

# “Honey=Sugar” Means Unhealthy: Investigating How People Apply Knowledge to Rate Food’s Healthiness

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## ABSTRACT

While previous research studied the high level attributes people consider when they assess the healthiness of food they are familiar with, little work has looked at how people assess arbitrary, potentially unfamiliar, food to decide whether it is a healthy choice. Since there is a growing body of work in Ubicomp around health practices, including systems to support healthy eating, it is important to understand how people apply the knowledge they have to food decisions. In our studies we identified 8 attributes participants use for determining if they think a food is “healthy” or not. Based upon our analysis, we reflect on current system designs and propose four future design opportunities: capturing context of healthy eating, preparation and reflection on healthy eating understanding, sharing understanding and in situ information support.

## Author Keywords

Health, behavior change, diet, healthiness of food.

## ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. J.3. Life and medical sciences: Health.

## INTRODUCTION

Obesity is framed by the World Health Organization as an “epidemic” [15]. Not coincidentally, ubiquitous applications to support better health practices have been an area of ongoing interest in the Ubicomp community [5,13,21]. Often these “persuasive technology” [11] applications are designed to provide information about attributes of a person’s practice relative to their health goals, with the idea that seeing one’s progress is a valuable motivator for ongoing behaviour change [6,21].

In the context of weight loss, most applications have focused on the seemingly easy to quantify but tedious to log calorie counters: generally progress with eating less is supposed to map to a progressive decline in weight. Recent

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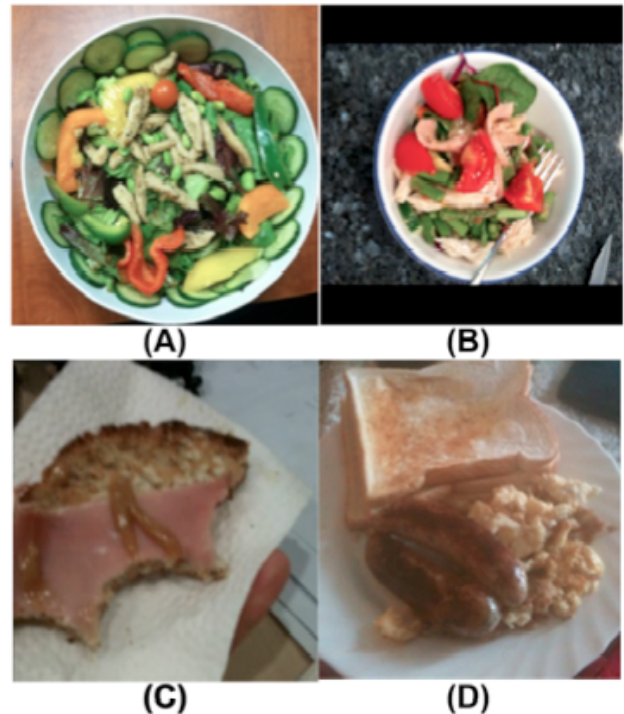


Figure 1 Sample food pictures from Pic Healthy and their ratings: (A) Chicken cucumber and pepper salad, 4 stars; (B) Chicken, tomato and spinach salad, 3 stars; (C) Beef sandwich, 2 stars; (D) Sausage, egg and toast, 3 stars

work has proposed that photos of meals can be crowdsourced to calculate calories [21], and so take the tedium out of entering food items from a database. Calorie counting, however, has been questioned as an effective means to support diet change [17]. An alternative approach has been to forego attempting to calorie count, and crowdsource judgments of whether a food or meal is healthy or not. Mobile applications like Pic Healthy<sup>1</sup> and the Eatery<sup>2</sup> encourage people to rate each other’s perceived food healthiness on a Likert-scale (e.g. Pic Healthy uses 5-point Likert-scale). Such approaches do not pre-define what a healthy food is but allow people to freely assess food’s healthiness based on their beliefs and opinions.

<sup>1</sup> [http://www.medhelp.org/photo\\_food\\_gallery/list](http://www.medhelp.org/photo_food_gallery/list)

<sup>2</sup> <http://eatery.massivehealth.com>

The assumptions informing these food-rating approaches seem to be that 1) eating “healthy” is an important step for weight loss and 2) that given sufficient numbers of people responding to an item, majority rating will mean accuracy. These application, therefore, at least implicitly seem to assume that participants have a basic understanding of what “healthy” eating is. But what if that is not the case? This quality of judgment problem is amplified by the fact that such applications only rely on a single numerical rating for each entry, without justifications or comments. As an anecdotal illustration of the issue, Figure 1 shows 4 images from the Pic Healthy site with their average ratings. Without comments regarding the rationale for the rating it is difficult to understand why one salad (Figure 1 A) is rated 4, but another one (Figure 1 B) is rated 3. Likewise it’s unclear why toast and sausages (Figure 1 D) receive the same rating as the salad in Figure 1 B. Without capturing any information about the rationale behind rating, it is not clear what factors people take into account to assess a food’s supposed healthiness.

