Smart City Intelligent Sensing: Productivity and Wellbeing

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Motivation

- The **interplay of mobile and cloud computing** enables innovative processes that bring about activities and services that were previously thought impractical or impossible for lightweight devices.
- A powerful example is how **Apple's SIRI**
  - supports speech interactions and provide wisdom to answer everyday questions based on the Web knowledge and crowd-sourced information, such as "would the weather be suitable for my planned activities tomorrow?" and "which nearby favorite restaurants serve my friends' favorite meals and not so busy at this time?"
- **Microsoft HoloLens** will bring this type of natural interface to the next level, via wearable device that can augment the information directly to the objects that people see, which also means that people can look at information without losing awareness of its surrounding.

The Internet of Things (IoT)

- The Internet of Things (IoT) is a system of **interrelated** computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
- IoT has evolved from the **convergence** of wireless technologies, micro-electromechanical systems (MEMS), micro service and the Internet.
- The convergence has helped **tear down the silo walls** between operational technology (OT) and information technology (IT), allowing unstructured machine-generated data to be analyzed for insights.

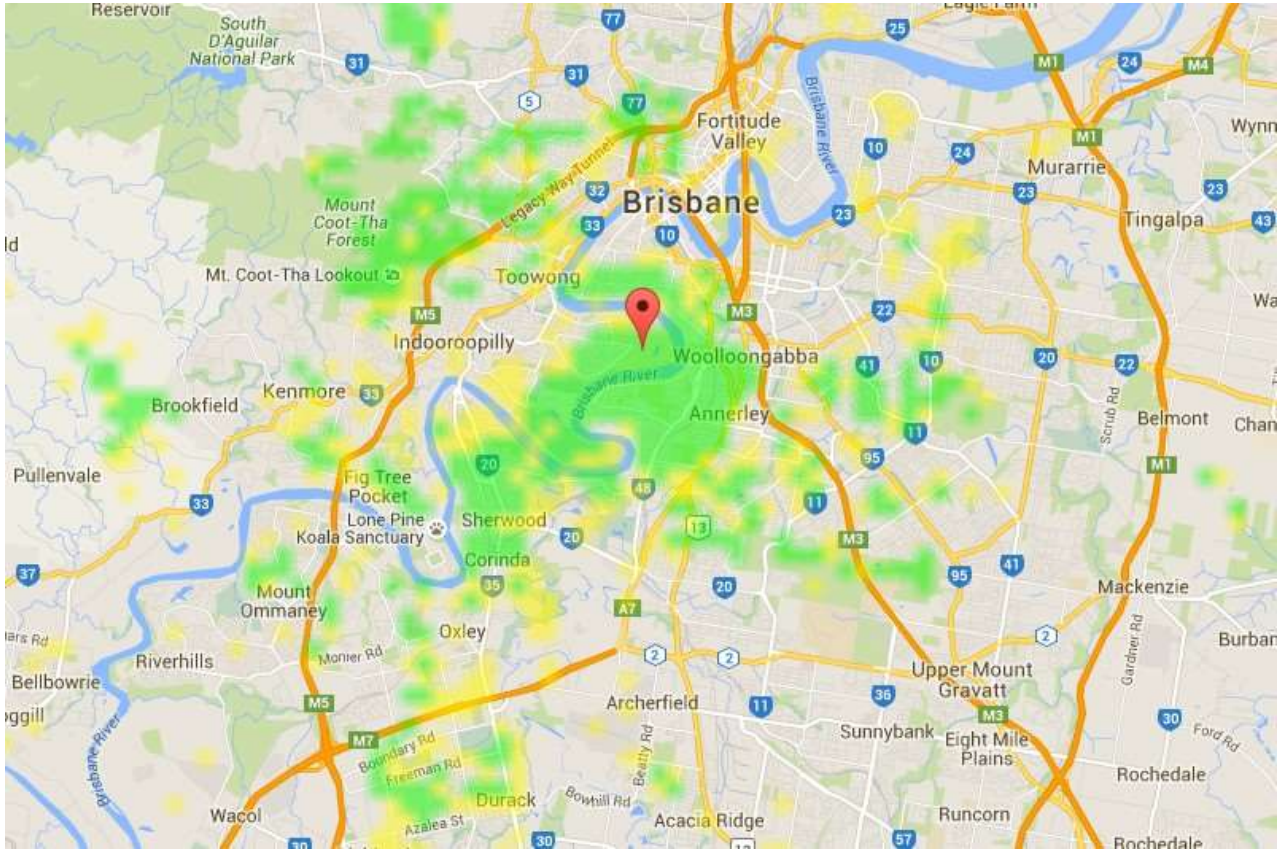
City-wide IoT Community Network

- Vision: to build an infrastructure for a public (open) access innovation platform where users can connect their “things” to the internet for free.
  - Empower people (residents, students, researchers, community groups & businesses) to monitor and track the “things” that are most important to them and sharing data easily using open standards technology.
- The Integrated sensors (and sensors network) in Brisbane city and surroundings will:
  - enable new transdisciplinary research initiatives,
  - trigger new industry and community collaborations,
  - enrich our teaching capabilities.
- The Institute for Future Environment (IFE) has multi-site research facilities including:
  - Connecting sensor data from these facilities will provide new opportunities for analysing and visualising a city-wide environment health, boosting IFE’s unique capacity to lead cutting-edge IoT enabled research initiatives.

LoRa WAN

- Designed to support low power (battery operated/solar power), long range (distances greater than 15km can be achieved with good conditions. 5km may be more realistic in large cities and less than 2km in dense urban areas.
  - The network uses the Industrial Scientific & Medical (ISM) wireless spectrum radio frequency 915 MHz band and LoRaWAN data rates range from 0.3 kbps to 50 kbps.
- A global open standard that is fast becoming the most prevalent IoT LPWAN solution given its bi- directional communication, security, reliability, flexibility and coverage attributes.
  - Effective remote monitoring and asset management solution for smart grids, smart metering, water AMR and smart farming.
- The technology is endorsed by the global LoRa-Alliance (lora-alliance.org) which has the support of the world's largest IoT device OEMs and systems integrators
  - robust, secure and scalable features and "no lock in contracts" business model.

City-wide Coverage



Initial Case Studies

- Low-bridges strike prevention (sensor to warn drivers in real-time, in conjunction a mobile the app – mainly used for the accident prone bridges)
- Real time flood level, wildlife movement strategy/ management
- School zone detection, temporary traffic management signs (on/off the e.g. signs for speed)
- Real time traveler information: volume of traffic, queue lengths (nano-modelling), sources of the traffic
- Cyclists/runners/aged care living exposure to air quality (respiratory illness or allergies)
- Users adopt city property (e.g. and help out the council to look after the assets
- Smart dynamic lights and video surveillance for environmental and safety monitoring
- Sharing economy: e.g. activity-based workspace design and productivity, bike shares
- Crowd-powered real-time public transports and on the road tracking (e.g. train is too full)

Top 3 Transformational Trends enabled by IoT

1. The Rise of Personalized, Autonomous, and Crowd-sourced Business and Services
2. The prominence of Big Data analysis, visualization, and machine learning for making sense of the interconnected things in the world
3. A Stronger Sense of Community to Face Future Challenges

Goal: Data-Driven Personalised Health

- **Ongoing recording** to understand the person's lifestyle
  - Diagnose, Prevent, Manage
- **Recommend** solutions based on the individual's profile, contexts & evidence
  - QoL-state, rules
- **Monitor and evaluate** the person's actions
  - Exercise, healthy diet, social

Image from Herox.com

What can the Cloud do with Data?

What can the Patients do with Data?

