Prediction of Human Performance from Brain Signal under Different Indoor Temperatures- A Preliminary Study

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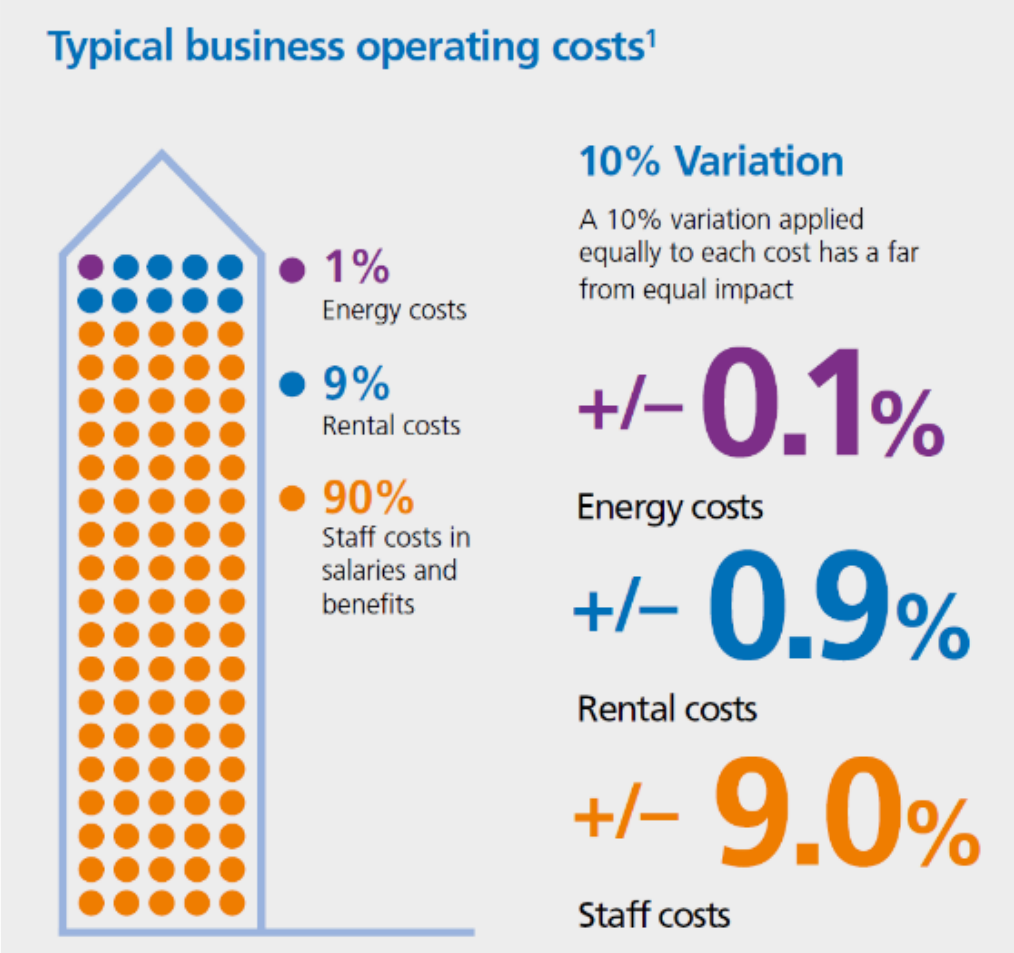
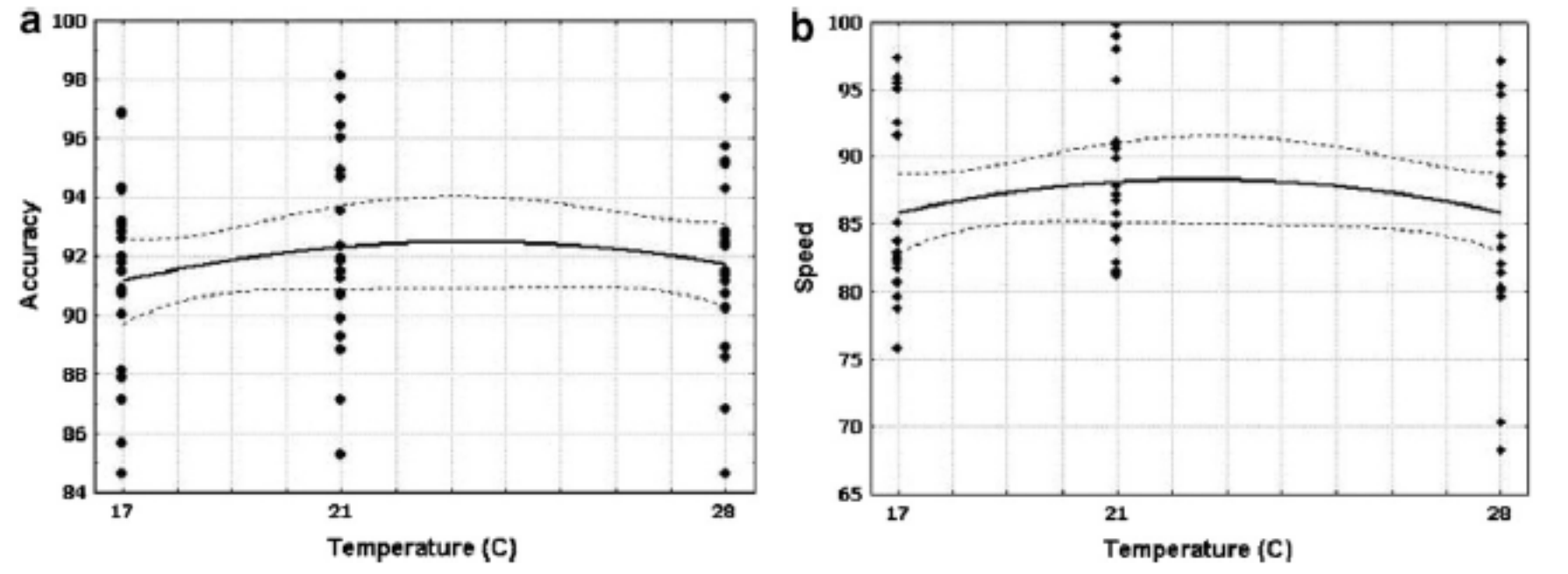
Motivation



