The eNutri app: using diet quality indices to deliver automated personalised nutrition advice

Article

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ABSTRACT

Personalising nutrition advice using digital technologies, such as web-apps, offers great potential to improve users' adherence to healthy eating guidelines. However, commercial offerings currently lack decision engines capable of delivering personalised nutrition advice. This article outlines the core concepts, content and features of the novel eNutri app, developed by researchers at the University of Reading. Uniquely, the app identifies and recommends food-based modifications that would be most beneficial for an individual taking into account both their current diet quality and their individual preferences.

BACKGROUND

There is mounting evidence that personalising nutritional advice based on a user's food intake, biomarkers of health, and/or genetic information is more effective at improving adherence to healthy eating guidelines than standard public health messages [(1)]. Healthy diets, typically characterized by high intakes of fruits, vegetables, whole grains, legumes, omega-3 fats and low intakes of refined grains and red and processed meats, are associated with a lower risk of overweight and obesity and cardiovascular diseases [(2; 3)]. Thus, there is great interest in effective tools for improving food intake at a population level. Digital technologies, such as apps, offer the potential to provide tailored advice at-scale with relatively low-cost (vs. face-to-face intervention). However, our review of popular nutrition-related mobile apps revealed that none of the apps reviewed were providing personalised nutrition advice [(4)]. To address this, our research team at the University of Reading have developed a mobile web app capable of delivering automated nutrition advice.

OVERVIEW OF THE ENUTRI APP

The online eNutri app was designed to encourage positive dietary behaviour change, and to promote wider uptake of digital nutrition assessment and personalised advice via the internet [(5)]. The eNutri system works by combining information from the user with datasets on nutritional composition, food preferences and diet quality to generate food-based recommendations aimed at improving the user's diet quality (see **Figure 1**). The 'input' data required includes self-reported sex, weight, height and food intake, the last of which is assessed using a novel Food Frequency Questionnaire (FFQ). The FFQ contains questions about dietary restrictions, what the user has eaten over the previous month, and the frequency of consumption of each item. The data processing phase includes 1) calculation of the users' body mass index (BMI), 2) nutritional analysis of their food intake, 3) assessment of the users' diet quality and 4) selection of the food items likely to have the greatest beneficial impact on the users' diet quality score (DQS). Following selection of these food items, they are ordered according to the user's inferred preference for individual items (e.g. likely to have a strong preference for "apples" based on apples having similar attributes to foods that the user is already consuming frequently in their diet) and presented in a report with advice messages appropriate for the user's BMI and reported dietary restrictions. The output (i.e. food-based recommendations) is generated for each individual user.

The app is designed to operate in a web-browser and be used across multiple device types including smartphones, tablets and laptops/desktop computers. Whilst mobile devices are most commonly used to access the internet, 40% of interactions occur on a laptop/desktop [(6)] and so in order to not exclude access via a

laptop/desktop, eNutri was developed as a web app rather than as a native app (e.g. specific to iOS or Android and requiring the app to be installed). It was important that the underlying technology was scalable, inexpensive to deploy and suitable for many populations, including low income communities. Therefore, it was built using commercially available technologies and deployed using the Google Firebase free plan [7]. For ease of use, some key design principles were followed such as: limiting the number of response options available to the user on any one screen, having an appropriate font size, having a help button always visible and having a linear user journey [8].