- Patients with chronic disease have **greater demand** to obtain basic information regarding their health status and difficult in finding consultation time with practitioners *(Triantafyllidis, Koutkias, Chouvarda, & Maglaveras, 2013)*
- Patients become **frustrated** with detailing their interactions with clinicians, tracking unaddressed health issues, maintaining a running list of questions and concerns *(Pratt et al., 2006)*
- Patients may have **difficulties to recall** their condition and situation when consulting with their health practitioners *(Patel, Klasnja, Hartzler, Unruh, & Pratt, 2012)*
- Patients' **lack of knowledge** about what they should track and how to track *(Patel, Klasnja, Hartzler, Unruh, & Pratt, 2012)*

- Patients can become **overwhelmed** by available information (Pratt et al., 2006)

Personal Health Management

"Putting the person in the centre of their own health and our healthcare system"

Access

- ✓Timely, relatable & actionable health info
- ✓Multi-channel communications
- ✓Choice

Partnerships

- ✓Participatory medicine
- ✓Trust and respect
- ✓Public-private

Personal Responsibility

- ✓Empowerment /self efficacy
- ✓Care giver networks (family, friends)
- ✓Community & volunteerism

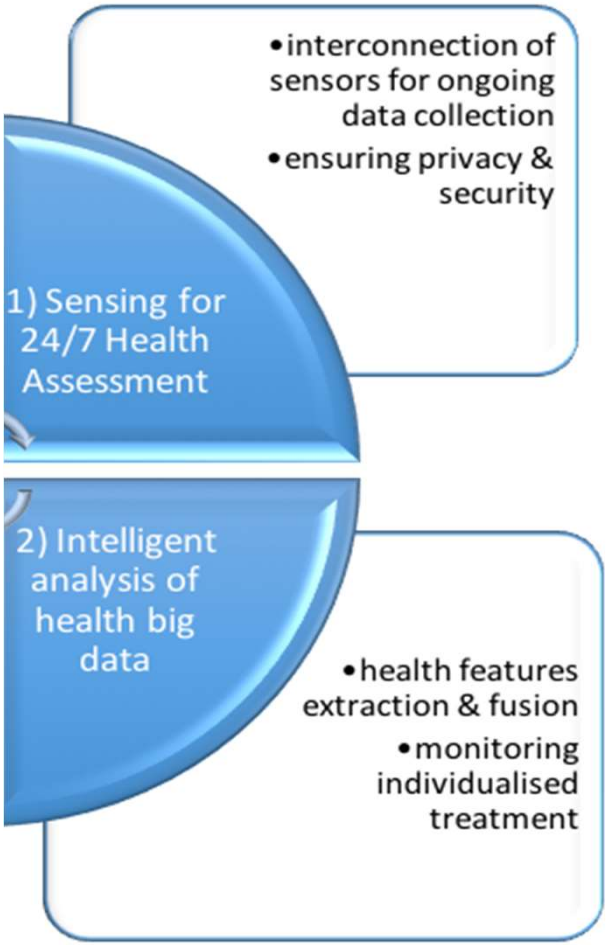
MoH Singapore Personal Health Management Strategy 2011

Overview

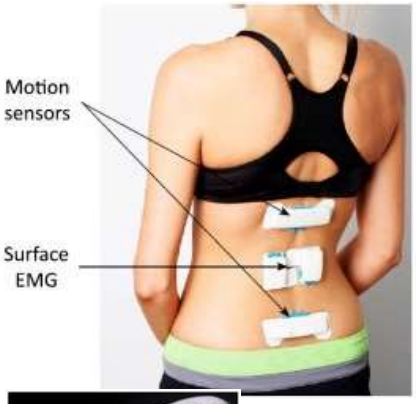
1. **Pervasive Analytical Framework** for sensing health and wellness
   - Interdisciplinary challenges of data-driven multimedia computing for quantifying wellness states

2. **Integrated System** for personalized and collaborative wellness promotion program
   - Emphasizes on individual's perceived control, planned behaviour, self-efficacy, and social (peer) supports.
   - Professional health service platform that actually work for each individual.

