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BRAIN-COMPUTER INTERFACE

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SJC Undergraduate Research Symposium 2018

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OVERVIEW

Development Process

- BrainGate
- To demonstrate progress of BCI
  i. Robot Control
  ii. Cursor Control

Potential

- Future possibilities of BCI technology

Concerns

- Safety
- Cost
- Non-stationarity

Prospects

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INTRODUCTION

- What is Brain-Computer Interface?
  - Technology to connect the brain to outside world by controlling a computer
  - To help people who have neurological disorders such as tetraplegia and anarthria

- Three major components of BCI systems
  - A sensor to detect neural signals (can be attached/implanted)
  - A signal processor (decoder) to convert the signals
  - A device to turn the converted signals into an actual action (e.g., robot)

Figure1. BCIs (Kamat, 2017)

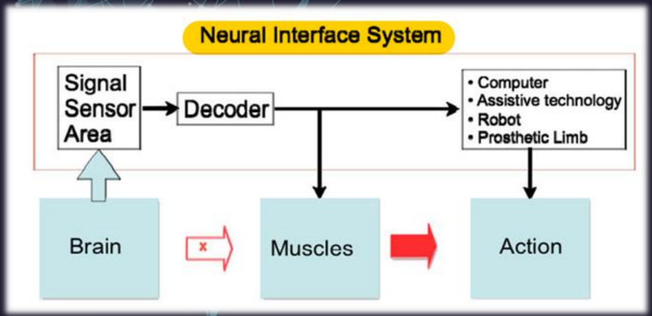

Figure 2. Design of a BCI system (Donoghue, 2002)

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ROBOTIC ARM

Positioned a robot arm by pressing a lever (1999)	
Rat	Need to convert neural signals several times

Used neural signals from motor cortex for hand motions (2002)	
Non-human primate	Rising public interest on BCI research

Controlled a robot arm via a control interface on a screen (2006)	
Able-bodied human	Not suitable for people with tetraplegia (wire sensors)

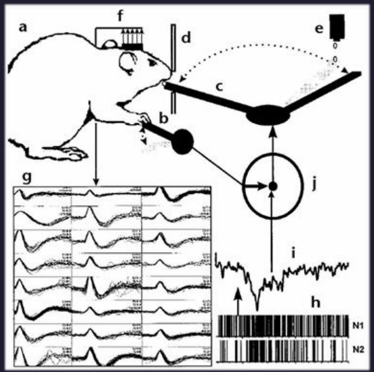

Figure 3. Robot control by lever-movement (Chapin et al, 1999)

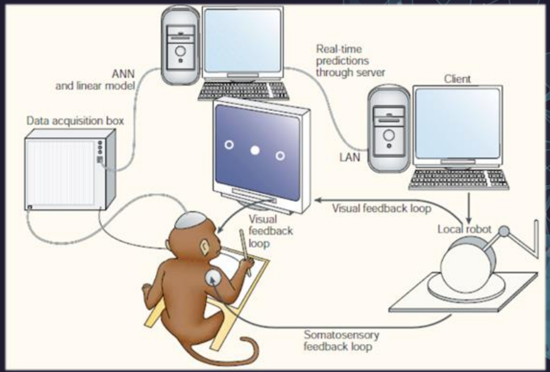

Figure 4. Using monkeys' motor cortex signals (Nicolelis et al, 2002)


Figure 5. A robotic arm controlled by thoughts (Emspak, 2006)

ROBOTIC ARM

Recorded neural signals via implanted wireless sensors (2013)	
Non-human primate & swine	Transmitted neural data at high speed but implantable microsystems produced heat

Coordinated movements with own paralyzed arm and hand (2017)	
Human with paralysis	Allowed to regain movements all through thoughts

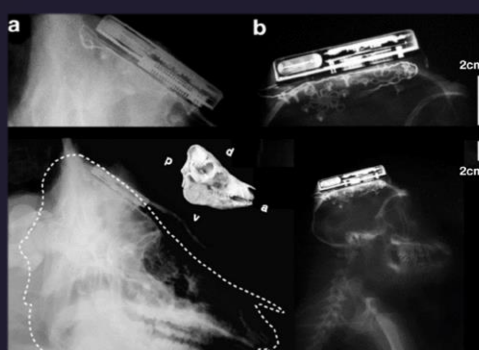

Figure 6. X-ray images of implanted neural interface (Borton et al, 2013)

Figure 7. A man moving his paralyzed hand (Yong, 2016)

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POINT-AND-CLICK TYPING

P300 speller

- Rows and columns
- Select letter slowly
- Nearly 80% correct classification

1D speller (2005)

- Letter-by-letter spelling
- Move up and down
- Still error-prone, very slow, and effortful

2D speller (2008)

- Sufficient movement in 2D to targets
- EEG sensor (electroencephalogram)
- 96-100% success rate

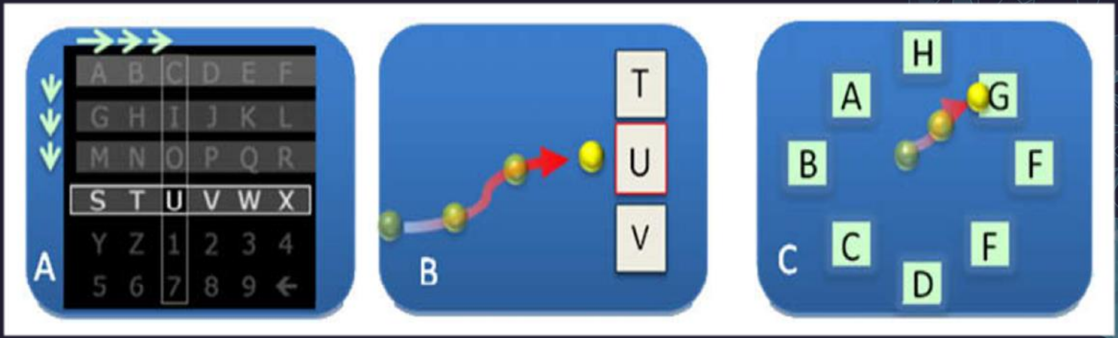

Figure 7. P300, 1D, and 2D BCI speller (Donoghue, 2008)

