Revealing Transient Factors in Diet Choices

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ABSTRACT

Identifying the factors that impact personal health choices can be a challenging task. While much prior work explores tracking the relationship between diet and exercise, there are many other transient factors that affect our nutritional choices. In this work, we designed an interface that allows users to explore how dietary choices are affected by factors such as time, company, mood, enjoyment and stress levels. This paper presents our design, implementation and preliminary evaluation of an interactive tool that allows visualization of diet related patterns based on transient factors. Our evaluation of the interface is based on a thorough two week long life blogging data collection, facilitating a detailed personal review of food choices and eating habits.

Categories and Subject Descriptors

H.5.m [**Information Interfaces and Presentation**]: Miscellaneous.

General Terms

Design, Human Factors.

Keywords

Self-reflection, habits, food, stress, photo diary, personal informatics.

1. INTRODUCTION

Eating habits are often elusive making it difficult to pinpoint exactly what makes someone eat, for example, half a tub of ice cream at midnight on a Monday. We all make unhealthy choices from time to time, but the lack of reflection on those choices is what carries some into a completely unhealthy lifestyle. Diet and exercise are the two main areas examined when it comes to personal health. However, diet is influenced by a number of fleeting, transient factors that are often ignored, such as mood, time, company, and location. Our work aims to use personal informatics to shed light on these factors in a tangible, intimate way.

The tool we implemented (figure 1) visualizes the relationship between meals/snacks and the transient factors that have been observed to affect dietary choices through the use of parallel coordinates. Since all the factors are presented in a single visualization, the tool allows the user to easily recognize patterns and trends between these factors and discover trends in her behavior. Our tool facilitated identification of not only unhealthy habits, but habits that improve well-being of the user, such as reinforcing and emphasizing the importance of eating breakfast in the morning (figure 10).

Identifying mentioned unhealthy (and healthy) habits and certain patterns in an individual's behavior may help her recognize certain situations and potentially opt for different diet choices. We

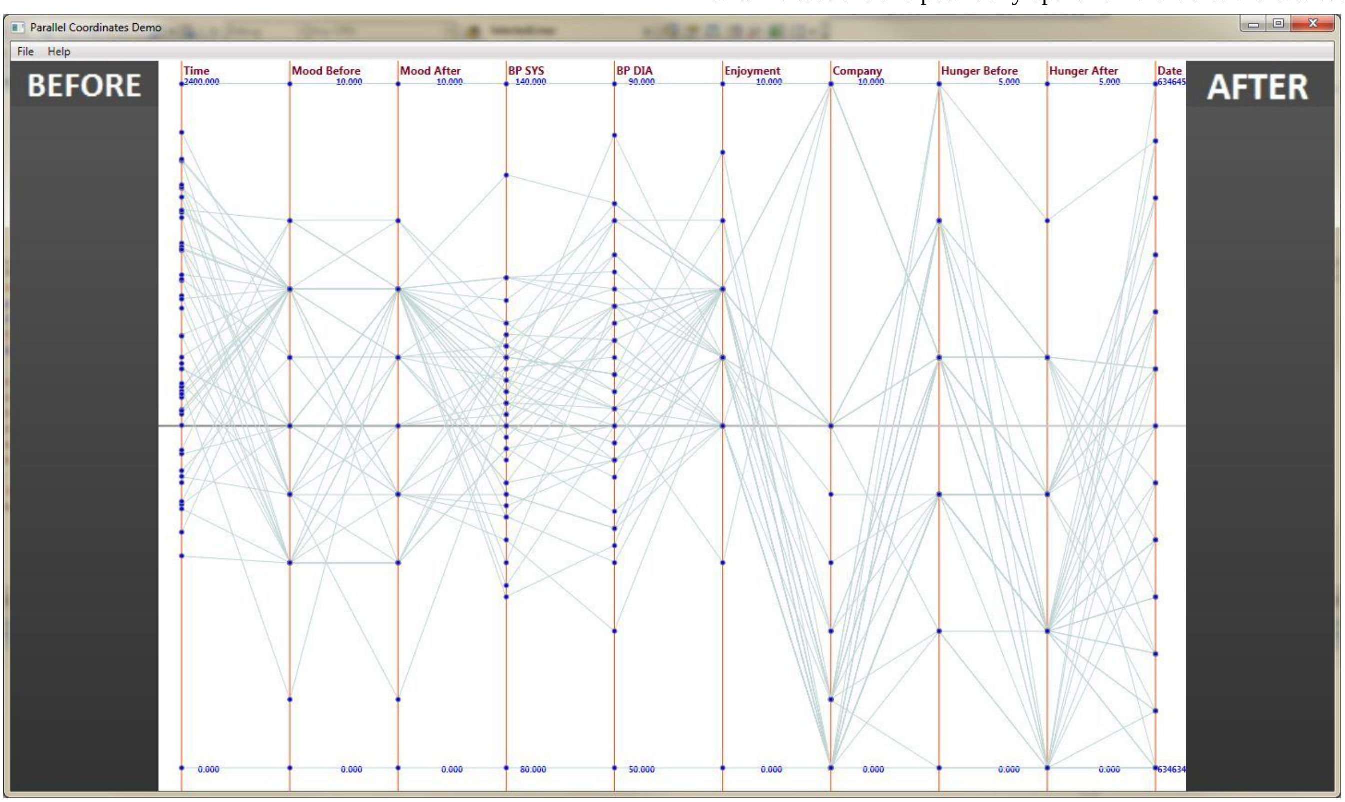


Figure 1. Parallel coordinates demo with loaded data

believe that personal information appliances can play a pivotal role in helping people gain awareness and track such transient factors, allowing them to make better diet choices.

