

An Evaluation of a Meal Planning System: Ease of Use and Perceived Usefulness

Johan Aberg

Dept. of Comp. and Info. Science, Linköpings universitet
SE-581 83 Linköping, Sweden

johab@ida.liu.se

ABSTRACT

Unhealthy eating is an increasingly important problem in the western society. Our approach to this problem is to provide a meal planning system giving recommendations of suitable food recipes, taking important factors such as nutrient content, cost, variation, etc into account. A user controls how the system takes these factors into account through settings after which the system creates an optimal meal plan. The user can then iteratively refine the settings until a satisfactory meal plan is produced. The system is evaluated empirically in terms of ease of use and perceived usefulness, factors crucial for eventual user acceptance. The results are positive, and several interesting possibilities for future system improvements are discussed.

Author Keywords

Meal planning, ease of use, perceived usefulness.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI):
User Interfaces.

INTRODUCTION

Unhealthy eating is a growing problem for people of all ages in the western society. It often leads to a decrease in quality of life as well as health-related problems, which in turn leads to increased costs for already heavily loaded health care systems. To overcome these problems a change in food consumption behavior towards healthier eating is needed. However, changing such a behavior, which can be rooted from many decades of similar behavior, is known to be difficult [12], and may require continual supervision and education [18]. Such individual support is not always available due to shortages in care resources. Thus, as an aid to changing food-consumption behavior we propose a food support system, to be used in the home, capable of

providing informed and individualized recommendations about what to eat. The system takes several important variables into account in the suggestions, such as taste, cost, preparation difficulty, dietary diversity, dietary restrictions, nutritional properties, and available food items. Hence, a health-care provider's suggestions can be incorporated into the system as individual constraints. Such a system, if used properly, has the potential of limiting the problems of unhealthy eating. For example, for users with economic constraints, low cost meals with good nutritional properties can be suggested that optimize the use of available food items, while still taking the taste of the user into account, and maintaining dietary diversity.

Our underlying assumptions with respect to the target population is that there is a *possibility* for changing food behavior and that social, cultural or economic factors do not make such change impossible. We also assume a relative freedom of choice of ingredients and recipes. These assumptions mean that we will not reach everyone with an eating problem, but the target population will likely be large enough for a successful approach to have a large positive impact.

For our system to have a real influence on unhealthy eating, users need to be able and willing to use it. Ease of use and perceived usefulness are thus two critical factors for the success of the system. Ease of use is the degree to which a person could use a particular system free of effort. In the case of changing food consumption behavior, our target population is very large so the ease of use criteria includes people with very limited computer skills as well as people with bad eye sight and shaking hands. Perceived usefulness then, is the degree to which a person believes that using a particular system would enhance his or her task performance. Applied to this context the task performance refers to the meal planning as done by the user today, perhaps browsing through cook books or recipe web sites for weekly inspiration, or applying dietary knowledge to the family's meals.

To summarize, the goal of this paper is to explore the following two research questions:

- Can the system be made sufficiently easy to use to not exclude anyone needing to change food consumption behavior?

- Can the system be made sufficiently useful? In other words, does it provide enough perceived value to make users consider using the system on a regular basis?

The rest of the paper is organized as follows. The next section describes the problem of unhealthy eating in more detail. After that we discuss the theoretical foundations for our approach to changing food consumption behavior, resting on the theory of planned behavior. Next, we describe our meal planning system. After that we describe two empirical studies of the meal planning system, with each study corresponding to one of the two research questions. The results are discussed, followed by a discussion of limitations. After that related work is described, and the paper is concluded and pointers are given to future work.

BACKGROUND ON UNHEALTHY EATING

There is scientific evidence that many of the biological changes and risks for chronic disease which have traditionally been attributed to ageing are in fact caused by sub-optimal diets and nutrient intakes [2,3,6,21,23,31]. While some nutritional surveys of the elderly have shown relatively low prevalence of frank nutrient deficiencies, there is a clear increase in risk of malnutrition [4,26], and a high prevalence of malnutrition of elderly patients admitted to different clinical settings has been reported in the literature [17,21,33]. It has also been shown that hospitalization as such has a negative influence on nutritional status of geriatric patients [10,17].

It is also important to note that suboptimal diets and nutrient intakes is not a problem only for people of old age. It can affect people at all ages, illustrated by the common obesity problems of the western society.

Having a varied and nutritious diet has many benefits, as often taught already in early school years, and can prevent the many dangers of malnutrition and obesity. However, there are many obstacles on the path towards healthy eating (e.g. [20,16]), including the following:

- Lack of time. For example, families with young children and working parents struggle to find enough time to spend with their children and may not be willing to spend extra time coming up with well-balanced, varied, and nutritious meal plans. And fast food is always around the corner.
- Lack of knowledge. Many people do not know the basics of nutrition theory. They don't know what constitutes a nutritious meal. They don't know the importance of variation, or the dangers of consuming too much sugar or the wrong type of fat.
- Lack of money. Some people struggle financially and may find it difficult to justify seemingly unnecessary expenses on e.g. fresh vegetables that have to be used in a timely manner to avoid being wasted.

- Lack of skill. Many people do not know how to cook. For example, having been cared for by a previous partner, and then suddenly being left in charge of cooking after a divorce may lead to a shift to fast food consumption.
- Lack of interest. For some people, eating is simply not important, it is just something that has to be done regularly to survive. There are illnesses such as depression that can cause a lack of appetite.

