

近紅外光腦血氧監測之測謊應用

fNIRS in Lie Detection

盧家鋒 Ph.D
2016.10.28

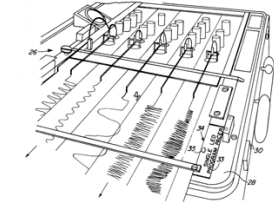
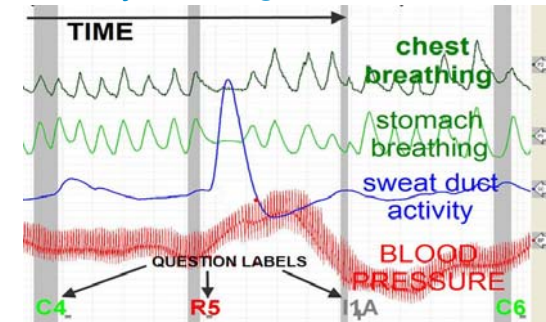
<http://www.ym.edu.tw/~cfly>

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Lie Detection = Difference Detection

- Control Question Test (CQT): control vs. relevant questions
- Guilty Knowledge Test (GKT): multiple-choice test



“Did you shoot your wife?”
“Was \$500, \$1,000, or \$5,000 stolen?”

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Syllabus

- 9:00~9:50 Deception indicators: physiological changes
- 10:00~10:50 Principles of functional near infrared spectroscopy (fNIRS)
- 11:00~11:50 Applications in Lie Detection



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9:00~9:50

說謊之生理訊號變化

Deception indicators: physiological changes

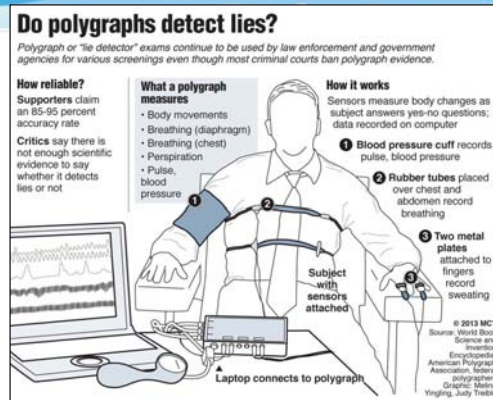
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Deception & polygraph

- **Physiological changes**
 - Respirations
 - Conduct electricity (EDA)
 - Cardio vascular activity
 - Occult body movements
- **Complex neuronal activities**
 - **Deception center???**



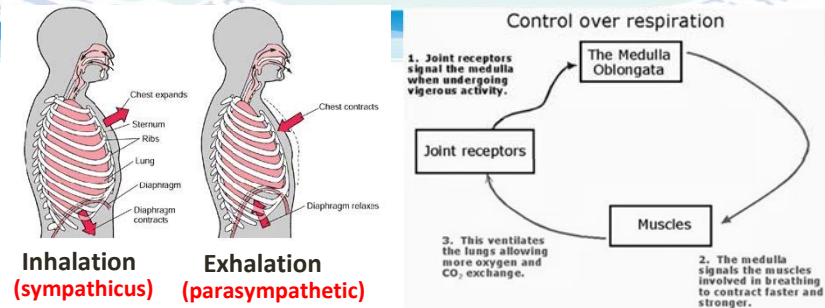
Polygraph System (Limestone Technologies)



Physiological Recordings

- **Endosomatic** (inside-body) or bio-electrical
 - Recording electrical activity that occurs naturally within the body.
 - Electrocardiograph (EKG or ECG), electroencephalograph (EEG), fNIRS
- **Exosomatic** (outside-body)
 - Recording the subsequent changes with an external source of electricity
 - Conductance (G): how easy the current passes
 - Resistance (R): how much difficulty does the current have in passing
 - To record sweat gland activity

Respiration

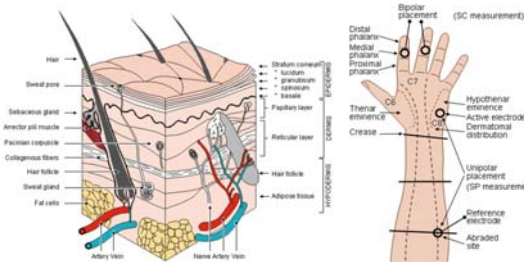


- **Respiratory rate**

- the number of breaths a person takes during one minute. It is usually measured at rest, while sitting.