In this paper, we detail the design, implementation and evaluation of an interface that facilitates self-reflection and pattern recognition of dietary choices in relation to several transient factors. Through an iterative process of design assessments, we created an interface design that presented an interesting view of how transient factors relate to diet choices. The evaluation is performed through the reflection on real data collected in the form of a food blog, which was carefully constructed with prior research of what transient factors may have the most significant effects on dietary choices.

2. RELATED WORK

The relationships between diet, exercise and other factors that affect our health have been studied extensively. A problem being addressed by many researchers is how to easily track, manage, and draw conclusions from personal data relating to our nutrition, with the ultimate goal of improving health related choices.

Our emotions/mood often play a role in what we choose to eat [6,7]. For example, "comfort food" (referring to unhealthy meals and snacks) are consumed in response solely to emotions, and not hunger. Multiple factors can trigger emotional eating, such as company, mood and situation, among others [6]. Depending on personal preference, certain moods can be related with choosing to eat certain types of food [7]. For example, stress prompts us to crave rich foods, but frequently responding to stress in this way can lead to serious health problems in the long run [8, 9].

Time of meals is often discounted as irrelevant due to identical caloric intake; however previous work suggests that eating late at night may contribute to weight gain [10]. Busy schedules and lack of necessary effort may lead to late meals and snacks, and skipping meals, sometimes even without acknowledgement of the average time of regular daily meals.

Eating out with a group of friends can be seen as another culprit for unhealthy choices. Lumeng and Hillman studied the effects of eating in larger versus smaller groups [5], finding that children are likely to consume 30% more food when eating in groups of 9 versus groups of 3. While eating at restaurants tends to be high in calorie count, one study suggests that a mindful eating approach can help individuals make better choices when dining out frequently [11], highlighting the importance of critically reflecting about what one consumes.

Brown et al. [1] address the problem that existing diet and exercise monitoring systems are inconvenient to use as they rely on hand-written diaries. FotoFit aims to promote a healthier life style through personal reflection. The system consists of a mobile application to track food on the go using a camera, an exercise machine application, and a PC visualization application for review, reflection, and goals. The photos were found to be effective in helping track dietary habits, and to aid interpreting exercise activity. Further, visualizing the relationship between diet and exercise was also effective.

Gonzales et al. [2] consider more deeply the utility of self-reflection in daily health-related decision making. Virtual Environments to Raise Awareness (VERA) is a mobile application focused on helping individuals become self-aware through self-observation of their actions and choices. VERA forces instant evaluation of health related choices by requiring users to log actions, forcing them to stop and think about them. After using the application, participants found that they were more likely to make better choices, especially if their choices were visible to other individuals. While it helped them self-reflect and make better choices, it did not in the long run change their health related habits, possibly due to the short duration of the study. This study further displays the importance of personal reflection on health related choices, but allows for review of only actions, missing the chance to better understand what affected the choice.

Stress is one of the major factors that significantly affect our health, but it is often overlooked. Sanches et al. [4] found it difficult to effectively measure and correctly interpret the cause of stress using non-invasive measures [4]. Rather, they explore the exposing of real-time biosensor data to people, allowing them to reflect on stress levels for diagnosis.

Creating personal health informatics applications that are customized to the needs of an individual can be a difficult and time-consuming task. Medynskiy and Mynatt identified the need for a platform to develop personal health informatics applications for individuals trying to manage chronic health conditions [3]. They developed the Salud! Application Programming Interface (API) and a personal health informatics application using the API. Salud! allows to easily develop automated and interactive data entry services depending on the requirements of the particular individual and his/her condition [3].

Much prior work has focused on capturing tangible "health choices" (exercise and diet); however, many transient factors actually influence these health choices. Earlier, we discussed how mood, timing of meals, company, and even meal location can influence our dietary choices. Revealing the relationship between these transient factors and diet might also help people to make better health choices, and was the main focus of our research.

Instead of focusing on relating exercise and diet as stand-alone activities, we wanted to create an application that provides the user with the tools to reflect on why she makes certain diet choices along with reflecting on the choices themselves.

3. DESIGN

3.1 Data Collection and Dataset Design

A vast number of possible factors may affect what we choose to eat. For the scope of this project, we were faced with the task of narrowing down transient factors that are most likely to have a strong and meaningful relationship with diet choices, and that are least painful to collect.

Faced with several options, we considered several factors: GPS location tracking could show us where the participant is when she eats; heart beat could indicate levels of stress and is easy to collect; videos of food consumption could reveal certain things about eating habits while providing a nice visual representation for the meal itself; before and after moods could show the effect of meal on the participant's emotional state.

After much deliberation, the factors were narrowed down to before and after mood, before and after hunger, enjoyment of meal, location, company, blood pressure as a more precise stress indicator, time, and before and after visuals of food as records of what was consumed. To ensure consistency of the dataset through the data collection, we narrowed down collection methods for each of the factors. While automatic collection of data would be the most suitable and convenient, unfortunately not all factors chosen allowed for collection of automatic data.

Mood. There are several ways to record mood. From neurological analysis to a word on paper, the precision of the records varies greatly. Ideally, it would be desirable to keep data as accurate as possible; however, the involvement and tools required for a proper evaluation of mood is unreasonable for the scope of this project. An acceptable alternative was to track mood through records of a few adjectives before and after each meal.

Hunger. There's a difference between perceived hunger and the physical necessity to consume food. It's difficult to measure how much nutrition one's body truly requires at a particular moment, so the simpler method of subjective rating of one's hunger was used.

Enjoyment. As this factor is completely dependent on the participant, it was measured using a subjective rating.

