The Design of a Mobile Portion Size Estimation Interface for a Low Literacy Population

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***Abstract*—Being aware of one's portion sizes is a key component of maintaining a healthy diet, however, it is difficult for individuals especially low literacy populations to estimate their consumption. Nutritional monitoring applications can help but most of them are designed for people with high literacy and numeracy skills. In this paper, we designed and evaluated six portion size estimation interfaces through a Wizard of Oz based experiment using low-fidelity prototypes with ten varying literacy individuals. The interfaces were designed based on the cognitive strategies adults use for reporting portion sizes in diet recall studies. Participants made correct estimates with interfaces designed for liquid and amorphous foods, but had difficulties with those designed for solid foods. Based on these findings, we provide recommendations for designing accurate and low literacy-accessible portion size estimating mobile interfaces.**

Keywords—low fidelity prototype; portion estimation aid; mobile application; low literacy; low numeracy; interface design

I. Introduction

Individuals need to maintain a healthy diet to prevent, treat and manage diseases such as obesity, diabetes and certain cancers. Part of this is done by becoming aware of one's portion size intake. Healthcare professionals use the portion size intake information of their patients to do nutritional assessment, and to educate them about specific servings and appropriate use of portion measurement aids.

Currently, people can estimate healthy portion sizes either by using serving size information on food packages or by making visual comparisons with various objects. Unfortunately, both methods present problems for low literacy populations. Ollberding and Wolf have shown that 47.2% of Americans use serving size information on food packages to consume less energy, fat and sugar [1]. However, Rothman et al. have shown that this information is difficult to understand particularly for low literacy and numeracy populations [2, 20].

The alternative is for people to determine portion sizes by associating food portions with visual aids recommended by registered dietitians [3]. For example, an appropriate portion size for pasta is ½ a cup, which is visually equivalent to a tennis ball. Such estimation aids, however, lack a standard definition [6] making their widespread use problematic. Moreover, people do not always eat portion sizes comparable with these aids, and hence the need to track and calculate total daily intake is not completely eliminated.

Based on the two most common methods described here, low literacy and numeracy populations have difficulty estimating the appropriate portion sizes because they cannot read the labels or perform calculations, thus they are susceptible to poor health outcomes.

Nutrition tracking services [4, 5] that allow users to send pictures of foods and get feedback on their caloric content can help. However, these technologies are subject to inaccuracies generated by Mechanical Turks (vision recognition technology is not there yet) which cannot be tolerated for sensitive populations like ours. Moreover, these applications create a reliance on the device whereas we want to enable users to learn and increase their ability to estimate. A diet tracking application for a touch screen mobile device with this goal has been designed, and evaluated for its usability with positive results by a low literacy population [23], but interfaces for selecting correct portions sizes has yet to be explored.

The first step towards developing an accurate dietary monitoring application for low literacy and numeracy populations is to design an interface which provides users the ability to enter their portion sizes without using text and numbers. While researchers explore portion size estimation accuracy skills of varying literacy individuals using computer-based images [17, 18], there does not exist any standard design guidelines for an interface which enables users to estimate portion sizes for different kinds of foods.

In this paper, we describe a user study that contributes to the development of these guidelines. The goal of this study was to evaluate low fidelity interfaces designed to help with the estimation of portion sizes of different kinds of foods. We recruited people from a chronically ill, low literacy and numeracy population. They were asked to estimate portion sizes of various food items with the help of various images on low fidelity interfaces (picture cards). At the end of the session, participants were asked about their preferences, and to make suggestions for improving these interfaces to better understand the issues involved in portion size estimation.

Our findings suggest that a population consisting of low literacy and numeracy people is able to accurately estimate the portion sizes of liquid (e.g., beverages) and amorphous foods (e.g., mashed potatoes) with the interfaces specifically designed for estimating them. Participants found it laborious and confusing to measure dimensions of a solid food (e.g., a piece of meat) to estimate its portion size. The ability to estimate the portion sizes of solid foods using images of everyday objects

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varied within this population. Lastly, participants preferred hand gestures for estimating portions of snacks. Based on these findings, we recommend interfaces with pictures of everyday serving containers and objects close at hand for the portion size estimation task.

