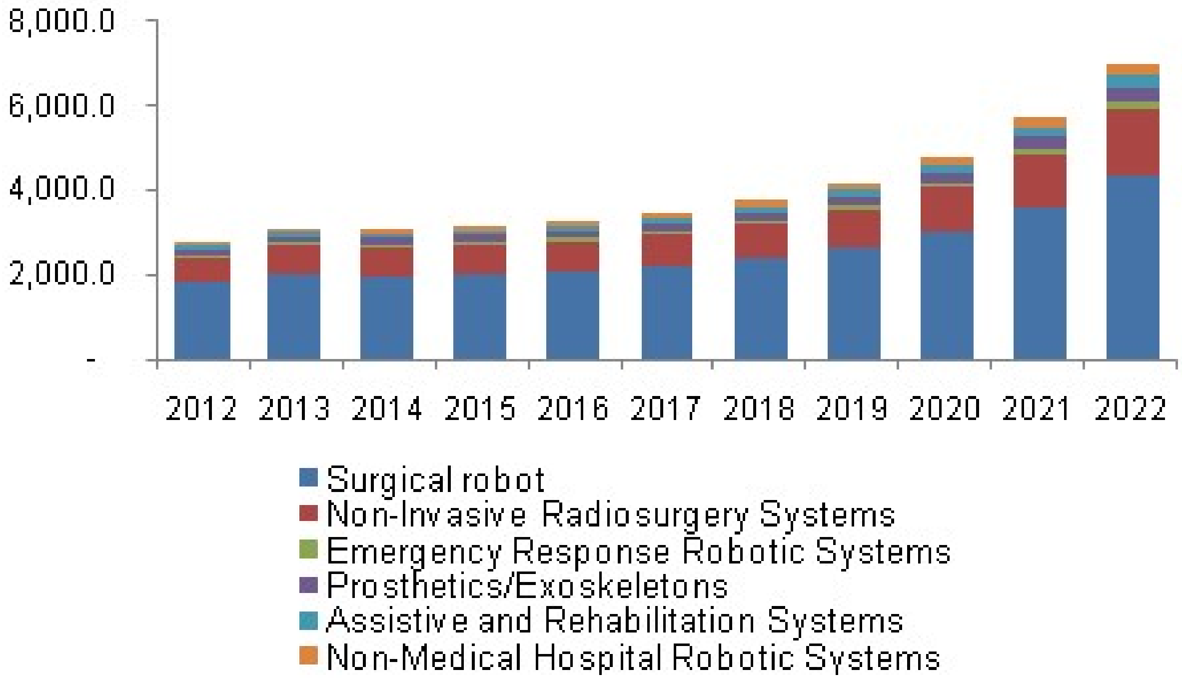




- The global surgical robot market size was valued at USD 4.0 billion in 2015 and is expected to grow at a **CAGR of 20.03%** over the next eight years. The rising incidences of chronic conditions coupled with increasing ageing population and related diseases.
- In 2014, it was reported by the CDC that about 50.0 million people suffer from neurological disorders causing an annual expenditure of over USD 450.0 billion, hence demanding a high volume of surgical intervention.

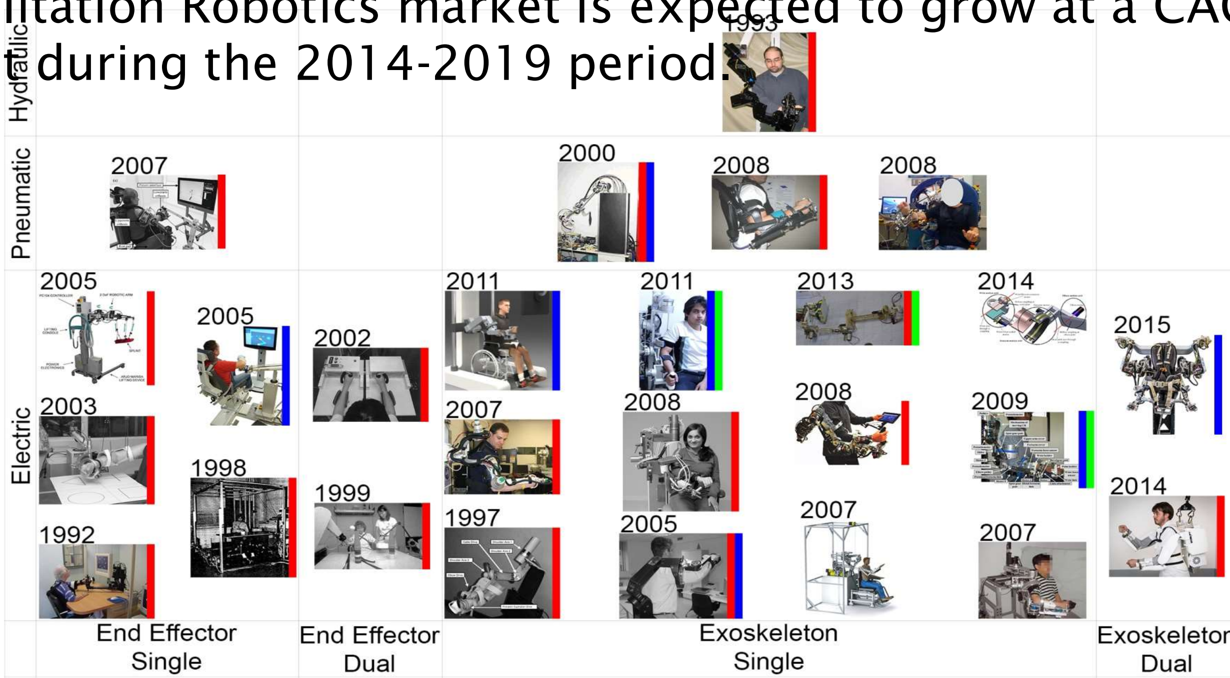
Grand View Research 2016

U.S. medical robotic systems market, by product, 2012 - 2022 (USD Million)



Graphical Summary of Existing Upper Limb Rehabilitation Robots

This healthy market competition is a big reason why the Global Rehabilitation Robotics market is expected to grow at a CAGR of 24.27 percent during the 2014-2019 period.