Location and Company. Ideally, a GPS tracking would automatically locate the participant at times of meals. However, since the data collection period was fairly short, the overall travel of the participant was minimal, and the project focus was not concentrating on precise location, but rather the setting itself, location was chosen to be recorded as one of school, home, work, or restaurant. Company could also be easily identifiable by the individual at time of meals without assistance of other tools.

Blood Pressure. In order to accurately measure blood pressure, a portable device was needed that would allow for automatic recording and later export of the collected data for the user. In this case, the ideal expectations were met exactly by a peripheral iPhone device.

Time. Time could be recorded as part of several other factors (blood pressure or photos, for example). Since we could not facilitate automatic records of the meals themselves, time records depended fully on the methods we used to record other data.

Food. Visual representation of food is the most telling and engaging for the user's reflection, since it includes not only what was consumed, but the aesthetic appeal of the dish and the relative size of the serving. While a detailed progression of the meal would likely reveal more information about the habits of the participant, recording every meal, snack and drink on video would require a disproportionate amount of effort and time for processing and review. A reasonable alternative was to take a before and after photo of all parts of the meal.

We considered collecting some nutritional information about the food itself, however as the partial intent of our application was to facilitate self-reflection, we assumed that the user will be able to identify approximate or relative healthfulness of the food by photo alone without needing further estimations about calorie count or food group percentages by image post-processing.

3.2 Tool Design

Through an iterative design process, we identified and highlighted the goals of our tool. Progressing from a simple photo album with visuals and pieces of information lacking connection throughout, we created a final design where the focus was put on exploration and personal reflection on diet choices and relevant factors.

3.2.1 Stage 1: Photo Album

Originally, our desktop app was supposed to allow one to review his/her meal diary in the style of a photo album. It was to be organized by date and grouped by meals, while displaying all other relevant information pertaining to the meal at hand. Visual representation of mood and blood pressure cycles would be

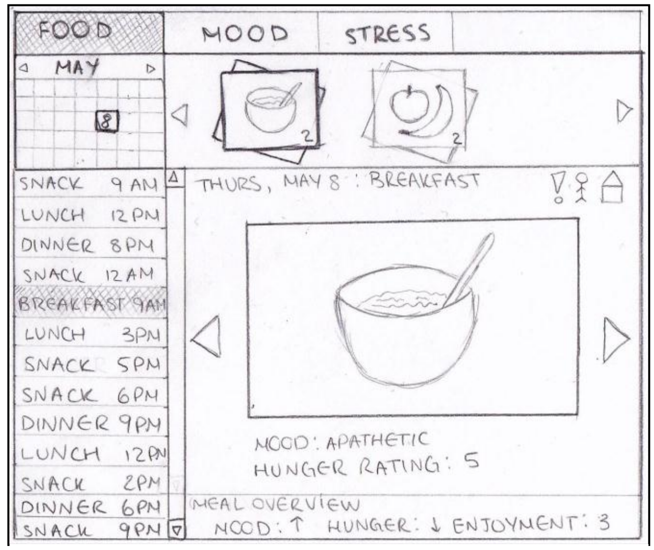


Figure 2. Photo album

available in separate sections to allow the user to see patterns in his/her personal data. In this design, it's easy to see that the predefined organization of the meals by day, mood, stress or any other factors acts as a limitation to the exploration of the patterns in the data. In fact, pattern recognition would be rather difficult in this type of interface because of the clear and strict separation in factors by groups. This design was simply a detailed photo album of food with additional information centered around the primary visual focus – the photos themselves.

3.2.2 Stage 2: Two-Dimensional Graph

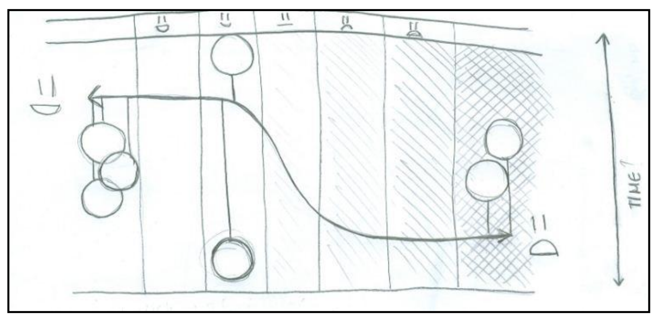


Figure 3. Two-dimensional graph – mood vs. time

The idea of a graph representation was brought up during the second iteration during the design process. Meals, represented by circles where the relevant photos would be contained, are sorted horizontally by mood and vertically by time. The idea behind the design was relating factor A to factor B using an AB-plane. Some factors may require different types of representation: for example, it would make more sense to use a map to relate meals to physical locations. Several issues came out in discussion of this interface.

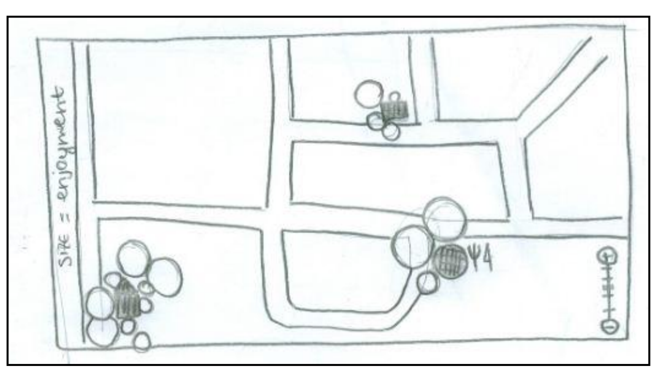


Figure 4. Meals on map sized by enjoyment

The limitation of relating only a couple factors at a time was a big draw-back of this design, considering the importance of exploration and discovery of patterns as a goal of the tool. It would be extremely difficult to relate, for example, mood before and after the meal, and time of day at the same time, a relation that proved to be meaningful considering our dataset. The location view would not give significant insight into the data due to lack of travel by the participant. The design is not unified under a single idea and several other considerations would have to be made for different transient factors.