II. Related Work

For the past three decades, much research has been done to develop and test various types of portion size estimation aids such as photographs [8, 9], utensils and volume measures [10], three dimensional models made from materials like wax and foam [11, 12], drawings of foods, abstract and generic shapes, house hold measures [13] and commercial plastic food replicas. In this section, we provide a brief overview of portion size research that was done both outside and within the context of a dietary assessment method. We also describe research from computer-based dietary assessment.

Kirkcaldy-Hargreaves et al. compared the accuracy of portion-size estimates obtained using four different sets of food models with pre-weighed amounts of food [14]. The food models tested were: Nasco food models, life-size color pictures of foods, abstract shapes and life-size black and white drawings. Participants were asked to estimate the actual food portions right after their presentation with two of the four models. Nasco food models had the lowest average accuracy rate, whereas life-size color pictures had the highest.

To evaluate the best cognitive strategies adults use in reporting portion sizes during 24 hour recalls, Chambers et al. compared four different sets of estimation aids [15]. It was found that the most frequently used strategy was visualization of the recalled item followed by its volume, size or shape comparison to the available aids. Other strategies included estimations based on known amounts, and actions such as pouring and creating distance between fingers. For liquid or amorphous foods, participants preferred an aid that resembled the actual size or shape of the food portion or its serving container, while measuring with a ruler was a preferred method to estimate portions of solid foods. The food categories that we used and interfaces that we developed were informed by the cognitive strategies described here.

In their study, Ovaskainen et al. assessed whether food photographs would be valid aids for estimating the actual amounts of food [16]. They also analyzed personal characteristics, food group and portion size options for their effect on the accuracy of estimation. The photographs became part of a booklet used in the National Diet Survey in Finland. They were not life-sizes images of the actual foods. Participants were recruited from a varying literacy population with 54% at and below secondary school education. Correct portion estimates were made only half of the time for all kinds of foods. Both men and women over- and under-estimated the actual amounts. The estimation error was higher in men than in women. No other background factor including education was tested for correlation with estimation error. Lastly, estimates for smaller and medium portions were found to be more accurate than for bigger portions.

Hernandez et al. have done research on computer displayed Portion Size Measurement Aids (PSMAs) in a higher literacy population (with Bachelors and higher degrees) [17]. This study is similar to ours in that it also tests perception rather than conceptualization and memory retrieval of portion sizes. Participants were asked to identify portions of different food they consumed in a study by selecting images on a computer screen and on a poster. While the portion size images on the posters were life-sized, those on the computer screen were not. The study showed that the computer-based photographs of food and containers are as effective as life-size photographs for portion size estimation. However, the study raised some important questions, such as within what error limits are portion sizes estimates acceptable for different food types, and what mental processes are involved in accurate estimations.

Subar et al. evaluated various types of images representing portion-sizes for estimation accuracy and preferences in a low-literacy population [18]. The effect of the size and number of portion size images on the accuracy of estimation was also studied. The results indicate that no one type of image was most accurate. Sequential versus simultaneous presentation of photographs/images also had no measureable effect. Lastly, size and number of images per screen did not affect the accuracy of estimation either. There was a preference, however for presenting portion images simultaneously rather than sequentially. Moreover, participants preferred larger images. Some of the results of this research (e.g, the number and presentation of images) support the design of our interfaces.

Although relevant research has been done, proliferation of nutritional applications and prevalence of chronic diseases have created an urgent need for the assimilation of current findings. Moreover, the current findings seem to be limited to the samples that were studied during research. Therefore, a study that can provide guidelines and consensus on the design of a mobile interface for the estimation of portion sizes of different food groups is critically required.

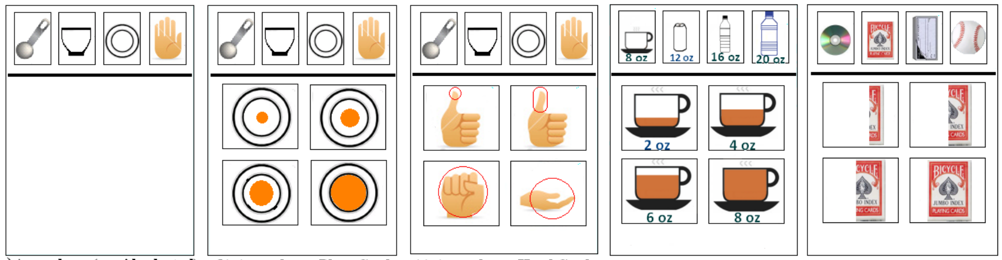
III. Study: Portion Size Interfaces

The aim of our portion size study was to determine whether our designed interfaces can be used by a low-literacy population to accurately estimate portion sizes of different kinds of foods. The following questions were investigated:

- Can our target users make accurate estimates of real food samples using smaller images of containers and objects?
- Does our selection of portion size estimation aids represent and correlate with the portion size estimation strategies of our target users?
- Which picture cards or card features are preferred and helpful for portion size estimation and why?

