Design for Health
A changing paradigm in health and care: technology-driven macro trends, → systems design perspective needed

More people with chronic conditions, fewer to care for them

Latest technology used to manage health, broadening reach of care

Balancing Technology, Behaviour, Healthcare delivery system for designing value-effective healthcare solutions

Dementia Monitoring and Support
Smart wearables are capable of both supporting people with dementia and generating data about their behaviour. The project explores how behavioural sensing could be leveraged in a connected care system for active ageing.

Listening Effort and Cognitive Function
This project uses new technology to determine whether increased listening effort is associated with cognitive function, and to investigate how to integrate this new tool at point-of-care in dementia and hearing care settings.

Healthcare Design for Collaborative Care
investigates how technology and services in hypertensive care can be designed such that digital and human-centered treatment models ensure better and more effective treatment for the chronic patient group.
Engineering Systems Design in Healthcare: Smart Wearables for Dementia Monitoring

Smart wearables are capable of both supporting people with dementia and generating data about their behaviour. This project explores how this could be leveraged in a connected care system to enable active ageing.

Background

Smart technology and wearable sensors are growing in popularity and being woven into our everyday lives. Concurrently, the population is ageing, giving rise to challenges such as an increasing prevalence of dementia. This motivates us to harness the capabilities of smart wearables in addressing such challenges.

Already, our smartphones and smartwatches are able to provide intelligent reminders, guide us home, enable us to engage with friends and family, and monitor aspects of our wellbeing. This functionality is well-suited to improving independence and quality of life among the elderly and cognitively impaired; however it is the young and healthy who are adopting these products. We are therefore interested in exploring how wearables might be adapted to match the needs and capabilities of the dementia care network, and integrated into care practices. In doing so, we hope to guide designers and other stakeholders towards realising this vision of a connected care system.

Project Objectives

The first phase of the project focuses on gathering information to understand
Listen Care-fully: Healthcare Design for Listening Effort and Cognitive Function

Background
For today’s ageing population, both the number of people living with hearing loss and dementia is projected to increase, and recent research suggests that hearing loss is the highest modifiable risk factor for dementia in later stages of life (Livingston et al., 2017). According to a seminal report in the Lancet, hearing impairment accounts for 5% of the predictive power of all risk factors associated with the development of dementia. Research also suggests a potential pathway between hearing and cognitive decline, with listening effort, working memory and cognitive load as principal mediators.

Project objectives
This project aims to determine whether increased listening effort is associated with cognitive function in healthy individuals and those affected by cognitive impairment. The project will use pupillometry, the measurement of pupil dilation, to determine listening effort and explore the potential improvement with the use of hearing aids in individuals both with and without cognitive impairment. Furthermore, this project will investigate how to facilitate the integration of this test together with current dementia and hearing care management to leverage this predictive power at point-of-care.
Healthcare Design for Collaborative Care

Background
The Danish Health Authority (Husdyrkelsesstyrelsen) assesses that up to 80% of total Danish healthcare costs come from patients with chronic diseases and forecasts an increase in population ageing. Chronic diseases are not only a mounting challenge for the Danish health service, a third of the Danish population also lives with one or more chronic diseases, which significantly impact their quality of life. The potential for developing sustainable solutions that elevate the long-term quality of life of the target group as well as lower demand for scarce health resources will have a significant societal value. In Denmark, about 1 million inhabitants are living with hypertension (high blood pressure), which is the leading cause of blood clots and bleeding in the brain, and may lead to heart failure and kidney problems if no precautions are taken. Despite understanding the implications, health, willingness, and motivation to follow life-enhancing guidance is experienced among chronic patients, i.e., due to side effects of medicines and unstructured cross-sectoral treatment. However, this is particularly distinctive with hypertensive patients, as the disease is usually symptom-free and the motivation to commit profound lifestyle changes may be lacking.

In order to drive the necessary patient responsibility for ensuring optimal treatment results, support for permanent behavioral change requires more than just the conception of a better life. Active participation in self-treatment necessitates continuous motivation and strengthening of the relationship between patient and health care professionals. This is exactly where this project strives to make an impact. Our claim is that increased patient participation and collaboration not only strengthens patient-provider relationships with shared decision-making and ownership of treatment, but also strengthens self-help skills and willingness, while increasing the patients' understanding of their influence on their own state of health, and thus self-efficacy. From this, patient compliance increases and can drive patient responsibility for making daily...
Francois Patou, Carrie Peterson, Jasmin Wistoft, Dennis Nygaard, Sebastiano Piccolo, Hysse Forchhammer, Anja Maier

From crowd-sourced clinical research to designing personalised, preventive interventions
Consumer-grade wearables and smart technologies: opportunities

- Cheap
- Extended longitudinal time-series
- Seamless integration in daily life
- Increasingly multi-modal

1. **Understanding**
   - shining new light on disease mechanisms

2. **Intervening**
   - new avenues for personalised, pervasive, participative, preventive health/lifestyle interventions
Prevalence and burden of cognitive decline

• 18.7% of the general population live with Mild Cognitive Impairment (MCI)¹ (eg Andrieu et al., 2015)

• 38% of MCI cases develop into dementia within 5 years² (eg Mitchell and Shiri-Feshki (2009))

36 million individuals live with dementia worldwide¹ (eg Andrieu et al., 2015).