3.2.3 Stage 3: Parallel Coordinates with Predefined Groups

The third iteration of the design process included the idea of parallel coordinates representation [12], with each line on the graph symbolizing a meal and its relevant factors on the axes. The obvious advantage of this visualization is the ability to see all

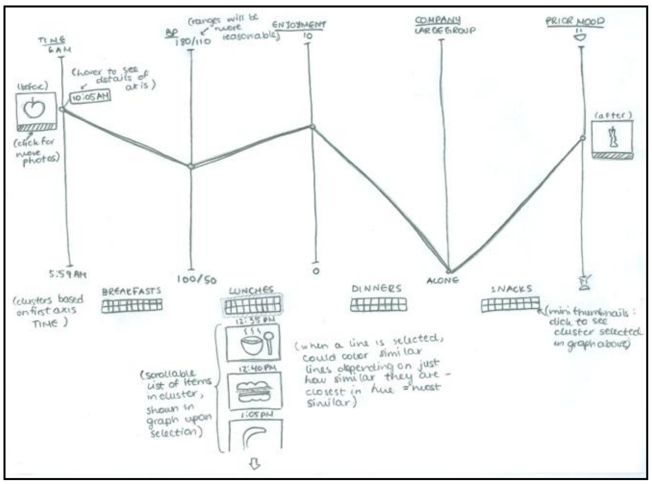


Figure 5. Parallel Coordinates with predefined groups

factors related to each other as well as the meals on one screen. Photos could be attached to each separate line and before and after could be displayed simultaneously on either side to help the user gauge the amount consumed during any selected meal. A particular ordering of the axes could visually relate certain transient factors in a meaningful way. Underneath the graph, the meals could be clustered into predefined groups based on the first left-most axis. For example, if time is the first axis, groups such as breakfasts, lunches, dinners and snacks (miscellaneous times) could be predefined for the user. Upon selection of a particular group, all meals within the group would be also selected on the graph. The predefined groups present a limitation of this design: they limit exploration by allowing only certain groups to be viewed selected in the graph. Considering the dataset, the loss of detail in translation from raw data to a scale is apparent, especially for mood. In this design, the idea of similarity of meals represented by intensity of line color was introduced (the more similar a meal is to the one currently selected, the closer it is in its hue to the intensity of the selected meal).

3.2.4 Final Design

The design ultimately chosen for the tool was the parallel coordinates representation. However, since predefined groups were a clear limitation, they were replaced with enabling the user to manually select custom ranges based on first axis points. All photos of the lines within the selected range would be displayed in the margins for a quick overview of what and how much was consumed (before on the left, after on the right). The ability to switch the axes' order allowed for the necessary flexibility of the representation to explore various possibilities and thus discover patterns in behavior.

4. IMPLEMENTATION

4.1 Data Collection and Dataset

The data was manually collected by a single user for the period of two weeks. We defined food as to include not only the things one eats, but also the things one drink as beverages may contain considerable nutritional value. The following data was recorded in the style of a diary with the help of the user's mobile device: food (a photo of what is available for consumption (before), and how much has been consumed (after), and a rating of enjoyment); mood (before, after meal—captured as one to three adjectives); location; time; blood pressure before the meal (as a measure of stress [9]); hunger (before and after), and company (how many people are dining).

Food. Every event of food consumption was classified as a breakfast, lunch, dinner or a snack. A photo of the food will be taken prior to consumption and afterwards: this will help the individual gauge how much of the serving was actually consumed out of the available amount of food and reflect on how the aesthetics of the dish and the eating environment affect the diet choice. A description of the meal was not recorded since the participant had high confidence that she would be able to identify the items based on the images. Whether or not the food was enjoyed was rated on a scale of 1 to 5 in order to better explain why food may not have been finished.

Mood. Before and after the consumption of the food, mood was recorded as 1-3 adjectives. At the time of data collection, the participant was not restricted to any particular subset of adjectives to describe mood and was free to use all words in her vocabulary. At the time of analysis, every mood description was placed on a scale of 1-10 as was deemed reasonable by the participant.

Location. At every event of food consumption, location was described as home, work/school, or restaurant. For the particular design chosen, we did not find that location was a meaningful factor due to limited travel by the participant.

Time. With the help of the mobile application used to record all the data in a diary format, all entries were precisely timed. Time data can also be extracted from the photographs taken at the time of the consumption.

Blood Pressure. Blood pressure was measured every hour for the duration of the waking day and prior to every consumption. This data was representative of current stress levels [9]. While blood pressure was recorded more often than once per meal, the extra data did not prove useful for the chosen interface design.

Hunger Rating. A rating of hunger from 1 to 5 was before and after every event of consumption. This data helped identify how often food is consumed without real necessity.