Alker, J., Malanca, M., Pottage, C. and O'Brien, R., 2014. Health, Wellbeing & Productivity in Offices. The Next Chapter for Green Building.

Background

Better thermal comfort condition does not mean higher productivity



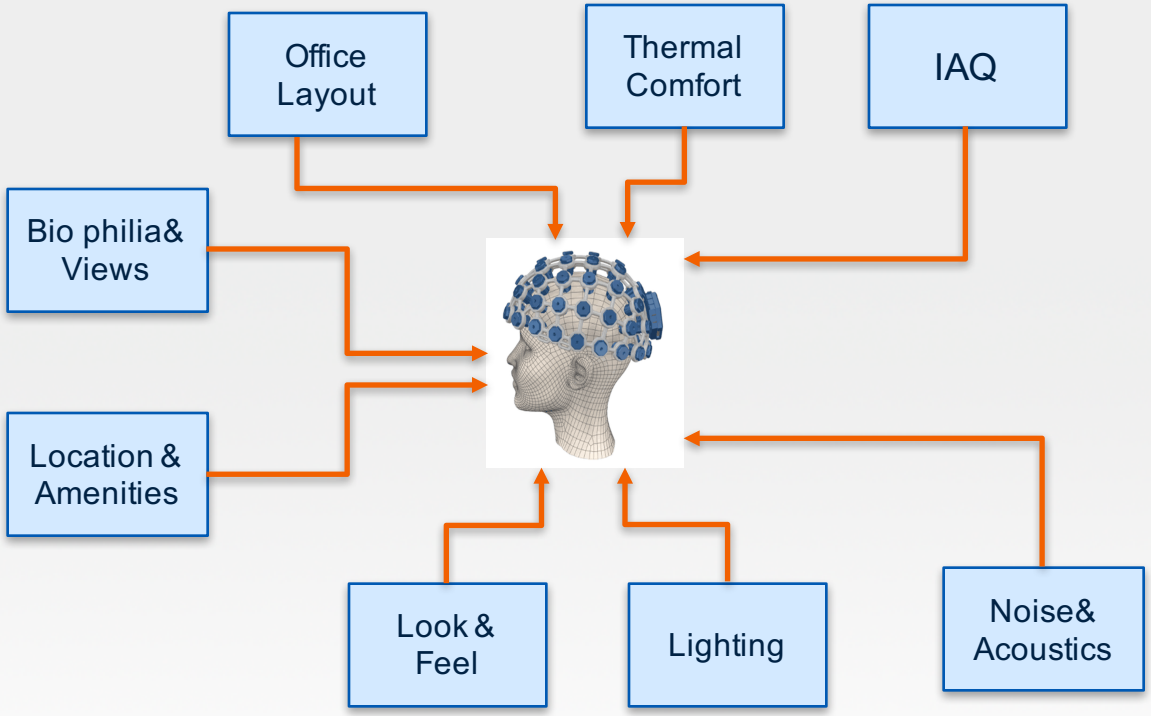
Lan, L., Lian, Z. and Pan, L., 2010. The effects of air temperature on office workers' well-being, workload and productivity-evaluated with subjective ratings. Applied ergonomics, 42(1), pp.29-36.