Yang Shen and Jacob Rosen 2018

Exsokeleton Robot Hand and Leg

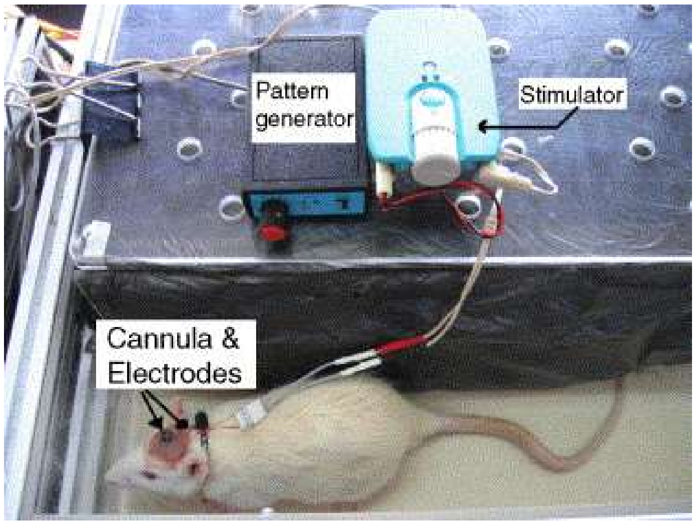
(Raymond Tong, Hong Kong)

- Detect **human intention** to drive the robot for rehabilitation

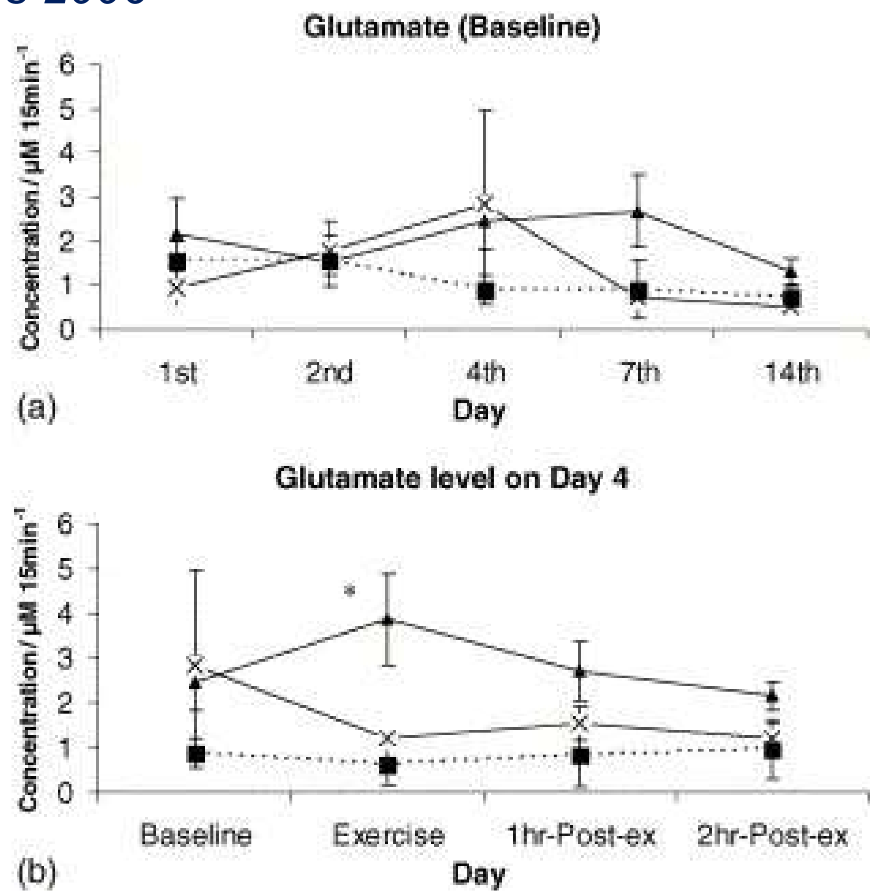
- Licensed to Rehab-robotic(Top 15 Rehabilitation Robotics Companies in 2014)
- Support Vincent-Medical IPO to be listed in HK Stock Market (2016)

Brain neuroplasticity after stroke?

Neurochemical effects of exercise and neuromuscular electrical stimulation on brain after stroke: A microdialysis study using rat model
Leung LY, Tong KY,et al. Neuroscience Letters 2006