A. Methods

We obtained approval for this study from the Institutional Review Board (IRB) at Indiana University. The study was conducted in a dialysis unit during the first two hours of dialysis to accommodate participants' comfort and schedules. We were not allowed to use video or audio recording as per the dialysis unit's rules. The participants voluntarily participated and were compensated with a $10 gift card. The first part of the study consisted of task-based interactions with the



(a) Amorphous (no aid selected) (b) Amorphous: Plate Card (c) Amorphous: Hand Card (d) Liquids: Coffee Cup Card (e) Portions: Deck of Cards

Figure 1. Portion Size Interfaces for different food groups

interfaces followed by a structured interview with participants.

B. Prototypes: Picture Cards

The design of the picture cards for this study was based on the findings from our background research on the topic and meetings with dietitians.

1) Food Categories and Estimation Aids. We had found that dietitians have devised four categories of foods based on their physical qualities. Portion size estimation strategies happen to be similar for all the foods within each category. For example, a lump of mashed potatoes or mashed cauliflower can be held in hands to determine its portion but the same cannot be done for water or tea. These categories are: *liquids* (for beverages), *amorphous* (for food that do not have any fixed shape and can be served as mounds), *solids* (for foods with fixed shapes) and *snacks* (for foods that are typically eaten a little at a time and not present on a plate at once, such as pretzels). We selected objects and containers (we will refer to them as portion size estimation aids) that could help participants estimate portion sizes of different foods within each of these categories.

The estimation aids that were selected for amorphous foods consisted of serving containers and hand gestures. Hand gestures are often used as visual aids in nutrition education programs to estimate portion sizes [24]. We will refer to the group of estimation aids for amorphous foods as *Amorphous* (Figure 1a-1c). They include: (a) a spoon, (b) a bowl, (c) a plate and (d) a hand. The group of estimation aids for liquids will be called *Liquids* (Figure 1d), consisting of containers of different volumes in which beverages are most frequently found in the grocery: (a) a coffee cup, (b) a can, (c) a 16 oz bottle and (d) a 20 oz bottle.

It was much harder to determine a set of portion size estimation aids for solid foods due to their various sizes and shapes. For example, a piece of meat is not always the same size and shape as a piece of pizza, and a portion of cheese cannot easily be measured in the same way as an apple. Therefore, based on the kind of solid a portion size estimation aid could help measure, we divided portion size estimation aids into three groups. The first group will be named *Objects* (Figure 1e). It consists of four different objects that are used in nutrition education programs to help people visualize their portion sizes. They are: (a) a CD disk, (b) a deck of cards, (c) a check book and (d) a softball. The second group called *Shapes* (Figure 2a) is similar to *Objects*, but has several aids of different sizes categorized according to their shapes: (a) a flat circle, (b) a square, (c) a round sphere and (d) a triangle. We will refer to the third group as *Measurements* (Figure 2b). This group only has one aid – a mobile device for measuring each dimension of a solid food item (e.g., ¼, ½, ¾ or a full length of the device).

The estimation aids for snacks are classified into a group called *Amounts* (Figure 2c-2e) which consists of: three units of weight – (a) ounces, (b) grams and (c) pounds to allow entry of known amounts; and (d) numbers to allow entry of items in numbers (e.g., the number of pretzels).

2) Prototypes. We designed low fidelity prototypes in the form of picture cards. A set consisting of 4-5 picture cards was designed for each group of estimation aids – *Amorphous*, *Liquids*, *Shapes*, *Objects*, *Measurements* and *Amounts*. We will refer to each set of interface by the name of estimation aid group it represents. Table 1 summarizes which interfaces were designed for the different food categories.