To address this issue, in this paper, we report a study to understand how users and potential users of food support technology make decisions about the relative healthiness of food options. Our aim for this work is to identify attributes that people take into account when evaluating food choices in order to inform the design of tools to better support people in their choices. In the following sections, we first review previous work around the interpretation of healthy eating and system designs for healthy eating. Then we present our study method and report our results. Finally, based on the analysis of the data we collected we propose a suite of intervention opportunities for future system designs for healthy eating.

## RELATED WORK

Related work falls mostly in two areas: research on attitudes and understandings of healthy eating and HCI research to support healthy eating.

### Interpretation of Healthy eating

A person’s ability to evaluate whether a food is healthy or not is one key determinant informing what people choose to eat [23]. Research has shown that people generally categorize food into healthy or unhealthy based upon particular, recurring attributes [3,22]. One approach to identify those attributes is to interview people how they define healthy food. This approach allows eliciting attributes at a general level and from a large population.

The literature reports attributes including macro nutrients (protein, fat, carbs), types of food (vegetables, fruit), perceived food quality (fresh, processed) and portion size. For example, some studies [8,29] highlight that people tend to consider *low amounts of fat, sugar, and salt* as good for health. Studies involving children, adolescents and adults [1,9] reported that *vegetables and fruits* were most often mentioned as healthy food. *Freshness*, as opposed to

*frozen, canned and processed* food, tends to be perceived as healthy or healthier [24,28]. On a similar note, another study [29] indicates that *home-made* food is considered the most healthy. The concepts of *balance* and *variety* are also attributes found in the literature [7,10,28]. However, there also seems to be a general confusion about what a “balanced diet” or meal actually is [8,16]. Related to balance is *proportion*: we generally make poor judgment when it comes to either describe or identify what a good serving size is [2,14].

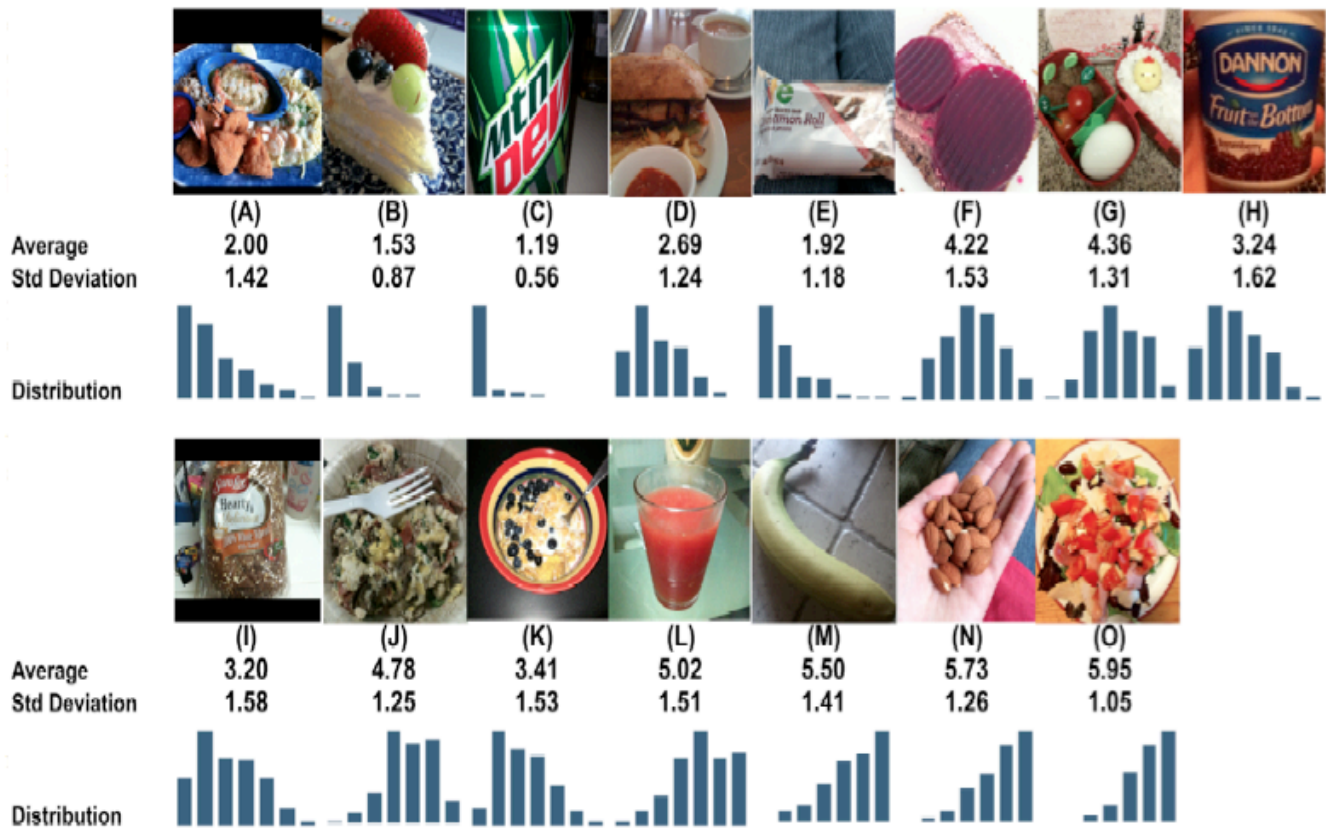
Carels et al. [3,4] tried to solicit food rating attributes by asking participants to rate 16 foods and explain their rating in writing. In a first study [3], they asked 75 undergraduates to list 10 healthy and unhealthy foods they know. Then they selected the top 8 healthy and unhealthy entries to construct a “Food Healthiness Questionnaire,” which asks to rate the healthiness of the 16 foods (described in plain text) and justify the rating with a written explanation. They then recruited 55 participants from an obesity care program to complete the questionnaire. In a second study [4], the same questionnaire was answered by 101 undergraduates. Both studies reported a set of nutritional attributes such as low/high fat and low/high protein as well as perceived quality attribute and portion size attribute. However, these two studies are limited in two ways: first, foods in the questionnaire are simple foods (e.g. an apple) and no multi-food items (e.g. chicken, spinach and tomato salad). Second, foods are described by plain text therefore people are required to imagine those foods while evaluating them. Social food photo applications like the Eatery and Pic Healthy use images and take images not only of single items but seemingly more often of meals, that is, of plates of multiple food, rather than single food items. It is not clear, therefore, how either seeing an actual image rather than text, or dealing with multiple food items rather than single items inform health assessments/food choices.

