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Testing the Feasibility of Intake24 as an Portion Size Estimation Aid

Leonie Mauerhoefer, Pia Kawelke, Ivan Poliakov, Patrick Olivier and Emma Foster

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Abstract

In the context of the assessment of nutritional intake, it is important to improve and extend traditional food report methods by taking the development of new technologies and the changing lifestyle of the population into account. Therefore the Intake24 system, as a web-based 24-hour recall tool with integrated food photographs as an estimation aid, was developed. The aim of the presented studies was to evaluate the accuracy and precision of estimates made by participants using Intake24 and gain a greater insight into the needs of the users. A controlled feeding study was conducted, in which 40 participants attend four meals and were requested to enter their intake into the system on the next day. Concerning the accuracy of estimations, the results indicate a mean underestimation of 11%, so Intake24 is a promising tool and may provide an adequate substitute for 24-hour recall interviews with some modification.

Bibliographical details

Added entries

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About the authors

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Emma Foster graduated from Aberdeen University in 1998 with an MSc in Human Nutrition and Metabolism. Most of her research to date has focused on methods of assessing dietary intake of children. In 2004 she completed her PhD on the subject of Dietary Assessment in Primary School Children under staff regulations. In 2011 she was appointed Lecturer in Public Health Nutrition.

Suggested keywords

Testing the feasibility of Intake24 as an portion size estimation aid

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ABSTRACT

In the context of the assessment of nutritional intake, it is important to improve and extend traditional food report methods by taking the development of new technologies and the changing lifestyle of the population into account. Therefore the Intake24 system, as a web-based 24-hour recall tool with integrated food photographs as an estimation aid, was developed. The aim of the presented studies was to evaluate the accuracy and precision of estimates made by participants using Intake24 and gain a greater insight into the needs of the users. A controlled feeding study was conducted, in which 40 participants attend four meals and were requested to enter their intake into the system on the next day. Concerning the accuracy of estimations, the results indicate a mean underestimation of 11%, so Intake24 is a promising tool and may provide an adequate substitute for 24-hour recall interviews with some modification.

Author Keywords

Intake24; estimation of portion size; dietary assessment; food recall; 24-hour recall; web-based assessment

INTRODUCTION

One of the most important goals in the understanding of eating behaviors, health care and its provision is the accurate measurement of food intake. Due to a more sedentary lifestyle and richer diet the amount of overweight people globally increased to 34% in 2008, almost doubling from 1980 [1]. Unhealthy nutrition and obesity are problems, which are increasing in prevalence worldwide and are associated with increased risk of diabetes, high cholesterol, high blood pressure, coronary artery diseases and other health problems. Consequently dietary assessment gains further importance in research. Besides the identification of food intake, the accuracy of estimation of portion size is a difficult topic in dietary assessment [2], as it is considered as a major source of error in nutrient analysis [3]. Therefore a variety of tools were developed to support people with their estimation of consumed food. Certain capabilities are required for reporting portion sizes by using these aids: perception, conceptualization and memory [4]. The ability to compare the actual food amount present with the amount the tools represent is called perception. Previous studies could show varieties in the accuracy of perception and estimation depending on age, type of aid, study conditions and food type [5, 4, 2]. The ability of conceptualization includes the development of a

mental picture of a food portion, which was consumed beforehand and comparison with the aid. The third element, memory, is related to conceptualization, as it is the ability to recall the portion size previously consumed. Also for conceptualization and memory a difference in estimation accuracy could be found [2]. A common finding in portion size estimation studies is the flat-slope phenomenon, which describes the underestimation of large and the overestimation of small portions [4, 6]. Furthermore literature indicates that amorphous foods like scrambled eggs and foods like butter, which are consumed in small portions, tend to be reported with less accuracy than food with other morphologies [5, 4]. Common portion size measurement aids include household measures like cups, rulers, food models and food photographs [7]. It is useful to connect one of these estimation aids with the dietary assessment methods. Three commonly used types of self-reporting dietary assessment tools are food-frequency questionnaire (FFQ), food record and 24-hour dietary recall [3].