To summarize, unhealthy eating is a serious problem in the western society among people of all ages. To come to terms with the problem a person must change the food consumption behavior, and eat food that better fits his or her body's current needs.

CHANGING FOOD CONSUMPTION BEHAVIOUR

According to one of the dominant theories in social psychology, the *theory of planned behavior* [1] (which is based on the *theory of reasoned action*), human behavior is determined by specific considerations (see Figure 1). Behavioral beliefs refer to the outcome of a behavior and the evaluation of the outcomes (e.g. "eating better means that I feel better and look better"), and lead to an *attitude toward the behavior*. Normative beliefs refer to the perceived expectations of others and the motivation to live up to these expectations (e.g. "I want to please the doctor and reassure my family"), and lead to a *subjective norm*. Control beliefs refer to factors that can help or hinder performance of the behavior and their relative importance (e.g. "to eat better I need to understand nutrition theory"), and lead to *perceived behavioral control*. Together, the attitude toward the behavior, the subjective norm, and the perceived behavioral control lead to a behavioral *intention*. Finally, given an intention to perform a behavior and the perceived behavioral control, a person is expected to succeed in performing the behavior (assuming the perceived behavioral control is close to the actual behavioral control).

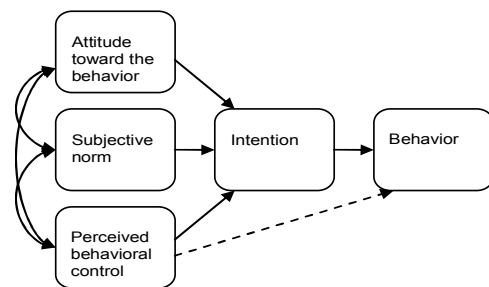


Figure 1. Theory of planned behavior

This theory has been shown to be a useful framework to predict eating intentions and behavior (e.g. [8,24]).

Our approach to help people change their food consumption behavior (and thus deal with malnutrition problems), is to provide them with a tool for meal planning to be used in their homes. Connecting to the theory of planned behavior,

which serves as a motivating framework in our work, we expect this would raise the perceived behavioral control of the users¹, in the sense that they feel that they have all the knowledge and resources needed for actually changing their behavior and prepare and consume meals suitable for them. Our approach also corresponds to giving users a concrete *when* and *how* plan for their target behavior, which has been shown to be effective for behavior change [32]. The meal planning system is described next.

A MEAL PLANNING SYSTEM

Our approach to helping users change their food consumption behavior is a system that recommends meal plans.

Requirements

The factors influencing a person's food choice have been studied to a fairly large extent in the science of food and nutrition. Shepherd [25] described several attempts to identify factors influencing food choice, and went on to propose the use of the theory of reasoned action as a general model for food choice. However, this model is completely based on user's attitudes, and does not seem suitable as a *normative* framework. After all, we are not really interested in *predicting* a user's food choice, but to *persuade* [11] the user of choosing optimal food, weighing in the relevant factors. Hence, we have taken the approach of gathering the most feasible² factors from all the models presented in [25]. This means that our system is required to represent and reason about the following information:

- Dietary restrictions, e.g. ingredients that the user is allergic to, or must not eat for other medical reasons.
- Nutritional values, e.g. amount of fat or protein contained in a recipe, or required by a user.
- Preparation time of a meal.
- Preparation difficulty of a meal.
- Cost of a meal, i.e. the cost of the needed ingredients.
- Availability of ingredients for a meal, e.g. to what extent does the needed ingredients match the ingredients available to the user at home.
- Variation with respect to other meals in the plan, in terms of used ingredients and the category of a meal.

¹ Our focus on increasing a user's perceived behavioral control does not mean that we neglect the other factors influencing intention and behavior, it is simply the first investigation step we take.

² By feasible we mean that the factor should be possible to make use of in the system, with respect to practical knowledge engineering and reasoning issues.

- The user's food taste, i.e. how the user rates a recipe on a taste scale.

Design

Our approach to construct optimal meal plans according to the factors presented above uses constraint satisfaction techniques. We make use of a specially designed XML-based mark-up language for food recipes that allow us to represent the needed content information for the recipes in the database. We model the constraint-satisfaction problem with a mix of weighted soft constraints and traditional hard constraints, similar to the approach in [29]. We have experimented with different ways of modeling the problem. In our current approach, variables are used for describing different aspects of a recipe, such as *time*, *cost*, *energy*, *protein*, etc, and the variable domains are composed of the values occurring in the recipe database. In order to make sure that a solution actually has a corresponding recipe there is an additional hard constraint requiring. This constraint requires a complete variable assignment to match only existing recipes in the database.

We employ a set of additional constraints to take the user's needs and preferences into account. Such constraints include hard constraints, e.g. for ingredients to avoid, and soft constraints, e.g. for variation between meals (a recipe with many ingredients in common with a recipe for a previous meal gets a penalty) and for taste (recipes with high rating or predicted rating get low penalty).

For solving the constraint-satisfaction problem we base our approach on the well-known depth-first branch and bound algorithm. We have also been experimenting with a set of forward-checking approaches and variable ordering heuristics. The implementation used in the user studies presented below uses depth-first branch and bound with partial forward checking. Note that the forward checking approaches and the variable ordering heuristics do not affect the end result, it is just a matter of how fast the optimal solution is found.