DATE	TIME	SYS	DIA	BPM	Meal
2012-01-30 11:02	11:02	113.00	70.00	81.00	breakfast
MoodBefore	**MBRating**	**Company**	**HungerBefore**	**Location**	**MoodAfter**
apathetic	5	0	2	home	energized
MARating	**HungerAfter**	**Enjoyment**	**PhotoBefore**	**PhotoAfter**	**ID**
7	1	5	IMG_0000003_2012.01.30.jpg	IMG_0000004_2012.01.30.jpg	1

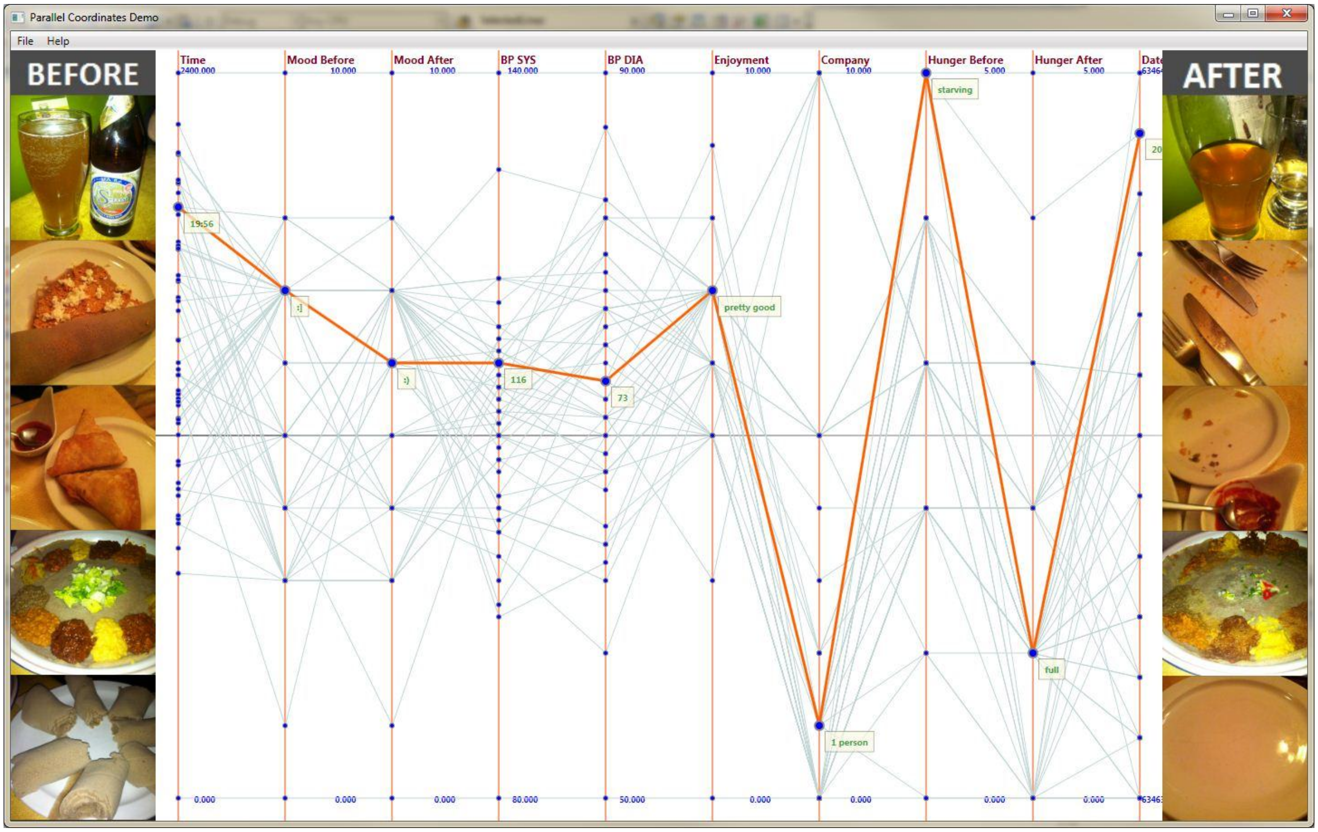
Table 1. Sample data for meal 1

Company. The participant recorded whether she was eating alone or with 0 people (alone), 1-4 people (few individuals), between 5-10 people (larger group), or over 10 people (crowd). A person counts as company whether or not they are concurrently consuming food.

4.1.1 Collection Tools

Initially, we considered Vicon Revue as the primary collection device for photos and other data as it's very convenient to use for automatic data collection. However, none of the chosen transient factors overlapped with the additional data collected by the Vicon

