SleepCare: Persuasive Technology for Personalized Sleep Coaching

Robbert Jan Beun

www.ikgalekkerslapen.nl
Today

1. intro SleepCare project
2. what is sleep?
3. insomnia
4. behavior and sleep
5. sleep therapy
6. persuasive technology
7. SleepCare project
   a. therapy model
   b. the interface
   c. inside the machine
Goal

Development of computerized strategies to improve exercise adherence

In particular: personalized coaching system using mobile persuasive technology in the domain of sleep therapy.
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
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
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
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
Why sleep therapy?

- Sleep is important
- >10% of population suffers from insomnia
- Proven therapy
- Large variation in exercises
- Adherence rate 52%
Why smartphone?

Natural flow of activities
- Always present and accepted
- Inclusion of sensors
- Interactive (dialogue)
- Communication with others

Powerful tool
- Computational power
- Large data store
- Graphical possibilities
- Virtual character

Disadvantage
- Still very simple
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 is sleep?
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

(Dikke Van Dale)
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>
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<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>
Circadian rhythm
Sleep pressure

www.howsleepworks.com/how_homeostasis.html
Measurement of sleep stages: polysomnography

EEG: elektro-encefalogram
EOG: elektro-oculogram
EMG: elektromyogram
respiration
bloodpressure
oxygin in the blood
ECG: heartbeat
Sleep Diary

4-week sleep diary

<table>
<thead>
<tr>
<th>Dates</th>
<th>16 June 2010 --</th>
<th>23 June --</th>
<th>30 June --</th>
<th>07 July --</th>
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<td>w t f s s m t</td>
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<td>w t f s s m t</td>
<td>w t f s s m t</td>
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<td></td>
<td></td>
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<td>18 19</td>
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<td>20 21</td>
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<td>22 23</td>
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<td>02 03</td>
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<td>06 07</td>
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<td>08 09</td>
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<tr>
<td>10 11</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>12 13</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>14 15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tiny dab melatonin | 1/2 mg melatonin | Light box

EVE | NIGHT | DAY

GOAL

zzzz
# 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>
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<tr>
<td>wake</td>
<td>active</td>
<td></td>
<td></td>
<td></td>
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<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
- Too much sleep
  - sleep apnoea, restless legs, narcolepsy
- Problems sleep/wake rhythm
  - nightshift, jetlag, ...
- Parasomnia
  - teeth gnash, sleepwalk, nightmare, ...
We concentrate on insomnia
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
15% of the population suffers from insomnia
In the Netherlands
1.9 million people use hypnotics.
Yearly costs of insomnia are estimated at 5 billion Euro (in the Netherlands)
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 ...
... the stress in our life, the medicine/drugs that we take, behavior of our spouse ...
... the food that we take, the drinks that we drink, the circumstances in our bedroom, ...
Some factors cannot be changed, but many of them can: thoughts, behavior, circumstances, ...
How change?
Existing support to wake up
And...
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 liet 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 ontwaak 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) ontwaak. Onderzoek laat zien dat het blauwe ochtendlicht een ontwakend effect heeft. Bruin goed nachtelijk licht ontwaakt niet.
Existing support to sleep well
Slaaptips

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.

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

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

Auping nights, Better days
And...
Dream machine

Japanese doll

Girlfriend pillow

Boyfriend pillow

Chillow

Dreammate

Sleepkey

Wensveen

Sleeptacker

Digital mattress
And...
Many many apps
Sensors

- ART
- Actiwatch
- Fitbit
- Lark
- Jawbone
- Mobile phone
- Nike Fuelband SE
- Zeo
Cognitive Behaviour Therapy for Insomnia (CBT-I)
Sleep therapy

- Sleep education
- Cognitive restructuring
- Sleep hygiene
- Relaxation
- Bedtime restriction
- Stimulus control
Exercises