User Interface

The user interface of the system has been designed with accessibility in mind, particularly for elderly users. The current user interface design is the result of an explorative design process where two separate prototype designs were created as paper prototypes and evaluated empirically with elderly users. Based on these user studies the current user interface was designed and implemented, in an attempt to use the best features from each of the two earlier prototypes. The system uses graphical settings to let the user control the constraints used in the optimization. Figure 2 shows a part of the settings management, where a user can select ingredients or categories of ingredients to avoid. Among other things, a user can also select required intervals for energy, fat, cholesterol, etc. Such settings are crucial for our purpose of helping people avoid unhealthy eating, and could be done in collaboration with the user's

care givers. The user can also select preference levels for cost, preparation time, preparation difficulty etc, and mark ingredients as currently available. There is also the possibility of including friends and family members and take their settings into account as well.

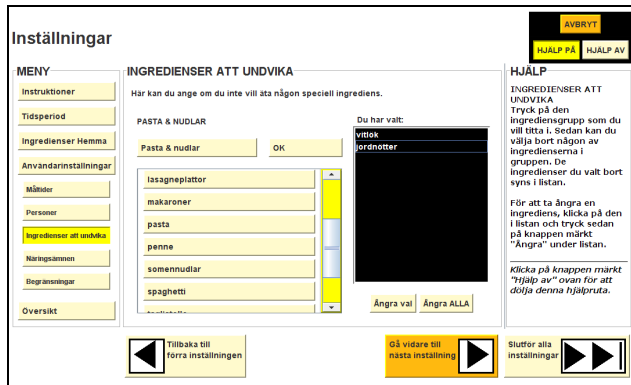


Figure 2. Meal planning system settings: selecting ingredients to avoid. [The central area lets the user select ingredients to avoid from different categories of ingredients. The menu to the left provides short-cuts to the different settings. The arrow buttons on the bottom of the screen gives another way of navigating between the settings. To the right there is a help text.]

Figure 3 shows an example of a recommended meal plan for a specific time period. Note that the user can switch between the top-5 meal plans, and give taste ratings on suggested recipes (on a scale from 1 to 5) and re-plan to take the new ratings into account, or create special settings for a certain meal, such as allowing a greater cost and preparation time for the Sunday meal.

Interaction Mechanism

The system's interaction mechanism is based on the principle of having suggested meal plans always being the result of an optimization process. This is to make sure that meal plans proposed do not override any hard constraints and that soft constraints are satisfied to the extent possible. This means that in order to refine a suggested meal plan, a user has to go through the settings and refine them, and then re-plan. There are no direct means of modifying the suggested plans, e.g. drag and drop of recipes between the different plans proposed.

This design decision is highly experimental, even controversial, and is obviously a trade-off between optimality and user control. For the approach to work, refinements of settings have to be very easy to do, and all needed settings must be possible. Otherwise the user is likely to feel frustrated by a lack of control, and may decide to ignore the system's suggestions altogether.

We now move over to our user studies of the system.

STUDY 1: EASE OF USE

Can the system be made sufficiently easy to use to not exclude anyone needing to change food consumption behavior?



Figure 3. Meal planning system output: a recommended meal plan for a 4-day period. [Currently the first alternative is displayed. The user can toggle between different suggestions with the topmost buttons. To the right of each recipe name there is a slider for changing taste ratings. Above the area for the recommended recipes are buttons for changing settings and for re-planning based on new taste ratings.]

Method³

In our study of the meal planning system's ease-of-use, we decided to conduct a usability study with users of old age with some, but not very extensive, computer experience. Our reasoning behind this choice of participants goes back to two reasons. The first being that it is known that people of old age risk having some particular difficulties with using computers, based on age-related changes to the human body such as decreased motor control, and we do not want to exclude such users since people of old age seem to risk more severe effects of malnutrition. The second reason being that the computer experience of these participants is what we expect to be the minimum for most people coming into retirement 10 years from now, given the increasing prevalence of computers and the internet, at least in the industrialized part of the world.

Ten users were recruited among the participants to an introductory computer course taught by an association for people of old age. Eight participants were male and two female. The age of the participants ranged from 70 to 83 years, with an average of 76.2 years. 7 of the participants had some computer experience from their work, while 3 had little or no work experience with computers. 9 of the participants used computers daily or at least 2-3 times per week, mainly for accessing the Internet. 1 participant used computers 2-3 times per year.

The usability tests took place either in the participants own home or in a meeting room at the university. Some of the participants wanted the study to be carried out in their home since it would be difficult for them to travel to the university, while some felt more comfortable to not have

³ The studies in this paper were carried out in Swedish. All data from the studies presented in this paper has been translated from Swedish by the author.

strangers coming to their home. As equipment for all participants we used a laptop with mouse and mouse pad, with an external monitor.

Each participant was first briefed about the study and how it would be organized, and that we wanted them to think out loud as they were trying to carry out the tasks. We emphasized that we were evaluating the system and not the users. After that we conducted the actual evaluation by consecutively handing out a sheet of paper describing the current task the participant had to carry out in the system. There were 6 tasks⁴ in total with progressive complexity that were designed to take the users through the most important parts of the system.

During the study an observer was taking notes on usability issues encountered by the participant. After all tasks had been completed we conducted an interview with questions about their age, computer experience, household situation etc. We also asked open-ended questions about their perception of the system's usability. We also conducted an interview with respect to their food consumption behavior.