Figure 6. One line selected: displaying 1 meal



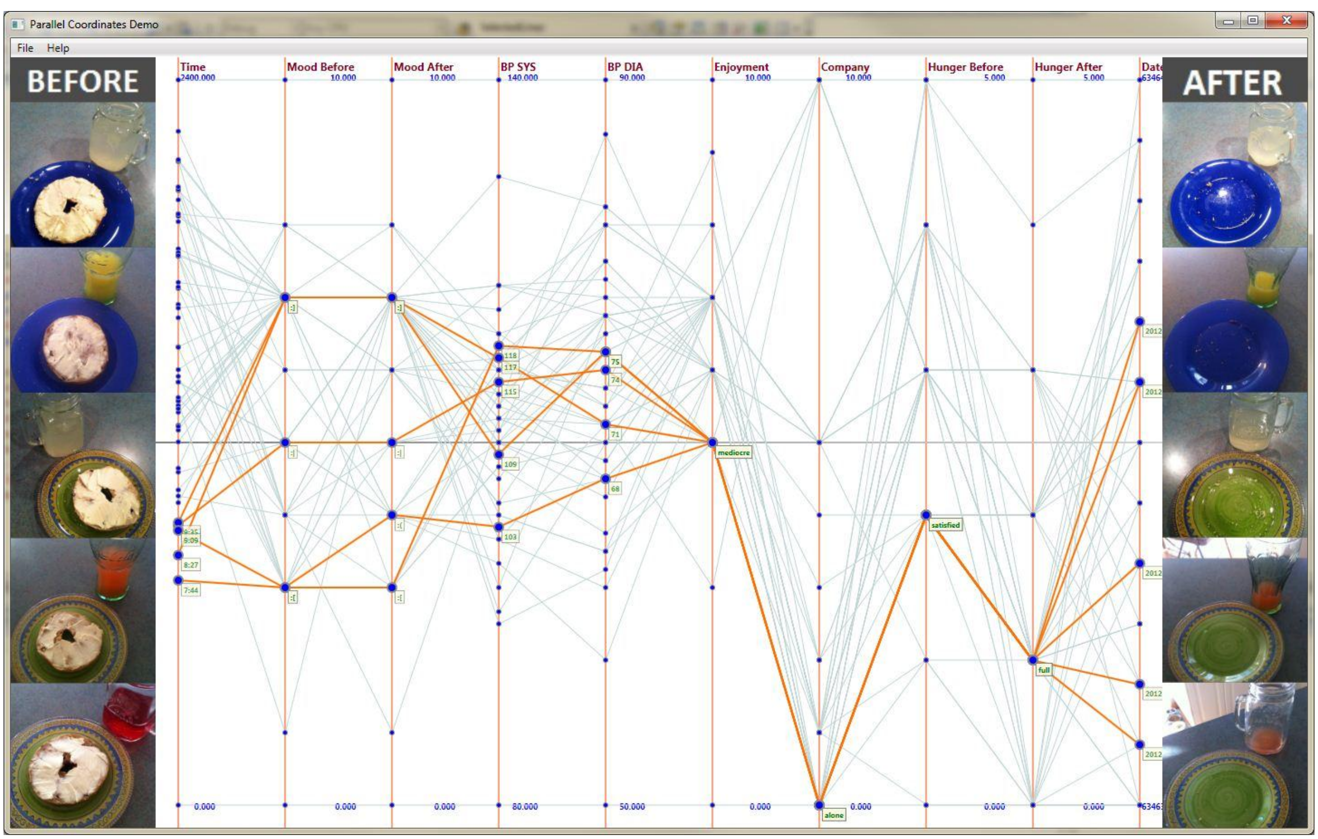


Figure 7. A range selected: displaying 5 meals

Revue camera, and the use of the device was rejected.

For collection of intangible data such as mood, hunger and enjoyment, the only reasonable way of data collection was through collective diary entries.

The collection process required versatility and mobility of collection tools for maximum convenience of the participant. Mobile applications provided the best solution to this problem: the participant's iPhone device met all of the requirements for most factors, with the exception of blood pressure monitoring, where an iPhone peripheral was necessary.

A photo food diary application Momento for the iPhone provided all the necessary tools to keep track of date, time, meals, moods, hunger levels, enjoyment, company and location. With each meal entry, or "moment", photos of the meal could be stored in an organized manner. All of the data could be exported in a combination of a text file and a folder of referenced photos.

Withings blood pressure monitor that connects to the iPhone using the Withings app provided a quick and easy way to collect, store and export blood pressure and heart beat figures. The data could be exported via email in an Excel file containing the date and time, systolic and diastolic blood pressure readings and heart beat.

4.1.2 Data Compilation

In order to meet the qualifications of the polar coordinates representation, our data had to be properly formatted (table 1). Throughout the process of this reformatting, some detail was lost. While data for factors such as time, blood pressure and location remained usable without any translation, and company, hunger and enjoyment were arbitrary scales, it was most difficult to deal with mood. The amount of detail lost in conversion of 2-3 adjectives onto a scale of 1-10 was significant, and the task of placing moods onto said scale was fairly arbitrary, as seen fit by the participant. For the purposes of this application, we believe that, since the reflection on the results is fairly personal, this type of translation was reasonable.

4.2 Tool Implementation

We were able to find an open source implementation of a parallel coordinates graph in C# created by Piotr Włodek from the University of Science and Technology in Krakow in 2009 [13]. This implementation displayed a randomly generated dataset on

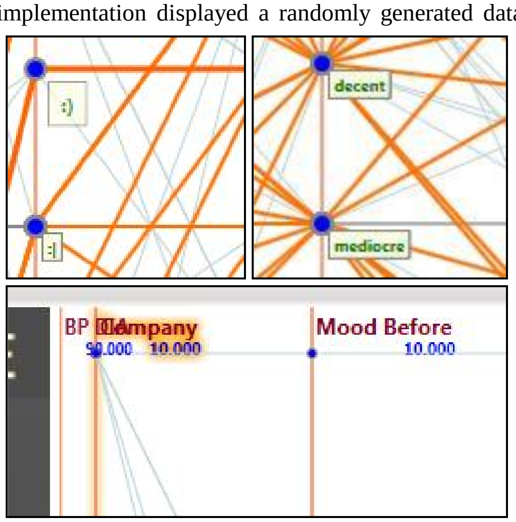


Figure 8. Labels on axes and switching of axes

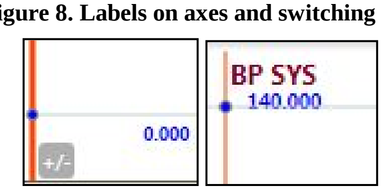


Figure 9. Flip axis functionality and axis title

arbitrary axes, and allowed for axes manipulation such as switching of the order, flipping of the scale (1-10 to 10-1), selection of single line as well as multiple lines individually, and label displays for axes titles as well as for values on each axis for a selected line. The framework provided was robust, and, after getting acquainted with the structure of the implementation, proved to be very accommodating for several changes.

Using Włodek's demo of the parallel coordinates graph, we were able to customize the code to input our own axes, dataset, link photos to lines and facilitate group selection. Within this type of visual representation of the data, the elements we added created an exploratory tool that allows the user to recognize patterns in behavior and reflect on food choices visually.