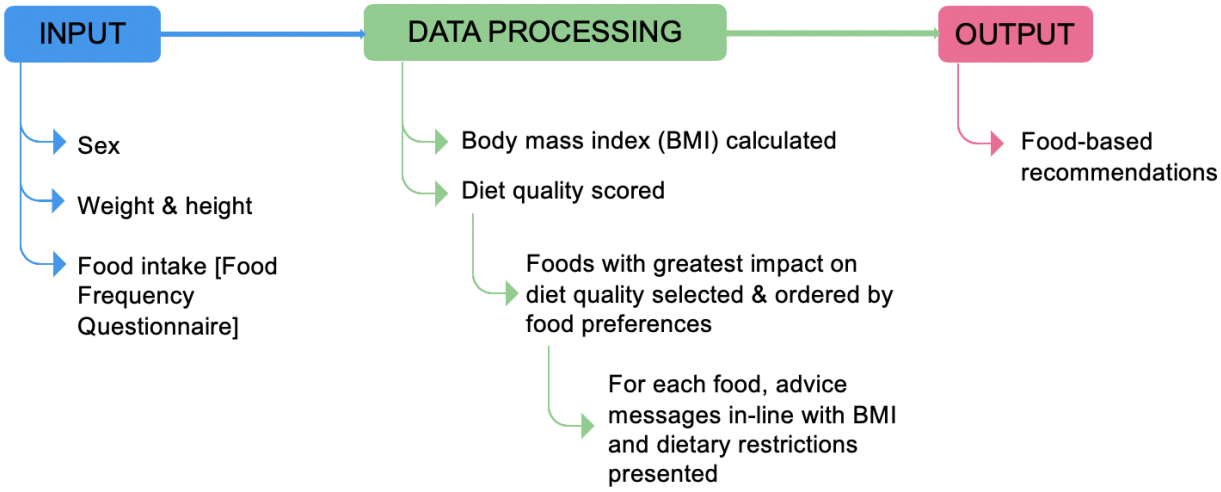

Figure 1. Summary of inputs, outputs and data processing for the eNutri app

ASSESSING DIETARY INTAKE

The novel *e*Nutri FFQ, which captured food and drink intake over the previous month, was adapted from the Food4Me semi-quantitative FFQ associated with photographs [9; 10]. Food4Me was an EU-funded project that aimed to identify the challenges and opportunities of personalised nutrition through an internet-based dietary intervention study across Europe [11]. To assess dietary intake in the large Food4Me Proof-of-Principle intervention study (n>1500), they developed and validated a 157-item online FFQ based on the EPIC-Norfolk FFQ (version CAMB/PQ/6/1205) [12]. Nutritional composition and portion sizes were calculated from the Irish National Adult Nutrition Survey (NANS) database [13].

The Food4Me FFQ was adapted into the eNutri FFQ to better estimate a UK user's food intake and to increase the sensitivity of the FFQ to detect small dietary changes over time. For example, analysis of the UK's National Diet and Nutrition Survey (NDNS) food level data from years 1-6 of the rolling programme was used to a) identify commonly consumed items not included in the Food4Me FFQ, such as pulse-based dishes (e.g. houmous and falafel) and dairy/meat alternative products (e.g. soya/ nut milks, and Quorn, tofu and soya protein) and b) determine UK specific portion sizes based on the quantities and frequencies of foods consumed per FFQ category [14; 15]. In addition, we split other FFQ items where it was deemed nutritionally important, e.g. 'nut butters' were removed from the 'sweet spreads' category as they contribute to the 'nuts, seeds and pulses' component of the eNutri DQS. An online tutorial, with detailed instructions on how to complete the FFQ, and a new food portion image dataset containing 7 portion size images of each item included in the FFQ were also created.

The novel eNutri FFQ includes 155 foods/drinks, 8 key dietary supplements (e.g. long-chain n-3 polyunsaturated fatty acids (PUFA), multivitamins/minerals, vitamin D and whey protein) and 2 questions about salt use (i.e. added at the table and during cooking). Prior to filling in the FFQ, users are also asked whether they consume meat, fish, dairy products and/or supplements; the responses are used both to tailor the presentation of the FFQ and the personalised nutrition report. For each food/drink item, users are first asked to select to select how often they consume each item, from ten options ranging from "not in the last month" to "7+ times a day", then to identify their usual portion size. Portion size is selected by clicking 1 of 3 portion images displayed on the screen, or a button either side of the image if they consumed less than/ more than the images depicted (see **Figure 2**); with a total of 7 portion sizes available. eNutri is a responsive web app and adapts its layout to different device sizes. In the mobile version, the portion sizes are recorded in two stages rather than one, with the user selecting the photo closest to their portion size photo in the first stage, followed by a "refinement" stage asking whether their portion was exactly, more, or less than that shown in the image. This is similar to the approach used by FoodBook24 (https://www.ucd.ie/foodbook24/).