Each picture card in a set had images of all the estimation aids of the group at the top, and four portion sizes associated with each aid at the bottom. We refer to each card in a set by the estimation aid it describes. Estimating a portion size with these picture cards was a two-step process – (a) selection of an estimation aid at the top followed by the (b) selection of a portion associated with the chosen aid from the bottom section. The following sets of picture cards had the same design philosophy and layout: (a) *Liquids* (Figure 1d shows the *Coffee Cup* card, which the user would see had she picked the coffee cup/8 oz cup from the top); (b) *Amorphous* (Figure 1a-1c show some of the cards from this set); (c) *Shapes* (Figure 1e shows the *Deck of Cards* card from this set); (d) *Objects* (Figure 2a is the *Sphere* card from this set).

The picture cards for Measurements were designed to be used with a mobile device. The idea was to have the user measure each edge of a solid food by putting it along an edge of the mobile device. These picture cards had three images of a 3-D block at the top. Each image highlighted a different edge of the block as shown in Figure 2b. In the beginning, the user was shown a card with nothing in the bottom section. If she wanted to record the length of an edge, she had to select the top image with the corresponding edge highlighted. She was then presented with four possible length images from which she could select one. After this, she saw the same card but with the selected image added to the *portion bar* – part of the card under portion size images of estimation aids. The purpose of *portion bar* was to show all the images a user had chosen to represent a certain length or portion. The user also indicated to the researcher that she recorded all three dimensions and was done by pointing at the smiley face on the end of the *portion bar*.

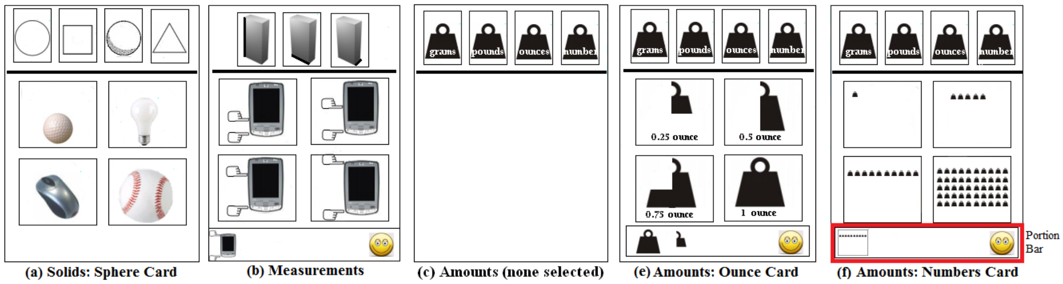


Figure 2. Interfaces for Solids and Snacks

The picture cards for *Amounts* are shown in Figure 2c-2e. The card in Figure 2c was shown before the user had chosen any estimation aid. The card in Figure 2d is the Ounces card, which was shown when the user pointed on the image labeled ounces at the top. Figure 2d is the Numbers card which the user saw if she picked the numbers image at the top. This set of cards also had a *portion bar* at the bottom where a participant could build up their actual intake portion. When the user selected an image from the bottom, the user was presented with a similar card, but with the selected image added to the *portion bar*. The user could then either select another image to build the portion or point on the smiley face on the bottom right of portion bar to indicate that she was done.

TABLE 1. INTERFACES FOR THE FOOD CATEGORIES

Food Category	Interfaces
Amorphous	*Amorphous*
Liquids	*Liquids*
Solids	*Shapes* *Portions* *Measurements*
Snacks	*Amounts*

C. Paticipants

Ten chronic kidney disease stage 5 (CKD 5) patients were recruited from an urban dialysis facility. We worked with this population because: (a) individuals with CKD 5 are at risk for a broad array of complications if they do not adhere to a stringent dietary and fluid regimen, and (b) our target population included people from a low literacy background [26].

We administered the Rapid Estimate of Adult Literacy in Medicine (REALM) test [19] in the beginning of the study to measure the reading levels of our participants. Three participants read at or below the 3rd grade, another three at 7th-8th grade and the remaining four at or above the 9th grade. We intentionally captured a varying literacy population, with over half of the participants under a 9th grade reading level, which is considered low literacy according to REALM. This segment included participants with 6 to 14 years of education. While some of our low-literacy participants had 12 to 14 years of education, the National Right to Read Foundation found that 20% of high school graduates can be classified as functionally illiterate at the time they graduate [25], explaining these cases. The remaining four participants had between 11 to 13 years of education, with the exception of one who had 16 years. Based on these facts, we conclude that our participants have varying literacy and the majority had low literacy skills.

