Quantified living
Self-monitoring, brain monitoring

Lars Kai Hansen
DTU Compute
Technical University of Denmark
lkai@dtu.dk
Cognitive Systems

10 faculty, 2 senior scientists
6 postdocs, 3 research assistants
25 Ph.D. students

Digital media

Statistical modeling
“Machine learning”

Social computing

Cognitive Neuroscience

Mobile Systems

Neuro-informatics
More direct access to our state of mind will revolutionize the ways we understand and work with ourselves, our collaborators and our computers.

Mobile brain scanning can be used to read wishes and plans, to improve diagnosis, medication, and rehabilitation.

At DTU Compute we have built the first truly mobile brain scanner. The scanner gives a 3D image of the instantaneous activity, we are currently working on making the system and real-time access to the brain useful for all.

Maybe we can help you to sleep better tonight?
Some friends did not sleep as well as they used to... the other night in Napa Valley.

Below is a visualization prepared by our Senior Data Scientist Brian Wilt that shows how the South Napa Earthquake’s effect on the UP wearers’ sleep changes with the distance from the epicenter.
OUTLINE

- Personal state decoding
  - William James and human behavior as habits
  - Human predictability: What happened February 2010?
- Big personal data
  - Open data, evidence based living
  - Quantified self
  - Privacy
- Mind reading in the wild
  - Danish Neurotechnology: HypoSafe, EarEEG
- Smartphone brain scanner
  - Engineering the SBS2
  - Applications: Neurofeedback, Bhutan experiment
- Future
  - A new era?

Do not multiply causes!

….Or I will haunt you with false positives
“**Oticon Tego** is directed by the DecisionMaker system, driven by (AI) Artificial Intelligence that processes sound intelligently. This super advanced form of computer processing. Artificial Intelligence is the process of performing logical operations enthused by the human brain.

The difference between AI-based and conventional instruments is distinct: AI-based instruments constantly adapt to particular situation where conventional instruments provide only a fixed response to selected types of sounds. AI-based, Oticon Tego evaluates the different sound processing options and selects the one guaranteed to give the clearest sound quality.

Just like the brain, Oticon Tego filters out the noise so you can concentrate on the speech you like to hear. The DecisionMaker system evaluates and decides exactly when and how to apply the various features to get the best speech understanding and sound quality in any situation. All the processing happens automatically, so you need not lift a finger at all! Completely hands-free Oticon Tego is an ideal hearing solution for the active you!”

http://www.hearingaids123.com/oticon-tego
Why personal state decoding? To make up for cognitive biases

Human senses & brains are not optimal from a behavioral point of view...

See e.g. the list of cognitive biases in Wikipedia

<table>
<thead>
<tr>
<th>Cognitive Bias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambiguity effect</td>
<td>The tendency to avoid options for which missing information makes the probability seem &quot;unknown.&quot;</td>
</tr>
<tr>
<td>Anchoring or focalism</td>
<td>The tendency to rely too heavily, or &quot;anchor,&quot; on one trait or piece of information when making decisions (usually the first piece of information that we acquire on that subject).</td>
</tr>
<tr>
<td>Attentional bias</td>
<td>The tendency of our perception to be affected by our recurring thoughts.</td>
</tr>
<tr>
<td>Availability heuristic</td>
<td>The tendency to overestimate the likelihood of events with greater &quot;availability&quot; in memory, which can be influenced by how recent the memories are or how unusual or emotionally charged they may be.</td>
</tr>
<tr>
<td>Availability cascade</td>
<td>A self-reinforcing process in which a collective belief gains more and more plausibility through its increasing repetition in public discourse (or &quot;repeat something long enough and it will become true&quot;).</td>
</tr>
<tr>
<td>Backfire effect</td>
<td>When people react to disconfirming evidence by strengthening their beliefs.</td>
</tr>
<tr>
<td>Bandwagon effect</td>
<td>The tendency to do (or believe) things because many other people do (or believe) the same. Related to groupthink and herd behavior.</td>
</tr>
<tr>
<td>Base rate fallacy or base rate neglect</td>
<td>The tendency to ignore base rate information (generic, general information) and focus on specific information (information only pertaining to a certain case).</td>
</tr>
<tr>
<td>Belief bias</td>
<td>An effect where someone's evaluation of the logical strength of an argument is biased by the believability of the conclusion.</td>
</tr>
<tr>
<td>Bias blind spot</td>
<td>The tendency to see oneself as less biased than other people, or to be able to identify more cognitive biases in others than in oneself.</td>
</tr>
<tr>
<td>Cheerleader effect</td>
<td>The tendency for people to appear more attractive in a group than in isolation.</td>
</tr>
</tbody>
</table>

“When we look at living creatures from an outward point of view, one of the first things that strike us is that they are bundles of habits.”