### Persuasive Technology and Applications to Support Healthy Eating

Persuasive Technology is technology to persuade people and help them change attitudes or behavior [11]. Food intake tracking, food preparation, and food planning has been a popular domain of its application.

Digital photos of food are at the centre of several projects in this domain. PhotoCalorie [21] is an online tool allowing users to take pictures of food and semi-automatically calculate the possible calorie amount based on computer vision. Another tool called Meal Snap [21] utilizes the Amazon Mechanical Turk<sup>3</sup> to hire trained labor to estimate the calorie amount of meals in photos for users. The main effort behind such applications is on reduction of the time people need to spend on evaluating the healthiness of food and they mainly focus on calories counting. In contrast to

<sup>3</sup> <https://www.mturk.com>



**Figure 2 The 15 Food Pictures in the Survey with Their Average Rating, Std Deviation of Rating and Distribution of Rating**

calories counting, Smith et al. [30] use patients blood sugar levels, in combination with photos, as a different measurement to help diabetes patients understand the healthiness of food. In addition, the Eatery and the Pic Healthy, as mentioned in introduction, all favor the idea of leveraging crowd intelligence to make judgments on food's healthiness. This approach creates new opportunity to look at how people think about healthy eating and apply their food knowledge.

In terms of food preparation and planning, Chi et al. [5] developed a smart kitchen to detect how people prepare food. Their aim is to provide just in time nutrition information for real time decision making. Mankoff et al. [20] focus on food shopping: they propose a system that analyzes grocery receipts to report the nutrition facts. The idea behind this work is to inform users how much nutrition they will consume and provide users with substitutions information to help them reach a more balanced diet.

Several studies focus on supporting reflection in the context of healthy eating. Grimes et al. [12] developed a voice-based system for one local community to share memories on healthy eating practice. This voice-based system works as a voice record repository for people to reflect on what they did. Moreover, through sharing those memories and listening to other people's memories, people get the chance

to gain insight into what other people in the same community did and reflect on what could be done based on other people's experience. Mamykina et al. [19] created an online space for patients with diabetes to post what they eat and write down text notes or record audio notes to reflect on what they eat and what problem they have. The system also allows experts to examine those food logs and notes to ask guiding questions to help patients frame their thinking on what is healthy eating for them. In later work [18], they hypothesized that tagging food pictures could lead to more accurate critical evaluation of food's nutritional value and they studied how three different tagging technologies could assist users in generating more assessment tags. They found that assessment tags generated by others can help people think critically on the food's nutritional value and generate more reliable assessment tags.

Our work in this paper thus favors the notion of reflection and takes one step backward from above works (especially [18] ) to find out how people interpret the notion of healthy eating and how they apply their understandings to evaluate food. We believe that understanding this issue could establish the foundation for tools designed to support reflection on diet.

## METHOD

In order to better understand how people evaluate arbitrary food (rather than food they are familiar with), we adopted a method similar to the one used by Carels et al. [3,4] to solicit attributes of food people take into account. In our study design, we first randomly selected 15 food pictures along with their text description (if available) from Pic Healthy to construct the survey. The pictures we selected, illustrated in Figure 2, include not just *simple* and *raw* food (e.g. banana) but also *complicated* everyday meals (e.g. triple shrimp meal). For each food picture (with text description), we instructed participants to rate healthiness of the food on one 7-star Likert scale and answer one open question to list attributes of the food to explain the rating. To mitigate order effects, the presentation order of the pictures was randomized. After the rating and explanation task, the survey asks for demographic data: age, country of residence and job.