IEQ Factors and Productivity

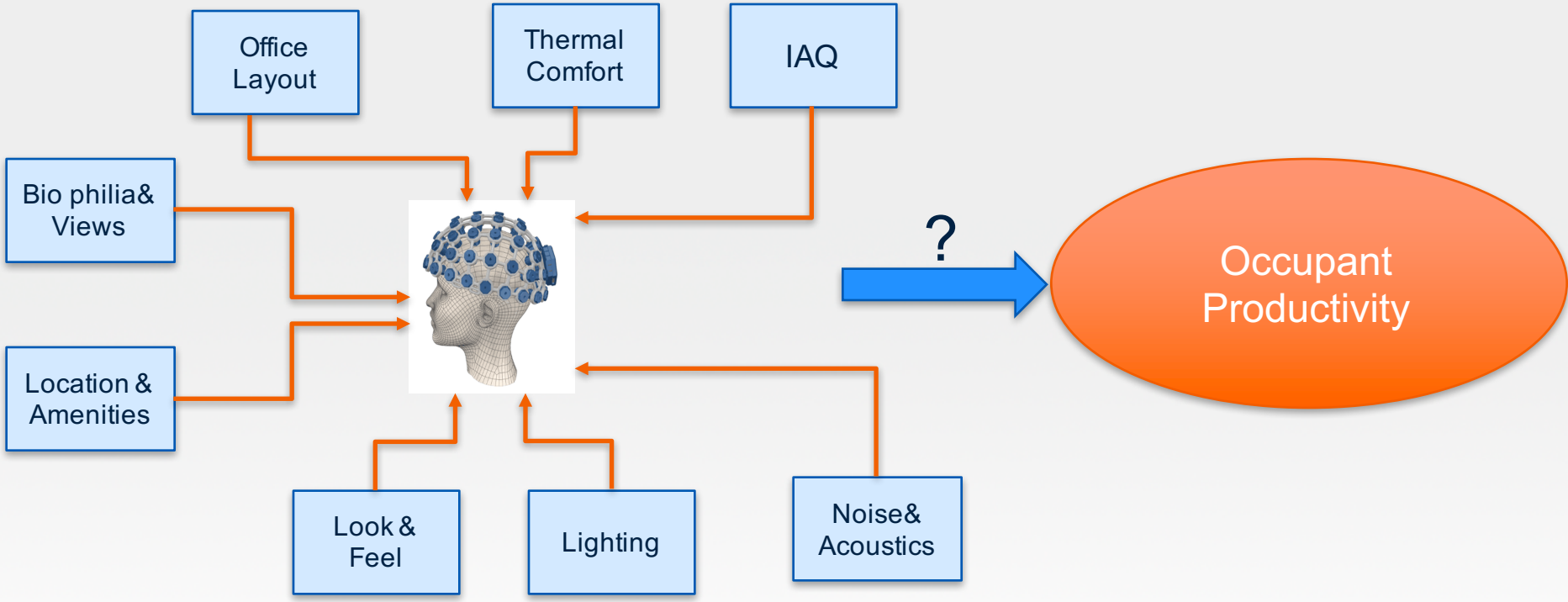
(based on >300 papers)

Al Horr, Y., Arif, M., Kaushik, A., Mazroei, A., Katafygiotou, M. and Elsarrag, E., 2016. Occupant productivity and office indoor environment quality: A review of the literature. *Building and Environment*, *105*, pp.369-389.

Question?


Office Layout
Thermal Comfort
IAQ
Bio philia& Views
Location & Amenities
Look & Feel
Lighting
Noise& Acoustics

Question?


Office Layout
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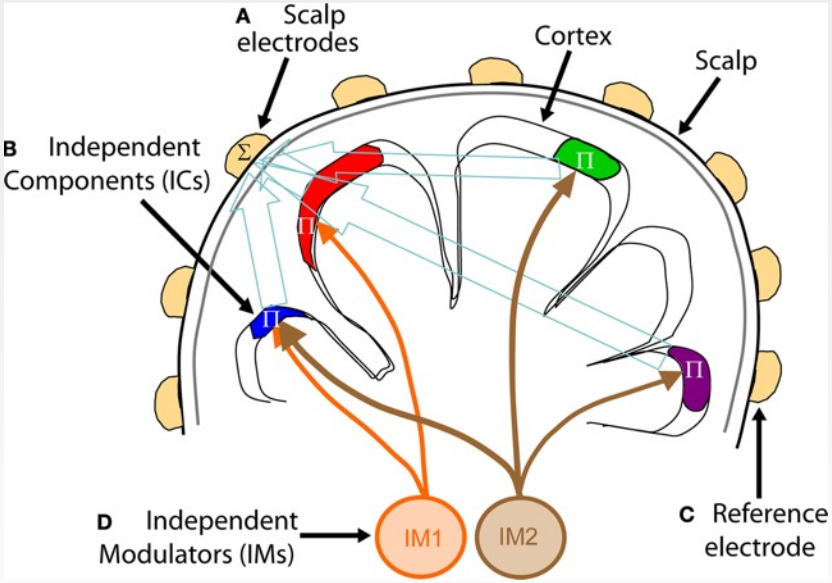
Noise& Acoustics
?
Occupant Productivity

What is EEG?

Electro**e**ncephalo**g**raphy (EEG): A non-invasive brain imaging technique measuring electrical signals from brain activities.