Skin Resistance

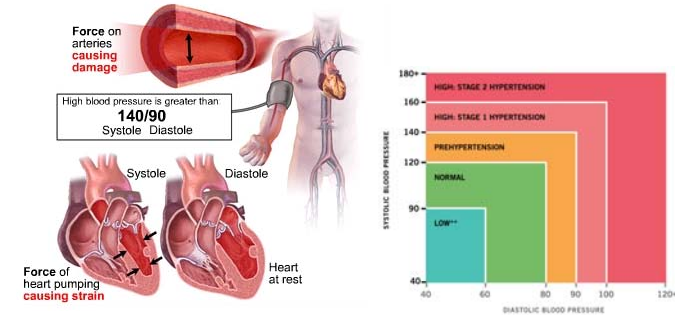
- Evaporation of water as a means of regulating body temperature must be facilitated
- Mediated by the autonomic (sympathetic) nervous system.



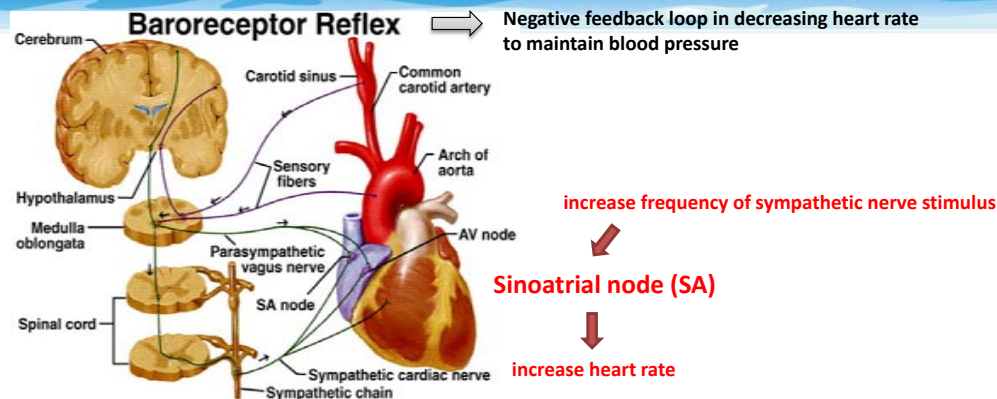
Measurement of the output of the sweat glands.

Blood Pressure

- Nervous, fear, emergency → sympathetic nerve activation → blood vessel constrict → increase blood pressure

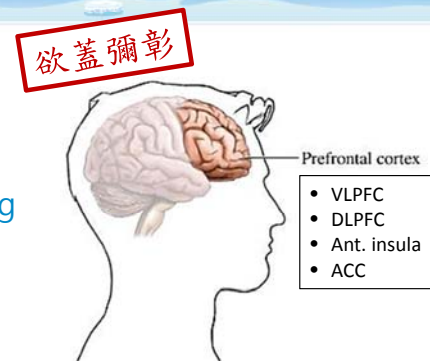


Heart Rate



Deception Center in Brain

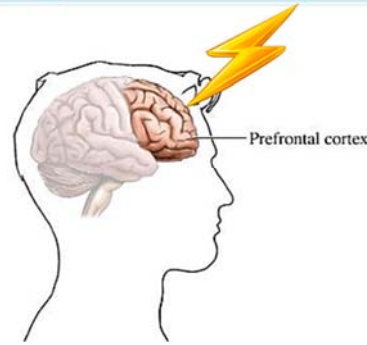
- Prefrontal Cortex
 - working memory (e.g., keeping truth in mind while formulating a deceptive response),
 - inhibitory control (e.g., suppressing a truthful response),
 - task switching (e.g., switching between truthful and deceptive responses)



