Eliciting Mental Models for a Mobile Diabetes Living Assistant

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Agenda

Diabetes Mellitus

- Disease, Treatment, Social Impact

Usability of Diabetes Assistants

- Mental Models
- Design of an Empirical Experiment
- Relation of Age and Expertise
- Measuring Performance and Eliciting Mental Models

Results

- Hypotheses and Effects of Aging on Performance
- Age, Mobile Phones and Mental Model Construction
- Effects of Mental Models on Performance

Diabetes Mellitus

Diabetes is a glucose metabolism dysfunction

- Main symptom: Insulin deficiency
  - Insulin: Glucose from blood -> cells
- High glucose levels cause vascular and neural damage
  - Secondary disorders: Blindness, Renal failure, Amputations, etc.

Type 1 Diabetes

- Autoimmune mediated disease => absolute insulin deficiency

Type 2 Diabetes

- Obesity & Lack of physical exercise => continuous increasing cell insulin resistance => Collapse of insulin metabolism

Diabetes Treatment

Main Task - Controlling:

- stable low blood glucose level

Means:

- low caloric diet, physical exercise, anti-diabetic drugs, subcutaneous insulin injections

Requirements:

- Accurate measurement and tracking of patients health parameters

Highly individual disease patterns require customized therapy

- Mobile Diabetes Living Assistants

Diabetes is Expensive

Forecast for 2010 in Germany (German Diabetes Union 2007)

- 10 Million people affected
  - (1/8th of population)
- 20% of Germanys total health care expenditure
- 40 Billion Euros for secondary disorder treatment

Demographic changes will increase Diabetes incidence

- sedentary lifestyle and high caloric diet increases likelihood
- Diabetes prevalence increases with age

Technical solutions become inevitable + Usability

- Diabetes patients rarely use digital diary functions (<10%)

Diabetes Conclusion

Demographic changes concur with higher Diabetes incidence

Secondary disorders

- caused by unsuccessful treatment
- cause the major amount of costs

Highly individual disease patterns require individual therapy

Patients keep track of their health status -> paperbased

- Bad usability of digital diaries

Better technical solutions are required

- Focus on usability!

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Mental Models

A mental model is an explanation for someone's thought process

- Cognitive representation of how the world works
- Contains:
  - Information about relationships of parts of the world
  - Intuitive perception of effects of personal interaction

Mental models of menu structures:

- How is a menu put together?
- How are parts interrelated?
- How do I reach the function I need for my task?

What we have

Diabetes Living Assistant Prototype

- Developed by and with Diabetes patients
- Testbed for performance measuring during user tests

Important factors:

- learnability of the device
- one device for all diabetes types
- unbiased participants for user tests (no branded device)

Design of the experiment

Target of the experiment

- Elicit structure of mental models for our diabetes living assistant
- Find determining factors for mental model construction
  - Age, technical expertise, domain knowledge, health status
- Measure impact of correctness of model on user performance

Experimental Study (Overview)

Independent Variables

- 1) Participants were surveyed about (paper-based)
  - demographic facts
  - expertise with technology
  - domain knowledge of diabetes

Dependent Variables

- 2) Participants took part in a user test of a simulated device
  - five tasks
  - Performance was measured along the way

Experimental Study (Overview)

Dependent Variables:

- 3) Mental Model Elicitation:
  - Participants were asked to perform a Card-Sorting-Task

- 4) Qualitative Analysis:
  - Experimenter asks questions about the mental model layout

User Diversity and Participants

Participants for user study selected prototypically

- Best case patients - „healthy diabetics“

Group of 23 participants (16 female, 7 male)

- 10x Non-Diabetics, 13x Diabetics
- Ages 25-87

Independent Variables

Assessment of Domain Knowledge

- survey knowledge of four key health factors
  - blood sugar
  - HbA1c
  - blood pressure
  - body fat percentage

Assessment of Technical Experience

- Survey of Perceived Ease of Use (PEU) and Usage Frequency (UF)
  - for everyday technology, mobile phone, medical technology

