Evidence-Based Development of a Mobile Telephone Food Record

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ABSTRACT
Mobile telephones with an integrated camera can provide a unique mechanism for collecting dietary information that reduces burden on record-keepers. Objectives for this study were to test whether participant’s proficiency with the mobile telephone food record improved after training and repeated use and to measure changes in perceptions regarding use of the mobile telephone food record after training and repeated use. Seventy-eight adolescents (26 males, 52 females) ages 11 to 18 years were recruited to use the mobile telephone food record for one or two meals. Proficiency with the mobile telephone food record was defined as capturing a useful image for image analysis and self-reported ease of use. Positive changes in perceptions regarding use of the mobile telephone food record were assumed to equate to potentially improved proficiency with the mobile telephone food record. Participants received instruction for using the mobile telephone food record prior to their first meal, and captured an image of their meals before and after eating. Following the first meal, participants took part in an interactive session where they received additional training on capturing images in various snacking situations and responded to questions about user preferences. Changes in the participants’ abilities to capture useful images and perceptions about the usability of the mobile telephone food record were examined using McNemar, Wilcoxon rank-sum test, and paired t test. After using the mobile telephone food record, the majority of participants (79%) agreed that the software was easy to use. Eleven percent of participants agreed taking images before snacking would be easy. After additional training, the percent increased significantly to 32% (P<0.0001). For taking images after snacking, there was also improvement (21% before training and 43% after; P<0.0001). Adolescents readily adopt new technologies; however, the mobile telephone food record design needs to accommodate the lifestyles of its users to ensure useful images and continuous use. Further, these results suggest that additional training in using a new technology may improve the accuracy among users.

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Dietary intake provides some of the most valuable insights for mounting intervention programs for the prevention of chronic diseases. However, accurate assessment of diet is problematic, especially in adolescents (1). Emerging technology in mobile telephones with higher resolution pictures, improved memory capacity, and faster processors allow these devices to process information not previously possible. Mobile telephones are widely used throughout the world and can provide a unique mechanism for collecting dietary information that reduces burden on record keepers. A dietary assessment application on a mobile telephone would be of value to registered dietitians (RDs) and researchers.

Previous results among adolescents showed that dietary assessment methods using technology, eg, a personal digital assistant with or without a camera or a disposable camera, were preferred over the traditional paper food record (2). This suggests that for adolescents, dietary methods that incorporate technology may improve cooperation and accuracy. In addition, adolescents have expressed difficulty describing and estimating portions of foods and beverages consumed (2). Even with the use of portion-size estimation aids, children’s estimates are considered a source of error in quantifying food and energy intake (3-5). Development of a mobile telephone application for dietary assessment that fits into the lifestyle of young people may address many of the barriers identified here (6,7).

Most technology development emphasizes the requirements of the system as determined by the engineer or software programmer rather than the interaction of the user with the system (8,9). The study described here is part of the evidence-based development of a mobile telephone food record for adolescents (2,7,10). Evidence-
Evidence-based development of technology is a novel idea intended to focus on the effects of the system on its users and their lifestyles (9,11). Using this process will allow the design of the mobile telephone food record from the perspective of the user or the client rather than the perspective of the engineer or RD.

A form of evidence-based development is interaction design, which is the discipline of defining the behavior of products with which a user can interact. This process of developing interactive products supports the way people communicate and interact in their everyday and working lives. The goals of interaction design are to develop usable products, in this case the mobile telephone food record, which are easy to learn, effective to use, and provide an enjoyable experience. This is accomplished by involving users in the design process and receiving feedback about the product. Therefore, it is an iterative cycle of usability testing in which the user feedback is applied to the next version of the mobile telephone food record and tested again.

The objectives of this study informed the next development phase of the mobile telephone food record. The two objectives were to test whether participants’ proficiency with the mobile telephone food record improved after training and repeated use and to measure changes in perceptions regarding use of the mobile telephone food record after training and repeated use. Proficiency with the mobile telephone food record was defined as capturing a useful image for image analysis and self-reported ease of use. In addition, positive changes in perceptions regarding use of the mobile telephone food record were assumed to equate to potentially improved proficiency with the mobile telephone food record.

METHODS

System Design

The client–server configuration for the mobile telephone food record is in Figure 1. In this system, a mobile telephone with an integrated camera can be used to capture
images of food before and after eating and sent to the server (Figure 1, #1). A digital image is different from a photograph in that useful information, called metadata, is captured that is not visible, such as the time stamp and digital codes. Image analysis uses metadata to automatically identify characteristic features in food, such as color, texture, and intensity, which are then used to identify a food. Methods for automatic identification of food using image analysis (Figure 1, #2) have been described previously (7,12).

An object of known dimensions and markings, referred to as a fiducial marker, must be included in the image as a size reference. The inclusion of a fiducial marker in the image (eg, the checkerboard square in Figures 2A and 2B) aids in the reconstruction of a three-dimensional environment that allows for estimation of the volume of the foods and beverages (Figure 1, #3). The image is then sent back to the user (Figure 1, #4) for the user to confirm that the foods are identified correctly (Figure 1, #5). Together the information from image analysis and volume estimation can be linked to a nutrient database (Figure 1, #6) to estimate energy and nutrients consumed (10). In the final step, the nutrient analysis can be sent to researchers or RDs.

**Study Design and Recruitment**

Data were collected from two samples of participants. For Sample 1 and Sample 2, the study methods were approved by the Purdue University Institutional Review Board, and informed assent and consent were obtained from the participants and their parents, respectively.
Sample 1. The first sample was drawn from summer camps for adolescents, ages 11 to 18 years, conducted by a variety of university departments and taking place on the university campus. Participants from these camps participated in one lunch (n=63) and 55 (87%, 55/63) returned for breakfast the next morning. Following lunch (ie, their first meal after using the mobile telephone food record) all of the participants took part in an interactive session.

Sample 2. The second sample was a convenience sample drawn from the local community (n=15). Recruitment was limited to those individuals between 11 to 18 years. Participants received all meals and snacks for a 24-hour period while being monitored under controlled conditions. These participants took part in the interactive session after breakfast (ie, their first meal after using the mobile telephone food record); and data from their first and second meals are included in this analysis.

Eating Occasions
A systematic method was used to design the menus using the most common foods reported during two 24-hour recalls administered among 162 adolescents between 10 to 18 years (13,14), as well as foods from local school lunch menus. For each meal, foods and beverages were weighed, plated, and arranged using a predetermined place setting (see Figure 2A). Three menus for breakfasts and three menus for lunches were cycled between the sessions. All participants received instruction for using the mobile telephone food record prior to their first meal. In order to obtain an image useful for image analysis, participants were asked to include two items in each image; ie, all food and beverages and the fiducial marker. Participants ate to satiation and they were served seconds, if requested. Procedures for capturing images were then repeated for any additional portions.

HTC p4351 mobile telephones (HTC Corp, Taoyuan, Taiwan) running Windows Mobile 6.0 Professional (2007; Microsoft Corp, Redmond, WA) were used. The software described previously (7,10) guided the user to select the meal occasion and capture an image of foods and beverages (see Figure 2B). After capturing the image, the user was prompted to review the image and then given a choice to retake the image or save the image. Once the user was satisfied with the image, the mobile telephone prompted the user to eat before proceeding to the next screen. At the next screen, the user was prompted to take an image of the place setting regardless of whether food and beverages remained. The final screen showed the before and after images prior to exiting the program. The participants were assisted during the meal by trained dietetics students and for Sample 1 only, staff recorded the number of images taken by each participant, as well as position (sitting/standing) while taking an image.

Interactive Session
Eleven forced-choice questions with appropriate visuals regarding the interaction design of the mobile telephone food record were shown using PowerPoint (Office 2007, PowerPoint 2007, Microsoft Corp). Response choices ranged from “strongly agree” to “strongly disagree” and responses were collected with the eInstruction Classroom Performance System (eInstruction, Cincinnati, OH). Three open-ended questions were presented:

1. If the program, cannot identify a food, how would you want the program to tell you that?
2. If you need to then label the food with the correct name, how would you want to do that?
3. Would you want to narrate into the telephone out loud the names of the food?

The oral responses from the participants were recorded by staff. The participants received additional training through activities where they practiced capturing images in potentially problematic snacking scenarios; eg, on the school bus, in the movie theater.

Data Analysis
For analysis, participants were separated into early and late adolescent age groups to address cognitive development: 11 to 14 years old (n=44) and 15 to 18 years old (n=33). Descriptive analysis included frequencies and percents. Differences in responses by categorical characteristics (ie, age group and sex) were examined using $\chi^2$, and analysis of variance for quantitative variables. Differences within participants were examined using McNemar (categorical variables), Wilcoxon rank-sum test (ordinal variables) or paired $t$ test (quantitative variables). The qualitative responses to the open-ended questions were examined using content analysis (15).

RESULTS AND DISCUSSION
A total of 78 participants (26 males, 52 females) ages 11 to 18 years used the mobile telephone food record for a first meal and 70 of those also used the mobile telephone food record again for a second meal. Characteristics of the samples are in Table 1. The participants were either in middle school or high school, and the mean age was 14.2

### Table 1. Characteristics of adolescent volunteers testing the usability of the mobile telephone food record (n=78)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>26 (33)</td>
</tr>
<tr>
<td>Female</td>
<td>52 (67)</td>
</tr>
<tr>
<td>Age (y)</td>
<td></td>
</tr>
<tr>
<td>11-14</td>
<td>45 (58)</td>
</tr>
<tr>
<td>15-18</td>
<td>33 (42)</td>
</tr>
<tr>
<td>Grade in school</td>
<td></td>
</tr>
<tr>
<td>Middle school (6th-8th grade)</td>
<td>30 (50)</td>
</tr>
<tr>
<td>High school (9th-12th grade)</td>
<td>30 (50)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>7 (9)</td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>55 (70)</td>
</tr>
<tr>
<td>Black</td>
<td>10 (13)</td>
</tr>
<tr>
<td>Multiple</td>
<td>5 (6)</td>
</tr>
</tbody>
</table>

*a Missing values because of nonresponse.*

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years. The participants were of diverse ethnic back-

grounds.

With regard to being able to acquire a useful image, the
majority of the participants saved images that included
all of the foods and beverages in both the before and after
images for the first meal (80%, 56/70) and the second
meal (84%, 59/70). A smaller proportion included the
entire fiducial marker in both the before and after images
for the first meal (71%, 50/70) and slightly more for the
second meal (77%, 54/70). After repeated use of the mo-

tile telephone food record, there was no significant
change in the number of participants who included the
entire fiducial marker in their images. There were nu-
mber of individuals that consumed all foods and bev-
erages, rather than capturing an image of completely
empty plates and glasses.

Repeated use allowed participants to familiarize them-
selves with the mobile telephone food record. Just under
half of Sample 1 took more than one image before the first
meal (42%, 21/50); however, this declined significantly
(P=0.033) to 22% (11/50) after the second meal. In all
cases, the likelihood of taking one image was positively
associated with standing rather than sitting to take an
image. A small fraction of participants changed the ori-


tation of the camera between the before and after
meals; ie, portrait vs landscape. This indicated the need
for a prompt to take images in landscape providing con-
istency for image analysis.

Responses to the questions regarding use of the mobile
telephone food record are shown in Table 2. A larger
proportion of the participants agreed it would be easy to
use a credit card—sized fiducial marker as opposed to
using a USB flash drive—sized fiducial marker. Although
a fiducial marker sized like a USB flash drive would be
smaller, the credit card—sized fiducial marker might be
more convenient because it would fit in a wallet. Most
adolescents have standard-sized school identification
cards, thus a credit card—sized fiducial marker may be
easier to incorporate into their current lifestyles.

The majority of participants agreed that the software
was easy to use. Just over one third of the participants
agreed that it would be easy to remember to take images
before meals and a slightly higher proportion agreed that
it would be easy to remember to take images after meals
(see Table 2). Despite the ease of using the software, the
perception of being less likely to remember to take an
image before eating vs after eating is consistent with
individuals being hungry and eager to eat. Responses
before additional training reflected the lowest proportion
of individuals indicating that taking an image before a
snack would be easy to remember (see Table 2). Following
additional training in which the participants practiced
taking snack images in awkward situations, significantly
more participants agreed that taking images before
snacking (t=3.89, degrees of freedom=69, P<0.0001) and after
snacking (t=3.78, degrees of freedom=67, P<0.0001) would be
easy.

Adolescents are assumed to have a high level of tech-

Table 2. Responses from adolescents (11-18 years) after using a mobile telephone food record (n=78)

<table>
<thead>
<tr>
<th>Statements, as presented</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Mean response</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think it would be easy to carry and use:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A credit card—sized fiducial marker</td>
<td>55 (78)</td>
<td>10 (14)</td>
<td>6 (9)</td>
<td>2.0</td>
</tr>
<tr>
<td>A USB flash drive—sized fiducial marker</td>
<td>30 (42)</td>
<td>19 (27)</td>
<td>22 (31)</td>
<td>2.8</td>
</tr>
<tr>
<td>The software was easy to use</td>
<td>55 (79)</td>
<td>9 (13)</td>
<td>6 (9)</td>
<td>1.9</td>
</tr>
</tbody>
</table>

*Missing values because of nonresponse. Percents do not always equal 100 due to rounding.

*Responses were coded as strongly agree=1, agree=2, neither agree nor disagree=3, disagree=4, strongly disagree=5.

*Paired sample analysis was performed comparing before snacks responses before and after training, P<0.0001.

*Paired sample analysis was performed comparing after snacks responses before and after training, P<0.0001.
participating in technology-themed camps. The results support that improved use of the mobile telephone food record can be achieved with additional training activities and interaction design changes. Specifically, alterations were initiated to ensure speedier capture of images of foods and beverages prior to eating.

Over half of the participants agreed that they preferred to stand while taking their images. Many participants found it difficult to capture all food items and the fiducial marker while sitting. These results in a controlled environment need to be confirmed in a variety of free-living situations. Adolescents may not readily stand to take images of their meals in more realistic situations.

Overall, there were no significant differences in the respondents’ perceptions of the mobile telephone food record and their proficiency with the mobile telephone food record by age group or sex. This suggests that the interaction design for the mobile telephone food record would be the same across the adolescent age span.

The open-ended questions addressed the interface issues of the automatic identification of the foods through image analysis (Figure 1, #2) and the subsequent confirmation with the user (Figure 1, #5). The participants stated their suggestions for notification to confirm the food and beverage items. Most preferred that a pop-up message appear on the screen if additional information was needed. Other ideas included the appearance of an “X” or an arrow on or by the food in question. Also, several suggested having a list appear or a space; each of which could be edited with the correct information. As a means of identifying a misidentified item, the majority preferred filling in a text box or selecting from a list of possible options. There was a predominance of negative responses for narrating the food identification into the mobile telephone. Participants noted social awkwardness (eg, “weird,” “creepy,” “they will think you are an idiot”) and underdevelopment of voice recognition software (eg, “voice recognition is too offy,” “Voice recognition doesn’t work. You say ‘call Bob,’ and it doesn’t even know who to call.”). These suggestions informed the next phase of the development of the mobile telephone food record.

CONCLUSIONS

Evidence-based development entails a shift from focusing on the product to focusing on the process and the interaction of the user with the product. Using this process will allow the design of the mobile telephone food record from the perspective of the user or the client rather than the perspective of the engineer or RD. Formative evaluation outcomes and user feedback are important components of evidence-based development used when designing applications (11). In the same way that evidence-based guidelines help RDs perform more effectively, we anticipate that developing a product that users can comfortably use throughout the day will lead to cooperation that will translate to an accurate and less burdensome record of dietary intake.

Results from this study suggest that additional training in using this new technology may improve user cooperation. Adolescents’ proficiency for capturing all foods, beverages, and the fiducial marker with the mobile telephone food record improved after the first use. Adolescents readily adopt new technologies; however, the design of the mobile telephone food record needs to accommodate the lifestyles of its users to ensure useful images and continuous use throughout the day or multiple days. Results from this study will be reflected in future versions of the mobile telephone food record, thus providing an accurate, inexpensive, easy-to-use method for dietary assessment in dietetic practice and research.

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