Cerebral Cortex July 2009;19:1557--1566

Mechanism of Deception

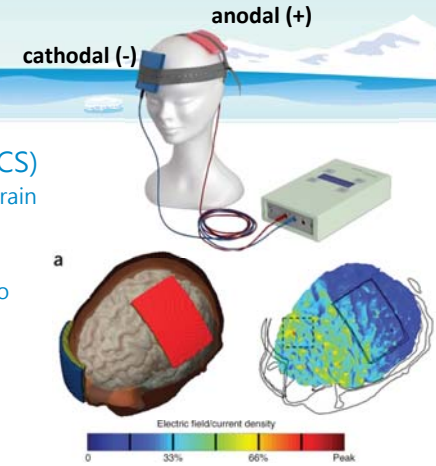
- If it is true that the deception center is PFC, what will happen if we modulate the PFC activity?



Modulate PFC activity

By neurostimulation

- Transcranial direct current stimulation (tDCS)
 - constant, low current (1~2mA) delivered to the brain area via electrodes on the scalp.
- Anodal tDCS
 - causes a depolarization of membrane potential to increase neuronal excitability.
- Cathodal tDCS
 - causes a hyperpolarization to decreases neuron excitability.

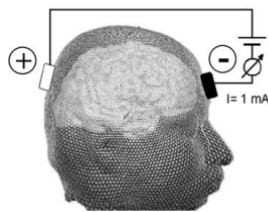


Nature Neuroscience 16, 838–844 (2013)

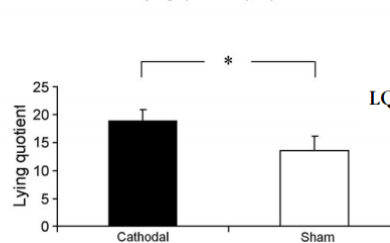
Inhibition of PFC Improves Deceptive Behavior

- A thief role-play experiment, 44 healthy adults.

a Cathodal tDCS of the aPFC



b Lying quotient (LQ)

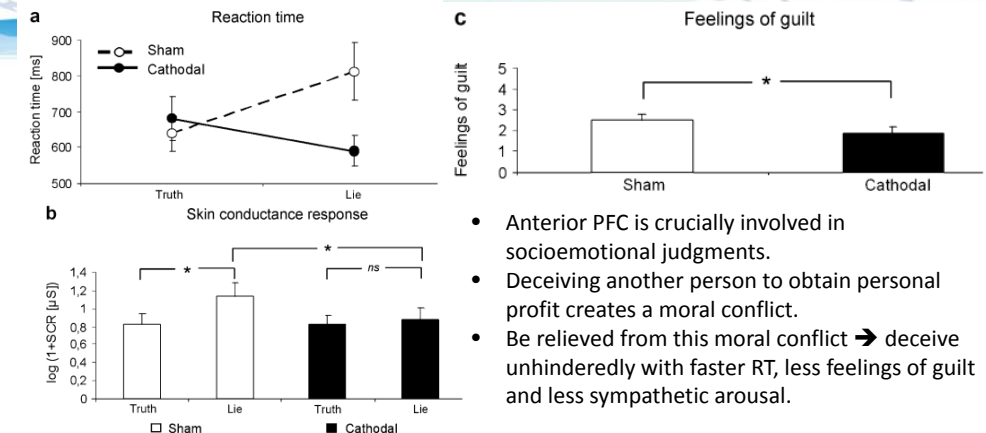


$$LQ = \left[\left(\frac{N_{crit}}{N_{tot_crit}} \right) - \left(\frac{N_{uncrit}}{N_{tot_uncrit}} \right) \right] \times 100$$