Ranking on a Six-Point-Likert-Scale

Relationship of Expertise and Age

Highly significant correlation between…

- age and expertise in everyday technology and mobile phones
  - Younger users are more experienced

No significant correlation between…

- age and domain knowledge
- age and expertise in medical technology

Diabetes Living Assistant

Self-developed Prototype

- JavaME based
  - PC/MAC/Mobile Phones, PDAs
  - logging function via Jacareto/CleverPHL

- Screen design similar to paper based solutions
- five core functions
  - Diabetes diary, BE-Calculator, Health-Pass, Medicine, Value-Plotter
- Visual ordering of Interaction Items suggests a spatial model of menu hierarchy

Simulation on a touch-enabled 15“ TFT-Screen

Rating User Performance

Five performance criteria were measured

- total success rate (in percent)
- total amount of time
- total steps
- detour steps (navigational mistakes)
- time per step (navigational pace)

Mental Model Elicitation

Method: Card-Sorting-Task with screenshots

- Users lay out screenshots on a table
- Spatial ordering from memory

Evaluation

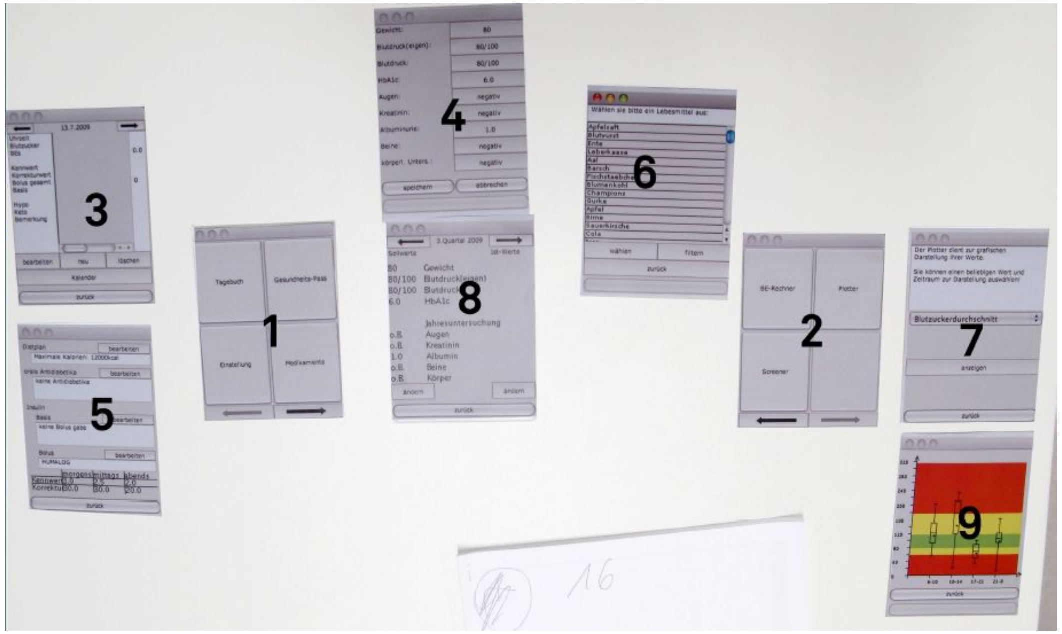
- Categorization by model complexity:
  - No model, linear, hierarchical, spatial map
- Quality assessment according to three navigational concepts
  - Overview, Route, Landmark

Mental Model Evaluation

Model quality assessed by scoring in each knowledge domain

Example: Spatial-Map Model

- Overview Knowledge
  - Correct spatial ordering
- Route Knowledge
  - Correct navigational distances
- Landmark Knowledge
  - Correct spatial neighborhood



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Hypotheses

Older users are outperformed by younger users

- higher technical expertise
- effects of aging on performance
  - (mental processing speed, psychomotor-skills)