ASSESSMENT METHODS

Each of the mentioned method has its own strength and weaknesses [8] while underreporting is a general issue for this kind of self-reports [9], FFQs tend to be associated with overreporting. The FFQ consists of questions about usual intake over a certain period of time hence is less detailed and doesn't give specific information about individual meals. The food record requests the immediate documentation of the participant's food consumption in the form of hand-written diaries or mobile phone applications like MyFitnessPal [10]. Although this method reduces memory errors, it is vulnerable to bias and has a high drop out rate due to the high subject burden [11]. In early studies the request to record food intake led 30 – 50% of the participants to change their eating habits [12] like reducing the amount of foods and snacks consumed [13]. The 24-hour recall collects detailed information about the food consumption in the last 24 hours. To avoid a change of eating habits the survey is usually performed unannounced and over multiple non-consecutive days to reflect not a single day, but the general diet of an individual. The interviewer based 24-hour recall has been considered as an ideal dietary assessment tool due to its high quality and less biased data for a day [14, 15]. The main problems in the accuracy of this method are caused by attention and memory difficulties, owing to the decreasing memory of

specific events like food intake over time [16], as well as troubles with the estimation of portion sizes. On an economical level the high costs caused by the employment of trained professionals impede the broad use of the 24-hour recall method [17]. Nevertheless the 24-hour recall has lots of advantages over other dietary assessment methods [18] and recent findings propose this practice as most feasible for recording dietary intake data [19]. Because of the 566.4% increase of the Internet use worldwide in the past 10 years [20], a cost-saving online platform offers the opportunity to respond to the aforementioned challenges. Thereby the participant's burden can be reduced to realize a large and widespread data record whilst maintaining accuracy and precision. As mentioned above the use of portion size assessment tools like food photographs, food replicas and food models help capture individual variation in portion sizes [21, 22]. Prior studies indicated an increase of accuracy of serving size estimation compared to unaided estimates [23]. Furthermore it could be shown that computer display photographs cause an equally good performance as life size photographs while they are more portable and accessible [2]. Against this background the automated self-administered food system (ASA24) [24] was developed in the USA based on the United States Department of Agriculture (USDA) automated multiple pass method. In US National Health and Nutrition Examination Survey (NHANES) this method, which is based on a "quick list" for entering the food for the last 24 hours, multiple pass prompts as a reminder for forgotten food and food photographs as an estimation aid, is most frequently used.

In our study we tested the feasibility of a newly designed web-based 24-hour dietary recall system called Intake24 for dietary assessment.

INTAKE24

Intake24, a computerized 24-hour recall tool, which was developed by Members of Newcastle University for research purposes, is also based on the multiple pass method and contains over 2000 professionally taken portion size photographs of over 100 different foods. The foods are based on the portion sizes consumed during the UK National Diet and Nutrition Surveys [25] and have been extensively validated in a feeding study (n=306) [26] and a relative validation against 4-day weighed intakes (n=283) [27] The traditional multiple pass method is managed by an interviewer who guides the participants through the different steps of the 24-hour recall. First the participant gets the chance to state every food and beverage intake of the last 24 hours. After they are questioned about potential forgotten foods and other possible additions, eating time and occasion are gathered. This is followed by a collection of detailed descriptions of type and portion size of each consumed food. Finally the consumption for the whole day is reviewed and a final check for any forgotten foods takes place. The questions asked in Intake24 are similar to those asked by the interviewer; accordingly the system takes over the role of the trained, "costly" employee. To get the amount of food consumed, the participants are requested to enter the served portion first and then the leftovers. The portion size images are presented as guide photos which depict a range of portion sizes available for items which usually come in pre-determined amounts e,g. bread rolls or cakes (see figure 1). For foods, which do not come in pre-determined amounts, e.g. baked beans or broccoli the photographs are arranged as seven equal images on a log scale (see figure 2). The decision on this presentation of photographs was made due to evidence from visual perception research concerning Weber's law. This asserts that with the increase of the size of the stimulus the just noticeable difference, that is to say the least perceivable difference between two stimuli, gets proportionally bigger. For example the distinction between 5g and 10g of beans tends to be perceived rather more than the distinction between 105g and 110g [28].

Figure 1. Food item identification

As a reminder to include all consumed food in the past 24 hours, the system recognizes the entered items and offers additional foods that are usually consumed together. For example the input of toast triggers questions for spread like butter and marmalade. To identify these connections the researchers designing the system referred to the results of the National Diet and Nutrition Survey [29]. After finishing the survey, the researcher not only has access to the entered food type and estimation of portion size but can also output intakes of energy, key nutrients and food groups for further analysis.

Intake24 has innovative features and is a promising tool. It is important to examine whether the system is easy to use and enables the user to make precise and accurate estimations of their food intake.