Before the study we ran a pilot study with 2 users to make sure that the tasks and the interview questions were understandable.

System status

The system was implemented in Java and run on a laptop with a portable monitor and a mouse. The database contained 250 recipes. The constraint satisfaction solver

⁴ *Task 1.* Create a user with your own given name. *Task 2.* Get a meal plan proposition without making any settings. *Task 3.* Get a new batch of meal plans based on your own settings. Your settings must take the following made-up needs into account: You want a meal plan for the 4 coming days. The plan must be for lunch (not breakfast or dinner). You have moose meat in the fridge that you want to use the coming days. You don't like garlic and therefore you don't want any recipes containing garlic. The proposed plans shall have good variation, and contain recipes easy to cook. *Task 4.* Look through the proposed plans. Rate some of the recipes based on how tasty they seem. Get a new batch of plans to see what effect your ratings have had. *Task 5.* You remember that your good friend Cecilia is coming for a visit the day after tomorrow. You are having lunch together. This means that you want to cook something special, possibly a more expensive meal with a longer preparation time for just this particular occasion. Continue from your previous settings and make adjustments for Cecilia's visit. Get a new batch of plans for the 4 days. *Task 6.* You change your mind about the time period. The third day in your chosen time period you have an errand in town, so you don't want a proposal for lunch that day. On the other hand you want to plan for another two days after the fourth day. Change your settings and get a new batch of plans for these 5 days.

used was a depth-first branch and bound algorithm with partial forward checking. All settings mentioned in the system description above were operational except the settings of nutritional values which were not taken into account by the constraint solver since real values were missing for the ingredients in the recipe database. The participants were informed of this limitation before starting the evaluation.

Results

The observation data shows a number of ease of use issues that need to be addressed to improve learnability and the system's walk-up-and-use factor. The study resulted in a total of 58 unique ease of use issues. Each participant had an average of 10.6 observed ease of use issues (ranging from 7 to 18). The graph in Figure 4 illustrates the number of new issues discovered for each consecutive test participant. Despite the exception of User 9 it can be seen that the trend clearly goes towards very few new issues per new test participant. This indicates that the issues discovered are fairly complete.

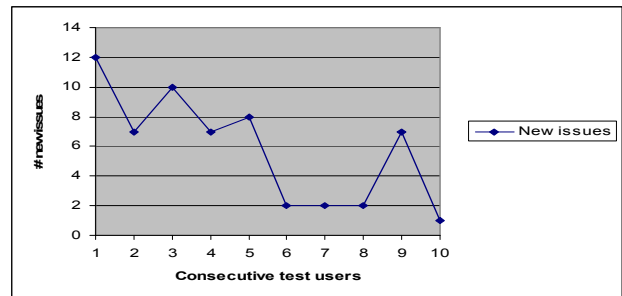


Figure 4. New ease of use issues per consecutive user

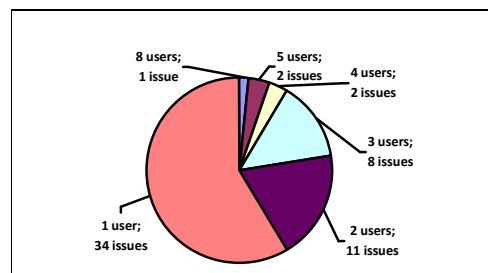


Figure 5. Number of users per ease of use issue

The pie chart in Figure 5 shows the number of participants who encountered each ease of use issue. There are five issues encountered by 4 or more users, followed by another eight issues encountered by at least 3 users and another 11 issues encountered by two users. The remaining 34 issues were encountered by unique users.

The most frequently occurring issues were related to the navigation of the system. Another important issue observed relate to problems that some of the participants experienced due to their shaking hands, which is a problem not uncommon among people of old age. In general they

handled the interface well, but had problems e.g. with a slider used for rating recipes on a scale from 1 to 5. The handle used for controlling the slider was too small which made it difficult to focus the mouse pointer on and clicking without drifting away from it before having had the time to click on it. Another similar example was a scrollbar where the handle of the scrollbar changed size according to the number of items in the scroll list, which meant that some participants had trouble controlling the tiny scrollbar for certain large categories of ingredients. These two examples are illustrated in Figure 6, where the mouse cursor is included to show the relative size of the objects. In order not to exclude users with shaking hands and related special needs one really has to avoid small interface elements at all cost.

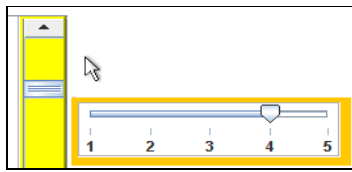


Figure 6. Screen objects too small to hit with shaking hands

While the issues emphasized are very important for our future re-design of the system we prefer to focus on the fact that all participants eventually got the hang of the system, and that all of the ease of use issues can be fixed given a few rounds of iterative development and usability testing.

In the interviews following the tasks we found out that only 30% of the participants were the ones who were actually doing the meal planning in their household. Hence we concluded that their perception of the usefulness of the system would be speculative, and we chose to not analyze that data any further. To study perceived usefulness we decided to do a second study, with different participants, which would also give us input and ideas from a different direction.

STUDY 2: PERCEIVED USEFULNESS

Can the system be made sufficiently useful? In other words, does it provide enough perceived value to make users consider using the system on a regular basis?