$1trillion³ (eg Prince et al., 2015)

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Modifiable risk factors of cognitive decline – in late life

- e.g. physical inactivity
- Modifiable risk factors, often tightly coupled
- Interventions to mitigate cognitive decline must target causal roots

Livingston et al. 2017, Dementia prevention, intervention, and care, The Lancet

Figure 4. Life-course model of contribution of modifiable risk factors to dementia. Numbers are rounded to nearest integer. Figure shows potentially modifiable or potentially non-modifiable risk factors.
Links between cognition, physical activity, and sleep

- Evidence gaps
  - Clinical evidence heavily based on point-assessments
  - Causal inference requires longer investigations in larger cohorts
  - Interventional studies encouraging physical activity still miss objective assessments of exercise intensity, duration, etc.

- Effective strategies for influencing modifiable risk-factors needed
  - Behaviour-change in people at onset of cognitive decline?
  - How to integrate daily-wearable data into clinical data flow for shared-decision making?

Healthcare international research competition: Personal healthcare technologies; crowd-sourced mHealth

- 6 finalists. Leading universities. DTU Engineering Systems only European
- Pilot study – April 2017-January 2018; >50 participants recruited & equipped
Photo impressions of the journey
https://medicinex.stanford.edu/2018/08/01/dtu/
Clinical setup

- **54 Participants**
- *Aged 52-86* (18 females, 36 males)
- **11 232 Days of data**

More than 51,000 hours of sleep were monitored with the Withings Aura - Smart Sleep System for monitoring sleep quality.

More than 32,470,000 steps over the study period of six months were tracked with the Withings Steel HR watch.

54 participants with scores between 17-27 on the Montreal Cognitive Assessment (MoCa) test were included.
Leveraging Withings’ smart devices for objective, pervasive observation of sleep and physical activity

- Self-reported memory difficulties
- Montreal Cognitive Assessment (MoCA) at $t_0$
- Inclusion: $17 < \text{MoCA} < 27$
- N = 54 follow-up ~ 3 months
- Data analysis
- Feedback to participants
  - Clinical findings
- Intervention design
Preliminary results:
Average daily step count and cognitive function

There is a positive association between individual average daily step count and age-normalised baseline MoCA score.

Multiple Linear Regression modelling using backwards predictor selection reveals step-count (log) significant predictor of the baseline MoCA scores (i.e. at time of inclusion).
Preliminary results:Sleep and cognitive function

- Baseline MoCA score is a significant predictor of the total average quality of sleep.
Preliminary results:
Activity, sleep and cognitive function

- Sleep fragmentation was significantly lower in the 25% most physically active participants (Figure above).
- The most physically active participants showed an average lower duration of time to “get out of bed” in the morning.
Digital(?) design for health behaviour change

• The right to information
  … or incentivisation strategies for behaviour-change?
New paradigm in design for behaviour change

Conventional: population-based
• 1- ”Us all” : Information pertaining to overall population investigated: population-based medicine

Best current practice: personalised
• 2- ”I compared to us all”

Proposed additions
• 3- ”I compared to patients like me”
• 4- ”Patients like myself compared to us all”

• The future of personalised feedback
• Objective and relational approach to incentivisation for behaviour change
Conclusions

• Pervasive mobile-health, wearables, ingestibles, implantables open up new venues for crowd-sourced clinical research

• First study looking at cognition-sleep-physical activity triangle in both a data-driven/’objective’ and continuous/pervasive way:
  more than 51,000 hours of sleep data and 32M steps over 6 months, insights into behaviour, nowcasting

• Clinical results preliminary. Platform for designing intervention studies
  – Evidence unravelled from such a crowd-based study feeds into behaviourally-informed development of new healthcare interventions
  – For diseases involving modifiable risk-factors, such a study offers valuable access point to attempt behaviour change
  – New ‘customised behaviour change intervention design paradigm’ now possible (technologically), needs further investigation in relation to cognitive and behavioural theory
Take home message

- **Design for Health** a fruitful research area
  where system design has got a lot to offer.
  Venturing out beyond traditional (mechanical) engineering design realm

- Close interaction with design, technologists, and clinical practitioner,
  **credibility for and from both sides**

- Enables a number of avenues for further research:
  - Crowd-sourcing citizens, (m, p) uHealth, huge interest
  - I in the crowd, data
  - Sustainable behaviour change through involvement of designers right from the very start of an intervention
Using wearable technology to explore dementia risk factors

By Martin Sorvillo, MD in Nokia Challenge

Much has been written about the possible links between lifestyle and the onset of dementia. There is some evidence to suggest that aerobic exercise may be protective. Even sleep quality has emerged as an important factor. Is there anything we can do to protect ourselves against cognitive decline? Can we detect dementia early by tracking subtle behavioral changes?

As one of five international finalists in the Nokia-Medicine X Digital Health Challenge, a team of researchers from the Technical University of Denmark (DTU) decided to delve deeper into the interaction between technology and dementia. Their work is presented here.
References to our healthcare-related work

Healthcare systems design, technology, behaviour

• Thorpe J.R., Forchhammer B.H. & Maier, A.M. (accepted). Development of a sensor-based behavioural monitoring solution to support dementia care. Journal of Medical Internet Research - JMIR mHealth and uHealth. DOI: 10.2196/preprints.12013


References to our healthcare-related work

Lab-on-Chip
Model-based systems engineering for life sciences instrumentation development

References to our healthcare-related work

Maturity modelling medical device design, clinical trials


Hospital work system improvement

- Andersen, S.N. (2016). The process of participatory ergonomics simulation in hospital work system design, International Design Conference
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Designing Engineering Systems