Two studies were conducted to answer the following questions:

1. How easy is the use of the system?

2. How accurate are the estimations of portion size made by the participants using Intake24?

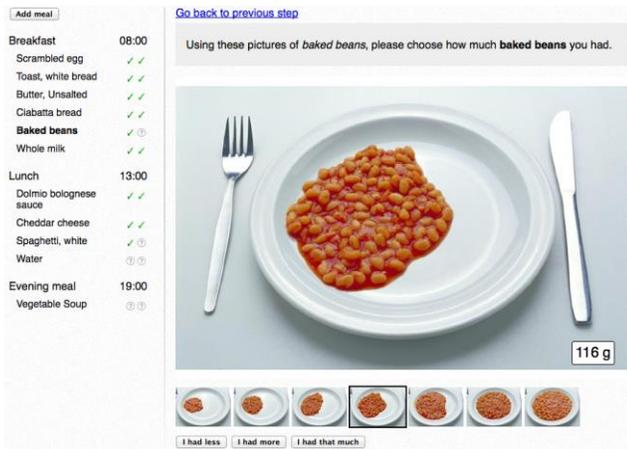3. Is assessment of food intake using INTAKE24 accurate?

Figure 2. Portion size estimation with Intake24

STUDY 1

Although the main focus of the study was on the examination of another technology, qualitative statements concerning the interaction with Intake24 were recorded.

Method

Study population
Seven male members of Culture Lab of Newcastle University were recruited to participate in the study. The age ranged from 21 to 25 (M=22.86; SD=1.574). Out of the seven participants six were of British and one of Chinese origin.

Study design
The study consisted of a one-day trial to examine the feasibility of Google Glass in assessing food intake and a follow up interview on the next day. One part of this interview concerned the use of intake24 as well as an evaluation of the ease and precision of the system and corresponding suggestions for improvement. To be able to answer these questions, the participants were requested to enter their food intake from the day before into the Intake24 system in advance.

Results

Evaluation of Intake24
In general people perceived Intake24 as a pretty easy system, and appreciated the questions as a stimulation to think harder about their food intake, but due to its high level of detail, they perceived it as quite time consuming as well. Hence they wouldn't use it in their everyday life. Moreover people's opinion regarding Intake24 and the available input options differed. On the one hand people praised the search algorithm, "which works quite nice" and very exact, but on the other hand they found some foods are missing in the database and for some meals no comparable substitute was available this along with different cooking methods can

impact on the reported calorie intake. Recommendations to improve the ease of use were an autocomplete search bit, further estimation options and different visualizations of the portion size as one participant had his pasta in Tupperware instead of one of the given bowls.
On the technical level problems occurred for one participant for whom the system stopped progressing after he had made an amendment

STUDY 2

This study's aim was to investigate the suitability of Intake24 as an estimation aid and as a substitute for a 24-hour recall interview. Furthermore the study was used for additional evaluation of Google Glass. Details are given in Mauerhoefer and Kawelke (2014, in press) [30].

Method

Study population
40 employees and students (21 male, 19 female) of Newcastle University were recruited to participate in the controlled feeding study via mailing lists. The average age was 31 (SD=7.813). For their participation they were offered a £20 reward at the end of the study.

Study design
Every participant took part on four different meals on non-consecutive days. The two researchers who carried out the study prepared every meal freshly.
The choice of meals was influenced by the intention to provide different food types with various morphologies (liquid, distinct, amorphous, and mixed). The aim was to examine the accuracy with which people could estimate portion sizes of foods with different consistencies [31]. Therefore the following meals were served: baked beans with scrambled eggs, toast and butter (meal 1), fish fingers, peas with chips and mayonnaise and ketchup (meal 2), vegetable soup with bread and butter (meal 3) and spaghetti bolognaise with grated cheese (meal 4). To enable a comparison between the estimate made by the participant using Intake24 and the actual portion, the study was conducted as a controlled feeding study. Therefore the exact weight for every food component for each participant was recorded.
Up to four people attend at every round and were located at different tables with their back to each other to reduce the probability of taking pictures of other participants as they wore the picture-capturing device Google Glass. On every day after of joining a meal, the participants received an email with the request to insert their food intake from the previous day into the Intake24 system. During the fourth meal the people were asked to complete a questionnaire about quantitative and qualitative statements concerning the use of Intake24.