Method

The participants consisted of 8 senior computer science and computer engineering students taking a course on multimedia information retrieval. They were all doing their own meal planning as well as the actual meal preparation. They were all male, aged 21-26 (average 24).

The study was organized as two separate sessions with 4 participants in each, and took place in a computer lab room at the department of computer science at Linköping University with 8 separate work stations. At the start of each session the participants were seated in the lab room, isolated in a way that prevented them from seeing each other's screens. The session leader gave a brief introduction to how the study would proceed and pointed out that both

positive and negative feedback was welcome in the questionnaire to be handed out at the end of the session. The participants were also asked not to talk about the study until both sessions had been completed. After that all 4 participants gathered around one of the computers at which the session leader gave a brief demonstration of the meal planning system, making sure to point the known issues with the system (i.e. that the nutritional value settings are not taken into account, and that the database did not contain any breakfast recipes, only lunch and dinner recipes). The session leader made sure that everybody could see the screen well. After the demonstration each participant was given a paper with instructions, and returned to their assigned computers. The instructions detailed two tasks⁵ that the participant had to perform with the meal planning system. These tasks were constructed to ensure that the participant would have sufficient experience with the system in order to be able to evaluate its usefulness.

After each participant had finished the two tasks he was given a questionnaire to fill in. The questionnaire had 10 statements about the system to which the participant could mark an agreement or disagreement. The questionnaire also asked the respondent to justify their response to each statement. The statements relate to overall perceived usefulness as well as more detailed issues focusing on the quality of the meal plans, their presentation, as well as the perceived difficulty in getting acceptable meal plans.

System status

The status was the same as for Study 1, except that the system ran on SunRay machines and that the participants used traditional desktop keyboards. The monitors used were the same. There was no noticeable difference in the time taken to compute the meal plans.

Results

First of all we note that none of the participants had any major usability problems. They did not get stuck and

⁵ *Task 1.* Create a user with your own given name. Get a meal plan for the rest of the week (Friday to Sunday). The database only contains recipes suitable for lunch or dinner so limit your settings to either lunches or dinners. Try to make the settings as realistic as possible by taking into account the ingredients that you know you have at home right now, etc. Rate recipes and re-plan, adjusting settings as needed. Continue until you're satisfied with the result, or until you feel that you cannot get a better meal plan. *Task 2.* Your friend Anna is coming for a visit on Saturday. Therefore you want a somewhat more expensive and more complicated recipe for Saturday. Continue from your settings from Task 1, and make adjustments to handle this situation and get a new meal plan for the rest of the week (Friday to Sunday). Adjust your settings and ratings until you're satisfied, or until you feel that you cannot get a better meal plan.

completed the tasks without any help at all. The very brief demonstration of how the main features of the system worked was enough for this group of computer users.

For presentation purposes the results from the questionnaire have been divided into three topics, covering *overall system usefulness*, *acceptability of meal plans*, and *how to get acceptable meal plans*. Each topic will be discussed in turn.

The first topic on overall usefulness is summarized in Figure 7. Only one of the participants thought that using a cook book would be more efficient. The justification was as follows: “Sometimes it takes a couple of iterations to get a good plan which takes more time than just browsing through a cook book. On the other hand the system has all possibilities to create a better plan from a nutrition perspective. After having [created a set of] good ratings and adjusted settings it will probably be quicker [to use the meal planner].” The participants who thought the system would be more efficient than using a cook book justified this mainly by referring to the many useful settings that the system can take into account so that the user does not have to bother checking whether a recipe satisfies a certain requirement (which has to be done manually when browsing a cook book).

Five of the participants indicated that they would like to use the system at home. Two were indifferent and one was partly opposed to using the system at home. The participant who was opposed to using the system at home thought the system was good, in principle, but did not like the “inflexible” user interface, referring to the system’s characteristic interaction mechanism where one cannot change plans through direct manipulation but has to change settings and re-plan. The two participants who were indifferent noted that the system would be good for inspirational purposes but was otherwise seen as too cumbersome or simply not needed. The positive participants noted that the system was fun to use and well adapted to their day-to-day needs with all the useful settings that could be done.

As for whether the system produces meal plans of high quality, we note that 6 of the users thought the plans were of high quality, while two users were indifferent. The users who thought the plans were of high quality referred to various reasons such as a good variation, and seemingly well balanced recipes. One user noted that there was a slight lack of recipes with a short preparation time, but still thought the plans were of high quality. One of the two indifferent users thought that the proposed plans were completely OK, but also noted that the taste rating may be given too much priority in that recipes given high ratings by the user tend to dominate the suggested meal plans, which may lead to a lack of variation after a while. The other indifferent user missed working nutrition values, which is something to add in future version of the system.