Cerebral Cortex January 2010;20:205--213

Inhibition of PFC Improves Deceptive Behavior

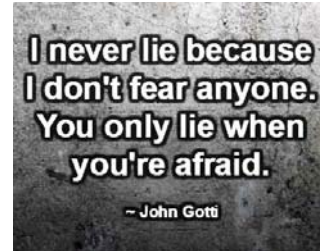
Cerebral Cortex January 2010;20:205--213



- Anterior PFC is crucially involved in socioemotional judgments.
- Deceiving another person to obtain personal profit creates a moral conflict.
- Be relieved from this moral conflict → deceive unhindered with faster RT, less feelings of guilt and less sympathetic arousal.

LIE detector or FEAR detector??

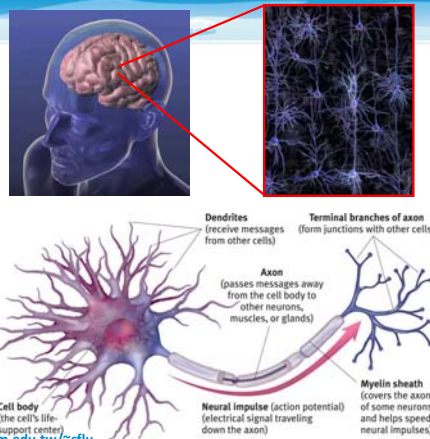
- Subjects who believe that...
 - the test works
 - they can be detected
 may confess or will be very anxious when questioned!!



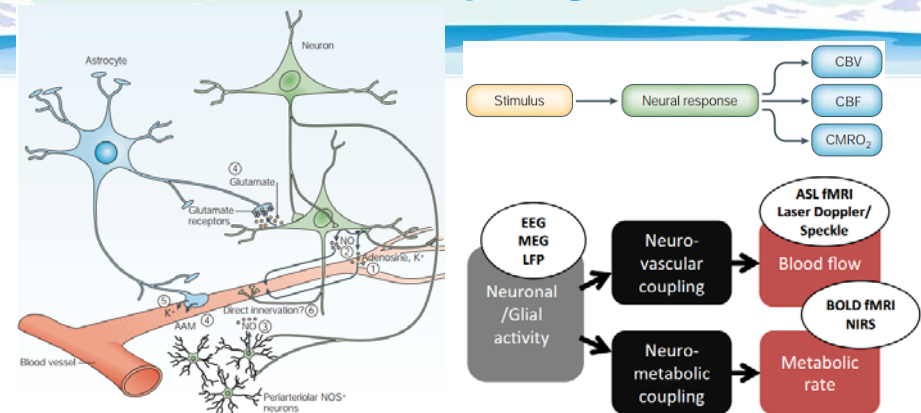
10:00~10:50 近紅外光腦血氧監測原理 Principles of fNIRS

Aspects of Neural Activity

- Synaptic transmission
 - Input to the neuron
 - Local field potential (LFP)
- Action potentials (spikes)
 - Output signals
 - Permit communications between neurons



Neurovascular Coupling

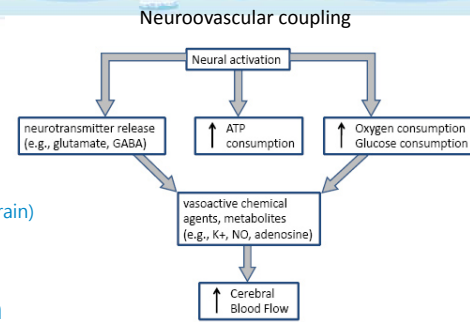


D'Esposito et al, Nature Reviews Neuroscience, 2003.

Huneau et al, Frontiers in Neuroscience, 2015.