Statistical analysis
A statistical calculation was conducted to test the accuracy and precision of portion size estimation. For this purpose the method of Bland and Altman was used [32], which

calculates the difference between the participant's estimation and the actual weight of the foods. This is achieved by plotting the difference between the estimated weight of food minus the actual weight of food against the mean to emphasize a possible connection between the measurement error and the true value whereas the mean of the measurement is the best measure for the true value. The limits of agreement are specified between two standard deviations; thereby 95% of the differences would be located between those limits. In this context a negative value implies an underestimation whilst a positive difference expresses an overestimation. A perfect agreement is indicated by a value of zero.

For reasons to do with dysfunctional form and to facilitate a degree of comparability for food types with distinctly different usual portion sizes such as comparing estimates of butter and chips, the analyses were performed on the logged ratios of estimated weight to actual weight. It should be recalled that the differences of logs are the same as the log of the ratio of weights, and the mean of logged weights is the log of the geometric mean weight [32].

Results

Performance using Intake24

Considering all captured data over the various meals and food components, people underestimated their food intake on average by 11%. These results appear for women (M=0.892; SD=1.772) and men (M=0.889: SD=1.774) when considering a gender difference. When analyzing the average differences between the 15 food groups, the two components fish fingers and spaghetti bolognaise were highly underestimated by 48% and 46%, whereas the highest overestimation by 198% concerned grated cheese. The best estimations were achieved for baked beans and toast with an underestimation of 7%, butter and chips with an overestimation of 6% and scrambled eggs with an overestimation of 3% (Table 2). As mentioned before the geometric mean of the ratio was calculated with the Bland and Altman method using the proportion of the estimated portion size consumed and the actual portion size consumed. Figure 4 shows the geometric mean of the ratio ±2 Standard Deviations for each food type. Although the mean estimates are close to the actual weight, a closer look reveals a wide range of individual estimation in-between the participants for some food types. The variability was especially great for foods like baked beans, bolognaise, grated cheese, mayo and spaghetti.
As said above Fish fingers and spaghetti were highly underestimated, but as it can be seen in Figure 3 the range of the individual differences was lower than for most of the other foods.

In order to investigate whether the wide distribution of estimates was due to a general inaccuracy in portion size

estimation made by the group or whether a small number of very inaccurate estimates skewed the data three different calculations including participants whose estimations did not differ more than 50%, 20% or 10% from the actual value were conducted. Out of the 460 estimates included in the 95% confidence interval (CI), 333 were taken into account for the 50% deviation interval, 126 lay within the 20% limit and only 58 estimations were good enough to be used for calculations within the 10% interval (Table 1). Grated cheese as the food type with the worst mean of estimation and one of the widest distribution was not even included in the dataset with the determined deviation of 50%. In the group of 50% of deviation, 50% - 89% (depending on the food groups) of the original amount of

	50% deviation from actual N weight %		20% deviation from actual N weight %		10% deviation from actual N weight %	
Baked beans	29	82.86	13	37.14	5	14.29
Bolognaise	3	75	-	-	-	-
Bread	26	70.27	11	29.73	3	8.11
Butter	31	70.45	16	36.36	6	13.64
Chips	28	84.85	15	45.45	10	30.30
Grated cheese	-		-	-	-	-
Fish fingers	28	71.79	1	2.56	-	-
Ketchup	24	64.86	10	27.03	5	13.51
Mayo	16	50	6	18.75	4	12.5
Peas	27	77.14	6	17.14	4	11.43
Scrambled eggs	33	89.19	18	48.65	6	16.22
Spaghetti	3	75	1	25	-	
Spaghetti Bolognaise	20	57.14	4	11.43	3	8.57
Toast	31	79.49	9	23.08	2	5.13
Vegetable soup	34	89.47	16	42.11	10	26.32

* Percentage of the amount of all estimations for the food type

Table 1. Representations of the amount of estimations, which are close enough to the actual weight to lie in the 50%, 20% or 10% deviation.

estimations included in the calculations of the 95% CI remained. For the 20% variation range, 2.56% to 48.65% of the total amount were left and for the 10% range, 5.13% to 30.30%. On the whole Spaghetti Bolognese was highly underestimated by 46%. This can be caused by 42.86% of participants whose estimation didn't lie in the 50% interval, therefore nearly half of the participants made extremely inaccurate estimations. Whereas for other highly underestimated food types, like fish fingers, 71.79% of the estimates lay in the 50% range, but just 2,56% in the 20% range. In this case the mean resulted from the fact that lots of people made moderate estimates, but just one was able to make