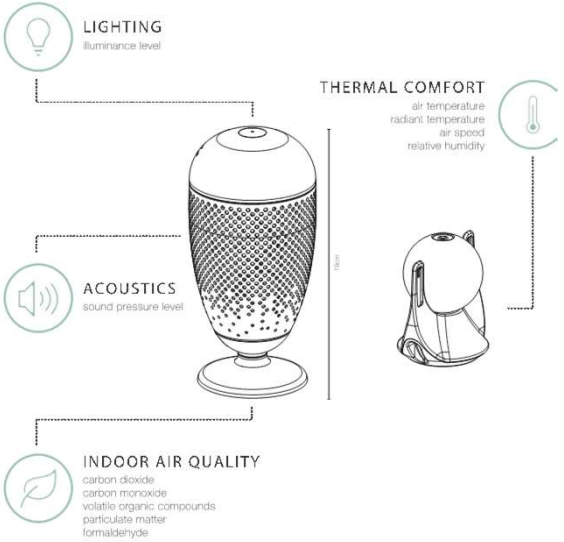
Pervasive Analytical Framework

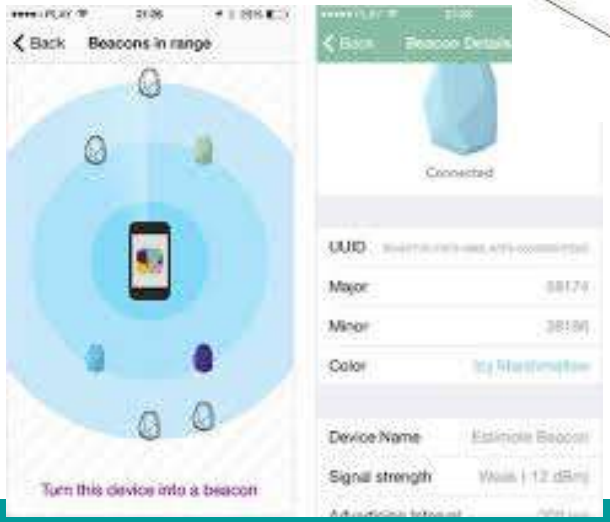


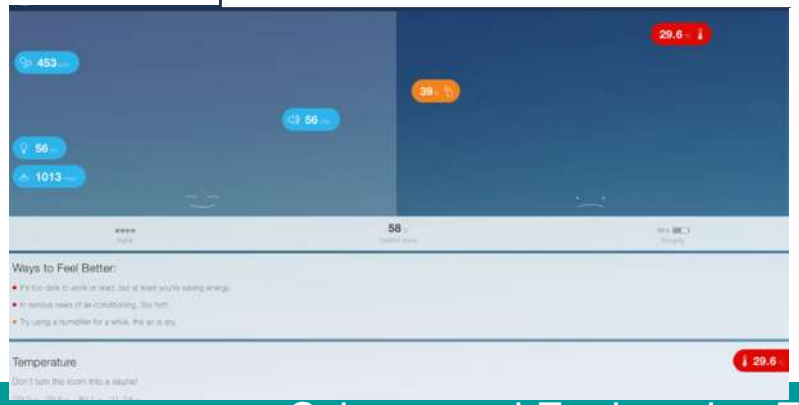
Mobile & Wearable Sensors



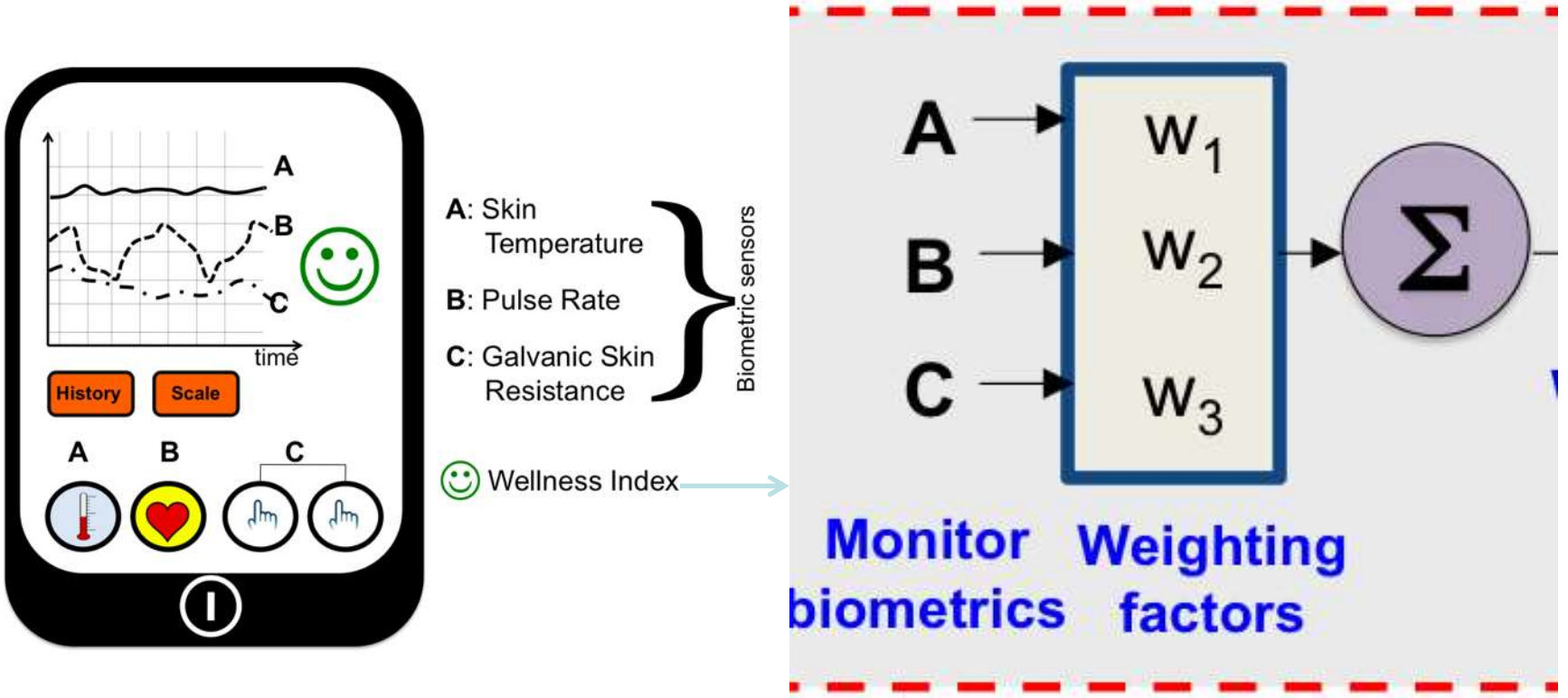
Ambient Sensors







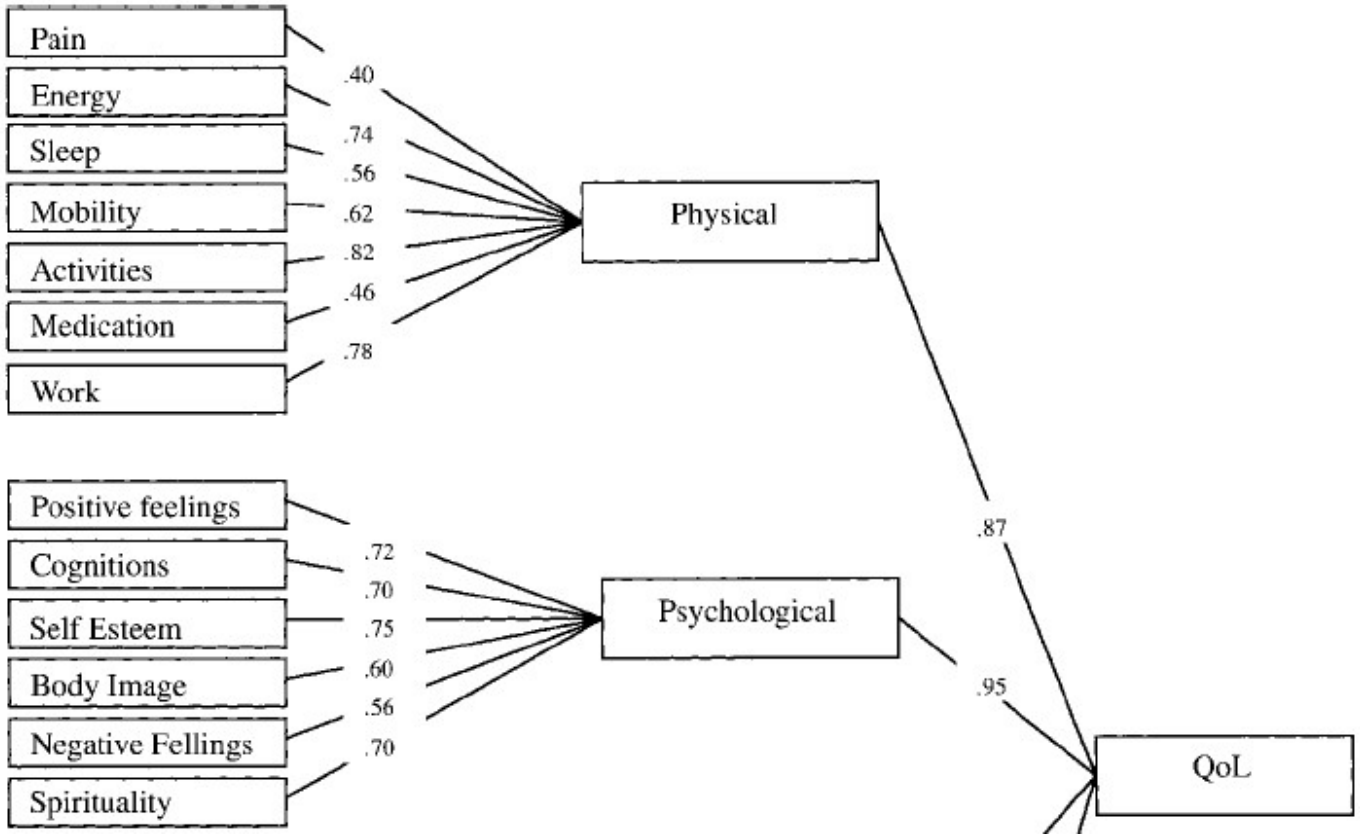
Sensors Aggregation: Wellness Index Quantification



A. Kailas, C.-C. Chong, and F. Watanabe, "From Mobile Phones to Personal Wellness Dashboards," *IEEE Pulse*, vol. 1, no. 1, pp. 57–63, Jul. 2010.

WHO QoL: 4-domain factor model

Skevington, S. M., Lotfy, M., & O'Connell, K. A. (2004). The World Health Organization's WHOQOL-BREF quality of life assessment: psychometric properties and results of the international field trial. A report from the WHOQOL group. Quality of Life Research, 13(2), 299–310.



Quantification of Physical Activity

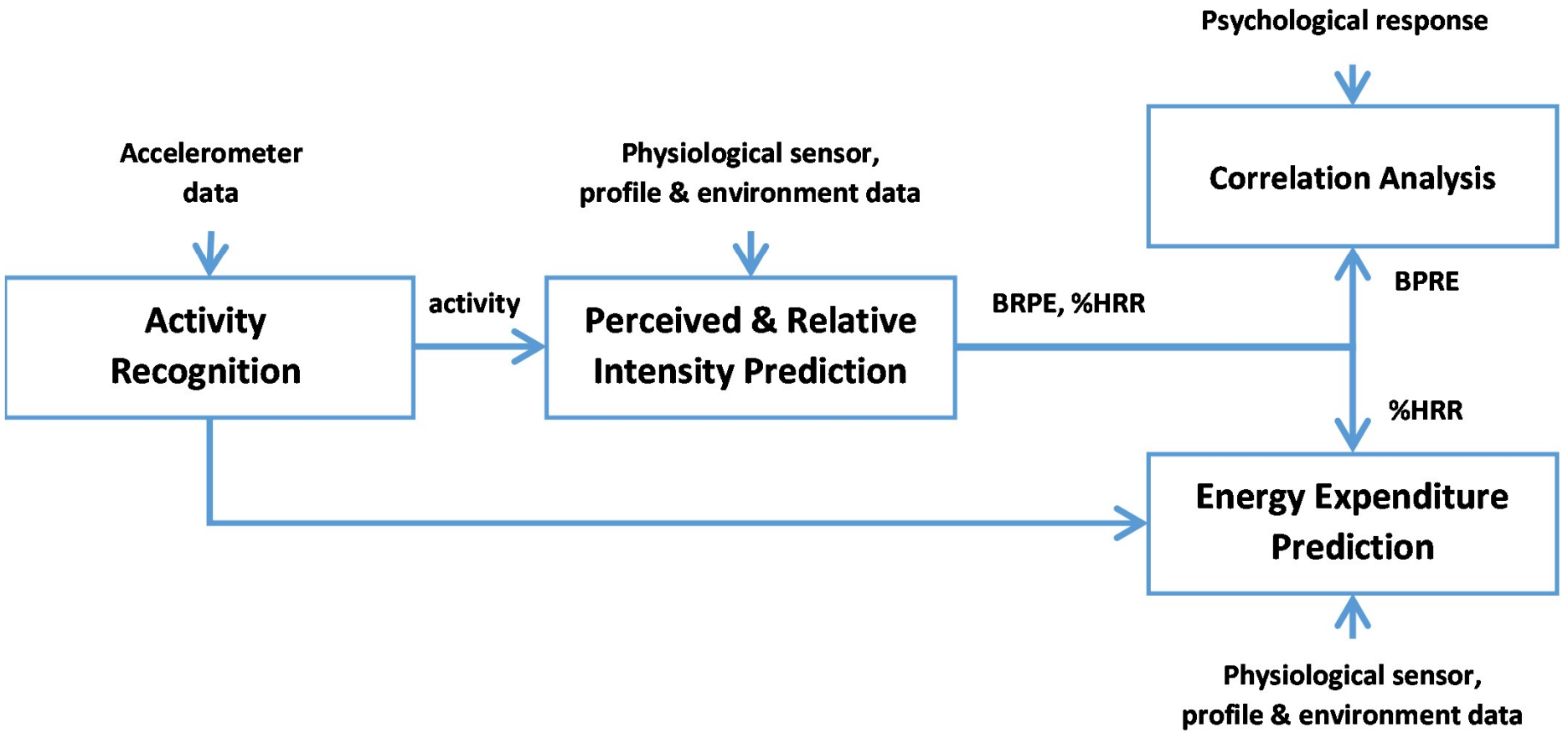
Chowdhury, Tjondronegoro, Chandran, Trost

Are you doing physical activities in an effective way?	
1	Are you doing physical activities in right intensity?
2	Are you be able to expend desired amount of energy when performing physical activities?
3	Do you know which intensity or activities can increase your mood?

