# Mental Models of Menu Structures in Diabetes Assistants

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**Abstract.** Demographic change in regard to an aging population with an increasing amount of diabetes patients will put a strain on health care rentability in all modern societies. Electronic living assistants for diabetes patients might help lift the burden on taxpayers, if they are usable for the heterogeneous user group. Research has shown that correct mental models of device menu structures might help users in handling electronic devices. This exploratory study investigates construction and facilitation of spatial mental models for a menu structure of a diabetes living assistant and relates them to performance in usage of a device. Furthermore impact of age, domain knowledge and technical expertise on complexity and quality of the mental model are evaluated. Results indicate that even having a simplified spatial representation of the menu structure increases navigation performance. Interestingly not the overall correctness of the model was important for task success but rather the amount of route knowledge within the model.

**Keywords:** HCI, Mental Models, eHealth, Diabetes, User Performance, Menu Navigation, Aging, Assisted Living.

## 1 Introduction

Slick user experience is becoming the critical factor for acceptance, sustainability and competitive capacity of any mobile technical system, especially in regard of demographic changes, world wide increasing life expectancy and the resulting increase of older users. The share of population over the age of 65 already reached 20 percent in Germany in 2008 and is expected to swell to a 38 percent level in 2038[1]. Similar forecasts apply to many western European countries [2]. Usage of electronic devices is also decreasingly voluntary because of either work or everyday life requirements [3,4]. This impact will be even stronger concerning medical appliances of mobile devices. Since the increase of age related illnesses like diabetes accompanies both demographic change and sedentary lifestyle, medical care and age appropriate independent domestic care can only be economically realized through mobile technical solutions [5].

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It is a central claim that mobile devices are designed to be in line with users' specificity and diversity. However, the intelligent interface design of mobile devices, which meets the demands and abilities of especially older users, is an extremely sophisticated task. Aging itself represents a highly complex process. Not all users age in the same way, and the onset of aging processes as well as the consequences show considerable differences across humans. Design approaches should therefore take the user-perspective seriously [6-9]. This includes that adults' behavior with current technical devices is carefully studied and also, that user abilities are identified, which affect the interaction with interactive computing devices.

The miniaturization of small screen devices may also contribute to usability shortcomings. Beyond handling and visibility problems, the restricted screen space allows only little information to be displayed at a time. By this, memory load is increased. In addition, orientation in the menu is complicated, because users do not experience how the menu might be "spatially" structured and how the functions are arranged [10-15]. In hierarchically structured menus disorientation occurs when complexity is high with respect to the depth and breadth of menu levels [12, 16, 17].

Earlier research has shown that having a suitable mental model increases usage perfomance of such devices [11, 18]. The concept of mental models stems from cognitive psychology and is defined as users' internal representation of how systems work and how they are structured [19]. Mental models are assumed to be formed through increasing expertise with the system, combining knowledge of prior experience, cognitive schemata, and problem-solving strategies [20]. Since aging decreases mental processing speed and is accompanied by declines in spatial capability (e.g. mental rotation ability) construction of a spatial mental model could be hampered.

However, it was found that age-related decreases could be compensated by expertise [21, 22]. Thus, performance of older adults can be just as good as that of younger adults when they can rely on elaborated domain-specific knowledge or prior exposure to similar technology.

This study aims to find determining factors of older adults in mental model construction. For this purpose factors such as age, expertise with technology, mobile phone expertise, domain knowledge (in the field of diabetes) were examined as mediating variables on construction of mental models of a diabetes living assistant.

## 2 Method

In this exploratory study 23 adults were asked to perform five tasks on a simulated diabetes living assistant. Before starting the device, participants were surveyed about their technical expertise in regard to everyday technology (i.e. computers, VCRs, GPS navigation systems, etc.), mobile phones and medical technology. Additionally domain knowledge of diabetes was assessed. After the trials participants were asked to lay out a spatial representation of the diabetes living assistant using screenshots of the program. After this card sorting tasks, participants were asked to shortly comment on their mental models.

Mental models were then grouped into four types (no model = 0, linear = 1, hierarchical = 2, spatial map = 3) regarding their complexity and in regard of their facilitation of spatial ordering cues in the diabetes living assistant. This can be seen as survey knowledge of the model. Furthermore models where also scored in regard to the expressiveness in route and landmark knowledge [23]. Route knowledge will be rated higher, if the relative distance of two nodes reflects the amount of navigational steps between these nodes. Landmark knowledge is seen as the relative spatial ordering of two screens to each other. A model's accuracy (or quality) is the sum of survey, route and landmark knowledge of the model. Higher score reflects a better incorporation of this knowledge into the model. In order to verify impacts of a constructed model, performance data of the five tasks was related to both type and accuracy of the mental model.

Performance data in this case are effectiveness (percentage of successfully solved tasks) and efficiency. Efficiency measures are the required time for solving tasks, the amount of navigational detour steps and the navigation pace.