Neurovascular Coupling

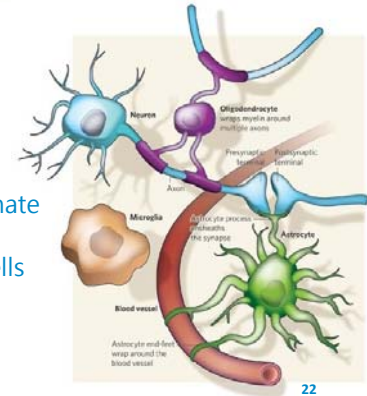
- ATP is essential for neural activity
 - Restoration of ionic gradients
 - neurotransmitter recycling
- Glycolysis
 - a small amount of ATP
- Oxidative glucose metabolism (90% in brain)
 - a large amount of ATP
- Cerebral metabolism depends on a constant supply glucose and oxygen



ATP: adenosine triphosphate

Neurovascular Coupling

- Requirement of metabolic nutrients
 - CO₂ and excessive heat
- Elimination of waste products
- Multiple mechanisms...
 - Astrocytes links neurotransmitter activity (glutamate cycling) to vascular responses.
 - Direct neuronal innervation of smooth muscle cells can also control blood flow (CBF).



Neurovascular Coupling

- A continuous supply of energy substrates is maintained by CBF
- Neural activity
 - Blood perfusion via capillaries ↑
 - regional cerebral blood flow (rCBF) ↑
 - regional cerebral blood oxygenation (rCBO) ↑
- Changes in rCBF or rCBO can be used to map brain activity
 - Functional neuroimaging

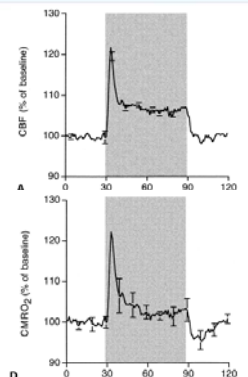
Brain vascular system: glucose and oxygen



Zlokovic & Apuzzo, 1998.

CBF and O₂ Consumption Mismatch

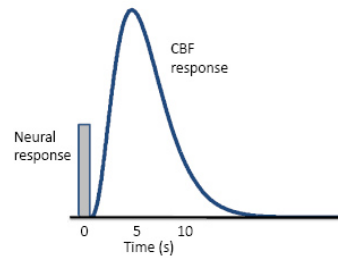
- During neural activity...
 - The fractional increases in CBF and glucose consumption are similar in magnitude.
 - Oxygen consumption increases much less than CBF.
- → A net increase of oxygen in the blood and tissue.



CMRO2: cerebral metabolic rate of oxygen
Ances et al., JCBFM 2001.

Coupling Properties: Time

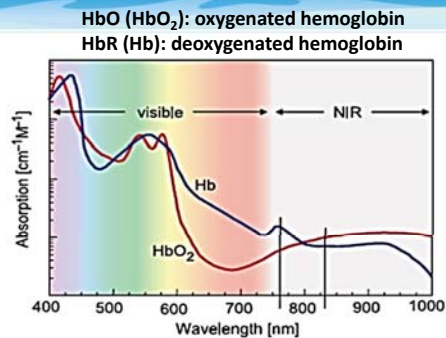
- CBF vs. neural activation
 - Delayed by 1 ~ 2 s
 - Peaks 4 ~ 6 s after the neural response
- Fast modulation of neural activity is unlikely to be reflected in the vascular response.
 - slow reaction of smooth muscle cells
 - slow diffusion and uptake of neurovascular mediators



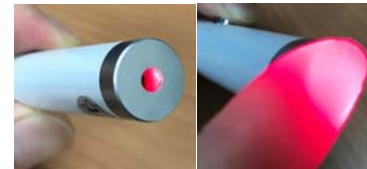
Coupling Properties: Space

- Spatial resolution of the vascular response
- Gray matter,
 - densest network of capillaries, intervessel distance of ~ 25 μm
- Vascular point spread function (PSF)
 - 1~5 mm
 - Depends on imaging conditions: monitoring tech., magnetic field, pulse sequence, species, and brain regions.

Tissue Migration and Absorption



lower absorption within Near-infrared wavelength.