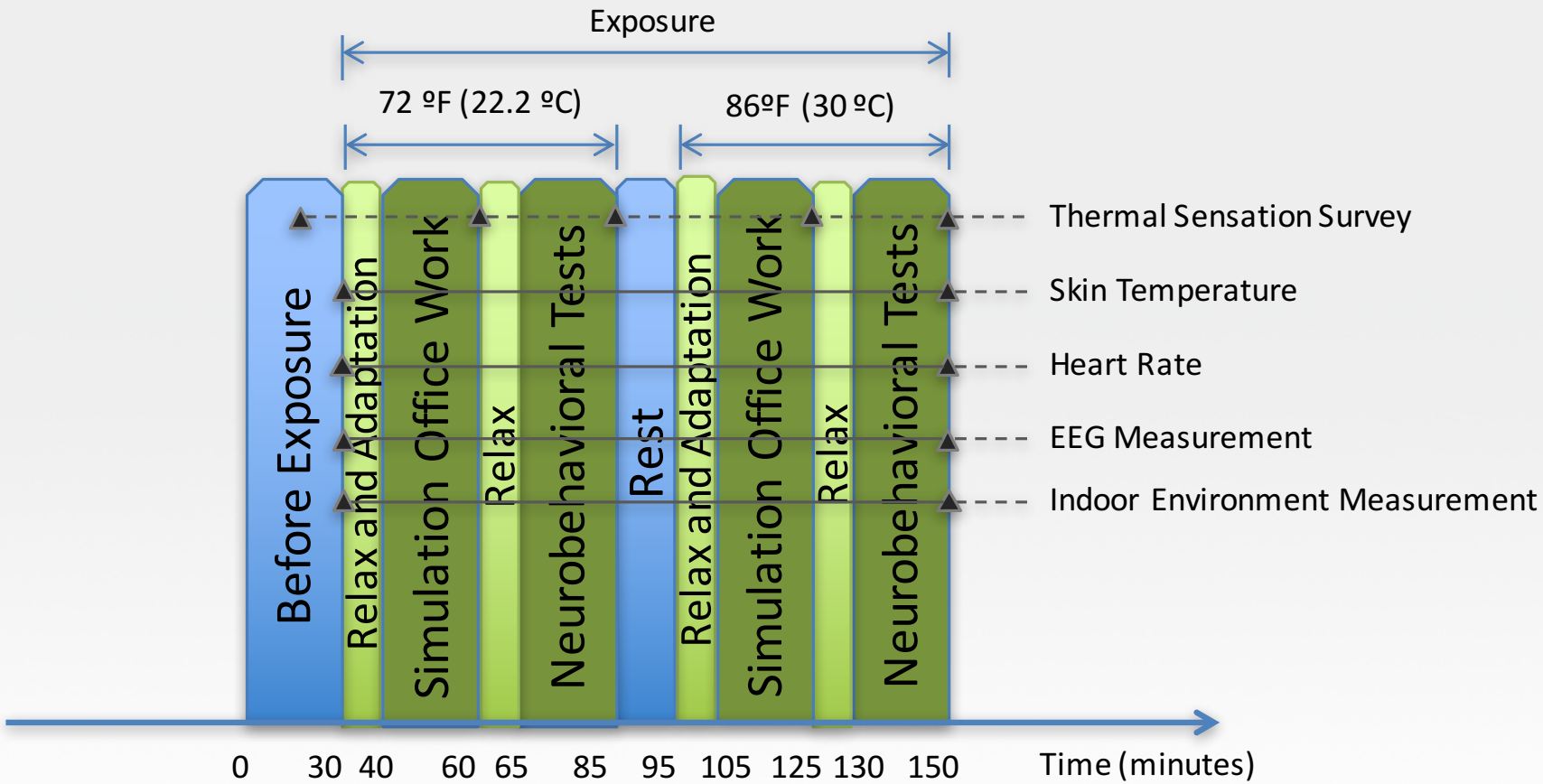


J. Onton and S. Makeig, *High-frequency broadband modulations of electroencephalographic spectra,* Frontier Human Neuroscience

EEG power spectral densities and its associations

Frequency Bands	Frequency Range (Hz)	Functionality
Delta	< 4	Deep dreamless sleep, non-REM sleep, unconscious
Theta	4 – 8	Intuitive, creative, imaginary dream
Alpha	8 – 13	Relaxed but not drowsy, tranquil, conscious
Beta	13 – 30	Active thinking, focus, alert, anxious
Gamma	30 – 100	Higher mental activity

Experimental Design



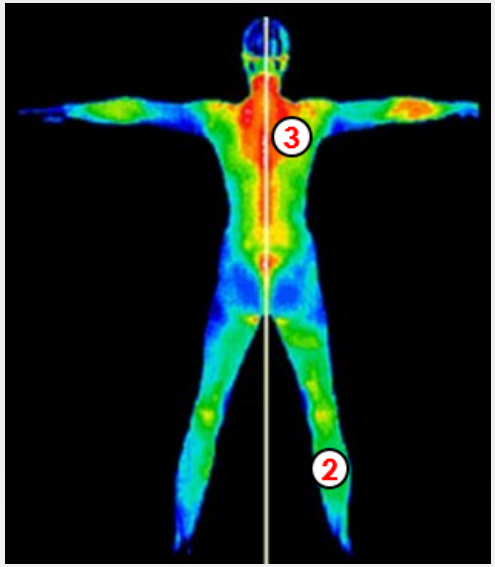
Experimental Subjects

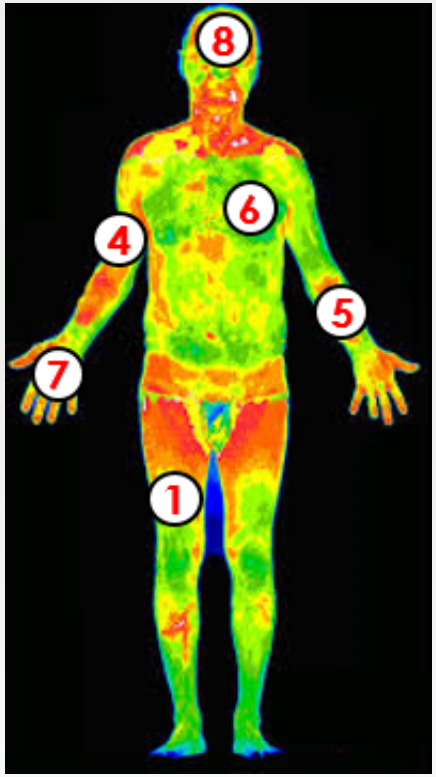
- 7 healthy participants (all male), aged between 25 – 30 years.

- All participants wear causal office attire on the recording day.