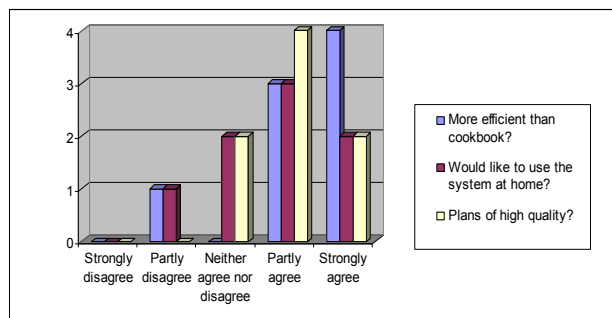


Figure 7. Overall system usefulness

Figure 8 illustrates the results from the statements on the acceptability of the meal plans that can be created by the system. All 8 users agreed that it is possible to reach acceptable meal plans, often referring to the fact that they had succeeded during the test tasks. But, the users had varying opinions as for how difficult it was to reach an acceptable plan. One user wanted the possibility to weigh the different constraints, e.g. to boost variation over cost, or to put more emphasis on taste. Another user wanted the possibility to interact more directly with the system, e.g. to be able to lock a certain recipe for particular occasion, and then only re-plan for the remaining meals, or to be able to drag and drop recipes from alternative plans. Another user noted that one has to learn how the system takes settings into account to be able to get the most out of it, i.e. to outsmart the system.

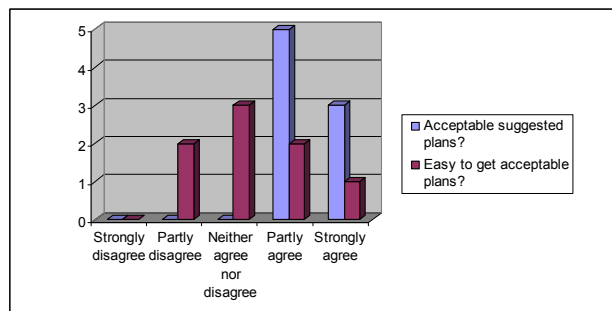


Figure 8. Acceptability of meal plans

Figure 9 summarizes the results on how to get acceptable meal plans. 6 users agree that iterative fine tuning of settings are required to get acceptable plans. The justifications refer to examples of how the users had iteratively fine-tuned the settings to reach acceptable plans. One user was indifferent and meant that he mainly used taste ratings as a means for reaching acceptable plans. Finally, one user thought that iterative fine tuning of settings did not have the desired effect and would have appreciated the corresponding constraints to have more weight compared to taste ratings.

5 users agreed that settings and taste ratings provide the user with sufficient control. One of these users noted, however, that there will always be factors that will be outside the user’s control. One of the 3 users who did not

agree with the statement observed that he would have liked to fine-tune the proposed meal plans by simply changing place of recipes within a meal plan. Such adjustments seemed impossible to achieve through settings. Another user referred to a problem that had occurred when trying to integrate another user's settings into a common meal, and where the invited user's setting weighed too heavily and he lacked the means to adjust this balance.

The question of whether all needed settings can be done, had users both agreeing and disagreeing. 5 of the 8 users partly agreed that it was possible. Still, some of them pointed out possibilities for improvement. One user would have liked the possibility to browse recipes as a complement to the current interaction mechanism. Another user wanted possibilities to better control the variation of the suggested recipes, e.g. by a "surprise me" feature that would focus on meals that had not been rated according to taste. Otherwise there is a risk of only getting recipes that have already been rated, the user reasoned. The two users who partly disagreed to the statement also provided reasons for their disagreement. One of them mentioned that it was not possible to say e.g. that one wants to have fish a certain day. The other user noticed that there was no possibility to set the actual amount of a certain ingredient that was available at home.

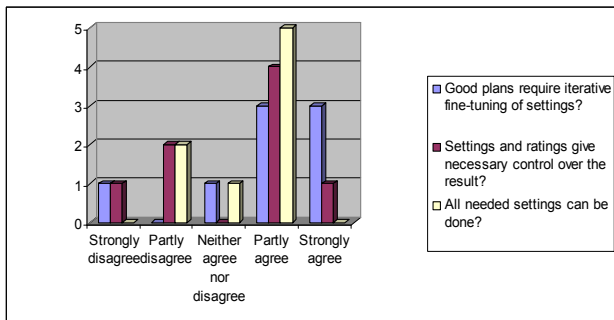


Figure 9. How to get acceptable meal plans

To summarize the results we note that the test participants were generally in favor of the system and its usefulness, with 5 of 8 users clearly stating that they would like to use the system at home. We also note that there are plenty of interesting suggestions for improvements to the system.

DISCUSSION

One issue that stands out in our results concern the interaction mechanism and the trade-offs between optimality and user control. As many of the study participants imply, a meal plan's mathematical optimality is only of importance if the user actually perceives it as optimal. If the user sees possibilities for improvements he or she must be given the opportunities to make these adjustments in an efficient way.

LIMITATIONS

Given that unhealthy eating is a general problem in the western society and can affect people of different age, we

have a very large target population. It is obvious that we cannot hope to show the system's ease of use and usefulness for people in general with any certainty based on our two studies. Indeed, this is exploratory work, but the studies have given indications that we are on a good path towards a user acceptable system.

There is a clear lack of female participants in our studies which means that we need to be careful when attempting to generalize the results to female users. This is something that we are looking to improve in our future studies.

We have not considered scalability issues in this paper, and the question remains of whether our algorithmic approach would scale for larger sets of food recipes. Currently when planning for a maximum of 4 days with our data set of 250 recipes the planning result is computed in a matter of 1-3 seconds, when run on a normal PC. We are currently studying approaches to optimize the algorithms to make it feasible also for much larger recipe collections. One important property of the constraint satisfaction algorithms is that they can be terminated anytime and return the best solution found so far. Thus it is possible to set a time limit in seconds and simply return the best solutions found so far. Since our ongoing experiments show that the improvements in plan quality found in the later parts of the computation process are marginal, pre-termination would not really affect the user negatively.