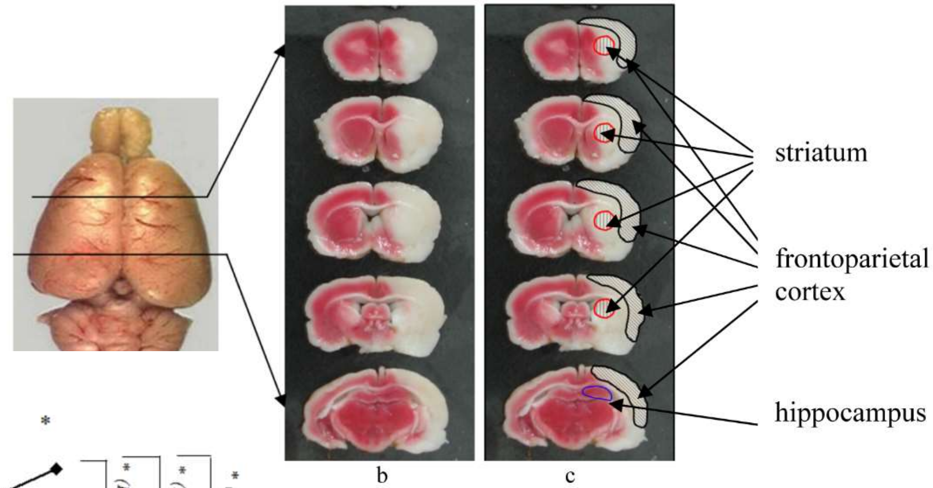


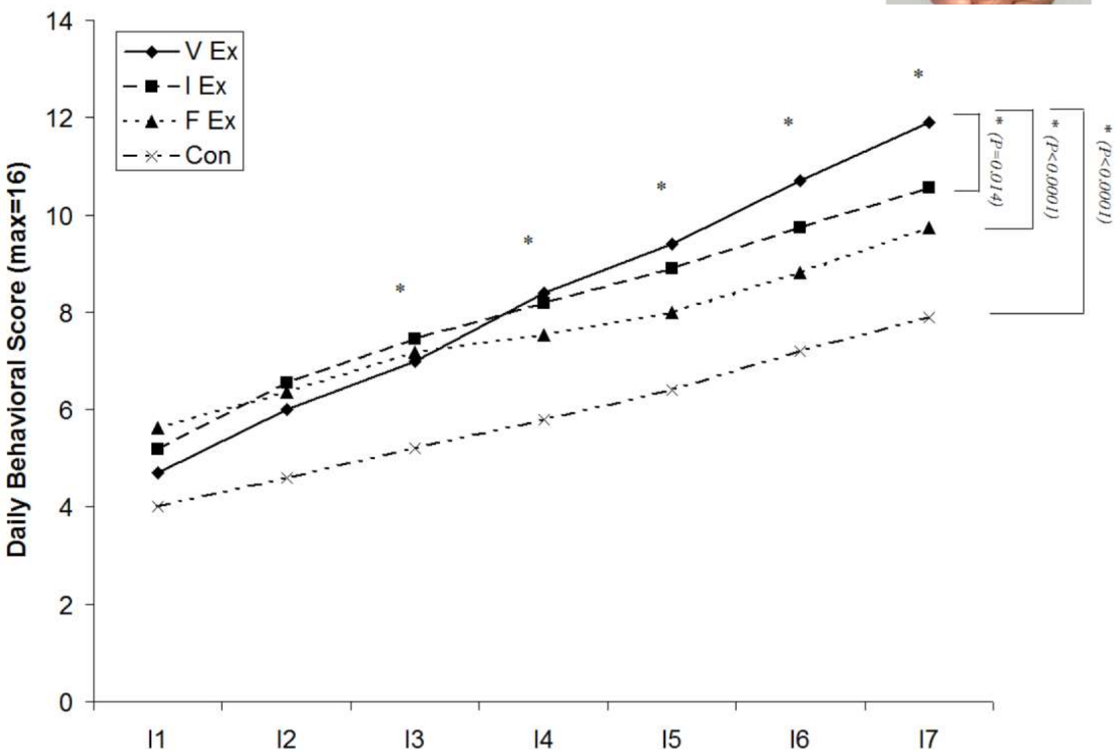
(a) Basal concentrations of glutamate of NMES group (×), Control group (■) and EX group (▲) over the 14 days. Data was expressed in μM 15 min^{-1} ± S.E.M. (b) The change of glutamate level of NMES group (×), Control group (■) and EX group (▲) on Day 4 after MCAo. Data was expressed in μM 15 min^{-1} ± S.E.M. * $p < 0.05$ compared between a particular time point with baseline level in a particular group.



The effects of voluntary, involuntary, and forced exercises on brain-derived neurotrophic factor and motor function recovery: a rat brain ischemia model Z Ke, SP Yip, L Li, XX Zheng, KY Tong
PloS one 6 (2), e16643, 2011

- Behavioral Score

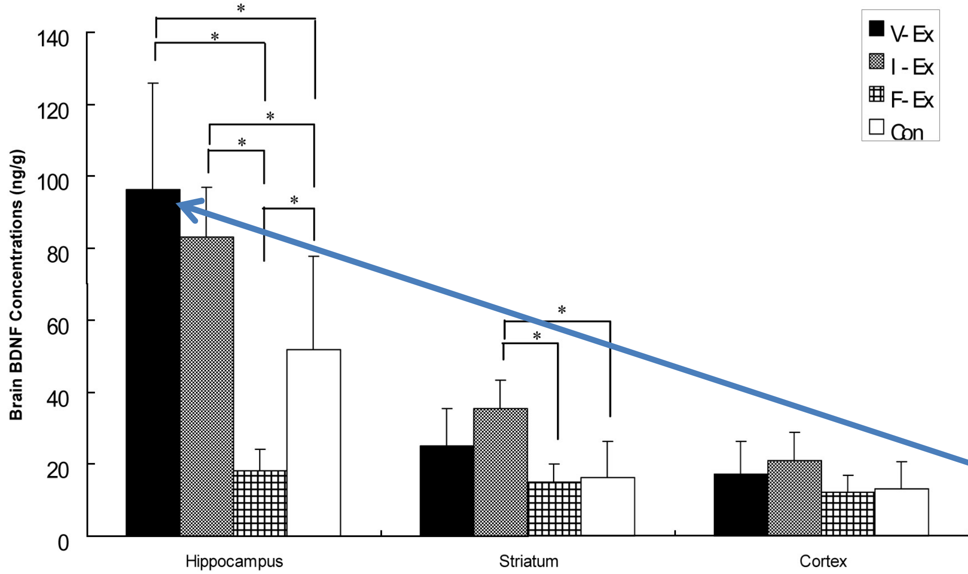




Voluntary Exercise has better recovery in day 7

BDNF

Good for the Brain



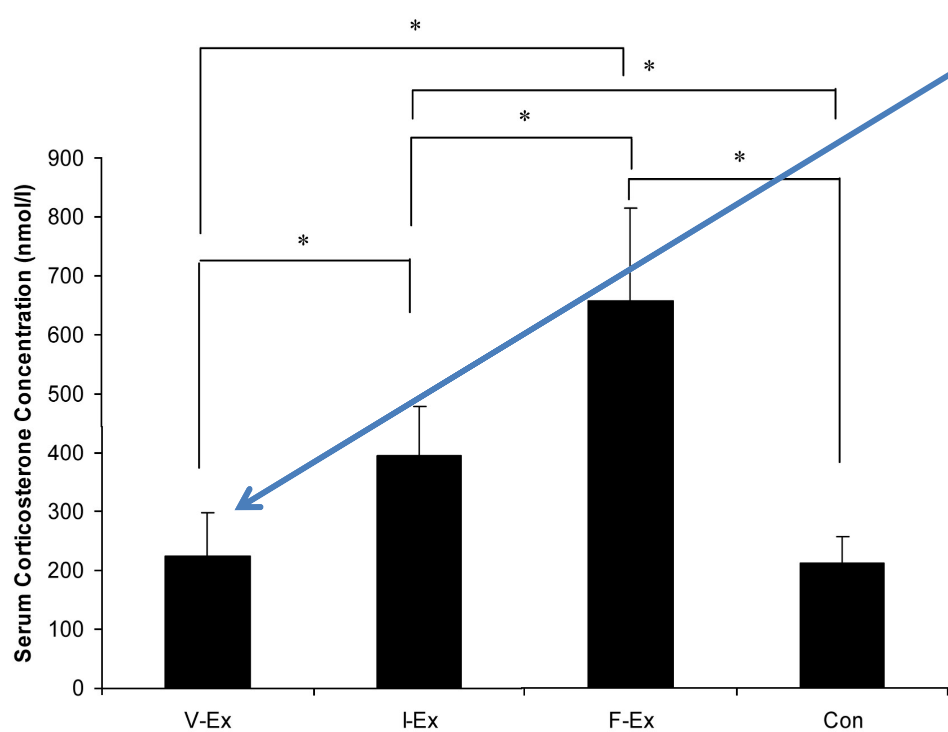
Voluntary Exercise is Good for the Brain & hasn't increased the stress