Experiment: Physiological Measurements

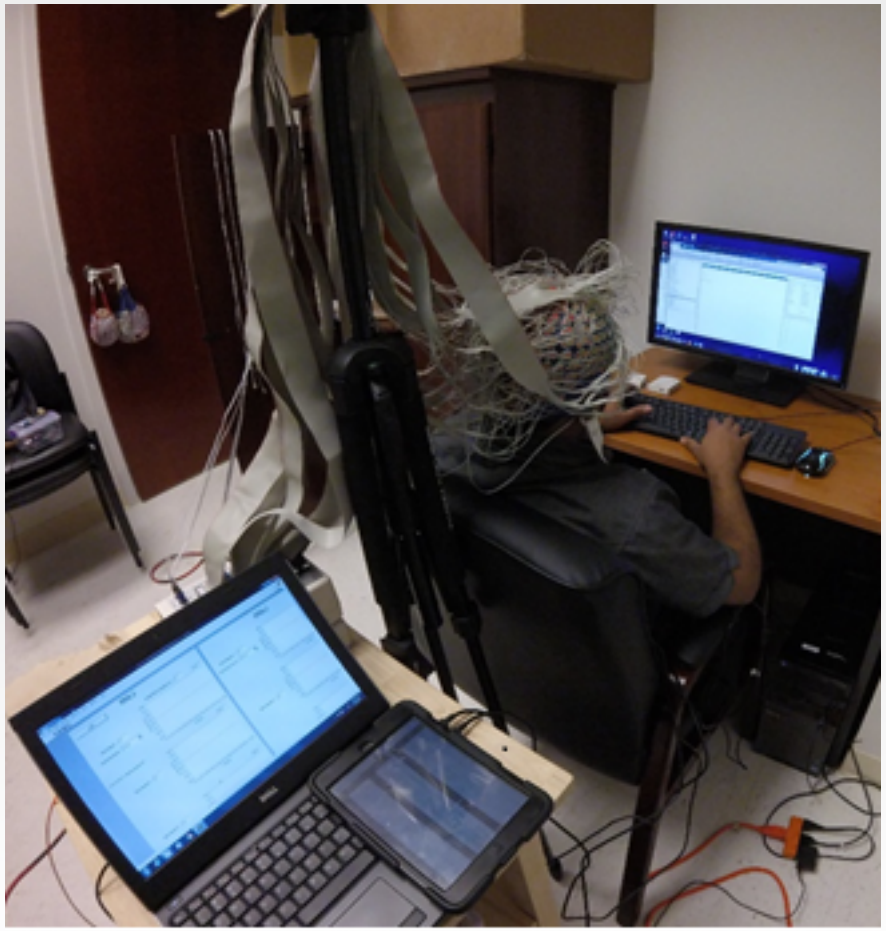
Heart Rate Sensor by POLAR H7 Smart Chest Transmitter.