“In wild animals, the usual round of daily behavior seems a necessity implanted at birth; in animals domesticated, and especially in man, it seems, to a great extent, to be the result of education. The habits to which there is an innate tendency are called instincts; some of those due to education would by most persons be called acts of reason.”

“It thus appears that habit covers a very large part of life, and that one engaged in studying the objective manifestations of mind is bound at the very outset to define clearly just what its limits are.”
Lifelogging for a quantified self

MyLifeBits is a Microsoft Research project.

Inspired by Vannevar Bush's hypothetical Memex computer system.

The project includes full-text search, text and audio annotations, and hyperlinks. The "experimental subject" of the project is computer scientist Gordon Bell, and the project will try to collect a lifetime of storage on and about Bell.

Jim Gemmell of Microsoft Research and Roger Lueder were the architects and creators of the system and its software.

Fig. 1. (A) Trajectories of two anonymized mobile phone users who visited the vicinity of $N = 22$ and 76 different towers during the 3-month-long observational period. Each dot corresponds to a mobile phone tower, and each time a user makes a call, the closest tower that routes the call is recorded, pinpointing the user’s approximate location. The gray lines represent the Voronoi lattice, approximating each tower’s area of reception. The colored lines represent the recorded movement of the user between the towers. (B) Mobility networks associated with the two users shown in (A). The area of the nodes corresponds to the frequency of calls the user made in the vicinity of the respective tower, and the widths of line edges are proportional to the frequency of the observed direct movement between two towers. (C) A week-long call pattern that captures the time-dependent location of the user with $N = 22$. Each vertical line corresponds to a call, and its color matches the tower from where the call was placed. This sequence of locations serves as the basis of our mobility prediction. (D) The distribution of the time intervals between consecutive calls, $\tau$, across the whole user population, documenting the nature of the call pattern as coming in bursts (11). (E) The distribution of the fraction of unknown locations, $q$, representing the hourly intervals when the user did not make a call, and thus his or her location remains unknown to us.
Short time predictability @ DTU (N=14)


Basic data collection with the “Context Logger” tool (Nokia N95).

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Sampling</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerometer</td>
<td>30/minute</td>
<td>3D Accelerometer values</td>
</tr>
<tr>
<td>GSM</td>
<td>1/minute</td>
<td>CellIID of GSM base transceiver station</td>
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<tr>
<td>GPS</td>
<td>2–3/hour</td>
<td>Longitude, Latitude, and Altitude</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>20–40/hour</td>
<td>Bluetooth MAC, friendly name, and device type</td>
</tr>
<tr>
<td>WLAN</td>
<td>1/minute</td>
<td>Access Point MAC address, SSID, and RX level</td>
</tr>
<tr>
<td>Phone activity</td>
<td>Event</td>
<td>Phone number and direction of call or message</td>
</tr>
</tbody>
</table>

Table 1. List of embedded mobile phone sensors used for collecting data.

Participants were students and staff members from The Technical University of Denmark volunteering to be part of the experiment. Thus mainly situated in the greater Copenhagen area, Denmark.

N= 14 participants took part in the experiment between 31 to 71 days, resulting in approximately 472 days of data covering data collection periods totalling 676 days. The average duration was 48.2 days.