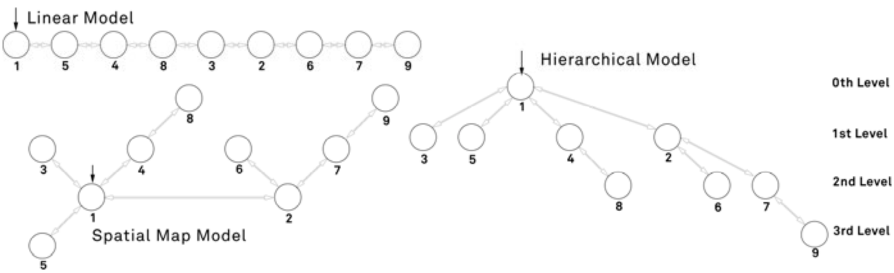


**Fig. 1.** Linear Model (top left) Hierarchical Model (right) and Spatial Map Model (bottom left)

### 2.1 Participants

A total of twenty-three adults volunteered to take part in this study. Among those, were seven young adults (M = 27.4 years; SD = 2.6; range: 25 – 33 years), seven medium aged adults (M = 51.3 years; SD = 8.3; range: 41 – 59 years) and nine older adults (M = 67.9 years; SD = 7.8; range: 61 – 87 years). The younger participants were mostly university students of different academic fields. Medium aged and older adults were reached by advertisement in local newspapers and through an exhibition on a local public diabetes convention and covered a broad range of professions and educational levels.

Twelve participants were non-diabetic adults, who were mostly recruited through their social networks. The eleven diabetic participants split up into a group of five participants diagnosed with Type-1-Diabetes and 6 participants suffering from Type-2-Diabetes.

### 2.2 The Diabetes Living Assistant

Our goal is to develop a portable device that supports diabetes patients in their therapy and in their everyday lives. Before dealing with the hardware part of these devices, we wanted to concentrate on the usability of the software. For the user studies, we needed an application that could be run on standard hardware. Furthermore we needed a user interface that could be used without a keyboard, so that it can later be used on a touch screen-enabled mobile device. Another constraint was given by our decision to use the Jacareto capture and replay toolkit [22, 24, 25].

Instead of creating a specialized application that is only useful for certain diabetes patients, we decided to include features that are required for the different types of the disease.

We have tried to keep the menu-depth and breadth at a minial level by using a combination of a hierarchical menu and a wizard-like linear structure for data input (see Fig. 2 – node 3). The main menu consists of two screens (nodes 1 and 2) with 4 (or 3 respectivly) function keys. In order to improve ease of spatial mapping each function key is placed in one corner of the screen, to suggest a spatial placement of the feature behind the function.

The diabetes living assistant was simulated as a software solution on a PC connected to a touch screen, which was masked with an opaque paper cutout to create a device like feel.

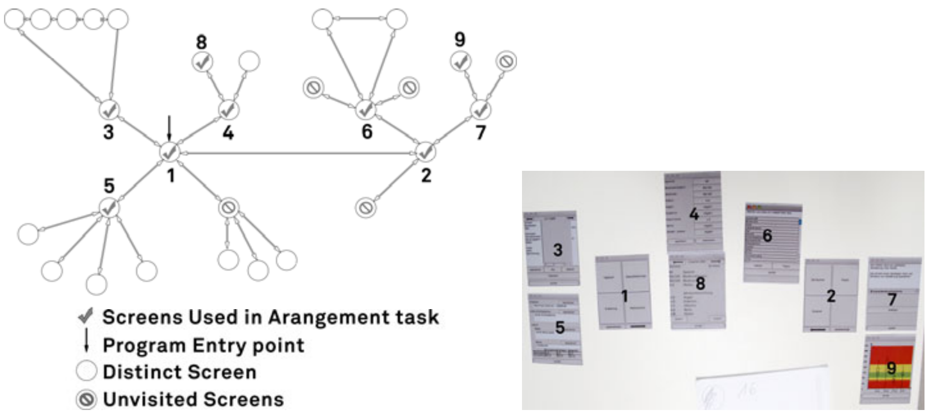


**Fig. 2.** Simplified Navigational Map of the Diabetes Living Assistant (left), Layout of Printed Screenshots (with a number overlay) as a Spatial Map (right)

## 3 Results

Results of this study were analyzed by one-way ANOVA, bivariate correlations, multivariate analysis of variance and univariate analysis of covariance with a level of significance set at 5%.

### 3.1 Did Participants Elicit the Model of the Programm Correctly?

Participants showed four different general types of mental maps. Only three older users were completely unable to arrange any model at all. Four users ordered the screens into a linear model, six into a hierarchical and eleven users arranged a spatial map as a mental model (see Table 1).

**Table 1.** Distribution of Models in Regard to Age Group, ordered from left to right in increasing complexity

| | No Model | Linear Model | Hierarchy Model | Map Model |
|---|---|---|---|---|
| Age 25-33 | 0 | 0 | 2 | 5 |
| Age 41-59 | 0 | 2 | 0 | 5 |
| Age 60-87 | 3 | 1 | 4 | 1 |

Correlation analyses show that age is highly significantly correlated with the complexity of the selected mental model (r = -0.566) as well as with the quality of the arranged model of the user (r = -0.467). The quality of the arranged model is also significantly correlated to the users experience with mobile phones (r = -0.430). Interestingly no significant correlation was found between complexity and quality of model with other technical expertise or domain knowledge.