Eight sensor locations to record skin temperature, according to ISO 9886

Experiment: EEG Measurement

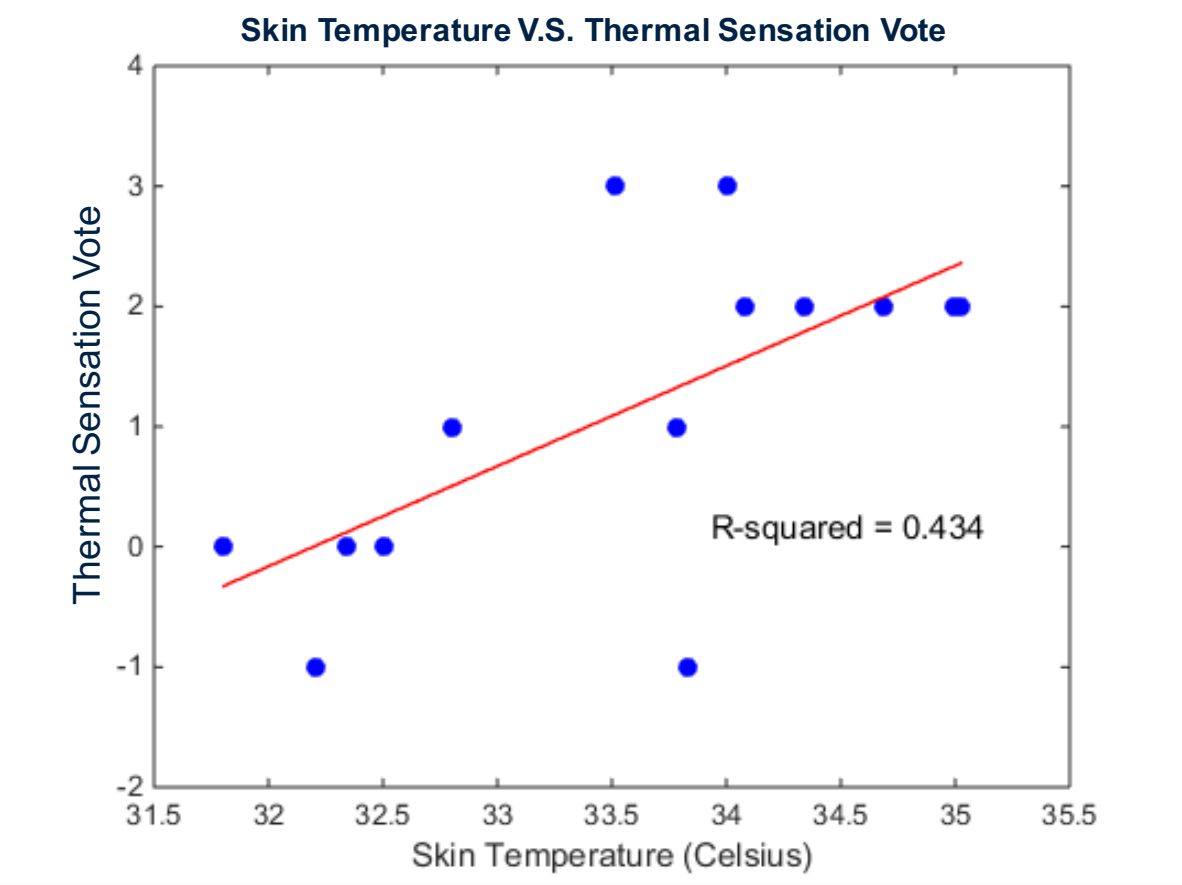


- EEG was measured using 256 channel BioSemi system at a sampling rate of 256 Hz.
- Room temperature, relative humidity, illuminance level were continuously monitored.

Types of Simulated Office Work

	Type of task	Performance Metrics	Duration of task
Office tasks	Additional Task	1. Reaction Time 2. Score/question	15 minutes
	Performance Index (PI) = Time taken to answer 20 questions correctly		
	Typing Task	1. Characters/sec 2. Number of times backspace key hit	15 minutes
	Net characters per minute (CPM) = Total number of key pressed – (Total cursor keys + 2 * Number of backspace keys pressed)		

Results Part I: Physiological Signals



Results Part I: Physiological Signals

R^2	Thermal Sensation	Thermal Comfort	Skin Temperature	Heart Rate
Typing Task	0.0775	0.105	0.0083	0.2378
Addition Task	0.00369	0.018	0.0127	0.0089

Conclusion:

- All these predictors showed a correlation (R^2) < 0.3
- Thus, these cannot be used as a reliable predictor for performance.

Results II: Room Temperature Impact Performance

Question: Does room temperature have an impact on office work performance?

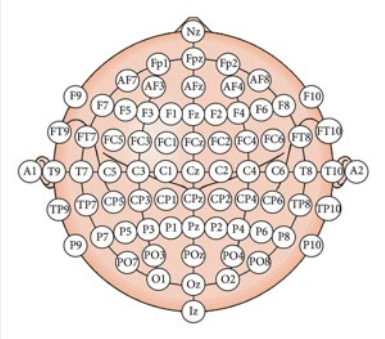
Method used: Kolmogorov – Smith (KS) test

Results:

Typing task: Five participants showed significant difference in performance.

Addition task: All participants showed significant difference in performance

P-values	KS-test	KS-test
	Typing	Addition
S01	0.0186	7.2741e-15
S03	0.1687	3.8359e-15
S04	0.0875	0.0051
S05	0.0076	3.7328e-11
S06	0.0420	1.2082e-18
S07	0.1687	6.4751e-11
S08	0.0420	0.0021