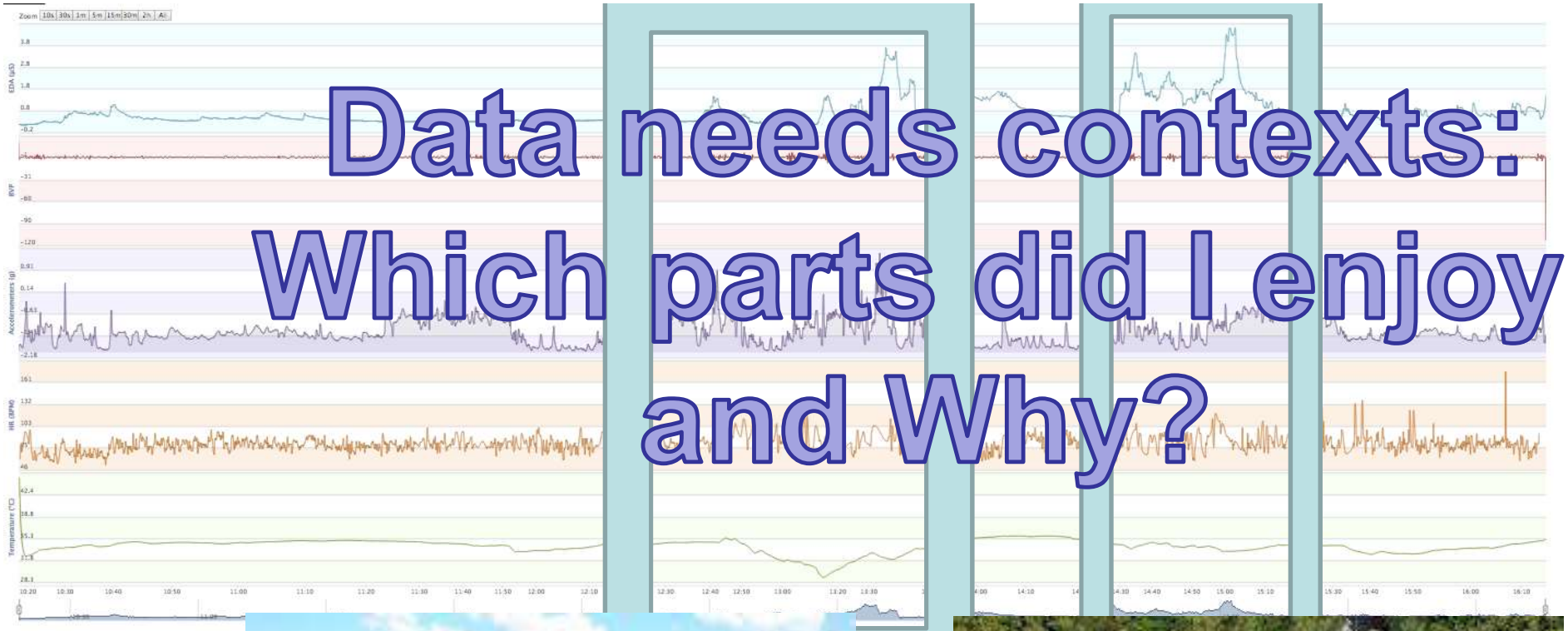
RESEARCH PROBLEMS

- Gold standards are expensive, lab based and not real-time!
- Inexpensive methods (wearable) are mostly inaccurate, still requires interpretation to complex raw data!
- Need for methods to estimate energy expenditure during physical activity reliably!

Framework


Psychological response
Correlation Analysis
Accelerometer data
Physiological sensor, profile & environment data
Activity Recognition
activity
Perceived & Relative Intensity Prediction
BRPE, %HRR
BPRE
%HRR
Energy Expenditure Prediction
Physiological sensor, profile & environment data

Data needs contexts: Which parts did I enjoy and Why?



Journal:
I had a **grea** tain (C
Coast).
It started wi
12:30 pm w nch, a
second wal

Quantification of Mood

Rastgoo, Nakisa, Chakraborty, Tjondronegoro, Chandran, Zhang

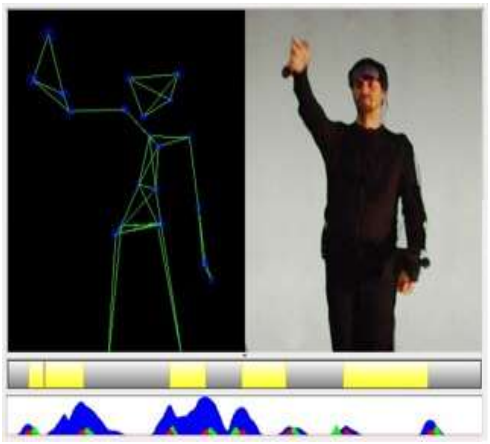
Reference	Emotions
(Paul Ekman and Oster 1979)	fear, sadness, happiness, anger, disgust, and surprise
(Arnold 1960)	Anger, Aversion, courage, dejection, desire, despair, fear, hate, hope, love, sadness
(Panksepp 1982)	Expectancy, rage, fear, panic
(S. Tomkins 1963; S. S. Tomkins 1962)	surprise, interest, joy, rage, fear, disgust, shame, and anguish.
(Johnson-Laird and Oatley 1989)	happiness, sadness, fear, anger, and disgust
(Frijda 1986)	Desire, happiness, interest, surprise, wonder, sorrow
(Gray 1985)	Rage and Terror, anxiety, joy
(Izard 1977)	Anger, Contempt, disgust, distress, fear, guilt, interest, joy, shame, surprise
(James 1884)	Fear, grief, love, rage
(McDougall 2003)	Anger, Disgust, elation, Fear
(Oatley and Johnson-Laird 1987)	Anger, disgust, anxiety, happiness, sadness
(Weiner and Graham 1984)	Sadness , happiness
(Mowrer 1960)	Pain, pleasure
(Watson and others 1925)	Fear, love, rage

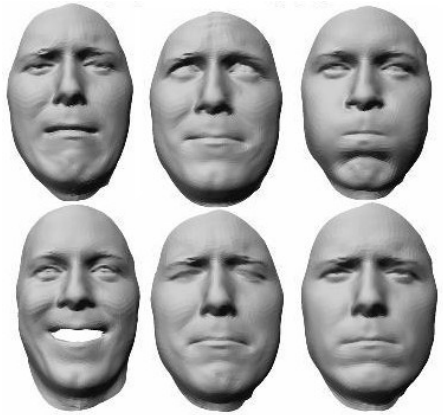
How can we quantify mood reliably and non-invasively?

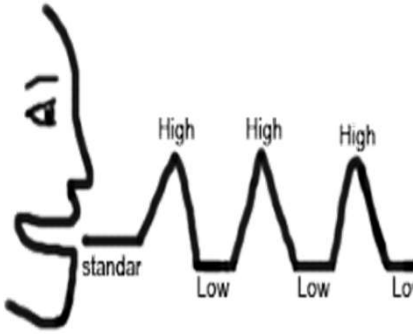
1	Which theory of emotion can be used to map with the signals?
2	How to extract useful features from multimodal emotion signals?
3	Which features are most reliable and how to fuse them?