Cortico-sterone

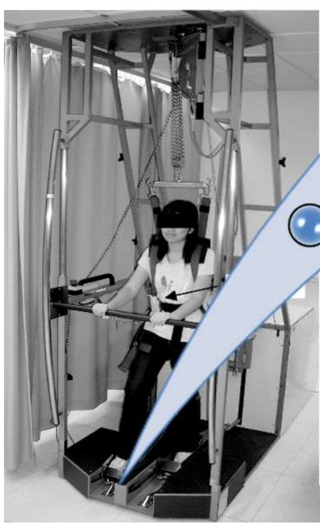
$\propto$

STRESS

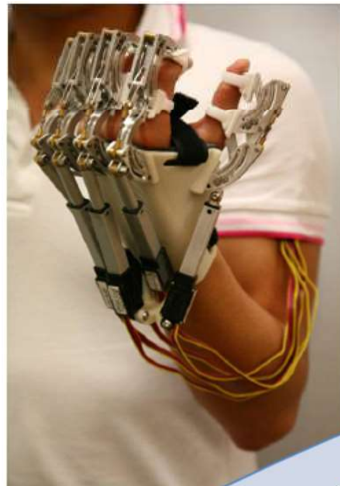
Bad for the Brain



Trend of Exoskeleton Robotics



Gait Trainer from Germany (2006-08)



PolyJbot Robot Tower (2008, HK)

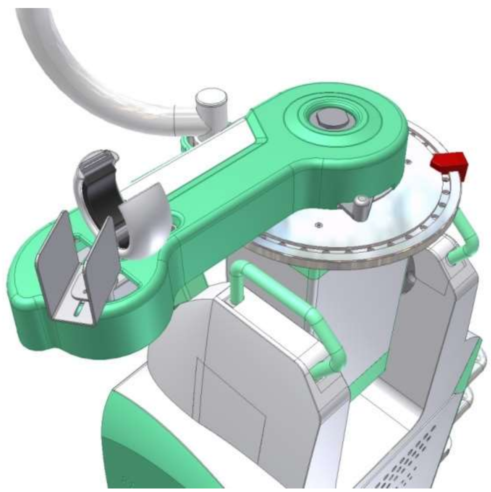
Hand of Hope (2011, HK)

Ankle Robot, Knee Robot (2016, HK)

Hong Kong Upper and Lower Limb Rehabilitation Robot using Human Intention (EMG) (2008)

Wrist joint

Elbow joint



Knee joint

Ankle joint

Hu X, Song R, Tong KY, Zhou W. Myoelectrically controlled wrist robot for stroke rehabilitation. *J Neuroeng Rehabil* 2013 Jun 10;10:52. [Link]

Key findings

(Human Intention-driven + Robot = Brain motor relearning)

- The myoelectrically controlled robot-aided training improved the motor impairment after the training for both the wrist and elbow joints in muscle coordination and spasticity reduction, which could be maintained for 3 months.
- The passive mode training mainly reduced the spasticity in the wrist flexor, but did not contribute to the muscle coordination improvement.

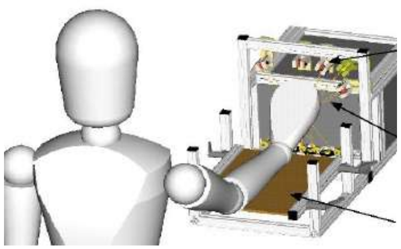
Hu XL, **Tong KY***, et. al. (2009), A Comparison between Electromyography (EMG)-Driven Robot and Passive Motion Device on Wrist Rehabilitation for Chronic Stroke, *Neurorehabilitation and Neural Repair*, 23:837-846

Hu XL, **Tong KY***, et. al., (2009) Quantitative Evaluation of Motor Functional Recovery Process in Chronic Stroke Patients during Robot-Assisted Wrist Training, *Journal of Electromyography and Kinesiology*, 19: 639-50

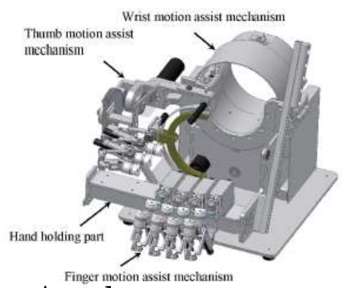
Hu XL, **Tong KY***, Ho SK, Xue JJ, Rong W, Li SW. Wrist Rehabilitation Assisted by an Electromyography-Driven Neuromuscular Electrical Stimulation Robot After Stroke *Neurorehabilitation and Neural Repair* 2014 Dec; 29(8):767-76. **[Link]**

Hand & Wrist Robots Review

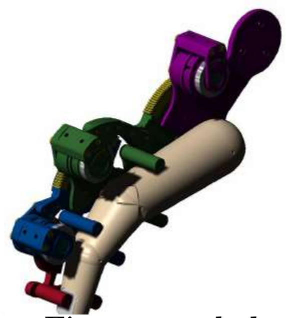
- Robotics training is defined as the use of computers, electronic in mechanical design to help the rehabilitation training process (Cooper et al, 2008).
- Different Design for hand function training



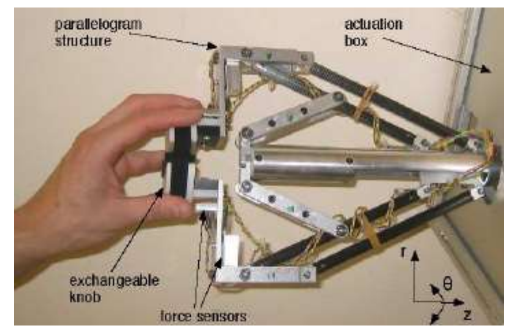
Cable driven robotic system by National University of Singapore (Dovat et al)



Another system uses the subjects' sound side to control robotic hand by Gifu University(Kawassaki et al)



Finger exoskeleton by Northwestern University (Worsnopp et al.)