Food ID	N	Geometric mean of the ratio* (M)	Lower limit of 95% CI (M -2SD)	Upper limit of 95% CI (M + 2SD)
Baked Beans	35	0.930	0.28	3.12
Bolognaise	4	0.652	0.20	2.11
Bread	37	0.883	0.29	2.71
Butter	44	1.064	0.39	2.90
Chips	33	1.056	0.49	2.29
Fish fingers	39	0.516	0.32	0.84
Grated Cheese	11	2.980	0.88	10.09
Ketchup	37	1.215	0.47	3.16
Mayo	32	1.124	0.29	4.33
Peas	35	0.660	0.22	1.04
Scrambled Eggs	37	1.035	0.49	2.18
Spaghetti	4	1.087	0.33	3.56
Spaghetti Bolognaise	35	0.536	0.28	1.02
Toast	39	0.930	0.35	2.46
Vegetable soup	38	0.799	0.42	1.50
Over all	460	0.891	0.28	2.80

*Ratio of the estimates of the amount of food consumed to the actual weight of the food consumed.

Table 2. Accuracy of estimates of food portion size consumed considering different food groups

estimation precisely enough to be included in the 20% interval. On the other side the estimations for some food types with just a slight deviation from the mean like scrambled eggs, baked beans or chips had 82.86% to 89.19% of the original number of estimates in the 50% interval, between 37.14% to 48.65% in the 20% interval and 14.29% to 30.30% in the 10% interval. Hence the outliers in the range are the result of some individual cases as more than 80% made moderate estimations.

Evaluation of Intake24
In total 71.8% (N=28) of the 39 participants who completed

the questionnaire found Intake24 to be an easy way to enter their food intake. They appreciated the "very detailed and good choice of multiple options", the "easy user interface", the "straight forward way to guide the user through the menu" and the "pictures of the food portions and food categories as very helpful" as "having pictures of the portion size is easier than amounts" to "adjust portion sizes easily". Negative comments included the "long time to enter everyday meal", that it was "tedious and too detailed", that it "takes quite a while to understand how the system works but is easy once you know". In this context they mentioned difficulties in understanding how to enter their
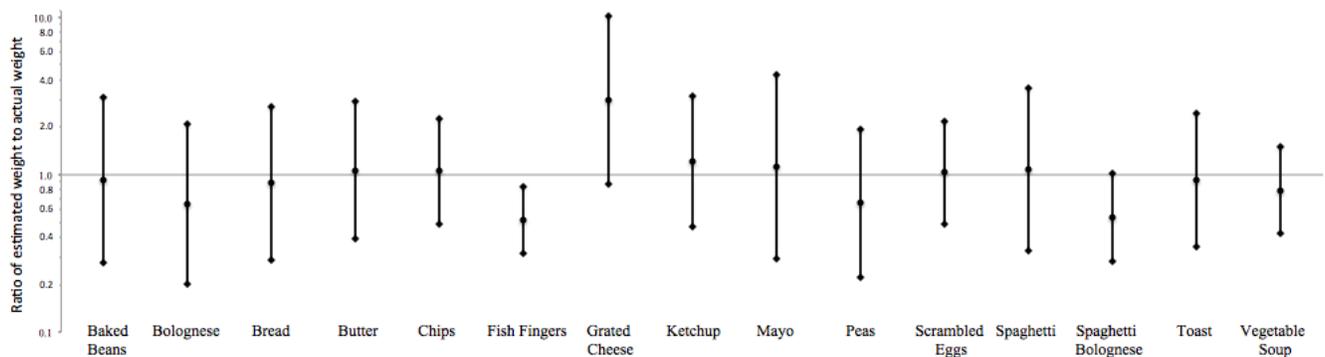

Figure 3. Accuracy of estimates of food portion size concerning each food component. The line at 1.0 indicates where completely accurate estimations of portion size would lie; ratios smaller than 0 indicate underestimation, those higher than 1 overestimation. The values are geometric means whereby the vertical bars represent ± 2 standard deviations.

meals as they were requested to report every single component and the whole portion and leftovers instead of the consumed portion.

Although the same amount of people considered the system to be precise about the available input options, 43.6% (N=17) suggested additional options as a necessary improvement to describe their own food intake. They noted, that the database should be improved as "it doesn't have all food" and sometimes they had more "quantity of an item on the plate than the system showed on the screen". But anyway the pictures as an estimation aid were able to make "portion size estimation more flexible". Furthermore the "quantity of food should be identifiable in the selected food domain", as for example lots of them "had trouble to find the exact match for the sliced ciabatta", they had to "find the next best match". They "didn't like the questions being asked at the end of the survey, when everything was already completed", because "sometimes you would enter an item which has an related item e.g. soup and bread and even if you already explicitly added the related item it would still ask you about weather you had it with your soup", so you "need to be careful not to double up an entry". They mentioned that "due to different brands and cooking methods it is likely very inaccurate" considering the nutritional value of the portion.