Recognising Emotion: Explicit Cues

- Facial expression (e.g. Ekman and Friesen (1978), Nikolaou et.al (2011))
- Body gesture (e.g. Coulson (2004), Van Den Stock, et.al. (2007))
- Speech (e.g.Healey (2000))

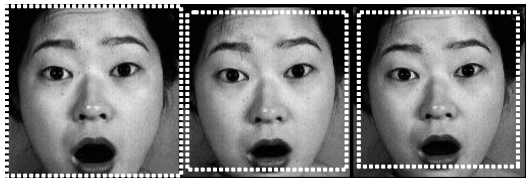




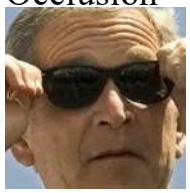


Facial Expression Recognition

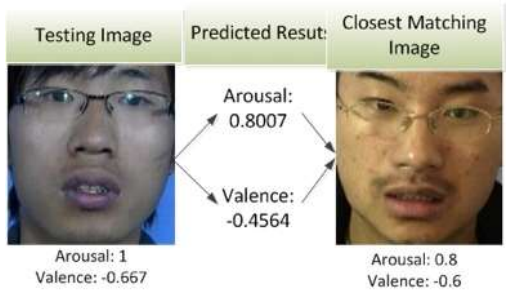
Face Location Error

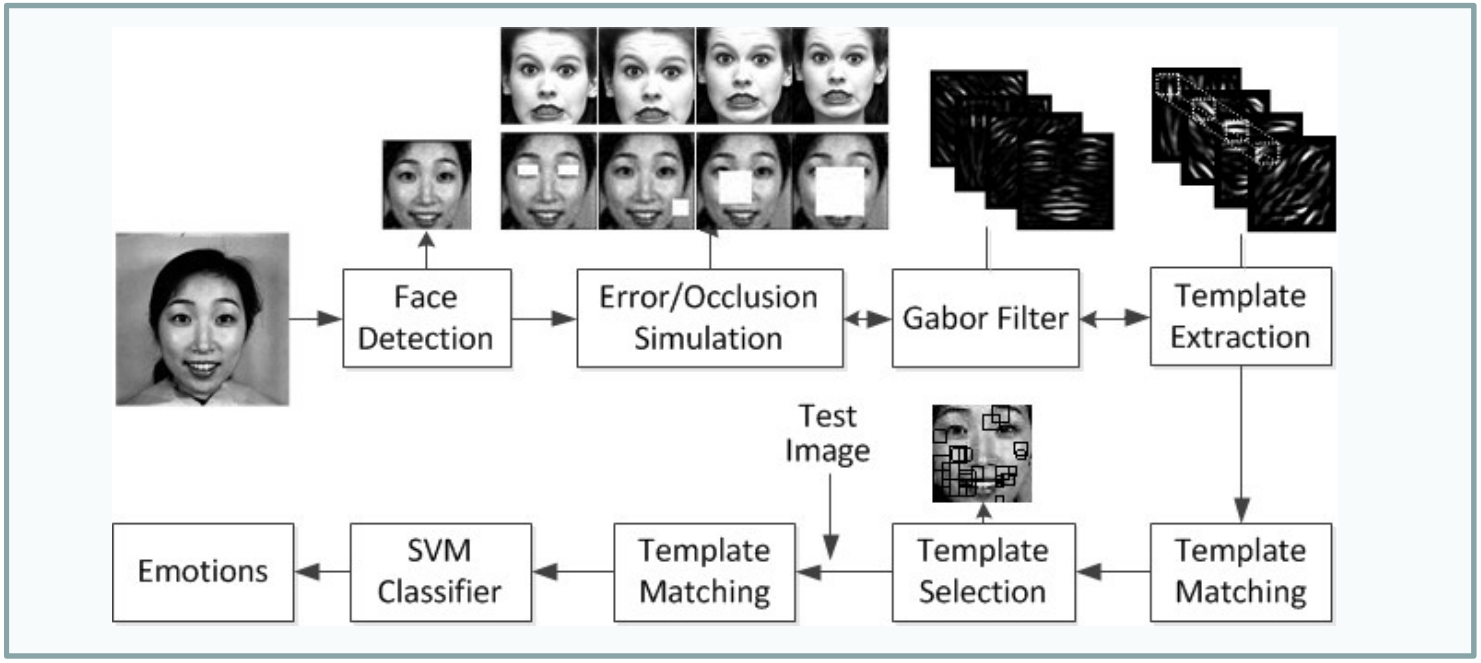


Occlusion



Posed vs. Spontaneous



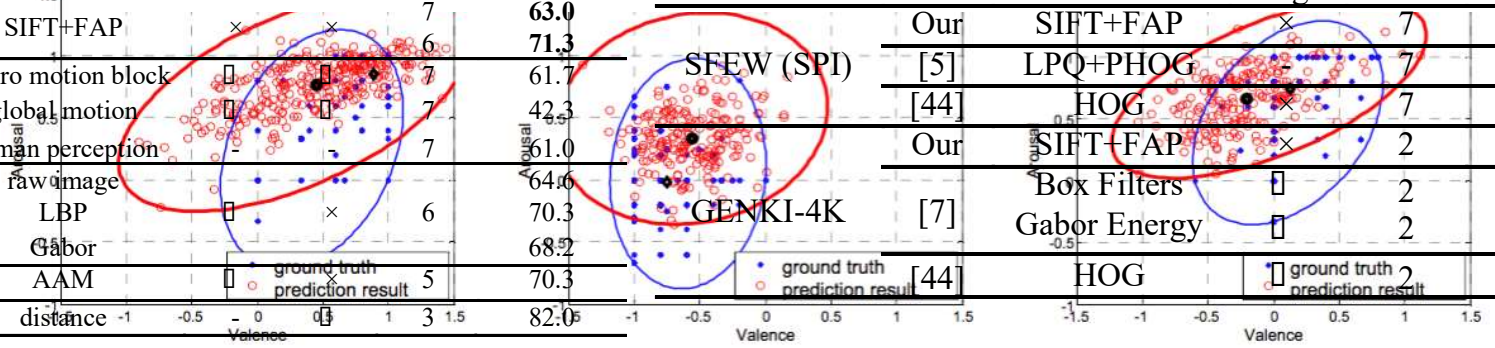


State of the Art Results

Database	Source	Emotion	Subject	Data size
luggage lost [9]	airport	humor, sadness, anger, stress and indifferences	109	209 video
Belfast [10]	TV	activation and evaluation	125	298 video
Yeasin et al. [3]	TV	six basic emotions	N/A	108 video
VAM [11]	TV	valence, activation and dominance	104	1421 video/1,872 images
HUMAINE [1]	TV	emotion words, intensity, activation and valence etc.	48	48 video
SFEW [5]	TV	six basic emotions and neutral	N/A	700 images
AFEW [4]	TV	six basic emotions and neutral	330	1426 video
HAPPEI [6]	Flickr	Happiness (six stages)	N/A	4,600 images
GENKI [7]	Web	smile	N/A	4,000 images
Gv [8]	Web	six basic emotions and neutral	328	350 images
QUT (this work)	**TV/web**	**six basic emotions, neutral, positive and negative**	**219**	**458 video/2,927 images**

Ref.	Feature	Reg.	Temp	Num	Accuracy
Our	SIFT+FAP	×	×	7	**63.0**
				6	**71.3**
[38]	macro motion block	□	□	7	61.7
	global motion	□	□	7	42.3
	human perception	-	-	7	61.0
[39]	raw image				64.6
	LBP	□	×	6	70.3
	Gabor				68.2
[39]	AAM	□	×	5	70.3
[41]	distance	□	□	3	82.0

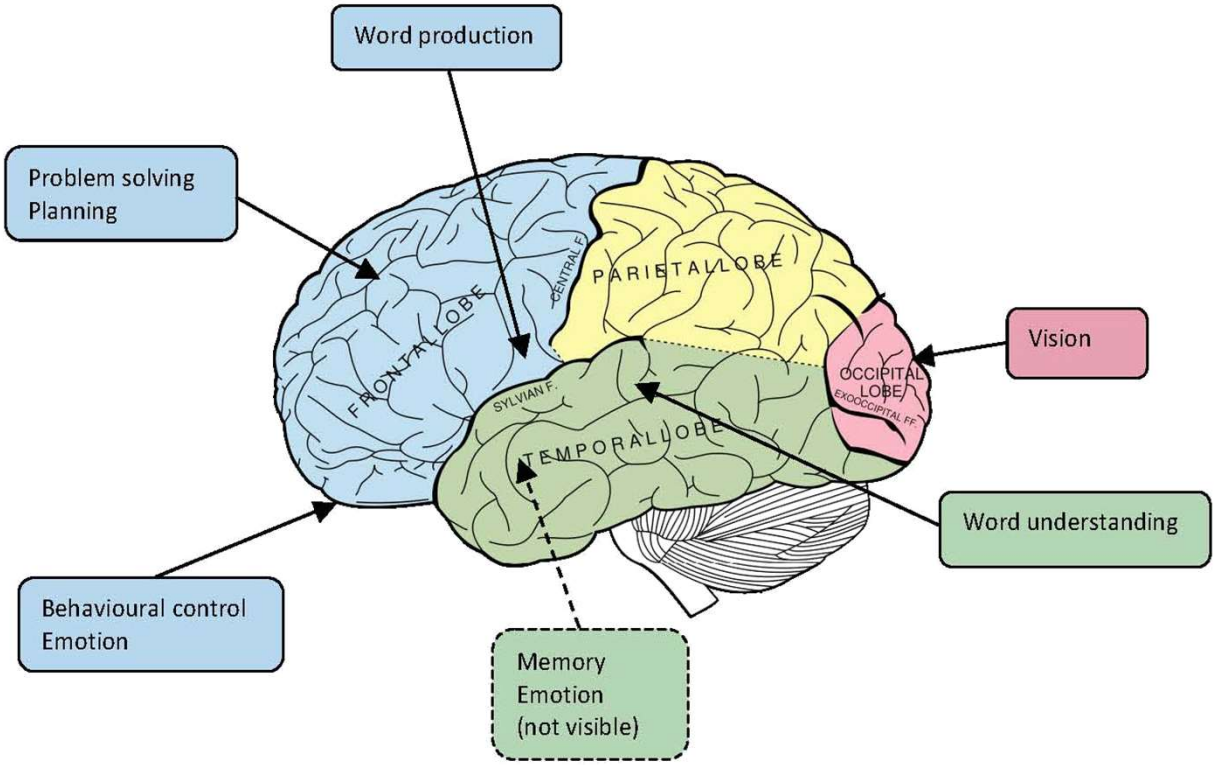
Database	Ref.	Feature	Reg.	Num	Accuracy
SFEW (SPI)	Our	SIFT+FAP	×	7	**26.1**
	[5]	LPQ+PHOG	-	7	19
	[44]	HOG	×	7	28
GENKI-4K	Our	SIFT+FAP	×	2	**90.2**
	[7]	Box Filters	□	2	91.6
		Gabor Energy	□	2	96.3
	[44]	HOG	□	2	92.3