• Sleep restriction
  – restrict total time in bed
• Stimulus-control
  – associate bed with sleep
• Relaxation
  – physical exercising, meditation, visualisation, ...
• Sleep hygiene
  – room temperature, light, sound, clean, ...
• Cognitive restructuring
  – change disruptive thoughts, stop worrying, ...
Sleep therapy

- Bedtime restriction
  - use bed for sleeping only
  - do not sleep outside the bed

Goal state: sleep efficiency ≥ 85%
Go to bed at 12 and get up at 5! Practice for five weeks.
Persuasive strategies

Two main strategies for desired behavior

– system facilitates spending less attention
– subject is willing to spend more attention
Ability

Motivation

High

Low

High

Low

Ability

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Ability
simplify or impede behavior

Desired behavior

Undesired behavior
Motivation
benefits or threats

Show goals and pitfalls, explain reason, manage expectations,
...
Motivation
avoid boredom, annoyance and stress

Include beauty, competition, positive user experience, flow, ...

Welcome to Yoga Retreat!

nott won't sleep
Motivation
include social influence

Elements:
trust, commitment, alignment, reciprocity, transparency, competition, collaboration, ...

Speech acts:
forbid, encourage, promise, negotiate, advise, judge, appraise, challenge, thank, compliment, welcome, ...

[Image of two people working together]
[Image of a virtual meeting]
SleepCare
Therapy model

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

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

Closure phase
- Evaluation
- Referral?
- Departure
SleepCare
Exercise model

Exercise

Alignment → Plan & Commit → Task execution → Evaluation → Closure
Daytime activity window

Daytime activity window

morning

- ob-d
- d
- d-r1
- r1
- r1-r2
- r2
- r2-ib

evening

daytime →

- diary

- relaxation
SleepCare
Interface metaphor

Dialogue

Tools

status bar

navigation drawer
Blablablab bla blablabba

Blablablabbla blablabl

Blablablabbla blablab

navigation bar
Example Dialogue:
Shared Decision Making
Deze week beginnen we met de oefening bedtijdbepering. Bij bedtijdbepering houd je regelmatige bedtijden aan en verkort je de tijd dat je in bed ligt. Omdat je dan minder tijd hebt om te slapen, word je vermoeider en dat helpt je met beter slapen.

Wil je meer weten voordat we beginnen?

Ik wil beginnen
Wat moet ik precies doen?
Wat kan ik verwachten?
Geef aan hoe lang je in bed zou willen liggen.

pill

6:00
5:30
6:30

Dan stellen we nu samen je nieuwe bedtijden vast. Op basis van je slaapdagboek stel ik voor dat de totale tijd in bed 5 uur wordt. Ga je hiermee akkoord?

Ja
Ik lig liever iets langer in bed
Ik wil geen bedtijdbeperking

Geef aan hoe lang je in bed zou willen liggen.

5:30
6:00
6:30
Ik lig liever iets langer in bed.
Volgende

Je hebt voorgesteld dat je de komende week niet langer dan 6:15 uur in bed gaat liggen. Daar ga ik mee akkoord.

Geef aan hoe lang je in bed zou willen liggen.

5:45  6:00  6:15  6:30

Volgende
Another Example Dialogue
Hello John,

Let’s have a look at your sleep overview of last nights

Go to sleep overview
Sleepcare gesprekken

Slaapfasen gedurende 24 uur

2014-12-07 960

Slaapfasen gedurende 24 uur

informatie
On average, you spent 8 hours in bed, of which you slept only 5.30 hours:

REM sleep: 20%
Light sleep: 50%
Deep sleep: 30%

I advise you to do a relaxation exercise before sleeping.