Discussion
Measurement errors will always occur in the context of food recall, as the consumed portion needs to be exactly perceived, conceptualized, remembered and finally reported. In this study the feasibility and usability of the system Intake24 was evaluated to determine whether it is a suitable alternative to 24-hour recall interviews.

In their qualitative statements, the majority of participants found Intake24 to be an easy and precise way to enter their food intake, whereby the high level of detail and its time consuming character caused the most dissatisfaction. Besides an improvement of the level of detail for example by avoiding double questions, suggestions made by the participants concerned additional options like a greater database, even though 1400 foods are already included, there are always some foods missing due to the huge variety of foods available. In addition more portion size options and different visualizations for those are required. To enhance the accuracy of estimation the provided estimation aids need to represent the selected food. However as the system has over 2800 portion size images this has to be balanced against cost. A visualization of every food container is not realizable in an adequate financial framework.

The results of the statistical analysis emphasize that Intake24 provided a good estimation aid for the participants. The general underestimation by 11% is in accordance with the results of further studies investigating 24-hour recall methods as the two largest studies using the multiple pass method, which is the basic idea behind the web-based realization of Intake24, showed an average underreporting between 12% and 23% [33, 34, 9]. In this study the accuracy of estimates varied between different food types. It is worth mentioning that the participants were able to estimate the amorphous food quite well in contrast to further studies, which report complications in estimating these food types [5, 4]. In general it is difficult to trace wrong estimations back to a fault in the system or the lack of certain estimation and memory capabilities of the participants. Furthermore different cooking methods can lead to different weights and cause an inaccurate outcome despite correct estimations on the side of the participants. For example the weight of the fish fingers in the system differed considerably from the actual weight of the fish fingers in the feeding study and therefore influenced the outcome. Just one person was able to make an estimation exact enough to lie in the 20% margin. The participants tended to select the correct item from the food type image and identified the correct number served. The discrepancy is likely to be due to a difference in cooking time between the items photographed and the items served to the participants. This is a problem for foods which differ greatly in weight but not in appearance with degree of cooking. Other errors in the estimation occurred because of missing food types like the selection of bread where no suitable match for the ciabatta was available as well as missing options of portion sizes when the actual weight was not included in the provided portion options. Further problems were caused as not all versions of all meals where available and the participants just got similar meals to use as an estimation aid. For example spaghetti Bolognese as a meal was an available option in the data basis but to estimate the portion size, the pictures and the weight of pasta with tomato sauce were used and this resulted in serious differences in weight. A continuous scale and an extended database are necessary and advisable improvements to overcome those burdens and limitations.

Another limitation may be that in the context of the study the participants were asked to fulfill additional demands. Hence they were wearing Google Glass while eating they could be distracted and influenced in their memory and natural eating behavior.

Although every participant received one (or more) reminder email, due to the knowledge based on prior studies, which showed that reminders enhance participation [35], some didn't enter their intake immediately on the next day and some didn't enter it at all, so that these cases needed to be excluded.

Concerning the recruitment of the participants it should be taken into account that the whole sample had access to the Internet and can be referred to as computer affine. To test the feasibility of Intake24 for an older population or minorities, other studies are needed. Participants used the beta version of the web application, and the results fed into further development of the system.

Conclusion
The results indicate that Intake24 is a promising tool in

dietary assessment as it seems to be an adequate alternative for accurate and precise estimations and recalls, while saving money and reducing participant burden for large scale data collection. However, some adjustments are needed to ensure an appropriate substitute for professional 24-hour recall interviews, like the extension of the database, the offer of different and more continuous visualizations of portions (dinner plate, bowl, Tupperware) and the avoidance of double-questions by customizing the algorithm. More specific instructions about how to enter the different components of a meal would improve the usability as well as further descriptions about how to report the food consumed as the food served needs to be entered first and then any leftovers. To test the feasibility of Intake24 for the whole population and to guarantee that nobody is disadvantaged, more studies with different samples are required as the capabilities in the handling of computers and the access to the Internet vary. Possibly a combination of Intake24 and the 24-hour recall interviews is necessary to assure a complete cover of dietary assessment in every society.

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