Haptic Knob by ETH Zurich and NUS (Lambercy et al.)

2012 希望之手 – Hand of Hope (license to Rehab-robotics (support Vincent Medical HK IPO 2016)

機械手助中風者復康

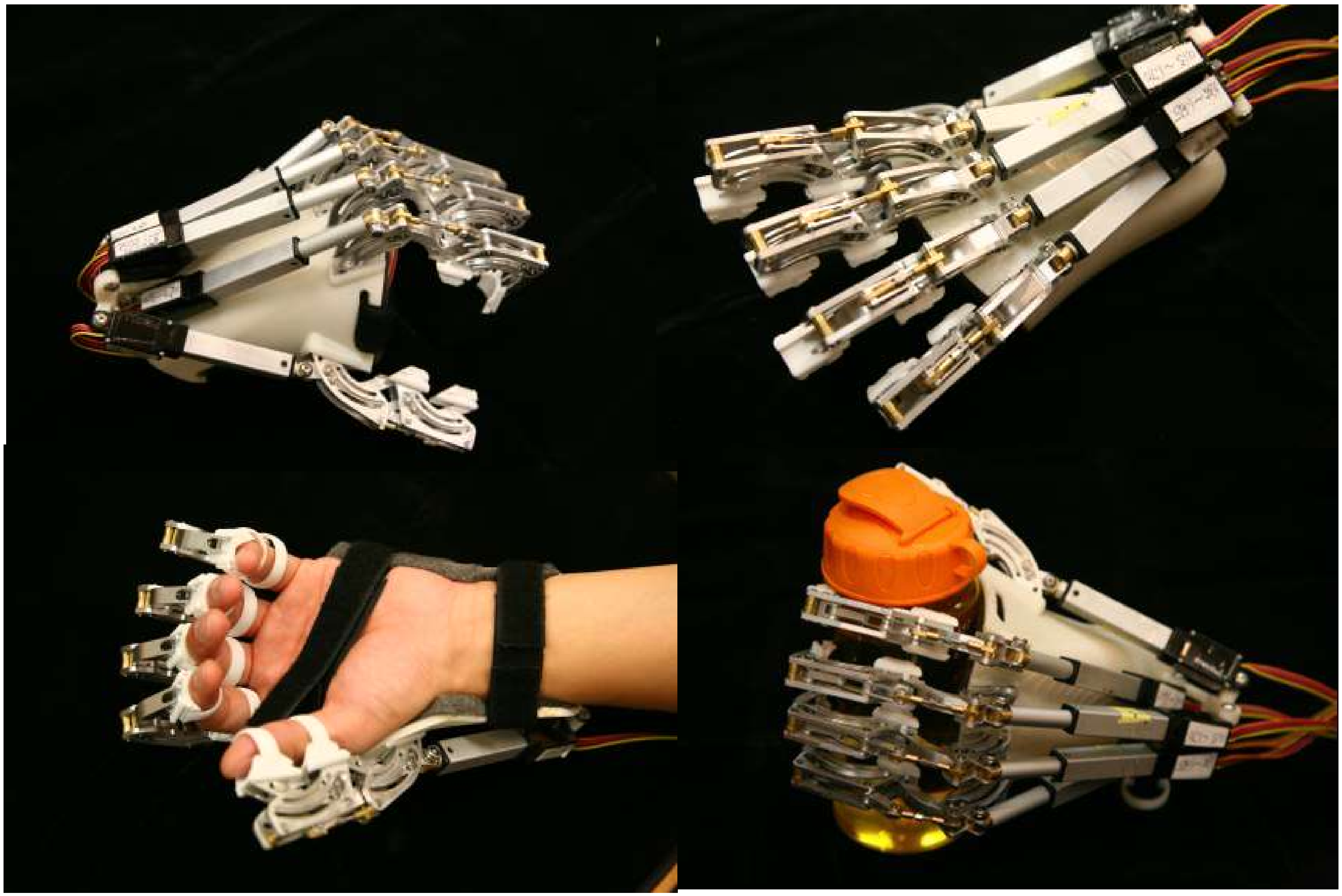
Raymond Tong joint collaboration with Industrial Centre

機械手系統透過受損肢體的肌肉訊號(EMG)探測使用者的意志，幫助中風病人強化腦部對手掌的控制。

https://m.scmp.com/video/hong-kong/2114006/how-hong-kongs-ageing-society-can-benefit-biomedical-engineering

(Video link from South China Morning Post 2017)

Hand Function Task Training Robot



EA Susanto, **RK Tong** ,et al *Efficacy of robot-assisted fingers training in chronic stroke survivors: a pilot randomized-controlled trial*. J Neuroeng Rehabil. (2015) **[Link]**