The survey was deployed on a public free service, SurveyGizmo, and an invitation to complete it was sent out to our university mail lists (accessed by staff and students), health-oriented forums, Twitter, and Facebook. In order to identify where our participants were recruited, we set distinct URL variables to track responses. In two weeks, we received total 153 responses. Participants' age ranged from 18 to 65, with the majority (35.3%) between 26 and 35. Geographic provenance: 45.8% (n=70) of participants live in North America and 39.2% (n=60) in the UK, the rest in European countries. Jobs: 12.4% (n=19) of participants work in the health-related industry, and other participants work in various industries from IT (n=27, 17.6%) to education (n=20, 13.1%) to sports (n=5, 3.3%).

## RESULTS

In this section we present the analysis of the open question on food attributes. For our analysis, we applied an open coding method [25,31]: answers were coded at the sentence level. A total of 26 codes were initially generated, then grouped into the following 8 more general categories: *Equivalence Labeling*, *Brand Association*, *Nutrient*, *Portion Size*, *Quality*, *Health Effect*, *Comparison*, and *Uncertainty*. Each category is described in the following subsections.

### *Equivalence Labeling*

Equivalence labeling is a special attribute of food perceived by people: people simply attach a label (e.g. "healthy", "fatty", and "super") to food, nutrition or other attributes without detail explanation. In our analysis, we found several interesting labels such as "honey=sugar", "cheese=fat", and "fruit=super". As expected based on the literature [1,9], the label "healthy" was regularly attached to vegetables and fruits. In addition to above labels attached to one type of food, participants also attached label to certain nutrient they identified within a complex food. For instance Figure 2 (A), the three shrimp dish, was rated 6 stars with the simple explanation: "Protein". So in this rating it seems

that protein outweighs any other consideration. Therefore, protein is perceived as the equivalence to health for this particular participant.

### *Brand Association*

Participants used the brand information to judge food's healthiness. The Figure 2 (C), (E), (H), (I) all contain brand information and participants did use this data as one criterion for assessment. For instance, one answer to the Figure 2 (I), a bagged loaf of whole wheat bread, said: "...Sara Lee brand = not identified with healthy; cellophane wrapper = not identified with healthy". As shown in this example, this particular answer did highlight the fact that the participant does not trust that Sara Lee could offer healthy food. The trust issue could be further explained by another answer to this bread: "...Most foods labeled whole wheat are in fact nothing but processed carbs". This answer helps us further understand that people actually doubt whether commercial brands tell the truth on their package. How the future information systems could offer information related to brand and verify certain claims of those commercial food products would be an interesting open question. Interestingly, we also found that people also identify certain packaging material as unhealthy. For instance, the cellophane wrapper, the package of the bread, was identified as "unhealthy". It might suggest that packaging material information could also be leveraged in future designs to help people identify healthy food.

Even though this attribute seems to be obvious one, we did not find it in the literature on how people assess food's healthiness, probably because prior studies used textual descriptions, while in our study food was presented through photos and texts. Therefore, we believe it is valuable that our study demonstrates how people actually use brand information in their food healthiness assessment.

### *Nutrient*

As we expected, the most used attribute (category) is Nutrient. Five major nutrients are mentioned in all answers: sugar (n=447, 32.67%), fat (n=371, 27.11%), protein (n=287, 20.98%), carb (n=208, 15.20%), and calorie (n=55, 4.02%). It is interesting that calorie is the least mentioned nutrient in participants' explanation and one possible implication based upon this finding is that calories are not the focus when people think about what is healthy eating. This finding particularly contrasts the current trend in system designs that favor calories counting [5,21]. Finally, in terms of the amount of nutrient, our findings accord with literatures [7,22,23] that people pursue low fat, low carb, low sugar but high protein food.

### *Portion Size*

Portion Size is a common attribute identified in previous literature [9,10]. In our analysis, we found that participants were particularly sensitive to the portion size of certain ingredients/foods. For instance, fruits and vegetables are

usually the focus of portion size assessment. If people think the food contains no or low amount of fruits or vegetables, they will give the food relative low ratings.

#### *Quality*

The quality of food relates to two issues: (1) whether the food is natural (not processed) and (2) whether the food is fresh. Generally, our findings resonate with previous literature [24,28,29] that people believe natural and fresh food is better than processed food. For example, one participant suggested eating raw grapefruit instead of juice to get fiber in Figure 2 (L), a cup of fresh juice, because:

Freshly squeezed juice is natural, and better than from a carton, although it lacks the fiber you would get from eating the whole fruit.

Our study, however, captured more details in terms of why people believe natural food, as opposed to manufactured (processed) food, is better. One major reason is people think that chemical additives and preservatives in processed food are bad:

Too much confectioned sugar. Too much chemicals and other sweeteners. Chemical flavoring...

In addition to the consideration about additives, some participants also raised the issue that how animals or plants grow before they are processed in the factory: "Also the rearing of these animals [shrimp] is mostly bad and they are fed chemicals."