All participants identified themselves as Black/African Americans. Four were women and six men. The average age was 58 years old (S.D. = 16.3 years). Four participants used computers at most once a month to play games. The rest had never used one or did not feel comfortable using one.

Our participants reported that they watch their portions while eating. Three of them were using measuring cups or some other visual aids to estimate their portion sizes. The rest reported that they stay conscious of their intake by either not cooking too much or by eyeballing the amounts they put on their plates. One participant also reported that he tried to stay away from unhealthy foods such as potatoes because of their high potassium content. None of the participants reported that they tracked or calculated their daily intake.

D. Experimental Tasks and Study Procedures

We first obtained participants' informed consent, and explained to them the purpose and procedure of the experiment. We did not show them the interface cards prior to the experiment. During the experiment, food samples were shown in the order and amount they are listed in Table 2, one at a time. We did not vary the order in which the food was shown from one participant to the next so that no participant had an advantage over the other. The task was to estimate each food sample with the help of the picture card interfaces designed for the category to which the food belonged. Participants were asked to only use the relevant set of picture cards to estimate the food samples such as *Liquids* for water and coffee and *Amorphous* for mashed potatoes and spaghetti. Both *Portions* and *Shapes* were to be used to estimate apple and pizza. Participants were instructed to pick the closest estimate if none of the images exactly matched the presented amount. They were allowed to take as much time as they needed to finish a task. Help was provided if they were confused or stuck. Correct answers were not given at any time during the study. At the end, we asked the participants to comment on all the interfaces and give suggestions for improvement. They were also asked to specify which interfaces they preferred and why.

While the participants interacted with the interfaces to complete the study tasks, the researcher conducting the study "played computer". For example, if the user was estimating the serving of mashed potatoes, the researcher would first show her the interface in Figure 1a (the picture card with *Amorphous* aids). If the user put her finger on the plate icon then the researcher would show her the *Plate* card in Figure 1b. If the user found a satisfying representation of the portion size on this interface, she would simply point at it and the researcher would record it. If the user was unsatisfied with the card, she could put her finger on another estimation aid along the top of the screen, such as the hand icon, in which case she would be shown the *Hand* card in Figure 1c. Now the user could choose a portion size from the bottom section or try another aid. The researcher would record the user's choice.

TABLE 2. FOOD ITEMS USED IN THE EXPERIMENT

Food Category	Item	Container	Portion
Fluid	Water	16 oz bottle	¼ bottle = 4 oz
Fluid	Coffee	8 oz cup	½ cup = 4 oz
Amorphous	Mashed potatoes	8 oz cup	¼ cup = 2 oz
Amorphous	Spaghetti	Dinner plate	¼ plate
Solid	Apple	-	½ apple
Solid	Pizza	-	½ slice
Solid	Steak	-	A small cube
Snack	Goldfish crackers	Bag	½ bag = 0.85 oz

E. Results

Over all, participants both over- and under-estimated the food portion sizes used in the study. Participants easily interpreted *Amorphous* and *Liquids* interfaces. For solids, *Portions* was preferred and it also had more correct estimates than *Shapes*. The *Measurements* interface was thought to be too complicated and no one could use it successfully. For snacks, participants preferred the *Hand* card of *Amorphous* instead of the *Amounts* interface. They liked the *portion bar* on *Amounts* and suggested we include it on other interfaces too.

1) Estimation Accuracy. Generally speaking, the ability to estimate accurately was higher when the interface did not require participants to do a complex abstract reasoning.

Liquids. Of the two liquids we tested, all ten participants were able to correctly estimate the amount of coffee with *Liquids*, whereas seven participants correctly estimated water (Table 3). All of the participants who incorrectly identified the portion of water overestimated, for example ¾ of the bottle on the *16 oz* card instead of ¼ of the bottle. Some participants were confused about choosing between the 16 oz and the 20 oz containers. When this happened, the researcher asked the participants to look at the numbers under the images of the containers. With some help they were able to decide which container to choose.

TABLE 3. CORRECT ESTIMATES FOR LIQUIDS AND AMORPHOUS FOODS

Item	Correct Estimates
Water	7
Coffee	10
Mashed potatoes	8
Spaghetti	8

Participants tried to find a container on the picture card that looked like the original one. Only one participant did not match the shape of the actual containers to the one on the picture card. This participant had selected half of the coffee cup (equivalent to 4 oz) to estimate the 4 oz of water presented in a 16 oz bottle during the study. Moreover, all participants picked the *Coffee Cup* card to estimate the amount of coffee.

a) Amorphous. With the *Amorphous* interface, eight participants correctly estimated the portion size of mashed potatoes and eight of spaghetti (Table 3). One participant who overestimated the portion size of mashed potatoes said that he would normally *eat the entire bowl* of mashed potatoes.