Movie clips – Subject with Chronic Stroke

Task without Hand robot

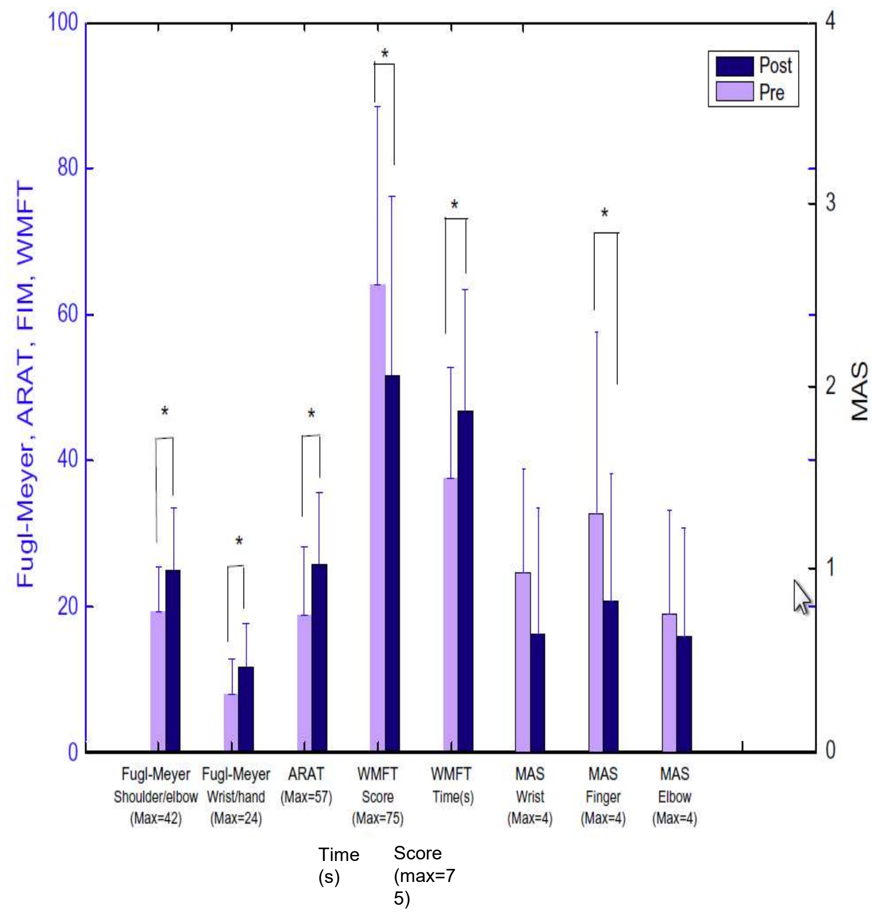
Task with Hand robot

Hu XL, …. **Tong KY**. The effects of post-stroke upper-limb training with an electromyography (EMG)-driven hand robot. *J Electronmyogr Kinesiol* 2013 Oct;23(5):1065-74. [Link]

Lu Z, **Tong K**, Shin H, Li S, Zhou P, Advanced Myoelectric Control for Robotic Hand-Assisted Training: Outcome from a Stroke Patient, *Frontiers in Neurology, 2017, 8*[Link]

Clinical Data from Chronic Stroke Subjects before and after 20-session training

It is found that significant motor improvements after the training could be captured by the FMA (shoulder&elbow (S&E), and wrist&hand(W&H), and ARAT. The improvement in ARAT score mainly reflects the motor recovery in hand and finger functions. The increased FMA scores suggest the motor improvement in the whole upper limb after the training. Significant reduction in spasticity of the fingers using MAS.



XL Hu, **KY Tong**, et al *The effects of post-stroke upper-limb training with an electromyography (EMG)-driven hand robot.*Journal of Electromyography and Kinesiology (2013) **.** **[Link]**

EA Susanto, **RK Tong** ,et al *Efficacy of robot-assisted fingers training in chronic stroke survivors: a pilot randomized-controlled trial*. J Neuroeng Rehabil. (2015) **[Link]**

Existing robotic system

Triggered by Joystick or Trunk Movement

Bulky

Heavy （15-20kg）=

Expensive

Smart Exoskeleton Robotic Leg

Patient wears it on his shank/thigh/hip

Effective

Nature walking

Improve balance

Light weight（500-800g）=

0.5L

Smart Intelligent System to automatically identify user intention

- The robot can sense the gait pattern of the user by using embedded motion sensors and force sensors, and then determine the walking intention.
- The robot can provide power assistance to actuate the ankle, knee and hip joint movement during walking on the floor, upstairs and downstairs, with proper feedback to enhance the quality and speed of walking pattern. The system design is portable and light-weight. Stroke patients can wear this exoskeleton robot to regenerate walking function, better to encourage patients walk more frequently.

Tong KY, Lau HY, Zhu H. Support Vector Machine for Classification of Walking Conditions of Persons After Stroke with Dropped Foot. *Hum Mov Sci* 2009 Aug;28(4):504-14. [Link]

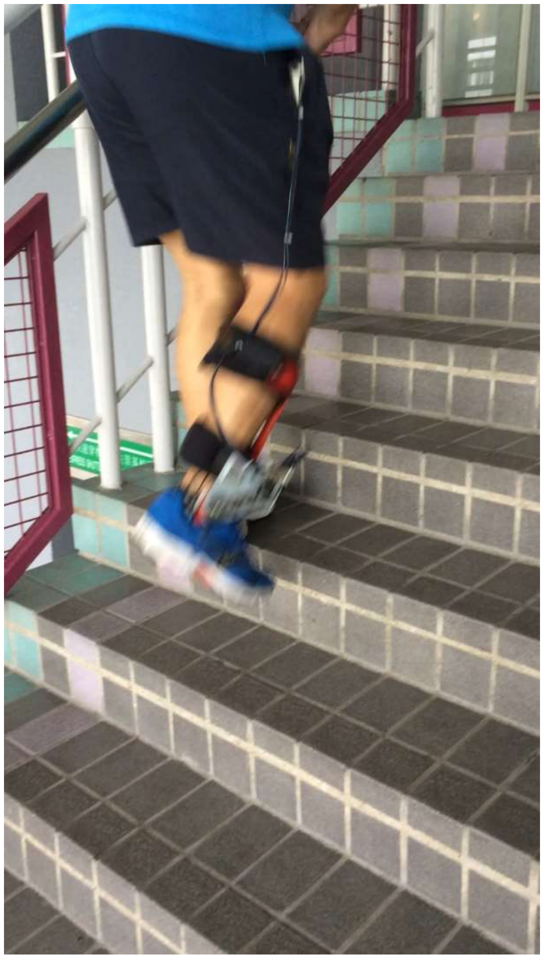
Tong KY and Lau HY. The reliability of using accelerometer and gyroscope for gait event identification on persons with dropped foot. *Gait Posture* 2008 Feb;27(2):248-57. [Link]