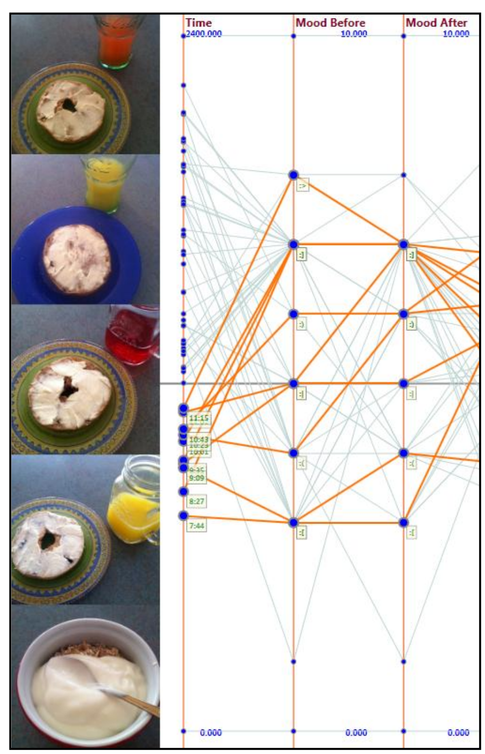
The data is automatically loaded upon application launch. No lines are selected and no photos are shown on either side. Upon the selection of a line (figure 6), the user will see the relevant labels on each axis where the line crosses, and all the before and after photos from the selected meal. When the line is deselected, the photos and labels will clear. Upon the selection of two lines (figure 7), all the lines between the selected ones will be automatically selected. For example, if the user would like to see the meals eaten in the morning, when the left-most axis is time, the user can simply select the two meals that bound the required range (let's say 7:30AM and 11:30 AM), and all meals within that range will become visible on the graph as well as the relevant photos in the margins ordered accordingly.

Each point on the axes displays a descriptive label with highlighted (figure 8, top: mood before/after, enjoyment of meal). Switching of axes is a crucial functionality of the tool and is implemented using a simple drag and drop technique (figure 8, bottom: BP DIA axis being dropped in place of Company axis). A custom title is given to every axis, and maximum and minimum ranges are defined appropriately. At the bottom of each axis, there's a functionality to flip the axis range: by default, minimum is at the bottom, and maximum is at the top (figure 9).

5. EVALUATION

The participant used our exploration tool to review the data

Figure 10. Breakfast and mood change



collected over the two weeks. Using manipulation of order of the axes, selection of groups and review of before and after photos, she discovered several interesting patterns in her behavior when it comes to meals. A few of them are highlighted in this section.

Starting off with the default configuration of the axes order, she grouped meals by time, as appeared natural to her. She discovered that, almost without exception, her mood is either maintained or improved by morning meals (figure 10). Upon review of the photos within the group, she found little variety in her breakfasts – a fact that may or may not be positive. Overall, she decided that, since having breakfast is likely to improve her mood, they are worth the effort. Using the same axis order, she discovered that, while in a bad mood, dinners tend to give her a boost, but if her mood if above average before dinner time, it often worsens after the meal (figure 11). This reinforces the fact that food is very likely to improve her mood, and may explain that her bad moods may often be related to hunger.

Rearranging the axes provided the participant with a completely different perspective. When she selected a group based on two top hunger levels (starving and very hungry), she found out that extreme hunger occurs very often before dinner time while she's alone or with a single other person, and the meals regularly results in the feeling of fullness or overindulgence (figure 12). Considering that there's often a long gap between lunch time and dinner time, filled with only rare snacks, the necessity for a snack or an earlier dinner was identified, as well as the issue of overeating. She recognized that it would be best if she was never in a starving state and would then be less likely to overeat during dinner time.

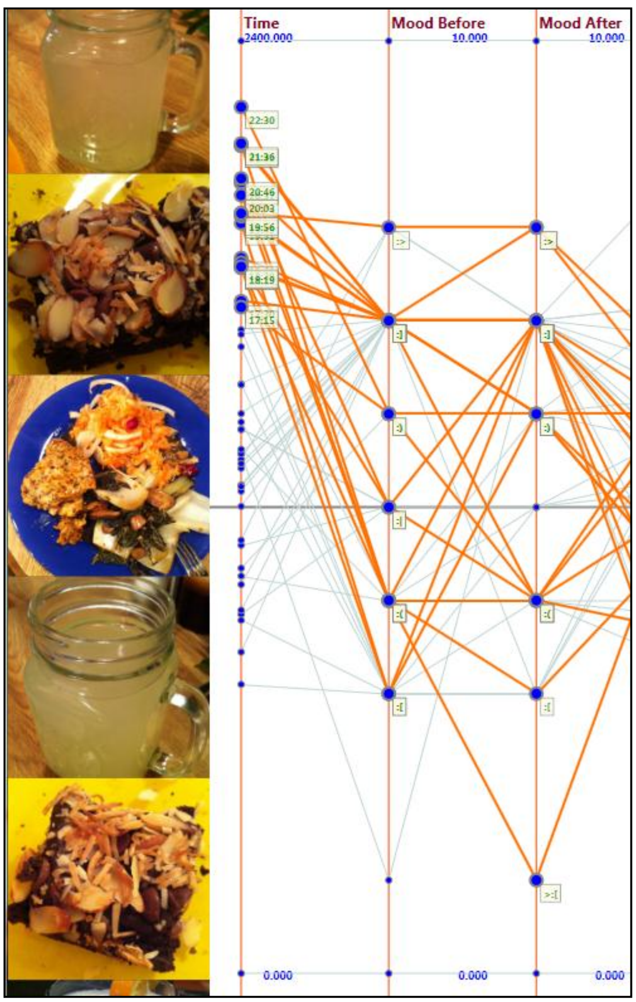
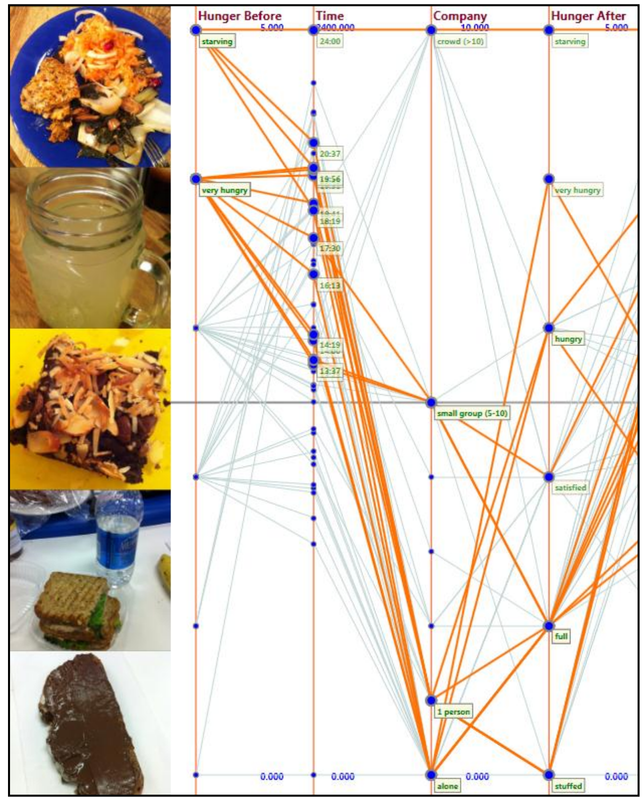