These two reasons potentially provide us with more insights into what type of quality information around food, especially processed food, should be given to people to judge food's healthiness.

#### *Health Effect*

Health effect is one interesting attribute identified by us. In our analysis, participants reported their concerns around specific health effects of certain foods on human body. For example, one answer to the Figure 2 (A), the three shrimp meal, mentioned: "...Shrimp are filter feeders and are thus not especially good for human consumption." Participants also explained the health effect from the perspectives of what nutrition the human body needs: "Fizzy drinks: lots of calories, carbonic acid and sugar to rot your teeth, various additives (like aspartame) of dubious effect on long-term health, and nothing your body actually needs (except water, but it's better to get that from the tap!)"

Another effect participants mentioned is the relationships to disease, for example:

This type of refined carbs leads to heart disease. I wouldn't eat this

This effect was also further explained as the interaction between medicine and certain food in the answer to Figure 2 (L):

I gave it 5 stars, because grapefruit juice has interactions with many prescription meds that could adversely affect your liver. If a person is 100% healthy and med-free, then I would give it 6 stars. Eat the whole fruit for 7 stars.

Based upon this finding, we suggest future designs for healthy eating should offer personalized information that highlight potential health effect to help people choose suitable food that neither influences the effect of medicine nor causes health problems.

#### *Comparison & Relation*

Some participants rationalized their ratings by comparison to other foods. For instance, one participant compared the rye bread with wheat bread in the answer to Figure 2 (F): "Rye bread is likely better than a 'wheat' bread as it's made with rye flour and definitely better than white bread" This type of comparison illustrates that people have certain knowledge that which type of food is better than another type of food and could apply this knowledge to their food evaluation.

Participants also compared portion sizes of different ingredients in a food picture. One answer to Figure 2 (B), a slice of cake, mentioned the small portion size of fruit as a topping cannot overcome big portion size of those less healthy ingredients: "The small amount of fruit on top isn't enough to overcome the white flour, white sugar and plenty of fat larding this cake." The comparison on portion size between different ingredients in one food should be paid attention in future designs because relative proportion information will be very useful when people consider the basic concept of balanced food. Future systems could try to offer the comparison result information to inform people which part of the food is not good enough and suggest possible solution. For example, if a person want to eat the cake shown in Figure 2 (B), the system might suggest that you should also get additional amount of fruits to add vitamin and other good nutrients.

#### *Uncertainty*

64% out of all answers were coded as *Uncertainty*. Uncertainty ranged from processing to the health background of the eater. In some cases, for instance, participants mentioned in their answers that they wanted to get more details about the food or the person who ate the food in order to make reasonable and fair judgment about a food's healthiness. The most common uncertainty we found was around ingredients. Questions pictures did not answer were around things like food processing (e.g. grilled or roasted) or how much oil was used or what type of meat was used. Many Participants wanted to know those details in order to identify nutrients and attach a label (i.e. Equivalence Labeling). For example, one answer to Figure 2 (G), rice, one boiled egg, two small tomatoes and 2 meatballs, said: "I'll give 4 stars... more detail on what's in the 'meatball' could change things..."

Sometimes participants offered their own assumptions on ingredients to rationalize their rating. For instance, in another answer to Figure 2 (G):

Rice has too high of a GI. Egg is good. Assuming the meatball is just ground beef, then that is good. Tomatoes are great. I give it 3 stars due to all of that white rice.

As we mentioned above, participants also questioned how a food was processed and the focus was on whether any additional flavor or additives has been used. For example, one participant mentioned the processing method: (s)he thought the nuts would be healthy in the answer to Figure 2 (N), a hand full of nuts only if “Unsalted and no oil”

Portion size was also at times a point of uncertainty. For example, the answer to Figure 2 (J) mentioned: “Yes, however healthiness depends on the fattiness of the cold cuts and the proportion of cold cuts in the dish.”

Another type of uncertainty is about the person who ate the food. Such type of uncertainty raised questions like: what type of lifestyle the person has, what type of physical activity the person did, what type of diet the person is on, what else food the person ate throughout the day and etc. For instance, one answer to the Figure 2 (B), a cake with fruit on top, mentioned:

It depends on what else you are eating, and your lifestyle. You don't need much of this type of food if you [are] sedentary. For your average person, it would be unhealthy to eat too much of this food. It is likely to be high in fat, and sugar; despite the fruit on top.

As this example shows, whether the cake is healthy or not is very context-dependent. It is different from other answers that did not consider the person who ate the food because it highlights the concept of healthy eating/diet/meal instead of the concept of healthy food, which is the mainstream concept encapsulated in most current systems. Therefore, we propose that future designs could think beyond healthy food to think about the big concept of healthy eating by capturing and modeling those rich contexts about the person who eats foods.