Recognising Emotion: Implicit Cues

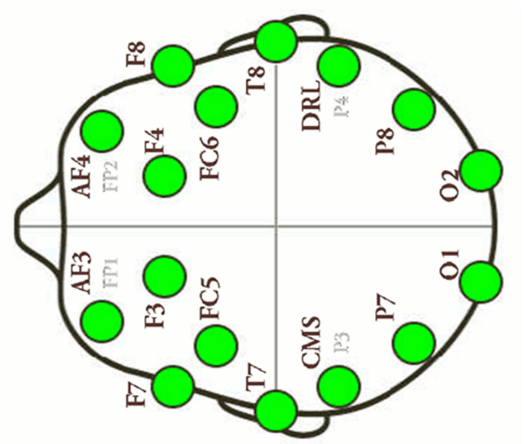
- Electroencephalography (EEG signal)
- Galvanic Skin Response
- Electrocardiogram (ECG signals)

Brain Map


Word production
Problem solving
Planning
Vision
Word understanding
Behavioural control
Emotion
Memory
Emotion
(not visible)
FRONTAL LOBE
CENTRAL F.
PARIETAL LOBE
SYLVIAN F.
TEMPORAL LOBE
OCCIPITAL LOBE
EXOOCCIPITAL FF

Equipment and software

- EPOC headset
  - In this study we use the EPOC headset to collect the EEG signals focus on finding the correlation between different emotions through EEG signal.
    EEG signals were acquired from all available 14 electrodes of Emotive EPOC neuroheadset; AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, O2.
  - MATLAB and EEGLab
  - Weka



Data Acquisition: EEG signal

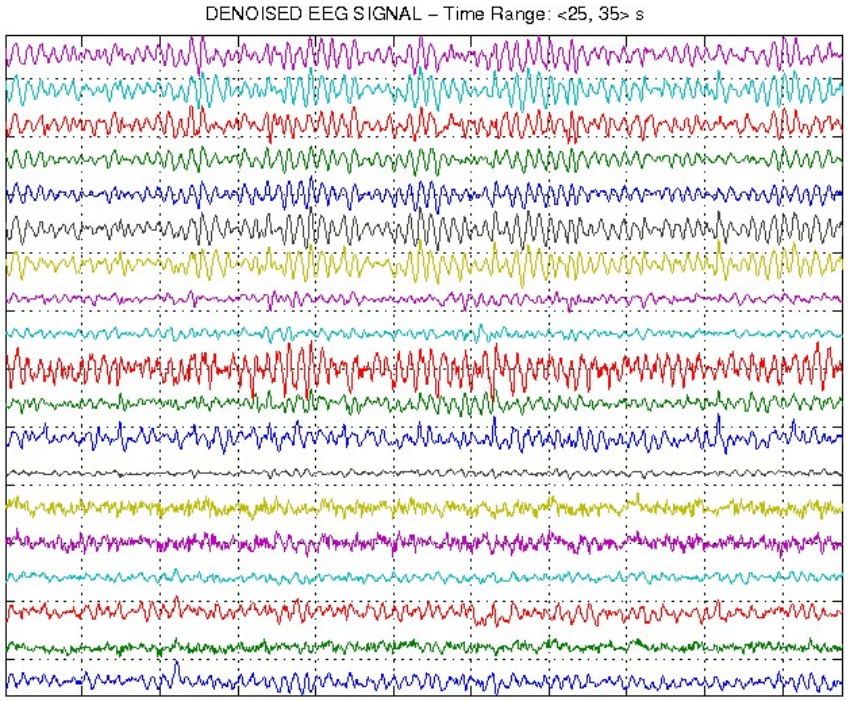
The neurons of the brain produces together a rhythmic signal

Delta band <= 3Hz. Mainly seen in deep sleep

Theta band 4-7Hz. Observed with drowsiness or meditation.

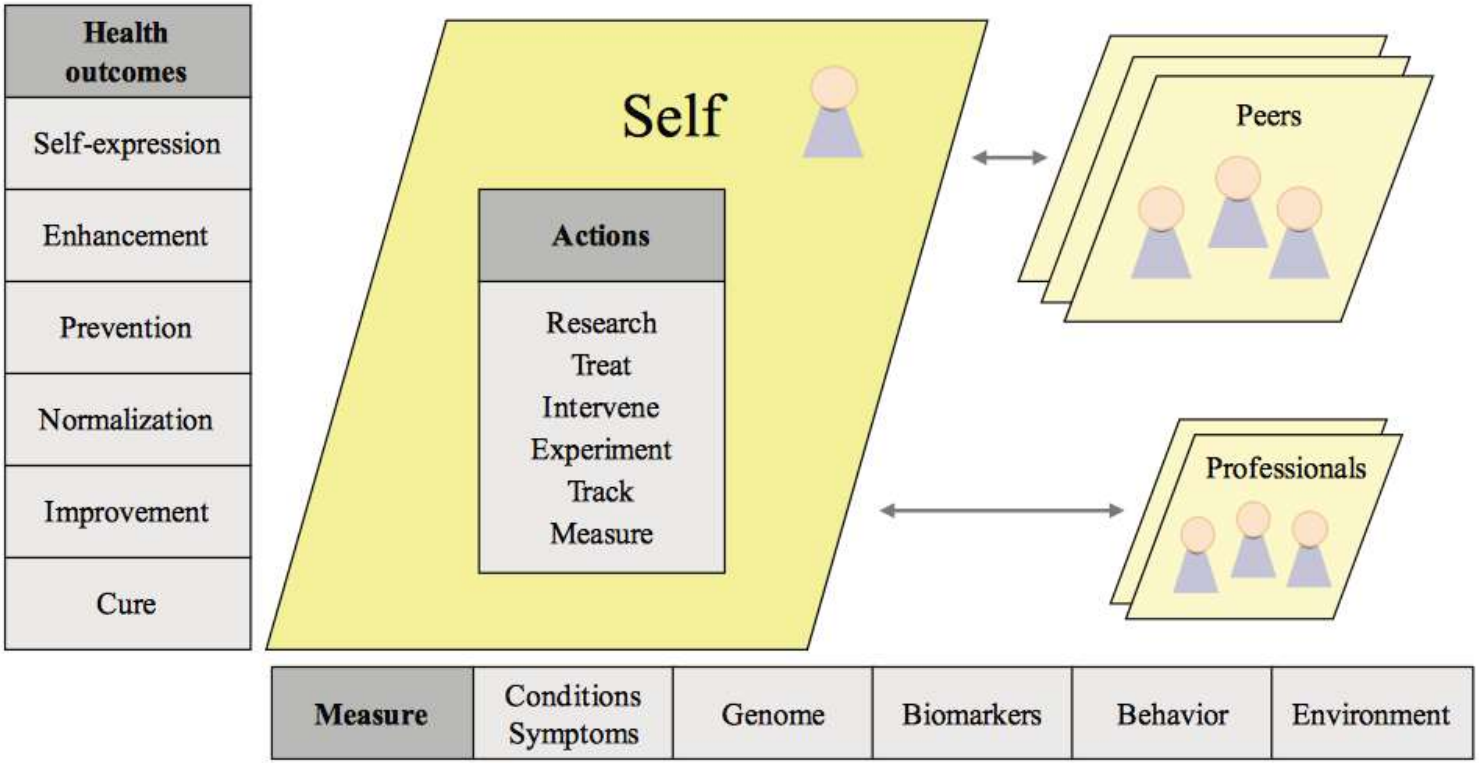
Alpha band 'basic rhythm' 8-12Hz. Seen when people are awake, and is known to be more apparent when eyes are opened.