### 3.2 How Did Personal Factors Impact Performance?

Age and expertise with technology show a significant correlation with performance measures in analyses. Younger age is highly correlated with better effectiveness (r = -0.664) and efficiency. Younger users need less total steps (r = 0.616), make less navigation errors (r = 0.472) and have a faster navigation pace (r = 0.693). Expertise with technology is mostly correlated with effectiveness (r = -0.449) such that users with better expertise are more effective than users that are more inexperienced. This correlation does only affect one efficiency measurement significantly (i.e. total time r = 0.476), which also shows that higher expertise is related with better performance.

### 3.3 Did Participants with More Acurate Models Perform Better?

Correlation analyses show that, having a general correct assumption of the complexity of the underlying spatial model of the program, is significantly correlated with task effectiveness (r = 0.496) and the navigational pace (r = -0.453, lower value is faster speed) in the menu of the device. The accuracy of the model only significantly correlates to the overall task effectiveness (r = 0.473).

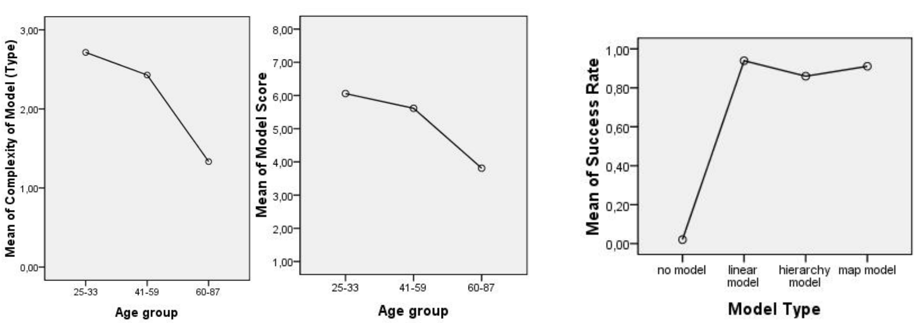


**Fig. 3.** Comparison of Mental Models in Regard to Complexity (left) and Quality (middle), Mean of Success Rate over Type of Model (right)

Still, one-way ANOVA comparison of means shows that not the type of the model alone can explain performance differences since users with a linear model performed equally well as users with a hierarchical or spatial model (see Figure 3). Linear Regression shows that route knowledge has the biggest impact on performance (22%) and outweighs survey knowledge (16%) and landmark knowledge (7%). Users who had a linear mental model incorporated about the same amount of route knowledge into the models as the users with hierarchical models (mean difference 0.166).

## 4 Discusssion and Conclusion

Not only do several factors affect performance of users during handling of a small screen device, but the mental model and especially lack thereof can heavily impact whether initial usage of a device is successful or has a propensity for failure. Age and lack of experience with mobile phones decrease the ability to create a correct or useful mental model. Interestingly not the overall correctness of the model was important for task success but rather the amount of route knowledge within the model. Users who arranged a linear model performed equally well as users with hierarchical and spatial map models (see Figure 3). Two possible explanations directly come to mind. Either the users arranged the screens by mapping their model (e.g. by traversing a hierarchy) onto a linear one or they truly created a mental map in a linear fashion.

Two participants with a linear mental model reported during the experiment that there were insufficient printouts of the main menu screens, so they tried to arrange them as good as possible, knowing there were missing connections between some screens and the menu screens. This leads to the assumption that they were not reusing the menu screens (like in a spatial hierarchy) and rather saw them as individual instances of a menu on a timeline based mental model.

Surprisingly, domain knowledge did not significantly impact the quality of the mental model, and as a consequence, the navigation performance. Thus, diabetic users could not profit from their more profound medical knowledge about what to do within a diabetes illness, when navigating through the device menu. In contrast, the expertise with mobile phone showed to have an enormous importance for the formation of a useful mental model.

### 4.1 Applications of This Study

The results of this study have shown that not all users might require a prefect mental model in order to operate a diabetes living assistant. Still, having a model at all is crucial to succeeding, corroborating findings of earlier studies [4][13]. Older users that are not familiar with hierarchical menu structures might be unable to elicit such a model from using a program. Since this study was exploratory in nature, results need to be validated with research. As the findings refer to a relatively small group of participants, we have to be cautious to transfer the outcomes to the broad variety of older users. Additionally the quality of specific parts of the mental model should be analyzed in regard to performance of tasks that require only aforementioned parts of the program. Designing a menu structure in a pure linear fashion, or in a way that it can easily be traversed into a linear mental model, could make usage easier for elderly patients. Showing a user a spatial overview of the program might also yield increased performance [11][13], due to priming of a mental model.

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