### **The Relation between Attribute Usage, Ratings and Demographics**

For ratings of foods, we investigated three statistical variables: average, standard deviation as a measure of agreement, and distribution of each food's ratings. The average rating indicates the aggregated numerical result of how healthy a food is. Based upon the definition of Pic Healthy, food that is rated greater than 4 stars is a healthy food, and all the other as unhealthy food. Then as shown in Figure 2, foods (A, B, C, D, E, H, I, K) are unhealthy foods and the rest are healthy foods. This result basically accords with common sense that packaged or fast food are bad and foods containing more fruits/vegetables are good. For complicated foods (A, D, G, J, O), we expected that overall

people would find it difficult to distinguish them and rate all of them around 4 stars (i.e. neutral). Instead, the ratings for these 5 foods clearly indicate healthiness (either healthy or unhealthy). Thus, this result seems to demonstrate that our participants are able to apply their knowledge to evaluate those complex/mixed foods.

The standard deviation and distribution indicate the variation of ratings of each food pictures. As shown in Figure 2, it is not surprising that the canned drink (picture C), the cake (picture B) and vegetable salad (picture O) have relative low standard deviation compared to other foods. This is because they are very common foods and most people know how healthy they are from mass media or public education. But it is very surprising that the banana, a fruit that is commonly viewed as healthy food, has a relatively high standard deviation. By looking at detail explanations contributed by participants, 82.4% people, who rated it lower than 4 stars, mentioned *Uncertainty* attribute and raised the issue that eating banana only will be bad for health and it should be served with other foods containing rich protein. From this we learn that *context* is important when people are evaluating food's healthiness.

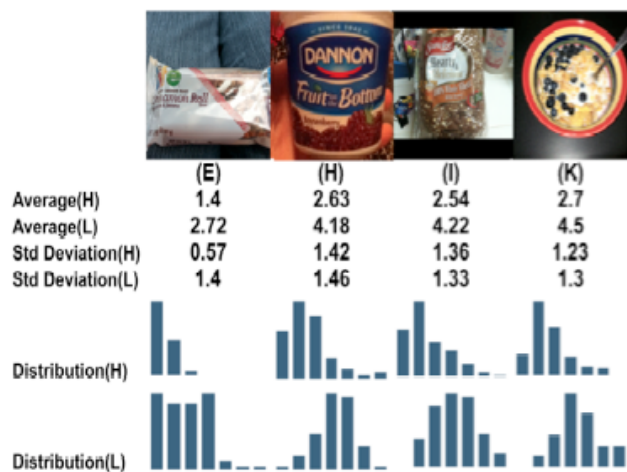
Next, we investigated the relation between ratings and demographics and looked at how attributes we identified could explain those relations. First of all, based upon where participants were recruited, we categorized participants into two groups: those coming from health-related forums and those coming from elsewhere (university mail lists, Twitter and Facebook). The reason to categorize people into these two groups is because people who are in health-related forums are relatively active in thinking, talking and practicing healthy eating. They might have deeper food knowledge than others, and their judgment may be informed by specific nutritional theories or diets. Our goal in making this distinction between groups was to see if and how far apart ratings and rationales of healthiness in these two groups might be. And the results might help us to understand how to better mediate possible communications between two groups to discuss healthy eating and what type of information should be delivered to which group.

In total 93 participants were from health-related forums: we refer to these as health community group (H). The remaining 60 people from other places: we refer to these as lay population group (L).

### **Differences in Ratings between Two Groups**

A chi-test revealed that the ratings of the foods in Figure 2 (E, H, I, K) were different between the two user groups with statistical significance (for all four pairs  $p < 0.01$ ). These pictures contain: a nut snack bar, one fruit yoghurt, a bagged loaf of whole wheat bread and honey bunches of oats with pecans and blueberries. As shown in Figure 3, the L group rated these four foods (E, H, I, K) on average higher than the H group did. The reason behind such





**Figure 3 The Four Food Were Rated Significantly Different by Two Groups**

difference, as indicated by attributes analysis, is the H group people are more sensitive to natural food. All these four foods are commercial food (three of them have the clear brand label in picture, however the Figure 2 (K)'s brand information is shown in the text description as honey bunches of oat) and the H group people expressed their strong concerns about added sugar and additives and doubted whether those foods contain real natural ingredients (e.g. fruit in fruit yoghurt) as claimed on package. In contrast, only 5.2% participants from L group had same consideration and only took into account macro nutrients to assess the healthiness.

A chi-test on the ratings of all other foods between the two user groups did not reveal any other significant differences.

#### *Differences in Attributes Usages between Two Groups*

In addition to investigating differences in rating, we also looked at how these two groups used those attributes differently.

First, we investigated the two groups' different interests in nutrients. The H group showed interest in sugar ( $n=312$ , 34.32%) then protein ( $n=208$ , 22.88%) and then fat ( $n=179$ , 19.69%). In contrast, the L group is more concerned about fat ( $n=192$ , 33.10%) then sugar ( $n=135$ , 23.28%) and then protein ( $n=79$ , 13.62%). By conducting a t-test, we found that the difference in mentioning fat is significant between these two groups ( $t(28)=2.40$ ,  $p<0.05$ , Cohen's  $d=0.88$ ). The presence or absence of fat for the L group was a very important feature. For instance, when judging Figure 2 (L), a cup of fresh juice, in one answer from L group, the low amount of fat was highlighted: "Contains lots of minerals and vitamins while low in fat so healthy." In fact, it is not surprising that the L group is more concerned with fat than the H group based on previous research [3,4]. In addition, low fat followed by low salt are currently the most popular features advertised in stores in relation to healthy food (e.g. low or no fat versions of classic products). Likewise cutting

fat is perhaps the most often-repeated strategy to lose weight, a popular reason for people to be interested in nutrition [27].