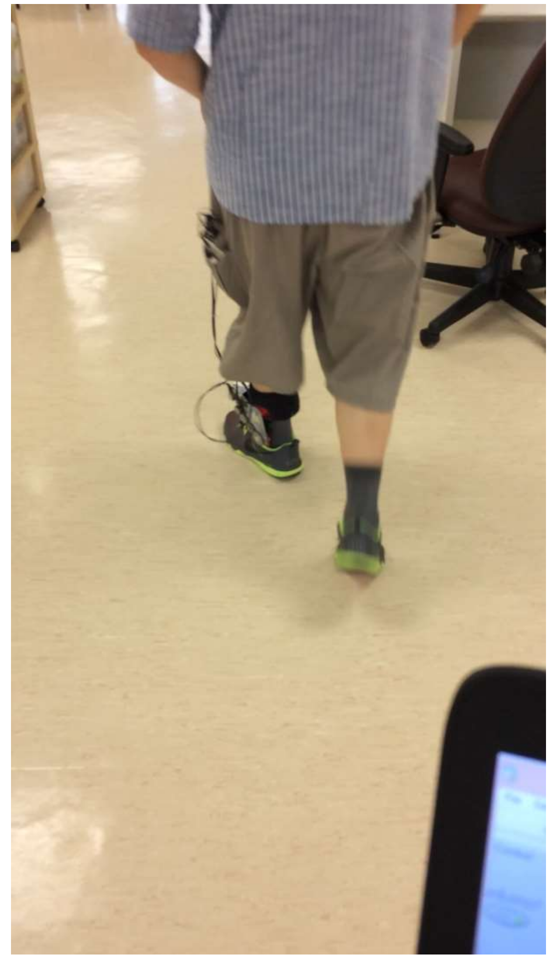
Tong KY, Lau HY, Zhu H. Support Vector Machine for Classification of Walking Conditions Using Miniature Kinematic Sensors. *Med Biol Eng Comput*. 2008 Jun;46(6):563-73. [Link]

Stroke patient with dropped foot

Ankle robot

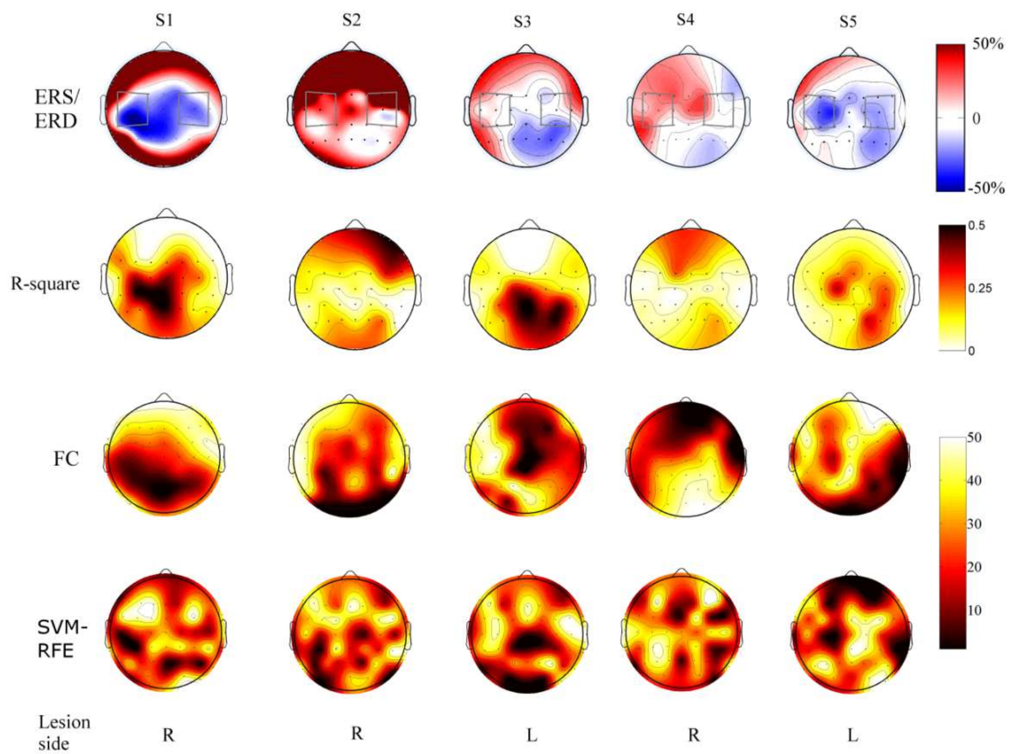
It is very unique for rehabilitation purpose :
stroke survivors can use it indoor as well as outdoors for rehabilitation training.





EEG biofeedback ?

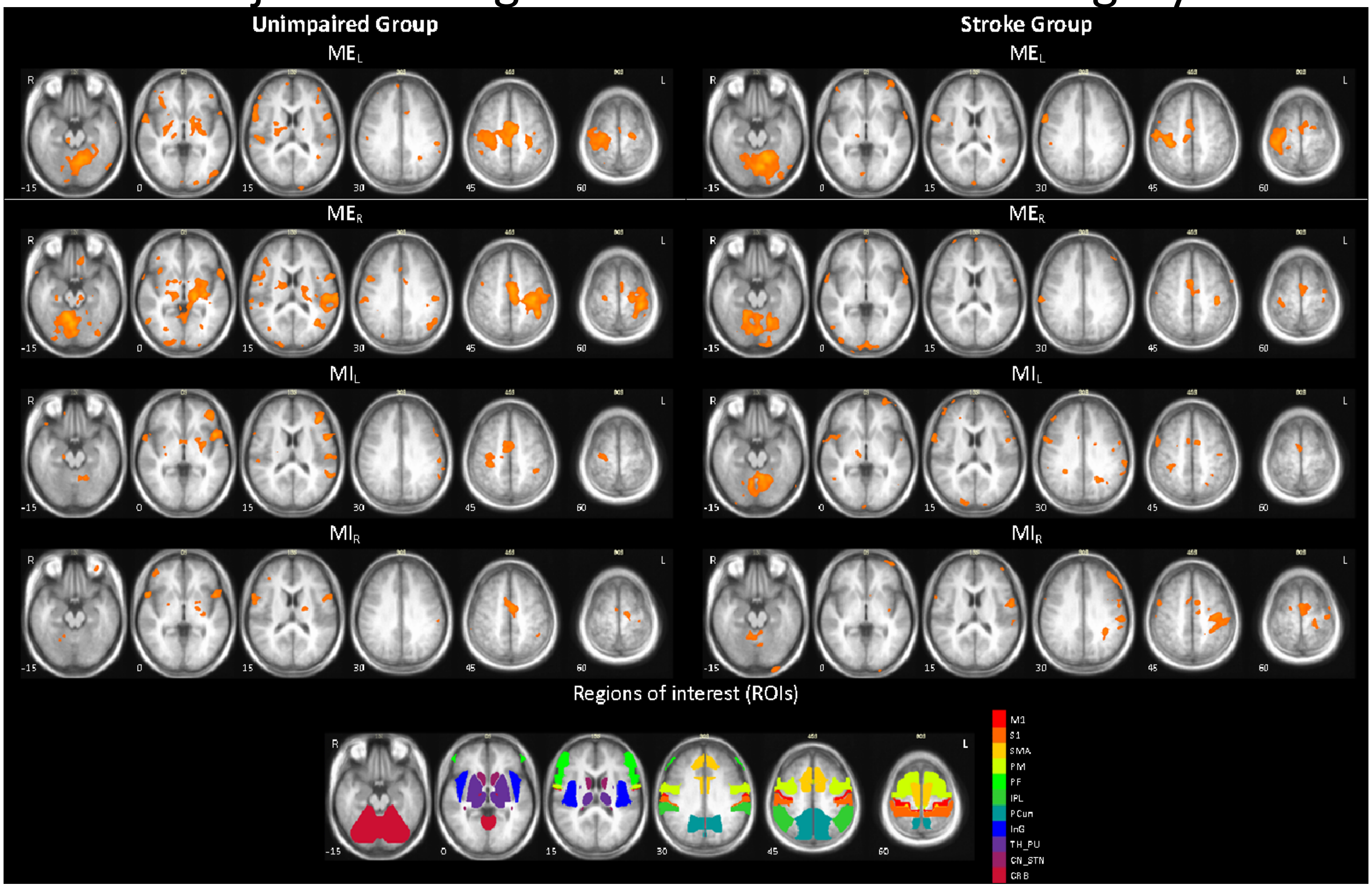
Brain Neuroimaging using **EEG** from stroke subjects