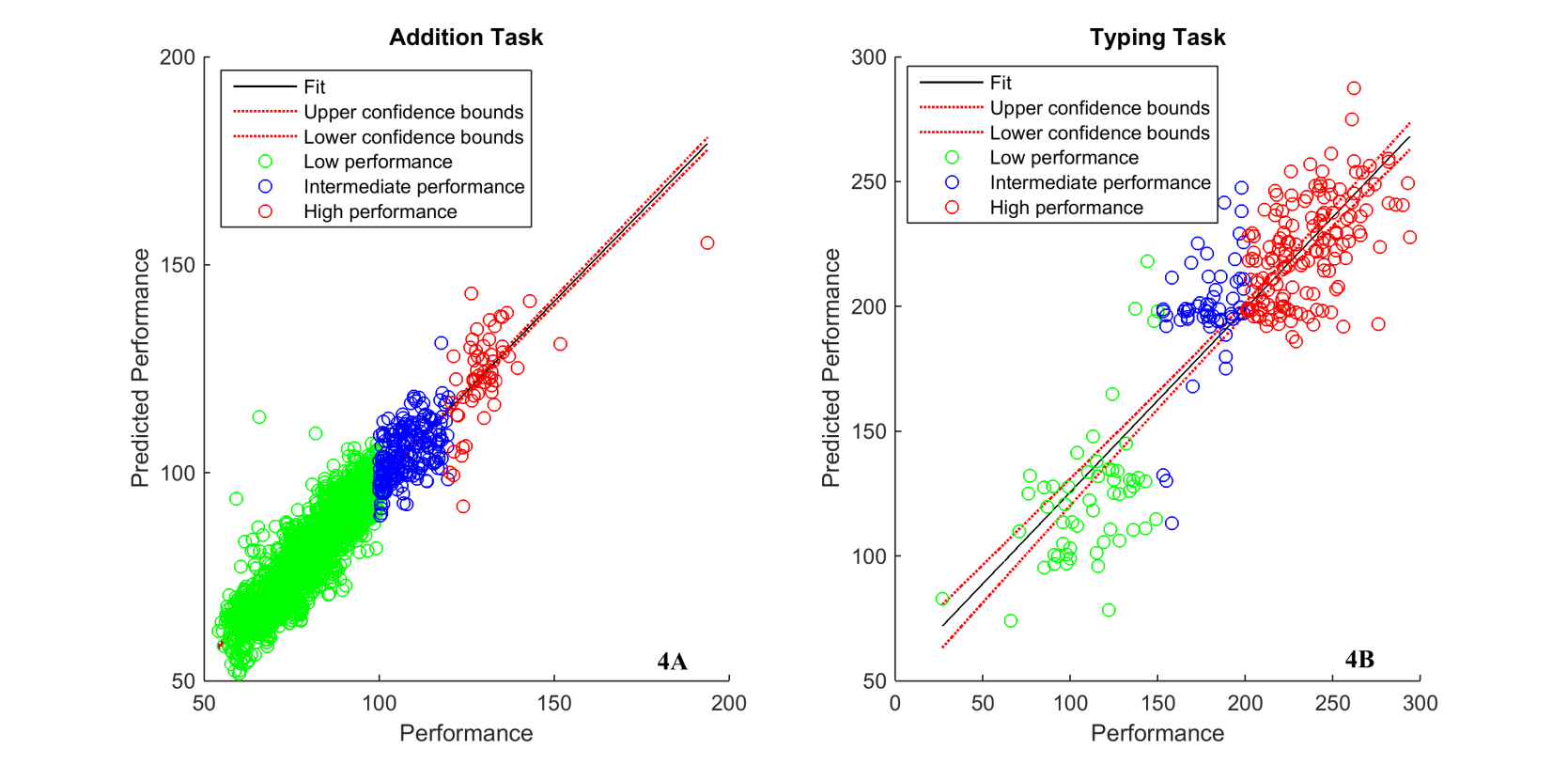


Results Part III: Brain Signals Predict Performance

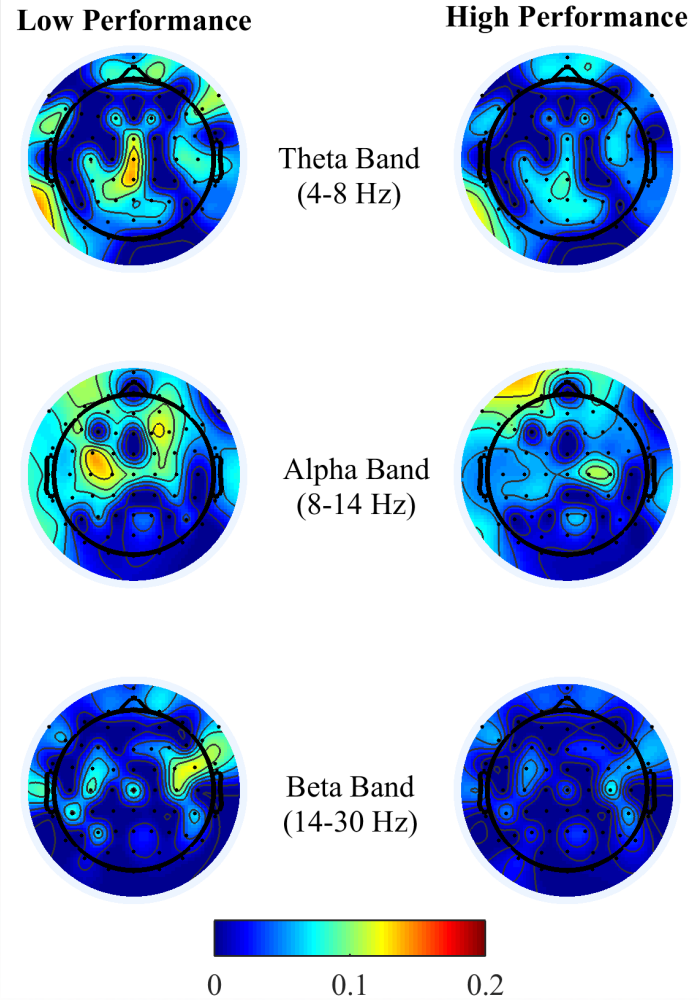
R^2	Theta Band (4-8 Hz)	Alpha Band (8-14 Hz)	Beta Band (14-30 Hz)	Combined Bands
Addition Task	0.647	0.798	0.66	0.789
(# non-zero coefficients)	(#64)	(#51)	(#62)	(#58)
Typing Task	0.743	0.802	0.736	0.743
(# non-zero coefficients)	(#37)	(#38)	(#33)	(#35)

Table 5: R^2 obtained between actual and estimated performance for office tasks using LASSO regression and the number of non-zero coefficients in the fitted LASSO model.