Beta band 13-30Hz. Apparent with active thinking or concentration.

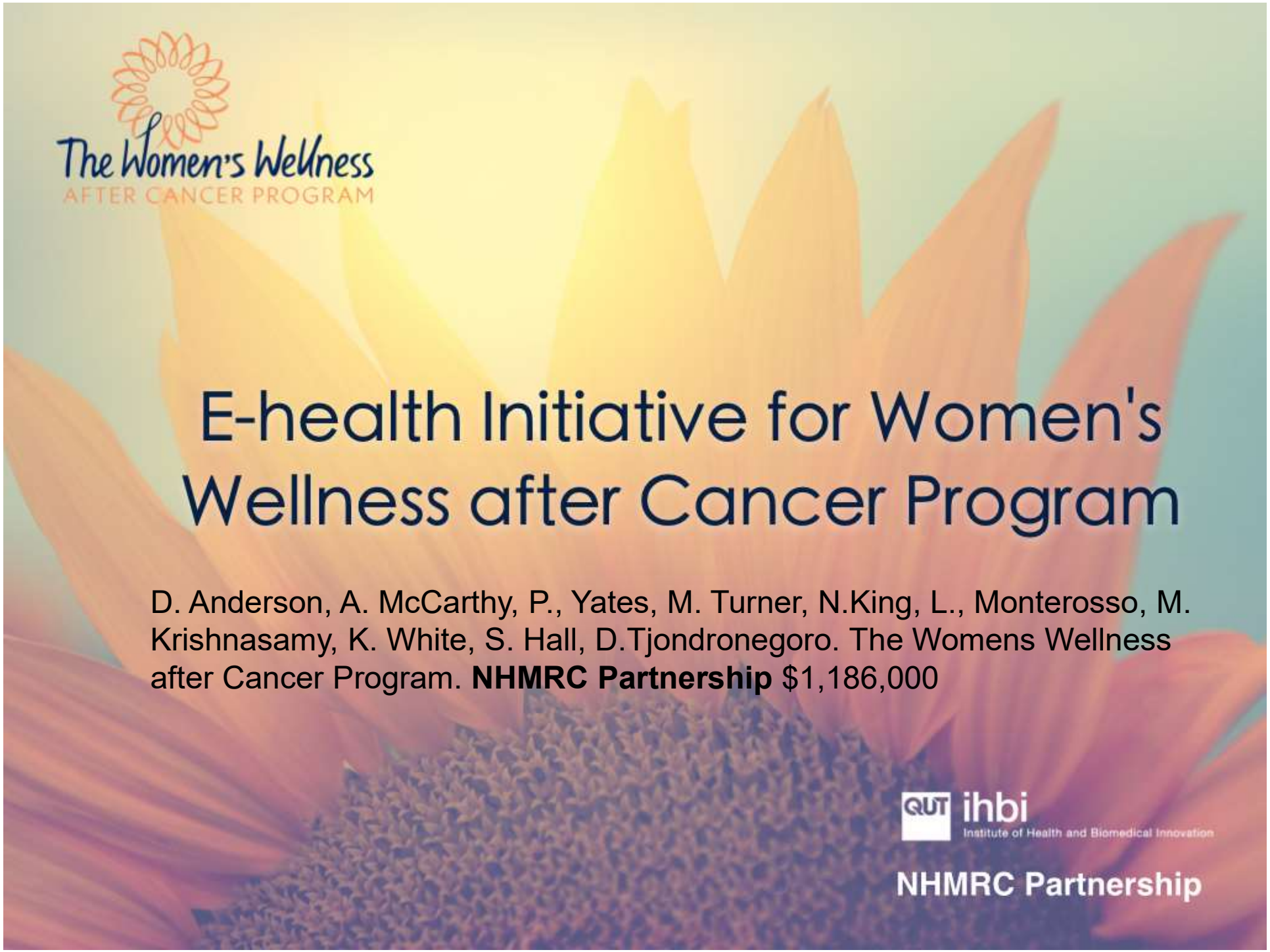


Design and Evaluate Integrated System

Patient-driven Healthcare Model



Swan, M. (2009). Emerging patient-driven health care models: an examination of health social networks, consumer personalized medicine and quantified self-tracking. International Journal of Environmental Research and Public Health, 6(2), 492–525. Retrieved from www.summon.com

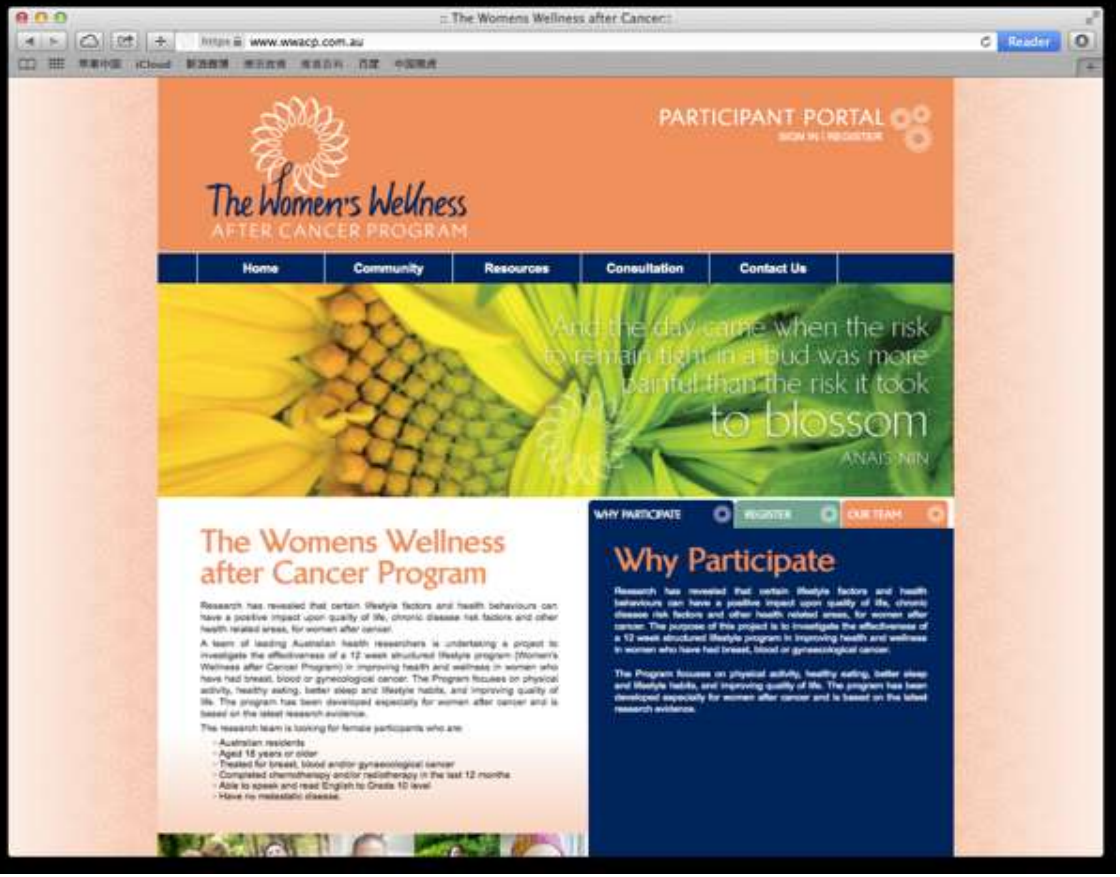

The Women's Wellness
AFTER CANCER PROGRAM
E-health Initiative for Women's Wellness after Cancer Program
D. Anderson, A. McCarthy, P., Yates, M. Turner, N.King, L., Monterosso, M. Krishnasamy, K. White, S. Hall, D.Tjondronegoro. The Womens Wellness after Cancer Program. NHMRC Partnership $1,186,000
QUT ihbi
Institute of Health and Biomedical Innovation
NHMRC Partnership

Interactive iBook

- self-learning
- self-motivation
- self-monitoring
- self-reflection

Collaborative Website

- community
- consultation
- communication



Younger WOMEN'S WELLNESS

- Education
- Social network + peer support
- Progress monitoring
- Virtual consultations
- **Sensor-enabled data collection and analysis**