Would you like to start now?
Choose length of exercise

1 minute

2 minutes

4 minutes
Sleepcare ontspanningsoefening

4 minutes
Sleepcare ontspanningsoefening

4 minutes
Inside the machine
Coaching knowledge

two types

• Background
  – timeless information about coaching process
  – e.g. disorders, utterances, constraints, tools

• Coaching process
  – repository of historical and planning information
  – e.g. state of coachee, performance, commitments
### Sleep Restriction scenario’s and negotiation space

<table>
<thead>
<tr>
<th>Average TIB (hours)</th>
<th>8.5</th>
<th>8</th>
<th>6</th>
<th>4</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>9</td>
<td>Excl</td>
<td>[6;8]</td>
<td>[5;8]</td>
<td>[5;8]</td>
</tr>
<tr>
<td>8</td>
<td>X</td>
<td>Excl</td>
<td>[6;7]</td>
<td>[5;7]</td>
<td>[5;7]</td>
</tr>
<tr>
<td>6</td>
<td>X</td>
<td>X</td>
<td>Excl</td>
<td>[5;5.5]</td>
<td>[5;5.5]</td>
</tr>
<tr>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Ref_therap</td>
<td>Ref_therap</td>
</tr>
<tr>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Ref_therap</td>
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<tr>
<td>2</td>
<td>X</td>
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<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

X = impossible  
[r ; s] negotiation, min = r, max = s
# Schedule

## entry types and status

<table>
<thead>
<tr>
<th>Types of tasks</th>
<th>Ontological type</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Tijd uit bed’ (wake-up time WT)</td>
<td>Event</td>
</tr>
<tr>
<td>‘Slaapdagboek invullen’ (SD)</td>
<td>Entry</td>
</tr>
<tr>
<td>‘Consult’ (CO)</td>
<td>Entry</td>
</tr>
<tr>
<td>‘Ontspanningsoefening’ (RE)</td>
<td>Entry</td>
</tr>
<tr>
<td>‘Tijd in bed’ (bedtime BT)</td>
<td>Event</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Status</th>
<th>Past</th>
<th>Today</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not-completed</td>
<td>Missed</td>
<td>Actual/near miss</td>
<td>Planned</td>
</tr>
<tr>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Ahead of schedule</td>
</tr>
</tbody>
</table>
Schedule

"[laatste notificatie of begroeting hier plaatsen]"

- 07:00: uit bed
- 08:00: dagboek invullen
- 15:00: ontspanningsoefening
- 21:30: dagboek invullen
- 22:30: naar bed

informatie
Ontology and architecture

• Knowledge representation classes (ontology)
  – sleep related
    • e.g. Disorders, Techniques, SleepEfficiency, Tools, ...
  – coach related
    • e.g. Contract, Situation, Schedule, Background, Clock, ...

• Sleepcare architecture
  – components
  – responsibilities
  – interaction
Persuasive elements

Improve ability
- tools for agenda, sleep diary and relaxation
- negotiation: user and system decide together
- rescheduling of agenda entries
- tells at the right moment what should be done (reminders)
- clear language (checked by communication language expert)
- intuitive interface

Improve motivation
- frequent alignment and adaptation
- negotiation: user and system decide together
- commitments: explicit agreement on bedtimes
- shows goals, rationale and results
- expectation management
- gives compliments
- shows danger and pitfalls
- attractive design (designed by professional designer)

Decrease ability
- offers default values

Decrease motivation
- show non-adherence (impede unwanted behavior)
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
• ...


Future show/proof genericity of design

- Experiments (RCT)
- Apply to other user groups and domains
  - truck drivers, people suffering from depression and psychosis
  - nudging with Philips Hue, sophisticated Eliza, mindfulness, ‘getting things done’
- Extension
  - sleep tracking (fun and improves ability)
  - include existing and useful functionality (e.g. alarm clock)
  - behavioral activation (fill the extra time)
  - motivation (measurement and adaptation)
  - social media
Principles for a good sleep

- Quiet, Cleanliness and Regularity (Rust, Regelmaat, Reinheid)
- Increase sleep efficiency
- Take care of good bedroom conditions
- Eat well and do physical exercises
- Use the bed only for sleep (and sex)
- Improve the quality of your life
- Do nothing and accept doing nothing
- Never think the same thought twice, unless the thought is nice
- Know yourself!

www.ikgalekkerslapen.nl
That's all Folks!