In terms of fat, we also observed differing degrees of nutrient sophistication. The H group mentioned the specific type of fat: saturated or unsaturated fat 79 times (44.1% of all answers mentioning "fat") and mentioned complete protein 20 times (9.6% of all answers mentioning "protein"). In contrast, the L group only mentioned the specific type of fat 21 times (44.1% of all answers mentioning "fat") and the complete protein 4 times (5.1% of all answers mentioning protein). This result indicates that L group's knowledge on nutrition is limited: they do not fully understand the difference between different types of fat or protein, and usually they treat all type of fats and proteins as the same and label them as bad or good.

Finally, we also noticed that the H group mentioned carbs much more frequently (18.7% of this group responses) than the L group (6.55% of this group responses).

Our next analysis was about the ways in which people from the two groups use the eight attributes: individually or in combination. It is perhaps little surprising that the H group has a more nuanced view of food choices than the L group, reflected in their greater use of multiple attributes to explain a rating, while the L group tends to use a single factor in assessing a food picture. One-attribute explanations featured in 51.2% of the H group responses, but in 68% of the L group. Based upon our observation, we suggest that future design should offer more guidance in judging food's healthiness. Potential method could be sharing thoughts from more expert groups with the general population in order to help users understand what attributes they might be missing. This is indeed inline with the method proposed by Mamykina et al. [19].

## **DISCUSSION**

The aim of our study has been to understand how people apply their nutrition knowledge when they assess food. With our study, we were able to solicit attributes of food that participants used to make these assessments. In the process of analysis, we avoided making judgments about the correctness of any assessment contributed by participants; instead, we focused on identifying attributes of food people wrote down to explain their judgments.

Of the 8 attributes we reported, 3 (*Nutrient*, *Portion Size*, and *Quality*) are the same as those identified by previous literature [8,28,29]. Most of our findings around these three attributes are in accordance with previous research. In relation to *Nutrient* in our analysis, we found that calories are not the focus in participant's answers. This confirms previous findings in the health field: calorie is just one aspect of food's healthiness. In terms of *Quality*, we reported two issues people concern about quality: how vegetables, fruits and animals are raised and how much additives and processed ingredients are added.

Since we used complicated/mixed food items and presented foods in images, we observed people referred to brand and compared the proportion of different ingredients in food items. The two attributes: *Brand Association* and *Comparison*, therefore, are, we believe, novel in HCI Health research. In addition, *Equivalence Labeling* opens a question for how future designs might leverage those labels (e.g. honey=sugar) to adjust or inform people's healthy eating understanding. Finally, we also reported the *Uncertainty* and *Health Effect* attributes, which to our knowledge have not been reported in previous literature on interpretation of healthy eating. These results suggest that designs may need to take context into account for interpretation and recommendations

The need to respect and reflect context was emphasized in the way participants used combinations of the 8 attributes. This observation reinforces that the concept of healthy food is not perceived to be one-dimensional (focusing on just calories or just fat for instance) as defined by many current system designs [5,20,21] but multi-dimensional, which means healthy food is not just about moderate calorie values – a popular message - but also about amounts of macro nutrients, quality of food, portion size, brand and health effect. Moreover, we found that participants referred to various contexts related to the person who eats the food. This suggests that in system design we need to think beyond the question that “Is it healthy food” and to consider the more important question that “Is it healthy food for the person in the specific context.”

In the following section we reflect on current healthy eating systems designs and explore how future systems might leverage attributes we identified to promote and support healthy eating.

### **Negotiable Definition of Healthy Eating**

Current interactive systems to support healthy eating define healthy food mainly based upon calories counting. Most systems for food logging [21], shopping [20] and preparation [5] try to promote healthy eating by recommending people to reduce caloric intake. As our results show, however, people have their own more nuanced understanding of healthy eating: it is a multi-dimensional and often context-dependent concept. However, as we found, the usage or awareness of different attributes varies from one person to another, and sometimes that awareness may not be entirely correct. These findings of nuance and (in)accuracy suggest that future system designs may try to identify current knowledge around food to guide a more effective course for dietary behavior practice. Specifically, we suggest future system designs may consider two challenging points.

First, we need to consider capture contextual data around eating behavior, such as whether a person has done some physical activity before the meal; whether the person has a specific health problem, and what type of diet the person

might be on.. How to collect this information without explicit interaction with the user but from interaction with the environment seems a challenge well-suited to ubiquitous computing.

Second, how and to what extent should a system negotiate with the user? Is it ethical for a system to always respect user's thoughts even these may be considered incorrect or biased? To what extent should a system try to correct the user? We highlight these as open questions for future investigation.