Although participants were shown ½ plate of spaghetti, we asked them to estimate only half of the shown amount to see how good people are at visual estimations (people usually do not finish everything on their plates). Most participants correctly estimated the amount by selecting ¼ of the plate on the *Plate* card of the *Amorphous* set. One participant incorrectly selected ½ of the plate. Later on, he explained that he thought that the full plate on the *Plate* card represented the actual amount of spaghetti used in the study. Therefore, to guess half of that amount he decided to choose ½ of the plate on the card. The other participant, who had misestimated, selected ¾ of the plate icon.

b) Solids: Measurements. No participant was successful in using the mobile device to measure all three dimensions of the steak. Participants could not decide which image to select from the bottom section of *Measurements* to record the length of steak's dimension. They also kept forgetting which dimension of the real steak they had already measured and which one to measure next. Initially, there was also some confusion in interpreting the interface. Some participants thought that the task is to visual compare the entire steak with the entire mobile device. Some participants also thought that having just four different lengths is not enough.

c) Solids: Shapes. In Table 4, we have listed the objects which participants chose from the *Shapes* interface along with the number of participants who chose each one. The bolded entries signify correct estimates. An estimate was considered to be correct if the food portion selected was close to the volume of the object. Based on this criteria, there were two correct estimates for apple and five correct estimates for pizza. None of non-similar shaped objects was a correct estimate.

TABLE 4. SELECTIONS FROM *SHAPES* INTERFACE

Item	Similar shape objects selected	Dissimilar shape objects selected
½ apple	1=disc 1=bulb 1=**hockey puck** 1=**mouse** 2=golf ball	1=dental floss 1=martini glass 2=Swiss army knife
½ pizza slice	4=**napkin** 2=dental floss 1=poker chip 1=**Swiss army knife** (in the shape of a triangle)	1=baseball 1=martini glass

Overall, participants chose a wide variety of objects showing that each participant perceived food portions differently. We observed that with the *Shapes* interface participants attempted a complex cognitive assessment of the objects on the picture cards. They tried to imagine with their hands how big an object on the picture card would be and then map those imaginary dimensions onto the real food samples. Moreover, most of the participants did not remember the actual sizes of the objects. For example, one chose a golf ball for a relatively bigger sized apple used in the study.

d) Solids: Portions. The choices that participants made with the *Portions* interface are shown in Table 5. Four participants correctly estimated the portion size of the apple and five correctly estimated portion size of the pizza. Some of the remaining estimates were close, but not accurate. The choices included portions of both similarly shaped and differently shapes estimation aids. This shows that this particular interface also encouraged participants to perform some abstract reasoning. Based on the number of correct choices that were made with interface, we can say that participants did better with *Portions* than with *Shapes.*

TABLE 5. SELECTIONS FROM *PORTIONS* INTERFACE

Item	Similar shape objects selected	Dissimilar shape objects selected
½ apple	4= **½ baseball** 1= ¼ baseball	2= ½ deck of cards 1= ¼ disc 2= ½ disc
½ pizza slice	3= **½ disc** 2= ¼ disc 1= ½ deck of cards 2= **¾ checkbook**	1= ½ baseball 1=baseball

e) Amounts. Although we wanted our participants to use the *Amounts* interface to estimate the portion size of goldfish crackers, not all participants used this interface to finish this task. Initially there was some confusion about the meaning of the images on this set of cards. For example, participants did not understand why we had chosen black weights to represent different units of measurement and why the weights were small on the *Numbers* card. Table 6 summarizes all the options participants used to estimate the portion size of snack.

Four participants used *Ounces* and/or *Grams* cards from the *Amounts* set for estimation. Two of them were at 7^{th}-8^{th} grade reading level and the other two were above 9^{th} grade. The estimates of the higher literacy group were incorrect. This shows that low literacy people might have developed some skills that help them estimate weights more accurately. Two participants used the *Numbers* card to estimate the portion size but they told us *that they do not count their foods and would prefer to report snack portions using hand gestures*. Both participants estimated the portion size correctly with the *Numbers* card.