<table>
<thead>
<tr>
<th>Part.</th>
<th>Accel</th>
<th>BT.</th>
<th>BT.*</th>
<th>GPS</th>
<th>GSM</th>
<th>GSM*</th>
<th>Ann.</th>
<th>PA.</th>
<th>WLAN</th>
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<td>20408</td>
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<td>2518417</td>
<td>28110</td>
<td>48.2</td>
</tr>
</tbody>
</table>

Table 2. Overview of collected data for each participant in the experiment: Participant, Accelerometer, Bluetooth, Unique Bluetooth devices, GPS, GSM, Unique GSM cells, Annotations, Phone Activity, WLAN Access Points, Unique WLAN Access Points, Duration in days.
Fig. 5. Predictive Information (normalized) vs. window length (log scale). Participant 3 is left out.
Personal state decoding

Aims to extract the mutual information between personal state and quantifiable behavior

- **Personal state**: Macroscopic variables, tags, behavioral categories ... $s(t)$

- **Sensed behaviors**: Micro/meso-scopic data/variables ... $x(t)$

- **Mutual information** is captured in the joint distribution ... $p(x,s)$.

Supervised machine learning methods assume $s(t)$ or parts of $s(t)$ known ... unsupervised methods consider $s(t)$ “hidden”.... and builds predictive models of the relation
Why is predictability interesting: Nudging

The Facebook experiment

- for internal operations, including troubleshooting, data analysis, testing, research and service improvement.
Smartphone Brain Scanner

Based on the Emotiv wireless transmission mechanism w/ the EPOC head set or modified EasyCaps (Stefan Debener, Oldenburg)

Version SBS2.0 for generic Android platforms (Tested in Galaxy Note, Nexus 7,...)

https://github.com/SmartphoneBrainScanner


Special issue: “Towards mobile EEG”

Towards a truly mobile auditory brain–computer interface: Exploring the P300 to take away

Maarten De Vos a,b,c,*, Katharina Gandras a, Stefan Debener a,b,c

Auditory odd ball detection: Control of Hearing instrument
Evidence based living “the quantified self”

More naturalistic conditions for brain imaging experiments

Long time recording in the wild: Neurotechnology for 24/7 brain monitoring

EEG real time 3D imaging for bio-feedback and “nudging”

Medical applications: Hypoglemia,

DTU mobility projects

Social EEG-
- Leaders and followers
- Joint attention

Mobile real-time EEG Imaging
- Neurofeedback
- Digital media & emotion
- Bhutan Epilepsy Project

Farrah J. Mateen, Massachusetts General Hospital
IMM, Technical University of Denmark

Camilla Falk


Privacy... it’s human to share

Intuitive data
Images, speech, economical, commercial, location, individual thoughts

Non-intuitive data
Health: diet, complete motion patterns
Physiology: heart beat, skin resistance, gaze, brain data, your mind set

Sandy Pentland calls for “a new deal on data” with three basic tenets:
1) you have the right to possess your data,
2) to control how it is used,
3) to destroy or distribute it as you see fit.
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EEG imaging

Linear ill-posed inverse problem

\[ X: \quad N \times T \]
\[ Y: \quad K \times T \]
\[ A: \quad K \times N \]

\[ N \gg K \]

Need priors to solve!

SBS2 functions current

Real time system
- Bayesian minimum norm 3D reconstruction with a variety of forward models (N=1024).
- Adaptive SNR model ($\beta, \alpha$) estimated every 10 sec.
- Update speed ~ 40 fps (Emotiv sample rate 128Hz, blocks of 8 samples)
- Selected frequency band option
- Spatial averaging in “named” AAL regions

Mobile experiment set-ups, so far...
- Common spatial pattern- BCI
- Stimulus presentation options: video, image, text, audio
- Neuro-feedback
Do we get meaningful 3D reconstructions?

Imagined finger tapping
Left or right cued (at t=0)

Signal collected from an AAL region (n=80)


Human behavior is quantified, modeled and predicted

The key technology is machine learning, not “big data”

Decoding the brain is around the corner: Simple brain states can be decoded with high accuracy...
... More complex mechanisms may be revealed with non-linear decoders even in high dimensional settings ... and some care!

Bring it to the masses: Mobility and ecological validity are challenging -
- minimally invasive devices and Ear technology are good candidates
Conclusion: An evidence based living?

Tracking/prediction technology can be used to

+ help humanity to cope with a sub-optimal brain
+ support recovery from physical or mental challenges
+ better understand the goals and actions of friends
+ create better, state dependent services

- Exercise mental control: Information -> power (M.J. Lynch)
- Decrease human autonomy
- Convert citizens to consumers
Acknowledgments

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