Results Part III: Brain Signals Predict Performance

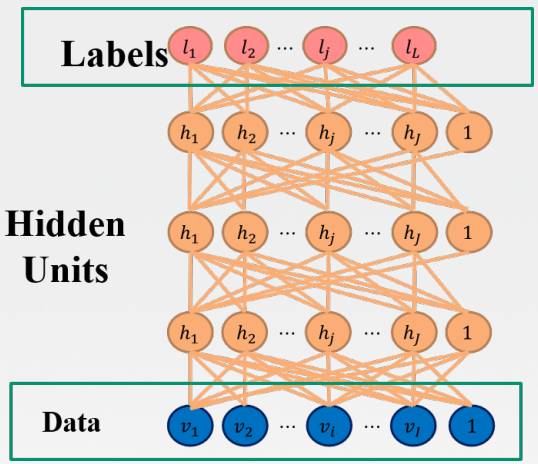


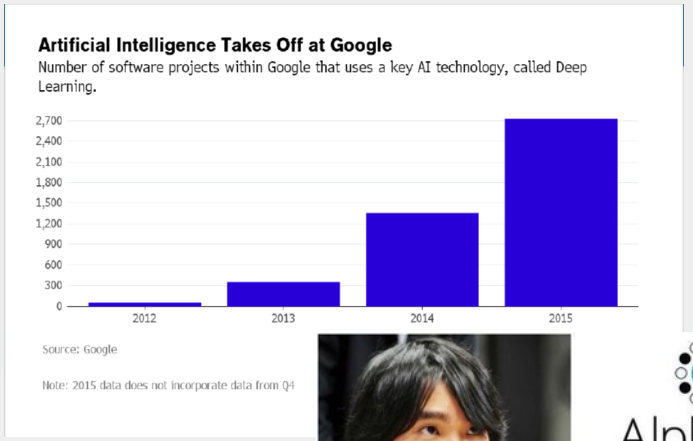
Results Part III: EEG V.S. Typing Task

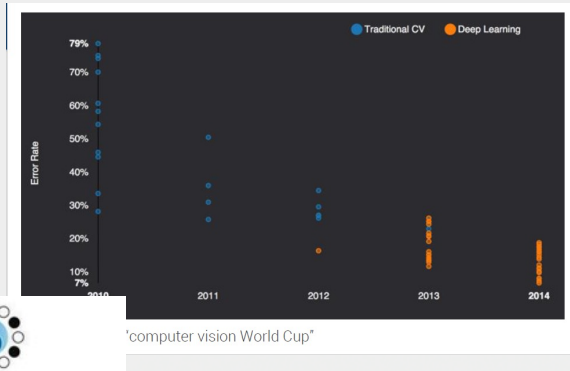


- Low performance: CPM < 100
- High performance: CPM > 150 sec
- High power was observed in all brain bands during low performance, corresponding to different brain locations.
  - Low alpha: focus and concentrate
  - Increase in theta : fatigue

Deep Learning for Real-Time EEG Data Analysis



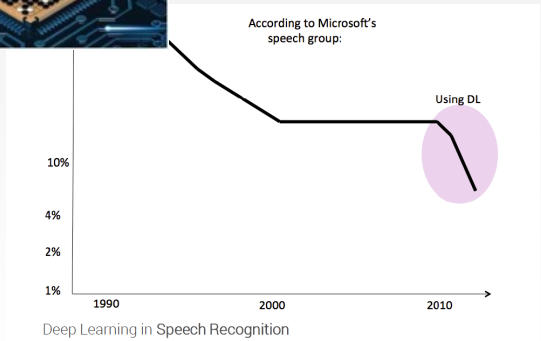




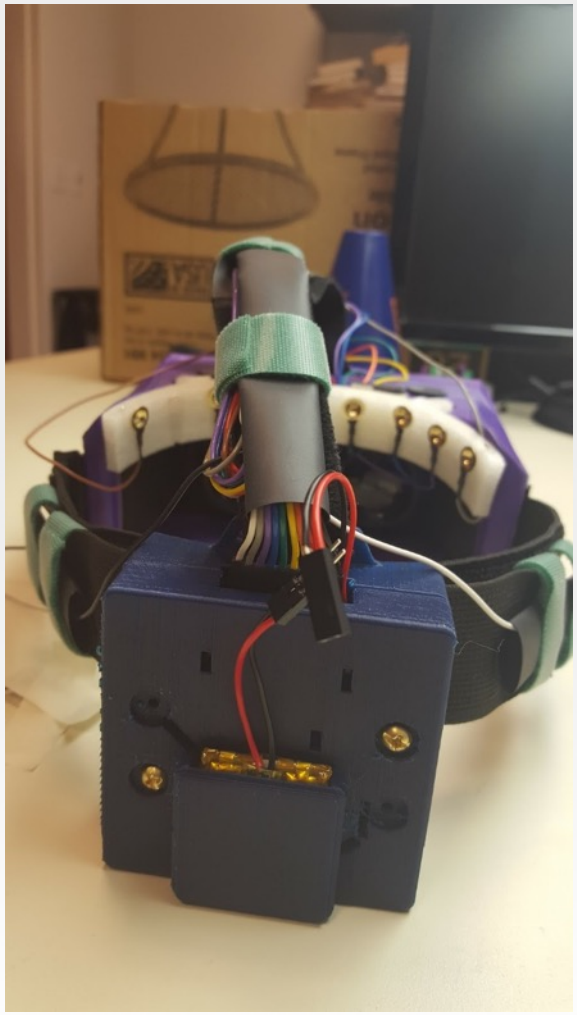
MIT Technology Review

Robotics

Baidu's Deep-Learning System Rivals People at Speech Recognition



Human Performance in a VR Environment-Demo



The (Merge)VR headset integrated with EEG

- Sensors in forehead (prefrontal lobe)
- Sensors in motor and visual cortex to be installed
- BCI and VR ready
- Low cost

Human Performance in a VR Environment-Demo

- A simulated journey in a park
- Park environment changes (flower blooming, bird chirping, tree growing …) according to mental states
- A concentration session and a relaxation session
- Points awarded based on ability to change the environment

Acknowledgement

- Army Research Laboratory under Cooperative Agreement Number W911NF-10-2-0022.
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  - Xiaojing Xu, Daniel Pack
- Umea University:
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Thank You