Figure 8. EEG (CBS News, 2014)

POINT-AND-CLICK TYPING

2D speller (2011)

- QWERTY Keyboard
- Decode moving and clicking signals simultaneously
- By humans with tetraplegia
- Unintentional selection of targets

2D speller (2015)

- BrainGate Radial Keyboard
- By humans with lock-in syndrome
- Higher typing performance than QWERTY keyboard

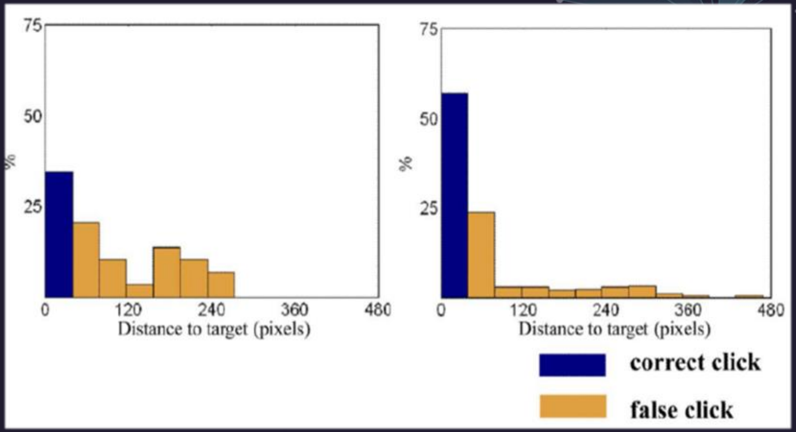

Figure 9. Histogram of clicks (Kim et al, 2011)

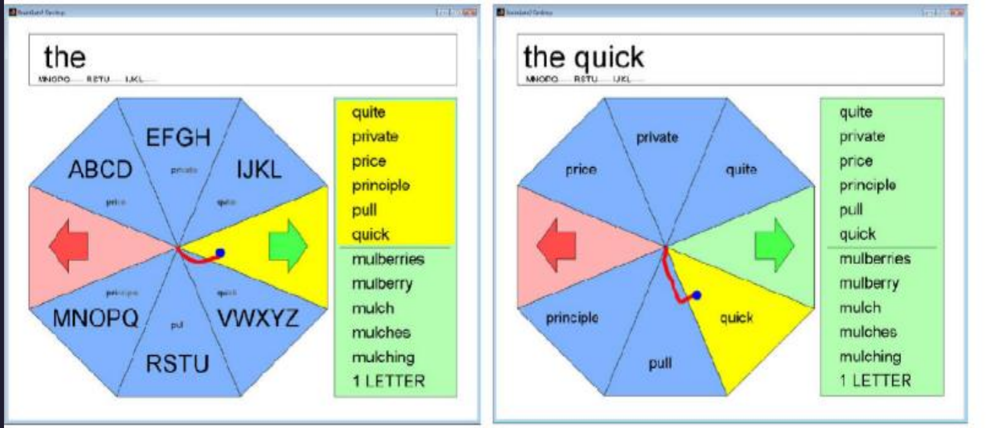

Figure 10. BrainGate Radial Keyboard (Bacher et al, 2015)

POTENTIAL

- Expanded target population

Rat/Swine → Non-human primate → Able-bodied Human → Humans with tetraplegia → Humans with lock-in syndrome

Advancement of Technology

Feedback Control Policy

Human Brain

- Rules to control BCI devices
  - New control policy model proposed in 2017 by Willet et al
    - Inform the design of higher performing BCI

Figure 11. Neuro Chip (U of C, 2016)

Figure 12. Unknown world of the Brain (Jacobs, 2018)

- Stable micro-neurochip
- Limitless possibilities

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CONCERNS

BCI for daily life application

Safety

- Unstable yet
- Might be dangerous to the sensitive brain
- Substantial FDA-approved BCI devices

Cost

- Too costly
- Growing interest and investment
- Valued at $724 million in 2014 (San Francisco based Grand View Research)

Signal Non-stationarity

- Declines in the number of signal quality and recorded channels over periods
- Self-decoder calibration developed by Jarosiewicz in 2015

PROSPECTS

BCI technology is "the final frontier because if we understand how the brain works, we can understand a lot of things that ultimately effect us and make us be humans" (Shein, 2017).

- Long time to make perfect and use commercially
- Infinite potential to drive innovation in the future
  - Medical field: help people with autism or mood disorders
  - Brainternet: connect neural signals to the Internet
  - Military purpose / Brain-to-brain communication

Figure 13. BCI for military purpose (Evans, 2013)

Figure 14. Telepathic communication (Futuristic News, 2018)

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FUTURE WORKS

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ACKNOWLEDGEMENT

- Dr. Phuong Doan (advisor)
- Chemistry Honors classmates

- This presentation refers to data from BrainGate.

For more information, please visit https://www.braingate.org.

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THANK YOU!