RELATED WORK

Related technology approaches to support food related activities exist. There are systems for supporting the online search for food recipes [27], recipe sharing [28], as well as technology for supporting the actual cooking process in different ways and with different perspectives [5,7,14,15,22,30]. None of these approaches are directly focused on the meal planning process, and should be seen as complementary to our approach.

Mankoff *et al.* [19] describe an approach to make people more aware of nutrition issues. It is based on a person's food store receipts that are scanned and read automatically. The ingredients found on the receipt are analyzed and a new annotated receipt is generated providing suggestions of new items that could be useful to complete the other items when there is a lack of a certain nutrient among the ingredients on the original list. We note that the idea of pointing out a lack in certain nutrients etc, could be a useful addition to a future version of our system once the users are given more freedom to modify meal plans proposed by the system. This way the nutritional implications of user modifications could be summarized to the user.

A different and refreshing perspective is taken by Grimes and Harper in their recent overview paper [13], where related approaches including some of the ones just cited are labeled as *corrective technologies*. While the authors acknowledge such research endeavors as being "both fruitful and important" they argue that there are

opportunities for complementary approaches that intend to, more directly, support the user's creativity and pleasure (to name two examples) with food-related activities. Notably, the authors suggest that technology allowing the user to adapt "recipes to fit their personal tastes and personalities" would support creativity. This is along the same lines as our discussion above on the importance of letting the user being in control, and the risks with technology that overtakes too much of the initiative.

CONCLUSIONS AND FUTURE WORK

In this paper we have presented a meal planning system aimed at providing users with the perceived behavioral control needed for changing their food consumption behavior. We have evaluated the system's perceived usefulness and ease of use, two factors of great importance for user acceptance [9]. The results indicate that the system is easy to use for users with extensive computer experience. For less experienced users learnability could be an initial problem, but nothing that could not be overcome by a re-design informed by our data on usability issues. As for the perceived usefulness we conclude that most of the test participants were positively inclined towards the system, with only one user clearly stating that he would not be interested in using the system at home.

The results are encouraging but it should be noted that the path towards a generally applicable tool for changing food consumption behavior is long and winding. This paper, however, represents the first step in this direction.

If we connect back to the theory of planned behavior which has served as a motivating framework for our work, we are currently focusing on supporting the user's perceived behavioral control by providing a tool to support the user. However, it is not hard to imagine further extensions to our approach that would also be directed towards the subjective norm as well as the attitude towards the behavior, i.e. the two remaining factors affecting the formation of an intention to change behavior (according to the theory of planned behavior).

As for the subjective norm, imagine an online version of the system with an active discussion forum where tips and ideas are exchanged and where it would be possible to ask questions and get feedback. This could make it clear to the user that he or she is not alone in the struggle towards a better food behavior. There is also the possibility of involving friends and family more closely by allowing users to create sub-groups and send meal invitations over the system as well as sharing meal plans with others. The system already supports meal planning for several people so this would be a fairly straight forward extension.

As for the attitude towards the behavior one could imagine extensions to the system such as online campaigns as well as interviews with health professionals. There are also possibilities of providing features that could simulate the consequences of not changing a diet, e.g. by a kind of

persuasive mirror, or simulate the long-term effects of actually changing the diet.

Apart from these ideas for further extensions to our system we are planning to put the next version of our system to test on a more long-term basis and study the effects on attitude and behavior change, guided by the theory of planned behavior.

ACKNOWLEDGEMENTS

This research has been partly funded by the Swedish Council for Working Life and Social Research. Thanks to Kajsa Lindén and Niclas Sundmark for their work on the implementation of the system. Thanks also to the study participants. The study on ease of use was done in collaboration with Birgitta Lorefält at the Dept. of Medicine and Care, Linköping University. Stefan Holmlid, Mattias Arvola, Fabian Segelström, and the anonymous reviewers provided helpful comments on this paper.

REFERENCES

1. Ajzen, I. The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes* 50 (1991), 179-211.
2. Beckman, K. B. and Ames, B. N. The Free Radical Theory of Ageing Matures. *Physiological Reviews* 78, 2 (1998), 547-581.
3. Blumberg, J. B. Nutrient Requirements of the Healthy Elderly – Should There Be Specific RDAs? *Nutrition Reviews* 52, 8 (1994), 515-518.
4. Blumberg, J. Nutritional Needs of Seniors. *Journal of the American College of Nutrition* 16, 6 (1997), 517-523.
5. Bonanni, L., Lee, C.-H., and Selker, T. Attention-Based Design of Augmented Reality Interfaces. *Proc. CHI 2005*, ACM Press (2005), 1228-1231.
6. Chandra, R., Joshi, P., Au, B., Woodford, G., and Chandra, S. Nutrition and immunocompetence of the elderly: effect of short-term nutritional supplementation on cellmediated immunity and lymphocyte subsets. *Nutrition Research* 2, (1982), 223-232.
7. Chi, P.-y., Chen, J.-h., Chu, H.-h., and Chen, B.-Y. Enabling Nutrition-Aware Cooking in a Smart Kitchen. *Proc. CHI 2007 Extended Abstracts*, ACM Press (2007), 2333-2338.
8. Conner, M., Bell, R., and Norman, P. The Theory of Planned Behavior and Healthy Eating. *Health Psychology* 21, 2 (2002), 194-201.
9. Davis, F. D. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly* 13, 3, (1989), 319-340.