Figure 11. Dinner and mood change

Figure 12. High hunger, time, company and satisfaction



6. DISCUSSION

6.1 Successes

From the evaluation of the tool, we learned that the main goal was achieved: the user discovered previously unrecognized patterns in behavior that relates diet choices to transient factors, while reflecting on the said diet choices through the use of before and after photographs. The utility of switching axes and selecting groups was a strong addition to the visualization of potential trends in user habits. Surprisingly, the expected limitation of a small dataset did not seem to greatly affect or limit the exploration of patterns using the parallel coordinates visualization. While some detail was lost in translation of data to arbitrarily defined axes in the graph representation, since the participant was intimately involved in the translation, it was reasonable for the particular user.

6.2 Limitations

There are likely many more factors that we could relate to affecting food consumption, but there was a necessity to limit the scope of the study. Consequently, only the listed factors were considered, as they seemed to be the most likely to produce interesting and relevant results. While the factors that we chose to investigate proved to be relevant in the context for the particular participant, we questioned their applicability to different users as a group. In this deliberation, we wondered if our personal biases affected the way we viewed particular coordinates and relationships as meaningful in this representation. Since we had only a single user at this phase of the project, the design of the application may be biased and may require revision if dealing with different eating patterns. An interesting layer of this work is understanding and compensating for the fact that the nature of the data collected may be very intimate to the participant, and the data collection process is fairly intrusive and labor intensive. This fact lead to some bias in the data. On a social level, parts of data collection raised questions from observers, especially frequent blood pressure measurements. As a result, the participant was likely to delay measurement of blood pressure to later, more private time. At times, it was difficult to record all necessary data due to certain social situations such as company of particular people, communal food dispensing (when one does not get her one plate), or urgency of another event. The participant noted that she felt compelled to abstain from small snacks because of the fact that they would need to be documented. This may have affected the frequency of snack times during the data collection period. When recording moods, the participant found that it was quite difficult to accurately identity her mood in only a few words. This fact combined with the loss of detail during translation of mood to the scale form could signify skewed mood data. Since the data was collected before final design of the interface, some necessary parts of data were missing such as matching after photo for every before photo (versus combining two items in one photo).

6.3 Future Work

The application for this short term project was developed strictly for the PC, and is mainly designed to facilitate self-reflection which would hopefully lead to better understanding of personal nutrition choices and motivate a change in unhealthy diet behavior. A similar future mobile application, however, would be able to offer a number of different services to the user on the go. Based on one's data, discoveries can be made about one's eating habits in relation to mood, stress, location, company, etc. In the future we see an application that could attempt to predict the most stressful times in one's day/month, one's eating habits based on location, as well as in relation to other factors, and remind or warn one about potential situations where one is likely to make unhealthy choices. Different factors may be considered in relation to one's food intake, such as tracking exercise patterns, giving more insight to food choices and eating habits. An infrastructure such as Salud! API [3] may be extremely helpful in data collection for a mobile application.

With the increase of popularity in social networking website, the desktop or mobile applications could both provide the functionality to share whatever information the particular user is comfortable with sharing over various websites such as Facebook and Twitter.

After interpreting details of the implementation of our tool, we believe it could be further improved to provide a better exploratory experience to the user. A weighted similarity algorithm could be used to give meals ratings of how similar they are to a particular meal. This functionality could shed light on different types of patterns within the transient factors relating to meals. Creating and saving custom groups of meals could allow the user to keep track of their habits as the dataset grows – are they consistent even after awareness, or is the knowledge and reflection motivating the user to change? Based on the fact that different transient factors may be more or less important to particular users, it would be useful to allow the user to remove axes and create custom axes with a custom scale and mapping from data to scale, opening up a whole other world of possibilities for this exploratory tool.

7. CONCLUSION

Personal reflection and understanding of factors that affect one's nutritional choices are substantial in the improvement of one's nutrition and this application gives individuals insight into patterns and behaviors previously unknown to them, whether advantageous or detrimental to their health. While the successful design and implementation provided us with an interesting take on how to discover patterns in eating habits relating to several influential transient factors, several improvements and further developments can help create a truly powerful exploratory tool that enables its users to gain significant insight into the inner workings of their subconscious dietary choices.

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