The average ERD and R-square topographies of all 20 sessions of training of the subjects, and their channel selection ranking distribution on the first day of training. ERD/ERS topographies were shown in the first row. The squares indicate the sensorimotor area. Blue color represented ERD and red color represented ERS. R-square topographies are shown in the 2nd row. The distributions of the ranking of the channel in FC and SVM-RFE were shown in the 3nd and 4th row respectively. Darker the color represents a higher ranking

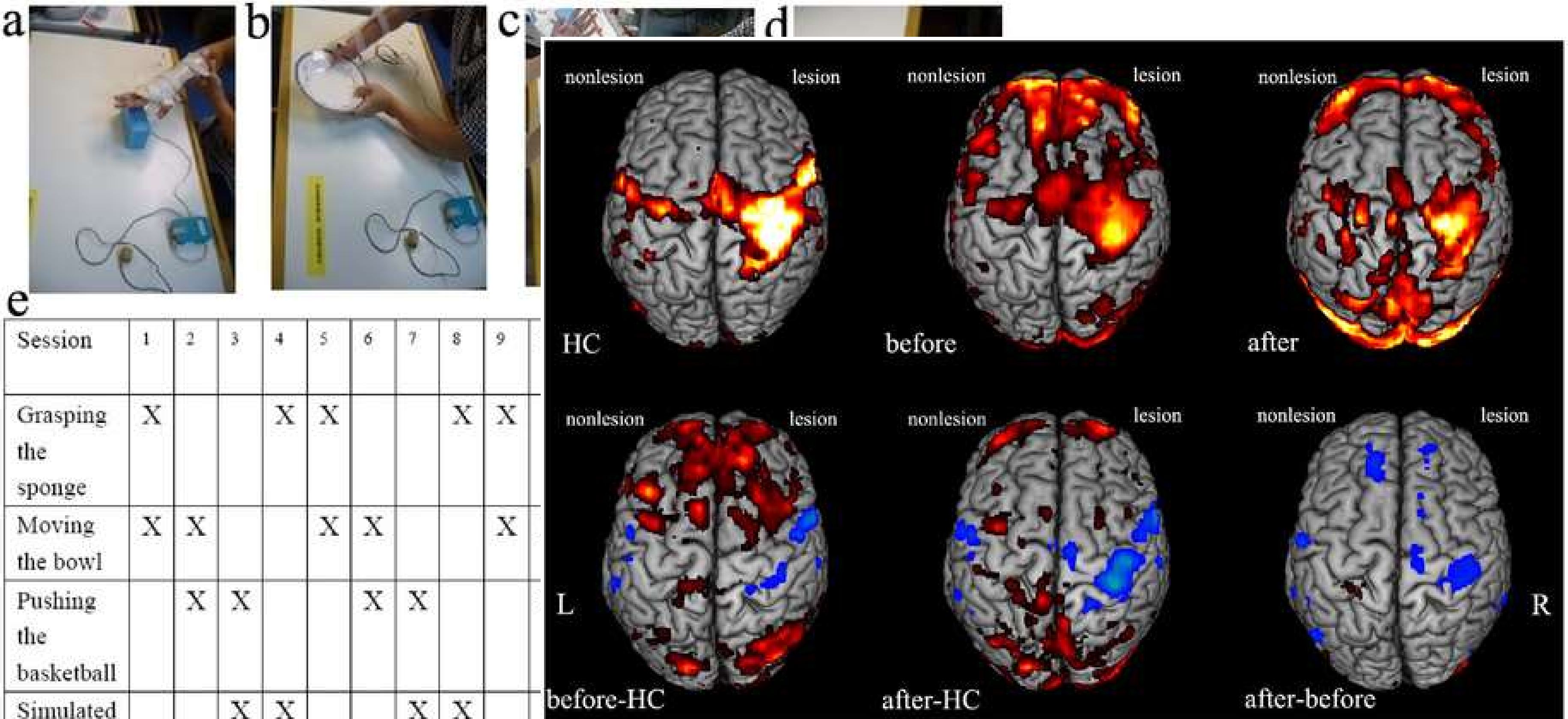
(Tam WK, **Tong KY**, et al. 2011 IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING, VOL. 19, NO. 6,).

MRI Comparison between Stroke and Unimpaired Subjects during Motor Execution or Imagery



(Wong WW, Chan ST, Tang KW, Meng F, **Tong KY**, 2013 Brain Injury.)

[A longitudinal study of hand motor recovery after sub-acute stroke: a study combined fMRI with diffusion tensor imaging](#)W Wei, L Bai, J Wang, R Dai, RK Tong, Y Zhang, Z Song, W Jiang, C Shi, ...
PloS one 8 (5), e64154, 2013



Session	1	2	3	4	5	6	7	8	9
Grasping the sponge	X			X	X			X	X
Moving the bowl	X	X			X	X			X
Pushing the basketball		X	X			X	X		
Simulated drinking			X	X			X	X	

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