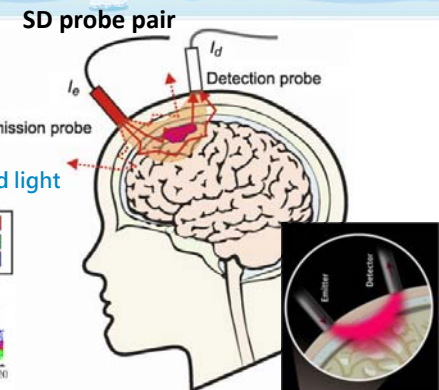
Near-infrared photons perform diffusive motion.

$$\mu_{780nm} = \epsilon_{HbO_2}(780nm) \times c_{HbO_2} + \epsilon_{Hb}(780nm) \times c_{Hb}$$


$$\mu_{820nm} = \epsilon_{HbO_2}(820nm) \times c_{HbO_2} + \epsilon_{Hb}(820nm) \times c_{Hb}$$

Photon Migration in Brain

- Modified Beer-Lambert Law
- $OD = \ln\left(\frac{I_e}{I_d}\right) \approx \mu_a \langle L_{head} \rangle + G$
 - $\mu_a \langle L_{head} \rangle$: assume the absorption in the head is homogeneous
 - $\langle L_{head} \rangle$: the mean optical path length of the detected light
 - G : the scattering loss



fNIRS Instruments

< portable/movable >			< wearable >
ISS instrument	Hitachi ETG-7100 system	DYNOT system	 <p>NIRSport</p>
NIRx NIRxCount			

fNIRS Instruments



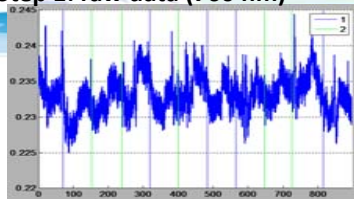
LED optical sources

Active optical sensors

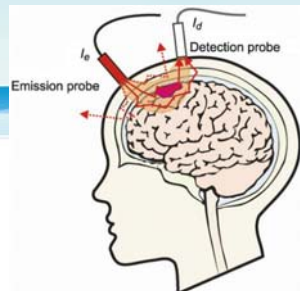
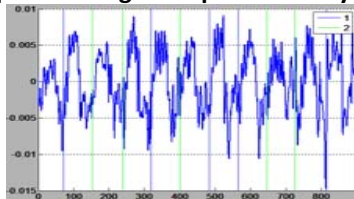
300g-weight only

fNIRS signal

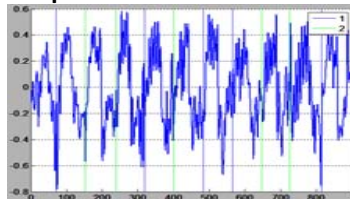
Step 1: raw data (760 nm)



Step 2: filtering and optical density



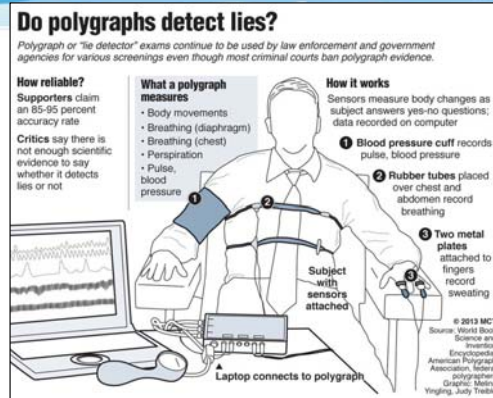
Step 3: relative HbO concentration



11:00~11:50
測謊應用實例
Applications in Lie Detection

Deception & polygraph

- Physiological changes
 - Respirations
 - Conduct electricity (EDA)
 - Cardio vascular activity
 - Occult body movements
- Complex neuronal activities
 - Deception center???



What's new ??

