Persuasive Technology for Personalized Sleep Coaching

Robbert Jan Beun
Information Science
Did you sleep well?
Join our research as a subject!

Android app with sleep diary and relaxation exercise

Use the app for three weeks and experience how it works. You will receive a questionnaire every week.

Register at: www.ikgalekkerslapen.nl
See also: www.facebook.com/Sleepcare
Sleepcare App

Main menu

Sleep diary

Overview diaries

Relaxation
Goal

Enhance understanding of personalized self-help therapy with mobile and internet technology (in the domain of insomnia).

In particular:

The development of a *generic framework* that integrates *persuasion strategies* for sustainable behavior change and the technology to support these changes.
This project is not about sleep, but about adherence!
Today

1. starting point: SleepCare project
2. what is sleep?
3. behavior and sleep
4. sleep applications
5. sleep therapy
6. ending point: the SleepCare project
SleepCare Team

Information and Computing Sciences, University Utrecht (UU)
- Robbert Jan Beun (Communication Modelling, project leader)
- Rogier van Eijk (Computer Agents and Relaxation)
- Sandor Spruit (Scientific Programmer)
- Peter Werkhoven (Human Computer Interaction)
- Fiemke Griffioen-Both (Postdoc)

Man-machine Interaction Research, Technical University Delft (TUD)
- Willem Paul Brinkman (Virtual Reality Exposure Therapy)
- Corine Horsch (PhD)
- Mark Neerincx (e-Coaching)
- Siska Fitrianie (Postdoc)

University of Amsterdam
- Jaap Lancee (Insomnia Expert)

Philips
- Reinder Haakma (Sleep and Technology)
Three lines of research

Empirical validation

Prototyping

Modeling
What counts as a solution for one individual does not necessarily count as a solution for the other.

→ individually tailored
→ user model
Starting point 2

We are not the only one in this universe and all day long we do things in a particular environment.

➔ contextually tailored
➔ task, communication and environmental model
Proof of Concept: Virtual Coach

• that provides personalized automated training program

• that integrates non-obtrusive devices in the therapy to obtain environmental and sleep related data

• that regulates interaction with other human participants, such as peers, family and care providers
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Proof of Concept: Virtual Coach

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• that regulates interaction with other human participants, such as peers, family and care providers
Based on:

- general principles of communication, coaching and persuasive technology (domain independent)

- existing cognitive and behavior therapies to improve the quality of sleep (domain dependent)
Our dream
Research & development

• Literature studies
  – Insomnia, CBT-I, mobile health, virtual coaching, persuasive technology, existing applications

• Development
  – Software infrastructure for registration and data collection (mobile experiments)
  – App design, formalization, user interface

• User involvement
  – Interviewing focus groups (therapists, possible users)
  – Real therapy data
  – Scenario development
  – (Early stage) testing and experimental evaluation
But ...  
What is sleep/insomnia?
Sleep is an essential activity for a person’s health and wellbeing
Sleep

Period of inactivity, where the body comes to rest

State of lower awareness, together with lower activity of physiological processes

State of rest of the senses and of consciousness
Sleep

1/3 of our lives, but unclear why. Some explanations, from:
- ‘repair and restore of the brain’
- ‘back to our origin’
## Sleeping time humans

<table>
<thead>
<tr>
<th>Age and condition</th>
<th>hours/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>newborn</td>
<td>til 18</td>
</tr>
<tr>
<td>1–12 months</td>
<td>14–18</td>
</tr>
<tr>
<td>1–3 year</td>
<td>12–15</td>
</tr>
<tr>
<td>3–5 year</td>
<td>11–13</td>
</tr>
<tr>
<td>5–12 year</td>
<td>9–11</td>
</tr>
<tr>
<td>Adolescent</td>
<td>9–10</td>
</tr>
<tr>
<td>adults and elderly</td>
<td>7–8</td>
</tr>
<tr>
<td>pregnant women</td>
<td>8(+)</td>
</tr>
</tbody>
</table>

Wikipedia
Randy Gardner
Stayed awake for 11 days and 24 minutes
# Sleeping time animals

<table>
<thead>
<tr>
<th>Kind</th>
<th>hours/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spit mouse</td>
<td>1</td>
</tr>
<tr>
<td>Giraffe</td>
<td>4</td>
</tr>
<tr>
<td>Ox</td>
<td>7</td>
</tr>
<tr>
<td>Human</td>
<td>7-8</td>
</tr>
<tr>
<td>Dog</td>
<td>8</td>
</tr>
<tr>
<td>Rabbit</td>
<td>10</td>
</tr>
<tr>
<td>Cat</td>
<td>13</td>
</tr>
<tr>
<td>Sloth (D:Luiaard)</td>
<td>20</td>
</tr>
</tbody>
</table>
Two processes