The remaining four told us that *they would not estimate their portion intakes of snacks with any of the picture cards in Amounts*. They asked us if they could use any of the others. We gave them all other sets of cards to make a choice. All of them chose the *Hands* card of the *Amorphous* set to estimate the snack portion. Three of these participants correctly estimated. One of them informed us that *he would also feel comfortable using one of the solid objects to report his snack intake.* He told us that *normally he consumes a snack about the size of a dental floss.*

TABLE 6. SELECTIONS FOR ESTIMATING SNACKS PORTION SIZES

Estimation Options	Actual Choices
Weight	1=0.5oz 2=**0.75oz** 1=0.25g
Numbers	2=**10 items (4 times)**
Hand	3=**handful** 1=fist

2) Preferences. We received suggestions for including more estimation aids on *Amorphous* and *Amounts* interfaces. Among the interfaces designed for solids, the *Measurements* interface was not well received - both in terms of preference and performance. Although *Portions* was preferred by more participants, the overall performance was better with *Shapes* (also shown in Table 8).

a) Amorphous and Amounts. Two participants suggested that we should also include measuring cups on *Amorphous*. One participant said that *he liked a plate and a hand as estimation aids of amorphous foods*. Another said that *for him the hand simplified the task of estimating portion size of any other food he could think of.* Moreover, six participants also thought the best interface to estimate snacks was the *Hand* card of *Amorphous*. Most participants did not like the idea of counting pieces of snacks and using the *Numbers* card to report the total. One participant, however, said, "*It really depends. Some snacks need to be counted, some cannot be separated and hence must be measured by hand.*"

b) Solids: Portions, Shapes or Measurements. Table 7 summarizes the number of participants who preferred each interface and the number of participants who made at least one correct estimate with the preferred choice.

Four participants preferred *Portions* and four preferred both *Portions* and *Shapes.* Even those participants who did not get even one estimate correct preferred *Portions*. The most popular reason for preferring the *Portions* interface was that *it was better at representing the amount of food people were consuming* and *that it was easier to understand*. One participant had more correct estimates with the *Shapes* interface but preferred *Portions.*

Participants, who liked both interfaces, made at least one correct estimate with one. They told us that *some food portion sizes were best represented via object portions, while others via objects of different shapes.* One participant also suggested that *we combine Portions and Shapes into a single interface*.

While we did not hear any negative comments about the *Portions* interface, participants had both positive and negative things to say about the *Shapes* interface. All of them had a different reason for preferring this interface. One of them said, "*I prefer shapes because they are easier to memorize as far as portion sizes are concerned*." This participant, however, did not always estimate portion sizes correctly using *Shapes* – he correctly selected a napkin for ½ a slice of pizza but incorrectly selected a CD for ½ of an apple. Another participant said, "*I like shapes because it shows a variety of objects.*" Participants who did not like *Shapes* complained that this interface does not represent the real portion sizes they are consuming. One said, "*This option needs to include portion sizes people normally consume. For candy I can pick dice because it represents the size I ate but I cannot always find something to represent my intake*." One more participant said, "*Estimation aids on the Shapes were not always representative of the food shown*." Another commented that *shapes make it hard to picture foods*.

TABLE 7. PREFERENCES AND PERFORMANCE

Interface	Preferred	Performed Correctly
Shapes	2	2
Portions	4	2
Measurements	0	0
Shapes and *Portions*	4	1

While no one preferred the *Measurements* interface over other solid interfaces, one participant did like it, although he was not successful in using it. He thought that *it was a good idea to use a mobile device as an estimation aid*. He was, however, not successful in using it. Two participants said, "*This method is too complicated.*" Another remarked, "*Some foods might not be good to measure against the device. For example, an apple has a curvature which cannot be measured with a device.*" Another said, "*Images [of the device] are too small to help with estimation.*" Overall, participants found the *Measurements* interface to be rather unintuitive and inadequate for portion size estimation.

c) Portion Building Concept. The *Measurements* and *Amounts* interfaces had a *portion bar* for portion building. Participants who used the *Numbers* card from the *Amounts* interface built the portion of goldfish crackers by selecting the ten items image multiple times. Three participants said that the portion building option should be available on other interfaces as well. One participant said, "*I would have built up the portion of mashed potatoes using the spoon. I would have taken two and a quarter spoons.*" Another told us that these interfaces would improve with the concept of portion building for example, "*If I can select a baseball two times to show that I ate two apples.*"

3) High Literacy versus Low Literacy Group. Table 8 summarizes the number of correct and incorrect estimates that participants made according to their literacy levels. Participants at or above 9th grade reading level were considered to be high literacy. Apart from the *Portions* interface, the performance with all the interfaces was similar between the two groups. The higher literacy group performed better with *Portions* as compared to the lower literacy group. The lower literacy group, on the other hand, performed better with *Shapes* and were also more creative in estimating portions of snacks.

TABLE 8. CORRECT AND INCORRECT ESTIMATES OF HIGH LITERACY GROUP (HLG) VERSUS LOW LITERACY GROUP (LLG)

Items		HLG		LLG	
		Correct	*Incorrect*	*Correct*	*Incorrect*
Water		3	1	4	2
Coffee		4	0	6	0
Mashed Potatoes		3	1	5	1
Spaghetti		3	1	5	1
Apple	***Shapes***	0	4	4	2
	Portions	3	1	1	5
Pizza	***Shapes***	3	1	3	3
	Portions	3	1	2	4
Steak		0	4	0	6
Goldfish Crackers		2	2	5	1

IV. DISCUSSION

The motivation of this study was to devise design guidelines for an interface that will empower a low literacy population to record its portion sizes without doing any calculations or using numbers. As a first step towards designing an effective and usable interface, we designed low fidelity interfaces with images of various objects and containers to act as aids in estimating portion sizes. Here we present some recommendations based on our findings.

A. Design Recommendations

Our study showed that a low literacy population could choose an appropriate estimation aid to estimate portions of liquids and amorphous foods. There was a tendency to select an estimation aid that resembled the shape of the actual container. Based on this finding, *we encourage designers to include frequently used containers when designing portion interfaces.* Moreover, some participants also asked us *to include measuring cups as an estimation aid for amorphous foods.*

Most participants thought that hand gestures were ideal for reporting portions of amorphous foods and snacks. Some dietitians even recommend estimating solid foods with hands [24]. *A hand, therefore, is a very important aid to include in the portion size estimation interfaces*.

We noticed that the volume amounts under the fluid containers helped participants choose between 16 oz and 20 oz containers. Parikh et al. had also found that while a rural semiliterate population in India had difficulty interacting with a textual interface, they were able to gather enough cues for comprehending the interface through its numeric data [21]. Therefore, we recommend that *designers should consider including some numerical data (related to volumes and amounts) with the images of portion size estimation aids.*

While the dietitians had informed us that some people consume small portions at a time, one participant told us that the amount of mashed potatoes he ate on a normal basis was much more than what we showed. Several other participants also complained about the small amounts. Another participant chose the smallest amount from the interface most of the time saying that she *eats very little.* Moreover, several liked the *portion bar* because they saw that it helped them build up to their portion sizes. Therefore*, designers should understand people's intake behavior (how they are eating, i.e., small or big portions at a time), and have either their portion sizes or a way of building up their portion sizes incorporated in the interface.*

Both *Portions* and *Shapes* interfaces required participants to do some abstract reasoning because the images of everyday objects were not in their original size and dimensionality. Jae and Delvecchio report that abstract reasoning is often impaired in low literacy population because it develops as a result of deciphering meaning from reading [7]. Therefore, *if portion size interface were to include objects as estimation aids, they should be readily accessible in real life such as the mobile device itself so that abstract reasoning is minimized*.

B. Limitations and Future Work

We acknowledge that a sample size of 6-10 people may be considered too small, however studies have shown that 80% of usability problems are uncovered by only 4-5 users [27]. We might not have received a fair assessment of the interfaces because we tested them in a particular order. The order might have biased the experiment in favor of interfaces at the end or the beginning.

Ultimately, we want to incorporate this interface into a diet monitoring application and validate the recommendations through long term, large scale usability studies. We realize that more work needs to be done to create a universal interface to facilitate portion size estimation. One possible solution is to have more than four food categories with a more representative set of portion size estimation aids for each category. To achieve this goal, we want to shadow this population and observe the kind of containers or other standard instruments they use in their kitchens to incorporate into the interface. Our current interfaces only give four options per aid. We want to investigate whether increasing the options to six or eight will better accommodate the range of portion sizes consumed by our population, and improve the accuracy of estimation.

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