10. Elmståhl, S., Persson, M., Andren, M., and Blabolil, V. Malnutrition in geriatric patients: a neglected problem? *Journal of Advanced Nursing* 26, (1997), 851-855.
11. Fogg, B.J. *Persuasive Technology*. Morgan Kaufmann, 2003.
12. Grimes, G., and Grinter, R.E. Designing Persuasion: Health Technology for Low-Income African American Communities. *Persuasive Technology* (2007), 24-35.
13. Grimes, A., and Harper, R. Celebratory Technology: New Directions for Food Research in HCI. *Proc. CHI 2008*, ACM Press (2008), 467-476.
14. Hamada, R., Okabe, J., Ide, I., Satoh, S., Sakai, S., and Tanaka, H. Cooking navi: assistant for daily cooking in kitchen. *Proc. International Multimedia Conference* (2005), 371-374.
15. Ju, W., Hurwitz, R., Judd, T., and Lee, B. CounterActive: An Interactive Cookbook for the Kitchen Counter. *Proc. CHI 2001*, ACM Press (2001), 269-270.
16. Kant, A. K., Schatzkin, A., Harris, T. B., Ziegler, R. G., and Block, G. Dietary diversity and subsequent mortality in the First National Health and Nutrition Examination Survey Epidemiological Follow-up Study. *American Journal of Clinical Nutrition* 57, (1993), 434-440.
17. Larsson, J., Unosson, M., Ek, A.-C., Nilsson, S., Thorslund, S., and Bjurulf, P. Effect of Dietary Supplement on Nutritional Status and Clinical Outcome in 501 Geriatric Patients – a Randomised Study. *Clinical Nutrition* 9, (1990), 179-184.
18. Maciuszek, D., Aberg, J., and Shahmehri, N. What Help Do Older People Need? Constructing a Functional Design Space of Electronic Assistive Technology Applications. *Proc. ASSETS 2005*, ACM Press (2005), 4-11.
19. Mankoff, J., Hsieh, G., Hung, H.C., Lee, S., and Nitao, E. Using Low-Cost Sensing to Support Nutritional Awareness. *Proc. Ubicomp 2002* (2002), 371-378.
20. McCormack, P. Undernutrition in the elderly population living at home in the community: a review of the literature. *Journal of Advanced Nursing* 26, (1997), 856-863.
21. Mowé, M., Böhmer, T., and Kindt, E. Reduced nutritional status in and elderly population (> 70 y) is probable before disease and possibly contributes to the development of disease. *American Journal of Clinical Nutrition* 59, (1994), 317-324.
22. Nakauchi, Y., Fukuda, T., Noguchi, K., and Matsubara, T. Intelligent kitchen: cooking support by LCD and mobile robot with IC-labeled objects. *Proc. IROS*, IEEE Press (2005), 1911-1916.
23. Potter, J., Klipstein, K., Reilly, J. J., and Roberts, M. The Nutritional Status and Clinical Course of Acute Admissions to a Geriatric Unit. *Age and Ageing* 24, (1995), 131-136.
24. Povey, R., Conner, M., Sparks, P., Rhiannon, J., and Shepherd, R. The Theory of Planned Behavior and Healthy Eating: Examining Additive and Moderating Effects of Social Influence Variables. *Psychology and Health* 14 (2000), 991-1006.
25. Shepherd, R. Factors Influencing Food Preferences and Choice. In Shephard, R., ed., *Handbook of the Psychophysiology of Human Eating*. John Wiley and Sons (1989), chapter 1, 3-24.
26. Sjögren, A., Österberg, T., and Steen, B. Intake of Energy, Nutrients and Food Items in a Ten-year Cohort Comparison and in a Six-year Longitudinal Perspective: A Population Study of 70- and 76-year-old Swedish People. *Age and Ageing* 23, (1994), 108-112.
27. Svensson, M., Höök, K., and Cöster, R. Designing and evaluating Kalas: A social navigation system for food recipes. *ACM Transactions on Computer-Human Interaction (TOCHI)* 12, 3 (2005), 374-400.
28. Terrenghi, L., Hilliges, O., and Butz, A. Kitchen stories: sharing recipes with the Living Cookbook. *Personal and Ubiquitous Computing* 11, (2007), 409-414.
29. Torrens, M. *Scalable Intelligent Electronic Catalogs*. PhD. Thesis no. 2690, Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland, 2002.
30. Tran, Q., Calcaterra, G., and Mynatt, E. Cook's Collage: Déjà vu Display for a Home Kitchen. *Proc. HOIT 2005* (2005), 15-32.
31. Vellas, B. J., Hunt, W. C. Romero, L. J., Koehler, K. M., Baumgartner, R. N., and Garry, P. J. Changes in Nutritional Status and Patterns of Morbidity Among Free-Living Elderly Persons: A 10-Year Longitudinal Study. *Nutrition* 13, 6, (1997), 515-519.
32. Verplanken, B., and Faes, S. Good intentions, bad habits, and effects of forming implementation intentions on healthy eating. *European Journal of Social Psychology* 29 (1999), 591-604.
33. Volkert, D., Kruse, W., Oster, P., and Schlierf, G. Malnutrition in geriatric patients: diagnostic and prognostic significance of nutritional parameters. *Annals of Nutrition Metabolism* 36, (1992), 97-112.