Research Report

BRAIN RESEARCH 1303 (2009) 120-130

Functional near-infrared spectroscopy to investigate hemodynamic responses to deception in the prefrontal cortex

Fenghua Tian^a, Vikrant Sharma^a, F. Andrew Kozel^b, Hanli Liu^{a,*}

J. Neural Eng. 9 (2012) 026012 (8pp)

doi:10.1088/1741-2560/9/2/026012

fNIRS-based online deception decoding

Xiao-Su Hu¹, Keum-Shik Hong^{1,2,4} and Shuzhi Sam Ge^{1,3}

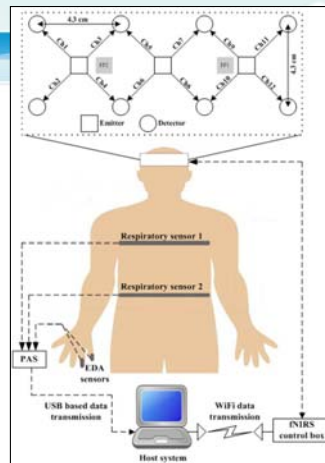
Front. Psychol. 6:709. 2015

Single-trial lie detection using a combined fNIRS-polygraph system

M. Raheel Bhutta¹, Melissa J. Hong², Yun-Hee Kim³ and Keum-Shik Hong^{1,4*}

fNIRS+ polygraph

- Isolate and measure the brain activities.
- Deception-related hemodynamic response



Mock theft scenario

- Subject is left alone in a room.
- Instructed to steal a watch or a ring.
- Taken to another room for questioning.
- The interrogator was unaware of the stolen thing.
- True/Lie questions.



Questions in protocol

"Neutral" Questions:

1. Do you like to swim?
2. Do you like to read?
3. Are you awake?
4. Are you asleep?
5. Are you under age 50?
6. Are you over age 18?

"Watch" Questions:

1. Did you take the watch from the drawer?
2. Is the watch in your locker?
3. Did you take the watch?
4. Did you steal the watch?
5. Was the watch stolen?
6. Did you hide the watch?

"Control" Questions:

1. Have you ever gossiped?
2. Have you ever done something illegal?
3. Have you ever done something immoral?
4. Have you used illegal drugs?
5. Have you ever deceived a loved one?
6. Have you ever made someone angry?

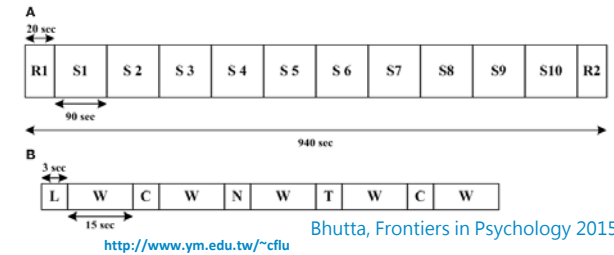
"Ring" Questions:

1. Did you take the ring from the drawer?
2. Is the ring in your locker?
3. Did you take the ring?
4. Did you steal the ring?
5. Was the ring stolen?
6. Did you hide the ring?

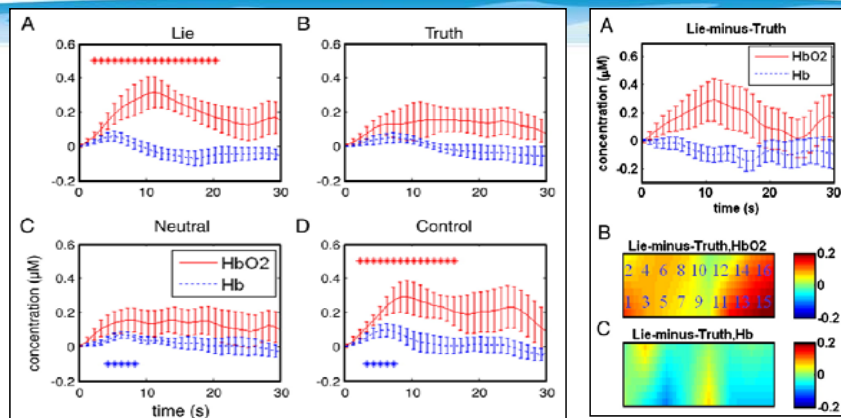
Experiment

- The subject was instructed clearly that he has to deny the possession of the stolen note and had to answer a lie for only the questions related to the stolen note.
- The neutral and control questions were asked just to keep the subject active.

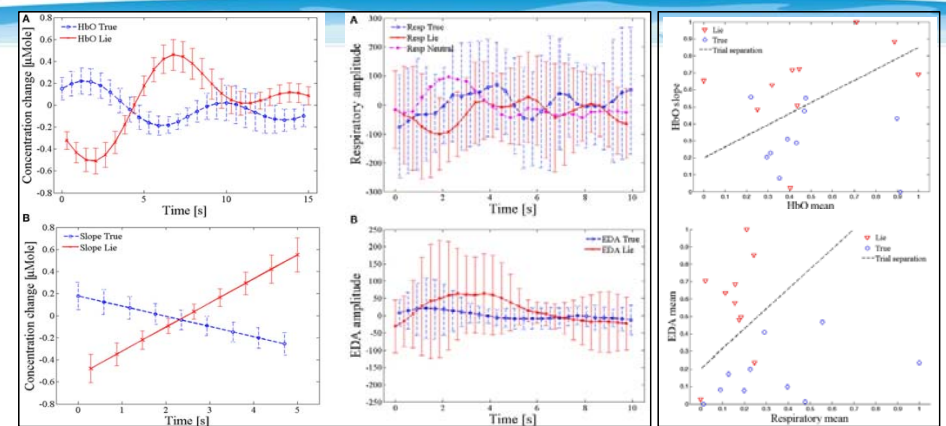
L: lie
W: wait
C: control
N: neutral
T: true



Results

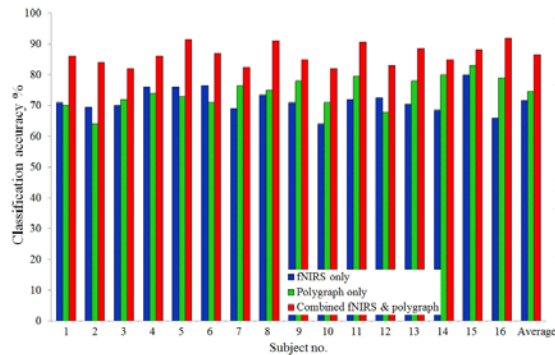


Results



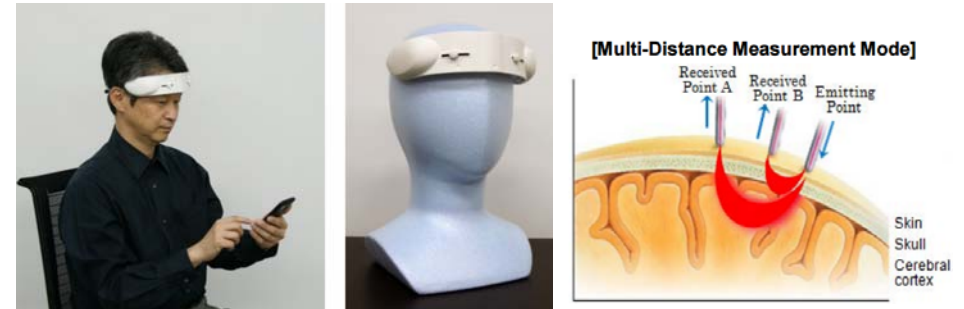
Conclusion

- The classification accuracy achieved by the combined system was much higher than those achieved by the single systems.



Future Lie Detection

Portable Brain Activity Measurement Device (Hitachi, 2014)



<http://www.hitachi-hightech.com/global/about/news/2014/nr20141126.html>

Future Lie Detection

- Real-life lie-detection !?



THE END