### **Preparation and Reflection on Healthy Eating**

Assuming it is somehow possible to determine activity and other factors about context, what do we then recommend? For instance, some approaches to diet may say any processed carbohydrates at any time are “unhealthy”; only whole non-gluten grains are healthy. In persuasive technology, what is neutral vs nuanced about what we persuade? How do we map a systems' capacity to detect a physiological state with where we get the data to say something persuasive about that state?

As argued by Purpura and colleagues [26], current persuasive systems may offer too much automation support and so decrease users' opportunities to actually think about their decisions. We suggest that systems for healthy eating *should* offer opportunities for people to actively express their own understandings of what is healthy eating, and possibly provide feedback showing multiple ways of thinking about food to help users reflect and improve their understanding.

### **Capture and Share the Richness**

Likewise capturing not just ratings but the rich thoughts behind judgments, so that they can be shared, too, may be useful. If a system can successfully capture why people think a food is healthy or not, then such systems could include a space for users to understand and discuss each other's explanations in order to reflect on their own thoughts. For example, a person who believes all fats are bad might benefit from seeing the argument that unsaturated fat are good for health. Design challenges here include: how could systems motivate people to share and reflect on their own thoughts? How could systems offer lightweight methods to capture thoughts? How could systems visualize those thoughts to highlight conflicts and surprising opinions to form discussion?

Moreover, in terms of food logging, our results already demonstrate that the combination of picture and text can offer a good amount of information related to food for people to judge its healthiness. However, the uncertainties mentioned by our participants point out that richer contextual information could better inform their ratings and offer better insights into the food's healthiness. The potential discussion around food's healthiness, hence, could help people understand how the same food might be



perceived as healthy or not in different situation and also help people to understand what type of foods might be suitable for people who are in a special situation (e.g. who is vegetarian and wants to build muscle). However, it should be noted that without the moderation of nutrition experts, how credible and reliable are those crowd's opinions is an unclear question. We recommend that researchers in Ubicomp might investigate this issue in future.

#### **In Situ Information Support: Shopping and Preparation**

Finally, we discuss how the eight attributes might be leveraged to offer in-situ information support, in particular for food shopping and food preparation. Prior work [20] proposed a system where users could scan grocery receipt to get suggestion on what other foods should be bought to get a balanced meal. Mobile applications like fooducate<sup>4</sup> allow users to scan food products barcodes and offer healthier alternatives. Our analysis suggests that systems for food shopping should also consider other information.

Based on our results on *Brand Association* system designers could try to take into account how people judge a brand as trustworthy. For example, the brand's product history might reflect its reputation on producing healthy products. We observed that if a company is known for its sweet cakes, users are skeptical about its ability to produce healthy food. For people who do not know a brand, a list of other products or a summary review of previous products, therefore, might be helpful to determine whether to choose this brand's food or not.

Systems that support food shopping should be context aware. If a person just back from gym looks for a snack in a cafe, it would be good to offer suggestions on how to pick food that would help the person recover from heavy workout.

The in-situ information support also could help people prepare food. For example, in [5]'s smart kitchen, the system offers calorie estimation for ingredients in order to help people be aware of calories intake and swap some ingredients. Based upon our results, calories should not be the only focus. Portion size might be another important thing people care during cooking. It would be good to guide people on how to balance the quantities of different ingredients relative to portion size. In addition, such smart kitchen could also suggest ingredient alternatives. For example, olive oil may be better than butter because it provides more unsaturated fat. If the system could detect the person usually uses butter for cooking then it could offer suggestion on swapping it for olive oil to help the person cook in a healthier way.

#### **CONCLUSION & FUTURE WORK**

In this paper we have explored what attributes people used to interpret whether a food presented in picture and text is healthy or unhealthy. The key outcomes of this study are:

- Evidence shows participants do have and apply (varying degrees of) food knowledge to make judgments about food healthiness.
- We identified 8 attributes in assessing food healthiness; these attributes are used singly or in multiples when making assessments.
- Calories are not the focus and we propose future design should shift focus from calorie counting to multi-dimensional healthy eating assessment.
- Context is one key to healthy eating and we propose future design should try to leverage context information about a person in order to offer reasonable suggestions.

Based on these findings, we reflected on current system designs and explored future design opportunities: capturing context of healthy eating, preparation and reflection on healthy eating understanding, sharing understanding and in situ information support. These opportunities each leverage the eight attributes we identified and we suggest Ubicomp community to particularly focus on eating-related context capturing and modeling to create novel healthy eating systems that leverage people's understandings and context to deliver persuasive messages.

Open questions from this work that will also help refine design interventions are to see if and how the eight attributes change as food assessments move away from a photo and into a real time context. For instance does a pie rated as "unhealthy" remain unequivocally unhealthy if one is picking it up to purchase it now, for lunch, rather than discussing it in the abstract? A related question to investigate is how both food selection practice and food assessment change over time as one is exposed to just-in-time, in-context information strategies as proposed in our discussion.

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