Diabetes patients outperform non-diabetics

- Domain Knowledge could help in construction of mental models

Users with higher quality mental models perform better

- Less navigational mistakes

Hypotheses

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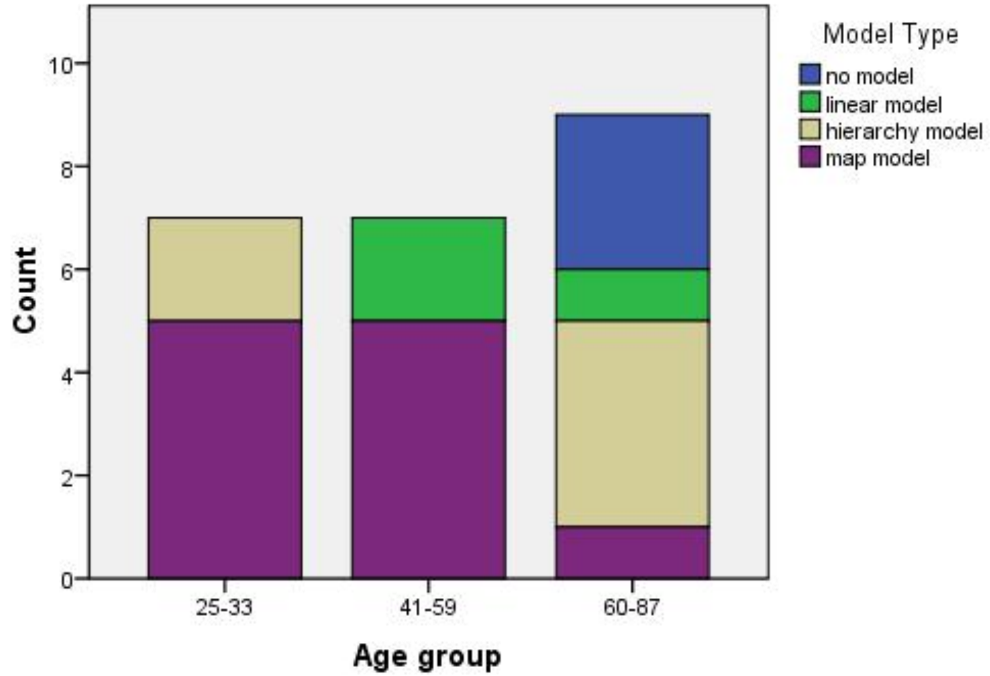
Mental Models, Age and Mobile Phones

Age correlates significantly with

- Model complexity ($p<0.05$)
- Model quality ($p<0.01$)

Model quality correlates with

- Expertise in Mobile Phones ($p<0.05$)



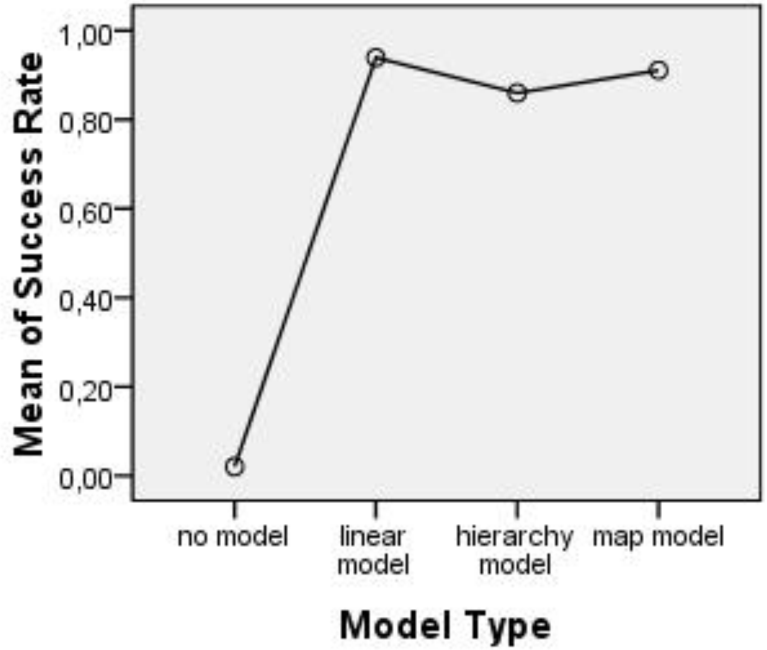
No Correlation between health and model

Mental Models and Performance

Model quality correlates with success rate

Model complexity correlates with

- Success rate and navigational pace
- But linear model perform as effective as more complex models
  - Similar amount of route knowledge



Linear Regression

- Route knowledge has biggest impact on performance
  - (2nd Overview, 3rd Landmark)

Discussion

Linear Models as a transformation?