• Sleep debt
• Circadian rhythm
Sleep debt
Circadian rhythm

pineal gland
Sleep rhythm

Sleep Cycle
During 8 hours of sleep

www.LucidDreamExplorers.com/dreamscience
Measurement of sleep stages: polysomnography

EEG: elektro-encefalogram
EOG: elektro-oculogram
EMG: elektromyogram
respiration
bloodpressure
oxygin in the blood
ECG: heartbeat
## Sleep stages and characteristics

<table>
<thead>
<tr>
<th>sleep-stage</th>
<th>body-movement</th>
<th>respiration</th>
<th>heartbeat</th>
<th>EEG (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>speed</td>
<td>variability</td>
<td>speed</td>
</tr>
<tr>
<td>wake</td>
<td>active</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>light</td>
<td>↓</td>
<td>↓↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>deep</td>
<td>↓↓</td>
<td>↓</td>
<td>↓↓</td>
<td>↓↓</td>
</tr>
<tr>
<td>REM</td>
<td>absent</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
</tbody>
</table>
Sleeping is a complicated process
Disorders

• Insomnia
  – onset, oversleep
  – primary, secondary
• Problems sleep/wake rhythm
  – nightshift, jetlag, ASPS, DSPS
• Other
  – sleep apnoea, restless legs, narcolepsy
• Parasomnia
  – teeth gnash, sleepwalk, nightmare, ...
We concentrate on insomnia
Insomnia

- A persistent difficulty initiating and/or maintaining sleep
- Primary and secondary insomnia
- Mechanism badly understood
- Chronic insomnia > three month
- Around 10% of the population
Insomnia may cause impairment of daytime functioning, ability to concentrate, memory, and mood.
Insomniacs are more likely to drop out of difficult jobs and receive fewer promotions.
Insomnia may cause depression.
Insomnia may cause physical illness: from a cold to rheumatism and heart diseases
Insomnia may cause death
In the Netherlands
1.9 million people use hypnotics.
Yearly costs of insomnia are estimated at 5 billion Euro (in the Netherlands)
So, how can this condition be improved?
First, some observations
The quality of sleep does not only depend on the quality of the mattress.
But also on:

- time spent in bed,
- age, health, attitudes,
- mental and physical activities,
And:

the stress in our life,
the medicines/drugs that we take,
the behavior of your spouse,
And on:

the food that we eat,
the drinks that we drink,
the circumstances in our bedroom,
...

Some factors cannot be changed (e.g. age), but many of them can (circumstances, behavior and thoughts)
How change?
Existing support to wake up
And...
Ontwaken

Een goede nachtrust zorgt ervoor dat u fris en vitaal wakker wordt. Een gezonde dag zorgt weer voor een goede nachtrust.

Sta op dezelfde tijd op
Sta iedere morgen (ook in het weekend!) op hetzelfde tijdstip op, onafhankelijk van het aantal uren dat u heeft geslapen.

Licht
Licht heeft belangrijke invloed op goed wakker worden. Wetenschappelijk onderzoek lijkt uit te wijzen dat een geleidelijk toenemende lichtsterkte in de ochtend een positieve invloed heeft op de beoordeling van de slaap en leidt tot een vermindering van slapenigheid overdag, en dus een comfortabele manier van ontwaken is. Er zijn speciale wekkers te koop met een lamp die langzaam aangaat.

Kleur
Ook de kleur in de slaapkamer speelt een rol bij (inslapen en) ontwaken. Onderzoek laat zien dat het blauwe ochtendlicht een gewelkend effect heeft, waarneembaar gedrag heeft, en onder其他人 ongedaan kan maken.
Existing support to sleep well
Slaaptips

Lichaam en geest tot rust laten komen. Vaste rituelen volgen. Er zijn allerlei dingen die u kunt doen om lekker te slapen. Er zijn ook een aantal dingen die u beter kunt laten...

Voorbereiding
Avondrituelen helpen u om beter te slapen. Het zijn gewoontes die uw lichaam en geest laten weten dat het tijd is om naar bed te gaan.
Lees meer over Voorbereiding

In slaap vallen
Wie bij het inslapen vaak abrupte spiertrekkingen vertoont, doet er goed aan niet te dicht tegen zijn partner in te slapen.
Lees meer over In slaap vallen

Ontwaken
Sta iedere morgen (ook in het weekend) op hetzelfde tijdstip op, onafhankelijk van het aantal uren dat u heeft geslapen.
Lees meer over Ontwaken

Auping nights, Better days
And...
Recent developments

ZEO

Monobanda

VGZ
Sensors

- ART
- Actiwatch
- Fitbit
- Lark
- Jawbone
- Mobile phone
- Nike Fuelband SE
- Tanita
- Zeo
And...
Cognitive Behaviour Therapy for Insomnia (CBT-I)
CBT pillars

• a cognitive component
  – to change a person’s dysfunctional cognition, such as negative thinking or unrealistic expectations with respect to poor sleep

• a behavioural component
  – to unlearn maladaptive habits and to learn sleep improvement behaviour
Dysfunctional beliefs

I don’t have time. I’m too tired. It’s too hard. I can’t afford it. It’s not working. It’s boring. I’m too fat. I hate sweating. It’s too hot. It’s too cold. What’s the point? I don’t know what to do...

LET GO OF THE EXCUSES
CBT-I Exercises

• Sleep restriction
  – restrict total time in bed
• Stimulus-control
  – associate bed with sleep
• Relaxation
  – progressive muscle relaxation, meditation, visualisation, ...
• Sleep hygiene
  – room temperature, light, sound, clean, ...
• Cognitive restructuring
  – change disruptive thoughts, stop worrying, ...
CBT-I delivery methods

• Human-human
  – Individual/group sessions
  – Telephone, internet consultations

• Self-help
  – Books, video, TV, ...

• Internet therapy
  – E.g. Somnio
Problems CBT-I

Human-human
- Face-to-face is expensive
- Long waiting lists

Technology
- Unreliable measurements
- Not evidence based
- Proliferation of applications

In general
- Adherence to the exercises
Improve on adherence

• Use of virtual coach
• Use of persuasive techniques
Let’s turn to ...

e/m-coaching
and
persuasive technology
e-Coaching

• 152.000.000 hits in Google (April 2014)

• various domains
  – lifestyle, nutrition, insomnia, depression, anxiousness, migraine, work, physical activity, ...

• various media
  – e-mail, web, telephone, video, cd’s, mobile, ...

• various functions
  – motivation, training, demonstration, feedback, integration, ...
What is coaching?

- awareness
- change
- support
This is not coaching

• Disapproving ideas or behavior of coachee
• Pulling coachee to let him/her do what you want
• Indicating where the problem is
• Solving the problem for the other
e/m-Coaching

Use ICT to support (parts of) the coaching process.

Advantages

• Low threshold
  – Affordable, anonymous

• Part of daily activities
  – Always available

• Stepped health-care
  • System first, then human therapist

• Integration of various application
  – sensors, sleep diary, evaluation, ...

• Inclusion of persuasive technology
Persuasive Technology
Persuasion

Persuasion ... is the process of *moving others by argument* to a position or course of action either temporarily or permanently. *Robert Cialdini, Arizona State University*

Persuasion is an attempt to *change attitudes or behaviours or both* (without using coercion or deception). *B.J. Fogg, Stanford University* [www.bjfogg.com](http://www.bjfogg.com)

Meestal gedragsverandering!
Cialdini: *Influence: The Psychology of Persuasion*

- **Reciprocity** - People tend to return a favour.
- **Commitment** - If people commit, orally or in writing, to an idea or goal, they are more likely to honour that commitment.
- **Social Proof** - People will do things that they see other people are doing.
- **Authority** - People will tend to obey authority figures, even if they are asked to perform objectionable acts.
- **Liking** - People are easily persuaded by other people that they like.
- **Scarcity** - Perceived scarcity will generate demand.
Persuasive technology

Interactive computer systems designed to change behavior, attitudes, and beliefs of people.
Domains

Commercial, education, training, safety, health, personal finance, public domain, relation, personal management, ...
Applications
Persuasion by Sensors

- Objective data collection
- No disturbance of main task
- The unreachable becomes reachable
- Improves motivation
- Improves ability
- Physical trigger
How change?
What is the meaning of change?
Two types of change

• Stop undesired behavior
  – Stop smoking
  – Don’t sleep while not in bed

• Learn desired behavior
  – Eat healthy food
  – Go to bed at right moment
To improve chance for desired behavior we should:

Increase or decrease
• willpower
• motivation
• ability
Change of Motivation

Means
  Direct: Simulation, gaming, virtual worlds, tamagotchi, ...
  Indirect: Language, Symbolen, ...

Reward/punishment
  Construct (un)desired goal state

Social structures
  Competition, monitoring, ...

Self-insight
  Reflection, diary, sensormeasurement, ...

Language
  Coercion, forbid, praise, encourage, ask, commit, remind, ...
Change of ability

– Behavior cannot be performed
  • Switch of car when drunk, safety tap, ...

– More difficult
  • hide cigarettes, ‘wietpas’, first general practioner, ...

– Improve ability
  • Exercising, knowledge, ...

– Triggering
  • Notifications/reminders for desired behavior
CBT-I Exercises

• Sleep restriction
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Basic ingredients of virtual sleep coach
Virtual Sleep Coach

CBT-I Protocols
Coachee Sleep-Coach Interaction
Therapy Adherence
Mobile Software Engineering
requirements
Mobile software engineering

Coachee's Mobile Smartphone

Personal Computer

Internet

Therapist

Adherence

eCoach for CBT-I
Information flow model

coachee  →  system  ←  environment

peer  →  therapist

communication

physical signals
Therapy(coach, coachee, environment, history)
1   establish contract //therapy agreement//
    Determine exercise type
    Determine exercise properties
2   if contract then
    Do exercises
    Evaluate results
else end
3   repeat 1-2 until end
Interaction

Opening phase
- Intro coach/coachee
- Intro therapy
- Inclusion / exclusion
- Plan & commit

Intervention phase
- Technique 1
- Technique 2
- Technique 3
- Technique 4

Closure phase
- Close therapy
Interaction

Technique

Introduction Technique → Plan & Commit → Task Execution → Evaluation → Closure
Information about user

• Profile
  – age, weight, health, gender, education, hobby, work, character(?), ...

• Sleeping diary
  – info about medication, drugs, alcohol, coffee, exercises, sleeping times, bed times, quality of night and day, adds, ...

• Tests
  – motivation, sleeping test, depression test, attitude test, ...

• Physical measurements by sensors
  – heartbeat, temperature, body movement, location, skin resistance, sound, light, touch, ...
  – Stages: NREM1, 2, 3, 4, REM-sleep, Wake
  – Emotion, ...

• Other interaction
  – dialogue
  – speaker identification
  – ...

Choices

– Therapy
  • what: type of exercises
  • when: order of exercises and other events/activities
  • how: characteristics of exercises

– Communication
  • content: what should be communicated?
  • when: the order of speech acts and other events/activities
  • how: modality (woorden, iconen), channel (auditory, visual), intensitiy (loud/bright, soft/dim), ...
Prototype 2: functionality

• Contains sleep therapy exercises
  – tailored relaxation exercises
  – sleep restriction
  – sleep hygiene
  – cognitive therapy

• Coaching/persuasive strategies
  – explicit commitment/contract
  – exercise adaptation
  – motivational support
  – basic reminders
Success criteria final system

- Improved adherence to exercises

Side effects:
- Improved subjective sleep quality
- Improved sleep efficiency
- Improved daytime functioning
- Reduced time to fall asleep
- ...
Back to reality
What have we learned so far?

Domain modeling

We are able to distinguish coaching, from sleep knowledge and communication knowledge

– coaching knowledge
  • build contract, evaluate results, determine state of change, send reminders, motivate coachee, negotiate exercises, ...

– sleep knowledge
  • ‘deep sleep mostly in the beginning of sleeping period’
  • ‘if SE > 75% then change(sleep_schedule)’

– communication
  • rules for cooperative dialogue
  • Gricean maximes
What have we learned so far?
The ‘Unexpected Obstacles’

• PhD from Utrecht left July 1, 2013
• No proper infrastructure for mobile research
  – security, privacy, ...
  – integration of data processing (surveys, mobile, sensor), notifications (email, ...) and other services (Google store, SurveyMonkey, ...)
• Complexity of daily life, e.g.:
  – two people are using one phone
  – people are frequently interrupted on mobile phones
  – empty battery
  – wrong day implemented (after three weeks + 1)
  – variety of Android phones (over 4000 versions)
  – SurveyMonkey didn’t work on a particular day
  – commercial available sensors don’t work
What have we learned so far?

Collaboration

Identify and involve stakeholders in early stage of the project.

In a multidisciplinary project that is developed at different locations communication between stakeholders is extremely important.

Don’t forget your research contacts over the world.
What have we learned so far?

Principles for a good sleep

• Quiet, Cleanliness and Regularity (Rust, Regelmaat, Reinheid)
• Know yourself
• Increase sleep efficiency
• Take care of good bedroom conditions
• Use the bed only for sleep (and sex)
• Eat well and do physical exercises
• Improve the quality of your life
• Do (only?) things that make sense
• Do nothing sometimes and accept doing nothing
• Never think the same thought twice, unless the thought is nice
• Put your memory in the physical world
What have we learned so far?

Persuasion
What have we learned so far?

Persuasion

Never give up!
The end

www.ikgalekkerslapen.nl