Interactive Website & iBook
Program information
& e-Journal
Social networking
& peer support
Progress monitoring

Health Sensors & Mobile App
Real-time activity &
sleep monitoring
Self-awareness
data visualisation

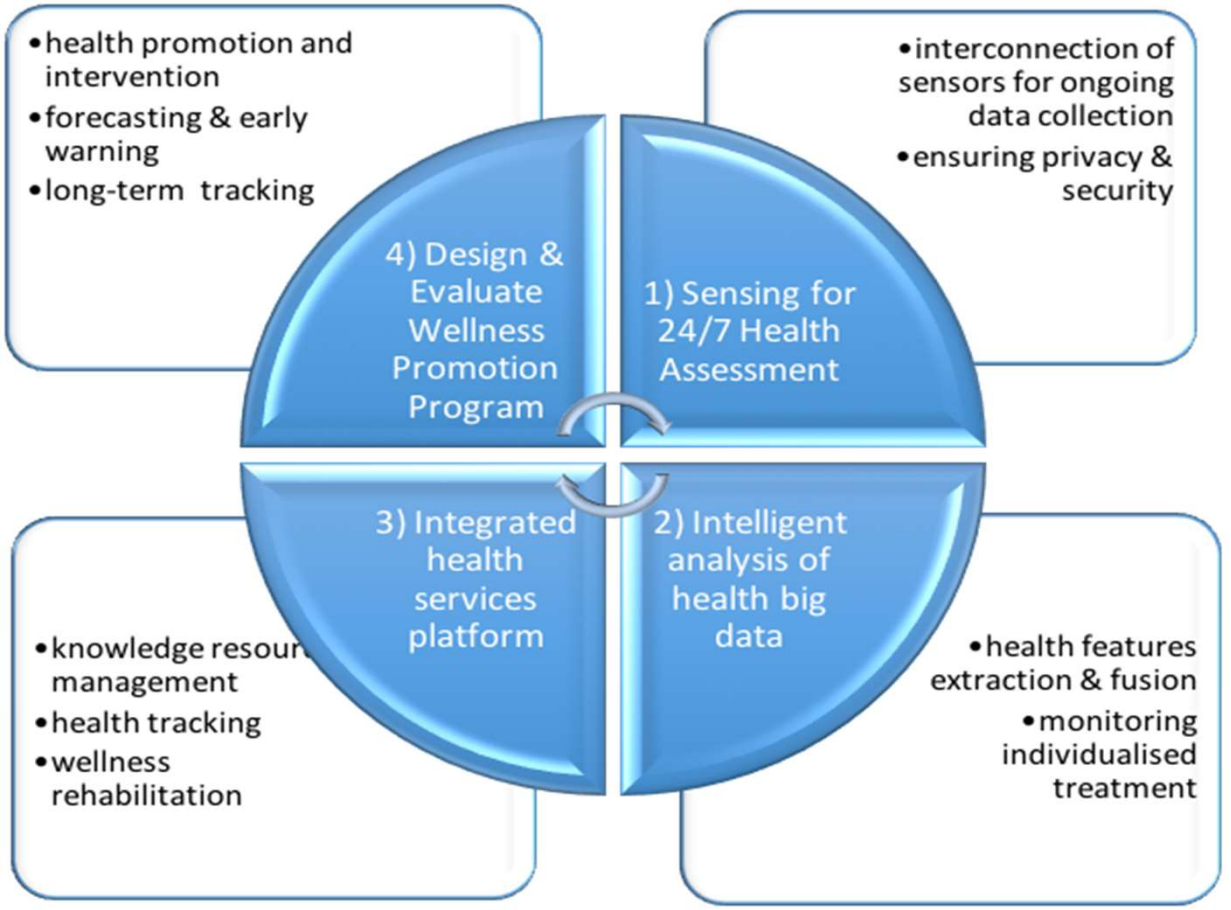
Virtual Consultations
Mobile enabled online
Professional advice
Psychosocial support

Scie Faculty

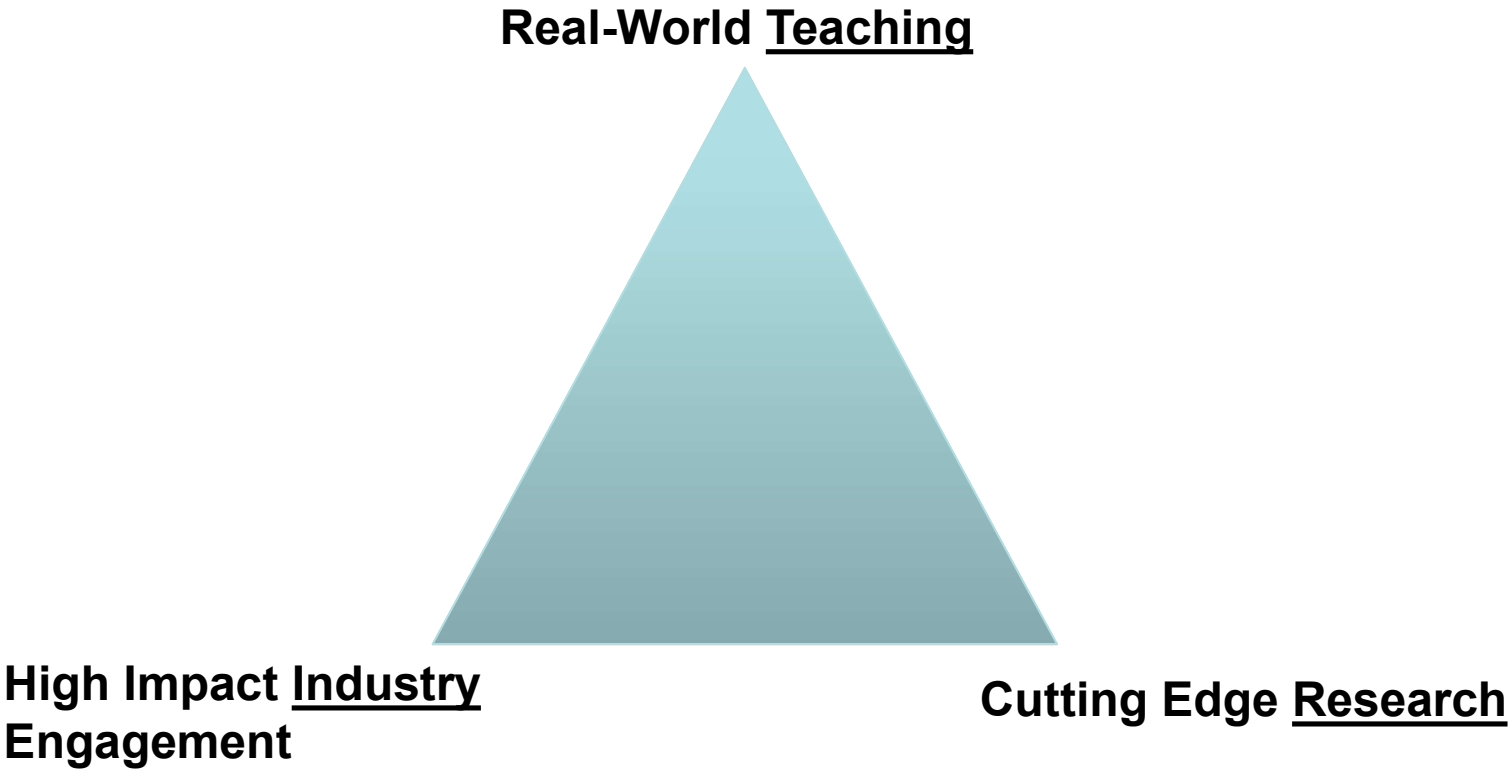
Conclusions: Research Scope

- **Investigate** models and framework to quantify wellness states
  - Intelligent sensor networks
- **Develop** tools, algorithms, and systems to extract, select, and integrate features to classify/detect the wellness states
  - Machine-learning, signal processing, data mining (PR)
- **Assess** and refine the system via a comprehensive field study results to evaluate the user experience
  - Clinical trial, RCT

Conclusions: The Overall Picture



The Nexus of Innovation



QUT BlueSky Forum

www.blueskyforum.com

QUT Mobile App Showcase

140+ students (up from 20 in 2010)
Industry: Microsoft, Apple, Telstra, Suncorp, Woolworths, LifeTec, Virginblue

THANK YOU

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- Twitter/LinkedIn: dianwt
- Publications:
  - http://eprints.qut.edu.au/view/person/Tjondronegoro,_Dian.html
- Websites:
  - www.milab.com.au
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