- „Missing Multiple Instances " => temporal Model? No!
- Traversing of menu tree? Possible!
  - When does it occur? During construction? During layout?

A high quality mental model supports the user in his navigation

- Not complexity but possibly route knowledge is important

Linear menu structures could aid usability of devices for the elderly

- Questions remains: How to cope with complexity in a linear menu model?

Thank you for your attention!

Performance Results

Bivariate Correlations

	Success Rate	*Total steps*	*Detour Steps*	*Total Time*	*Time per step*
Age	-0.664**	0.616**	0.472*	0.231	0.693**
Expertise with technology	-0.449*	0.330	0.244	0.476*	0,320
Expertise with medical technology	0.251	-0.266	-0.146	0.101	-0.342
Mobile Phone Expertise	-0.339	0.295	-0.006	0.393	0.301
Health Status	-0.179	0.342	0.181	-0.102	0.421
Domain knowledge	-0.53	-0.167	0.097	0.314	-0.244

Device Acceptance

Correlations between Acceptance, Expertise, Age and Success

	Age	*DK*	*HS*	*TE*	*MTE*	*MBE*	*Success rate*
Acceptance	-0.460*	0.200	0.027	0.276	0.409	0.287	-0.507*

$^{*}p < 0.05$

- Low Value for Acceptance = Good acceptance rating
  - DK = Domain Knowledge, HS = Health Status, TE = Technical Expertise, MTE = Medical Technical Expertise, MBE = Mobile Phone Expertise

Linear Regression

- 65% of variance are explained by age and success rate
  - success rate stronger predictor than age (2x)

Example Tasks

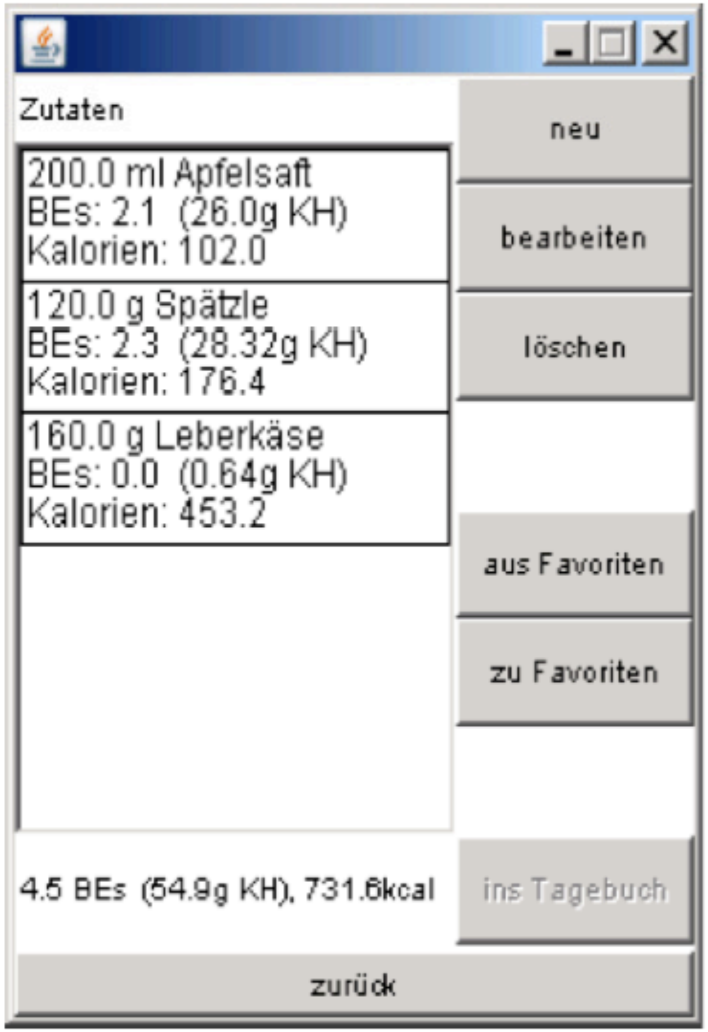
Digital-Diary Task:

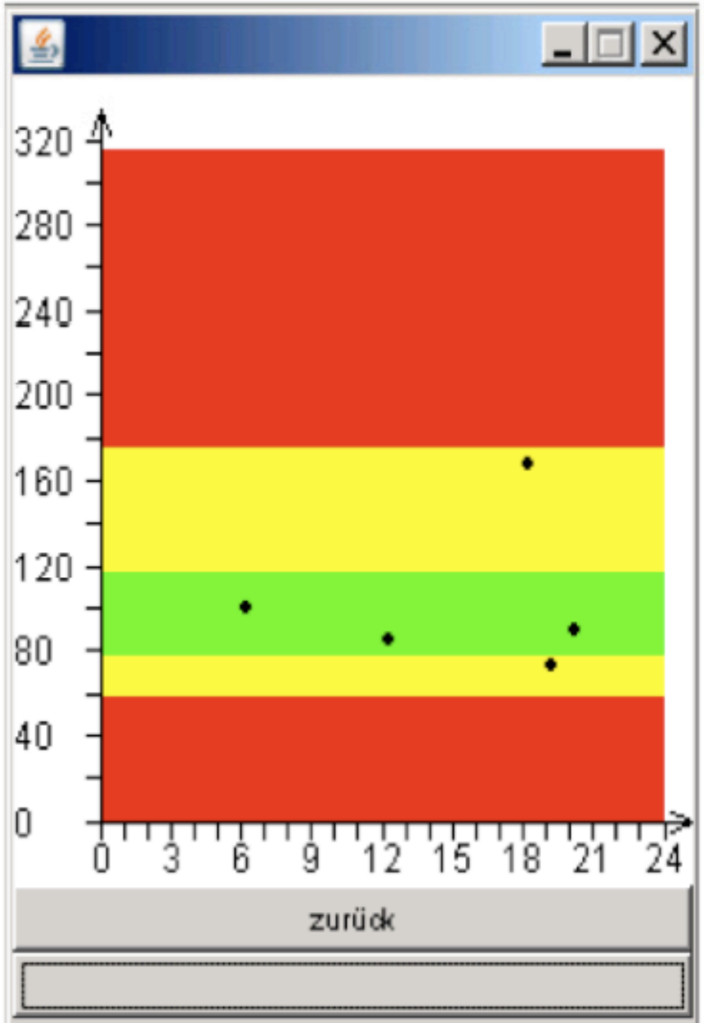
- After finishing configuration of your device, daily blood glucose measurements can be stored in the devices digital diary. Please enter the following measurement into the digital diary:
  This morning 9:20 am: Blood Glucose level 123, consumed 3 bread units, no correction of insulin dosage, no basal-insulin dosage, no hypo- or ketoacidosis measured

BE-Calculator Task:

- You are hungry and want to eat some fish sticks (200grams) and have a glass of apple juice (200ml). Please calculate the bread units for this meal using the BE-Calculator of the device

Example Screens





Example Screen: Learnability

Datum: 12.3. Arbeitstag X Urlaubstag ☐ Mo ☐ Di ☐ Mi ☐ Do ☐ Fr X Sa ☐ So ☐

Uhrzeit	6 30	12 30	18 00	19 30	20 00	2 00			Gesamt
BZ	104	89	172	77	94	113			
HZ/Az.									
BE	8	7			11				26
BE-Faktor	2,5	2			2				
Bolus	20	14			22				56
Basis					30				30
Blutdruck/ Puls			Sport						Korrektur-Regel: