Usability of a smartphone food picture app for assisting 24-hour dietary recall: a pilot study

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BACKGROUND/OBJECTIVES: The Recaller app was developed to help individuals record their food intakes. This pilot study evaluated the usability of this new food picture application (app), which operates on a smartphone with an embedded camera and Internet capability.
SUBJECTS/METHODS: Adults aged 19 to 28 years (23 males and 22 females) were assigned to use the Recaller app on six designated, nonconsecutive days in order to capture an image of each meal and snack before and after eating. The images were automatically time-stamped and uploaded by the app to the Recaller website. A trained nutritionist administered a 24-hour dietary recall interview 1 day after food images were taken. Participants' opinions of the Recaller app and its usability were determined by a follow-up survey. As an evaluation indicator of usability, the number of images taken was analyzed and multivariate Poisson regression used to model the factors determining the number of images sent.
RESULTS: A total of 3,315 food images were uploaded throughout the study period. The median number of images taken per day was nine for males and 13 for females. The survey showed that the Recaller app was easy to use, and 50% of the participants would consider using the app daily. Predictors of a higher number of images were as follows: greater interval (hours) between the first and last food images sent, weekend, and female.
CONCLUSIONS: The results of this pilot study provide valuable information for understanding the usability of the Recaller smartphone food picture app as well as other similarly designed apps. This study provides a model for assisting nutrition educators in their collection of food intake information by using tools available on smartphones. This innovative approach has the potential to improve recall of foods eaten and monitoring of dietary intake in nutritional studies.

INTRODUCTION

Scientists have increasingly recognized the close relationship between daily nutrient intakes and certain chronic diseases such as cardiovascular disease [1,2], diabetes [3], and cancer [4,5]. The ability of researchers and health professionals to accurately measure dietary intakes is rapidly becoming indispensable for determining risks of nutrition-linked chronic diseases as well as a host of other important tasks, including assessment of nutritional status, monitoring of compliance with dietary regimes, and evaluation of outcome of dietary recommendations. The 24-hour dietary recall, food frequency questionnaire, and food record methods are widely used tools for collecting food intakes and dietary information. However, these and similar self-report methods contain inherent dietary reporting errors [6,7]. Specifically, most

people cannot account exactly for everything they eat, have limited knowledge of the nutrient contents of foods, and are unable to accurately estimate portion sizes of most foods [8]. Underreporting of food intakes [9,10], selective misreporting of specific macronutrients (e.g., fat and sugar) [11,12], and persistent limitation of self-reporting methods with certain subject characteristics such as body mass index (BMI) have all been reported [13,14]. Furthermore, maintaining food records is restricted by the unique reporting error of reactivity, i.e., individuals may change dietary behaviors as a result of food recording [15]. These and other shortcomings within the framework of conventional nutrition reporting techniques must be addressed by novel solutions, or else nutrition research and treatment will remain restricted and deficient [9].

Advances in technologies have led to promising innovations

for recording and analyzing dietary intake data. Computers, web-based programs [16-18], smartphones with image processing [19-21], and voice recognition [22,23] all have the potential to improve the accuracy, validity, and reliability of dietary assessment as well as may reduce the burden of recording and analyzing dietary intake data [24,25]. Studies evaluating the use of information and communication technologies for recording and assessing dietary intake have examined the usability and acceptability of these devices, reporting a preference among college students [26], adolescents [27], and adults with type 2 diabetes [23]. However, few studies have sought to determine factors that might improve the usability of such devices [28,29]. The appeal of using information and communication technologies for dietary assessment is influenced by the perspectives of participants. For example, some participants may enjoy operating new technologies, desire real-time feedback, or seek tools to aid in achieving personal goals. A better understanding of the elements surrounding the use of devices would aid researchers in designing protocols for dietary assessment that include appropriate use of technologies.

Recently, we developed a smartphone application (app), called the Recaller, designed to aid an individual in recording consumed foods [30]. The Recaller app is an innovative tool that integrates smartphones, digital imaging, time stamps, location information, and note-taking to create a digital food record that includes images. With the Recaller app, users take pictures of their foods and beverages at the time of each eating event (Fig. 1); these digital images are then submitted wirelessly to the Recaller website in real-time for later assessment of dietary intake. The images on the secure website are instantly organized for later data management (Fig. 2), which allows nutritionists and health professionals to review the images at

any time and location.

In this pilot study, the usability of the Recaller app was investigated with adults/college students. Usability was defined as self-reported ease of use of the smartphone app (taking and sending images of foods to the Recaller website). Since it is critical to have continuously taken food images throughout the day for recording food intake, the number of food images taken and forgotten per day was counted. In addition, we examined relationships between the number of food images taken, interval (hours) between the first and last food images taken on a given day, participant ratings of their likelihood of using the Recaller app if it were available in the future, and participant characteristics (e.g., age and gender). Our hypotheses included 1) college students would rate the Recaller app as easy to use, and 2) they would be likely to use it in the future.

SUBJECTS AND METHODS

Subjects

Healthy college students between the ages of 19 and 28 years with BMIs between 18 and 35 kg/m^2 were invited to participate. Participants were excluded if they reported any health conditions that could result in unusual dietary behaviors; such as if they were pregnant, lactating, planned to become pregnant, or were taking anti-depressant medications. After the participants provided written informed consent, demographic information was collected. Each participant's weight was measured using an electronic scale (Tanita BC-418; Illinois, USA), and height was assessed with a stadiometer (Tanita HR-200; Wall Mounted Height Rod, Illinois, USA) using standard procedures performed by a trained research assistant [31].

Study design

Study activities were completed over a 4-week period (Table 1). The Recaller app was installed on study-provided smartphones with camera and Internet capabilities (HTC My touch 3G Slide, HTC Crop, Taoyuan, Taiwan) running on the Android platform system (Google Inc, Mountain View, CA). Participants were instructed to use the Recaller app at each eating occasion on designated days, capturing images of all food and beverage items before and after consumption. All participants were instructed to follow a standard protocol: 1) hold the smartphone at a 45º angle for a clear image, 2) take a picture of the meal or snack before eating, and 3) take a picture of any leftover foods (uneaten and partially-eaten foods) or the empty plate or package after finishing eating. Any food or drink served but not consumed was also to be captured as an image. At the time of each meal or snack, participants were asked to include all foods and drinks in one image if they were eaten at the

Fig. 1. A participant is using Recaller app on a smartphone to take an image of meal, and then sending the image to Recaller website

Fig. 2. Recaller website, including digital imaging of before and after meal, time-stamp, location, and note taking by participant

Table 1. Study design

Procedure	Week 1	Week 2 - Week 4
Consent	X	
Anthropometry	X	X
Feedback survey		X
Taking food images, meeting with a nutritionist for 24-hour dietary recall interview	X XXX (Weekday)	XX (Weekend)

X = Participant met a nutritionist in the lab

same time (Fig. 1). When participants ate snacks between meals, they were asked to take a picture of all foods and drinks at the same time. These images were automatically sent and saved to the Recaller project servers (Fig. 2).

Participants captured food images using the Recaller app 6 days per week over a 3-week period (four weekdays and two weekend days). Participants kept the study smartphone for all 3 weeks and were asked to use the Recaller app on each of their assigned days, which were given when they met with a trained nutritionist for their 24-hour dietary recall interview. Participants met with a trained nutritionist the day after using the Recaller app and completed a 24-hour dietary recall via face-to-face interview at the research lab. All interviews occurred within 24 hours after participants used the Recaller app. Each participant was asked to recall and describe all foods and drinks consumed the previous day. After the 24-hour dietary recall interview, the participant and nutritionist reviewed food images that were uploaded by the participant and saved on the Recaller website as well as identified all foods and missed foods that were not reported during the 24-hour dietary recall interview. If any images of foods were found on the Recaller website that had not been recalled ("missed" foods), the nutritionist asked the participant a series of questions to determine why the participant failed to recall those foods. In addition to "missed foods", participants were asked whether or not there were any eaten foods that were not photographed. If participants realized that some food pictures were not taken ("forgot to take pictures"), they reported these foods. The numbers of missed foods and times participants forgot to take pictures during the 3-week study period reflect the practice or training effects of using the Recaller app.

Following the completion of food image-taking and six 24-hour dietary recall interviews, participants were asked to complete a written questionnaire on the usability of the Recaller app. The questions included: 1) ranking ease of use of the Recaller app as a number from 1 to 5, with 1 as extremely easy to use and 5 as extremely difficult to use, 2) average length of time spent recording foods each day using the Recaller app, and 3) whether or not the participant would be likely to use the Recaller app to record food intake in the future. The participants were also asked to provide written comments on the Recaller app experience and suggestions for improving use of the Recaller app in the future. The study was conducted according to the guidelines laid down by the Declaration of Helsinki, and all procedures involving human subjects were approved by the University's Human Subjects Protection Program Committee. Written informed consent was obtained from all participants.

Statistical analysis

Statistical analyses were performed using STATA 11.2 [32]. The difference in the total number of images taken between genders was compared by a Wilcoxon rank-sum test, since the distribution of images taken by genders was left skewed. Average duration (hours) used for the Recaller app was calculated as time of the last food image minus time of the first food image taken each day (For example, 9 pm: last food image taken minus 8 am: first food image taken = duration of 13 hours used for Recaller app.) Multivariate generalized Poisson regression was used to model the numbers of images taken against the predictors (age, gender, duration of use of Recaller app, defined as the time between the first and last episodes of food images being taken, weekend versus weekday, and likelihood to use Recaller app in the future). A generalized Poisson regression was used to adjust for potential correlations among the number of pictures taken by an individual. The feasibility analysis consisted of evaluation of the number of eating occasion images taken as well as the numbers of "missed foods" and "forgot to take pictures" by each participant. Statistical significance of the relationship between "missed foods" and "forgot to take pictures" was also assessed using a generalized Poisson regression model to account for potential correlations across time within a given participant.

RESULTS

Number of food images taken by participants

Forty-five of 47 healthy college students (23 males and 22 females) aged 19 to 28 years completed this study. The reasons for study dropout were work-related. The mean age of participants was 22.8 ± 2.6 years and mean BMI was 24.5 ± 4.5 kg/m^2. The total number of food images taken throughout the 3-week study period (total of 6 days) by all 45 participants was 3,315, which includes all images taken before and after meals as well as snacks. The median number of images taken throughout the study period per participant was 84.5 (range: 30-144 images) for female and 56.0 (range: 33-118 images) for male participants. Female participants took significantly more food images than male participants ($P = 0.0211$). (Table 2)

Results of multivariate Poisson regression

The mean number of "missing" images per day was 0.66 (SD = 1.2) while the mean number of "forgotten pictures" (realized that images were not taken) was 0.83 (SD = 1.4) throughout the study period per participant. Based on the scatter plot of the numbers of "missing" images and "forgotten pictures" throughout the study period, there did not appear to be a strong trend in either "missing" images or "forgotten pictures" throughout

Table 2. Number of food images taken by participants

	Male (n = 23)	Female (n = 22)	All (n = 45)
Total number of images, during the 3 weeks	1,470	1,845	3,315
Images per person, week-end day (average number taken)	Median: 8.5 Mean, SD: 0.3 ± 4.7	Median: 13.3 Mean, SD: 14.2 ± 4.7	Median: 12 Mean, SD: 12.2 ± 5.0
Images per person, week day (average number taken)	Median: 9.3 Mean, SD: 10.0 ± 4.1	Median: 13.2 Mean, SD: 12.9 ± 12.8	Median: 11.3 Mean, SD: 11.4 ± 4.1

n = number of participants

Table 3. Multivariate Poisson regression on the numbers of images taken per day

Variable	Incidence Rate Ratio (IRR)[1]	P-value
Age	0.99	0.595
Likely to use Recaller app in the future	1.17	0.085
Female gender	1.34	0.001
Duration between first and last food pictures	1.05	< 0.001
Weekend	1.12	0.004

[1] Incidence rate ratio of number of images taken

the study. However, in the generalized Poisson model, the numbers of missing and forgotten pictures significantly decreased with time (i.e., numbers were higher earlier in the study period) (P < 0.01). The average duration between the first and last food images taken per day was 11 hours, with a range of 0 (less than 1 hr) to 23 hours. Multivariate Poisson regression of the number of images taken per day by each participant revealed that greater duration between first and last food images taken, weekend, and female gender were three significant predictors of a higher number of images taken. In the regression model, weekend became significant (P = 0.004) after adjusting for the other variables (Table 3).

Participants' opinions of the Recaller app

All participants, except for one male and one female participant, reported that the Recaller app was extremely easy or easy to use. The participants reported, on average, that they spent 11.3 min (range: 2 to 35 min) each day using the Recaller app to record the foods and beverages they consumed. When participants were asked whether or not they would use the Recaller app on their own smartphones in the future, 50% of participants said they would use the Recaller app daily to track the foods they eat. The reasons that participants said that they would not use the Recaller app in the future were 1) they would forget or be too lazy to take food images (n = 8), 2) they want more information (calories, nutrients, etc.) or feedback on what they eat (n = 7), and 3) they thought it would only be useful for those trying to lose weight or starting an exercise regimen (n = 4).

DISCUSSION

This pilot investigation examined the usability of the newly-developed Recaller smartphone app with an embedded camera and Internet capability. We hypothesized that taking and sending images of foods to the Recaller website using the Recaller app would be an easy task. Most (96%) participants agreed that the Recaller app was easy to use. Among all users, 3,315 food images were uploaded, with the median numbers of images taken per participant being 84.5 (range: 30-144 images) for female participants and 56.0 (range: 33-118 images) for male participants. Duration between the first and last food images taken per day ranged from 0 (less than 1 hour) to 23 hours, which may reflect the diversity of eating styles among participants, who were all college students aged 19 to 28 years. This disparity may also reflect compliance, i.e., participants who

had only a few hours between their first and last food images may not have complied with the protocol and failed to take pictures of all foods they ate per day. In addition, the numbers of food images taken did not vary significantly by age or body weight as well as did not differ in relation to the self-reported likelihood of using the Recaller app in the future.

All participants participated in 24-hour recall interviews with a trained nutritionist on the day directly following those days designated for taking food images. Eating events were categorized as "missing" (failed to report) or "forgot to take pictures" (realized that images were not taken) for assessment. Having the participant and nutritionist view the uploaded images together after each 24-hour dietary recall was a particularly unique feature of this pilot study when considering other studies involving image-capture approaches to dietary records. In previous studies, food images were decoded by automation [16,17] or a third party and then confirmed by participants for their dietary assessments [19,26]. It is interesting to note that the mean numbers of "missing" pictures and "forgot to take pictures" did not appear to decrease with time upon visual inspection of the relevant scatter plots, but there was significant reduction of the numbers of "missing" and "forgotten" pictures after adjusting for correlations between different days within a given participant. This suggests that there were limited practice or training effects when using the Recaller app. This finding is not consistent with a previous study, which seemed to indicate that additional training in smartphone usage could improve smartphone food record keeping in adolescents [21]. The participants in this study (college students) may be more experienced with using smartphones and possess higher levels of technology readiness. Our results suggest there was no fatigue effect, suggesting that ongoing use over the course of 3 weeks did not reduce the duration or frequency of Recaller app usage. Foods that were reported as missed foods, which would result in underreporting in self-report methods, were generally food items eaten between meals as snacks (examples: cookies, soft drinks, chips), as reported in previous studies [33,34].

Participants who declared they would not use the Recaller app in the future reported that it was difficult to remember to take food pictures, especially when busy doing something else (e.g., homework, exams, and appointments). Some participants also continued to forget to take pictures. A generalized Poisson regression model showed that the frequency of "forgot to take pictures" decreased significantly during this pilot study period. These results indicate that there likely remains some error with eating events that are never photographed or remembered, which may be attributed to the inherent inaccuracy of self-reported dietary recall. This problem may be mitigated by sending reminder text messages to participants to photograph their foods [35]. Short messaging service (SMS) text messaging has been used successfully to improve compliance with medication and appointments [36,37] as well as to promote healthy behavior for weight maintenance [38,39]. Some participants noted that they would be more likely to use the Recaller app if they could receive instant feedback after sending food pictures. Some other participants also noted that they would use the Recaller app in the future if they were trying to lose

weight. These comments show that the Recaller app should be tested in randomly selected individuals from the general population to determine its usefulness in participants with more varied characteristics.

This pilot study was limited to usability testing and information gathering to inform and guide future research. The results from this study are not generalizable. A validation study will be required to refine the Recaller app for integrated measurements (time, multiple recalls, joint users, instant messages, and imaging), which may improve the collection of dietary intake information and behavior.

In conclusion, this pilot study demonstrates that the smartphone food picture app for assisting with 24-hour dietary recall is easy for college students to use and has the potential to improve recall of foods eaten as well as to monitor dietary intake in nutrition studies. As a future work, the authors will continue conducting research projects to evaluate whether or not the Recaller app 1) improves dietary assessment, 2) is cost-effective compared to other dietary assessment technologies or methods, and 3) can be used to enhance dietary adherence for the treatment of some diseases.

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