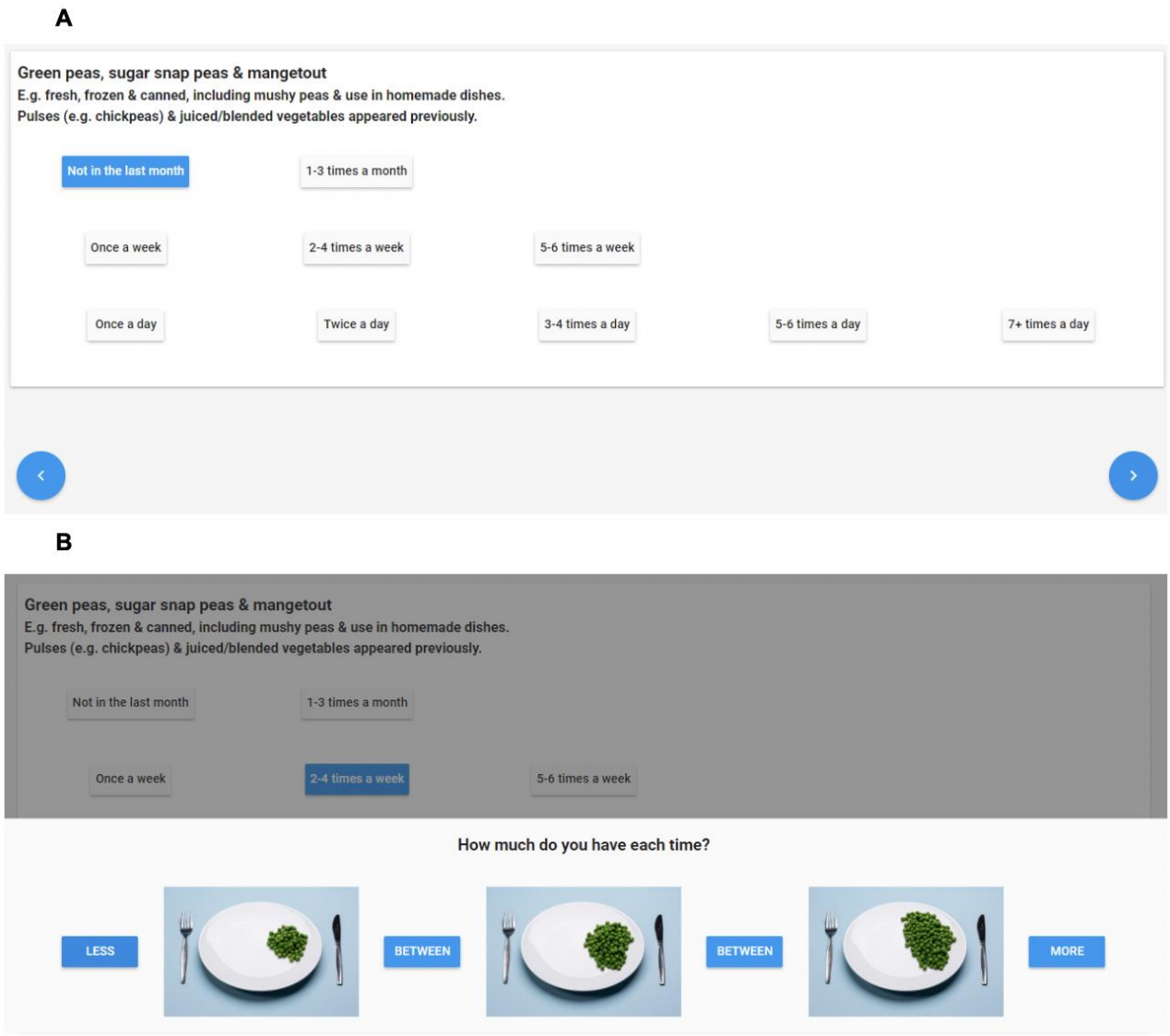

Figure 2. Images of the eNutri FFQ frequency (A) and portion size (B) screens for "large" devices (e.g. PCs, laptops and tablets).

The eNutri FFQ has been validated against a 3-day weighed food record and its repeatability assessed using test-retest methodology in a free-living UK adult population. The FFQ demonstrated good agreement with the 3-day weighed food record for estimation of energy and macronutrients, and good reproducibility for all nutrients studied *[unpublished]*.

MEASURING DIET QUALITY

Uniquely, the *e*Nutri web app makes an automated assessment of the quality of the user's diet using a novel DQS. A number of scores of overall diet quality have been developed to assess adherence to regional diets, nutritional guidelines or population-specific dietary advice, such as the Alternate Healthy Eating Index 2010, World Health Organisation Healthy Diet Indicator, Mediterranean Diet Score and Healthy Nordic Food Index. Scores typically include adequacy components (e.g. fruit, vegetables, whole grains, long-chain omega-3 fats) and moderation components (e.g. sugar, processed and red meat, sodium). To date, they have mostly been used a-posteriori to explore dietary patterns in population groups or test associations between dietary patterns and disease, as opposed to serving as a driver for dietary intervention.

The eNutri app includes a novel score, based on 11 components, that our team developed to suit Western European diets and nutritional guidelines. The score has undergone validation using European Investigation into Cancer and Nutrition (EPIC)-Norfolk data [*unpublished]*. The EPIC-Norfolk cohort study followed a group of adults aged 40-79 y from Norfolk and the surrounding areas (UK) who were recruited between March 1993 and December 1997 (n=25,636). The group were followed until March 2016, when mortality and incidence of cardiovascular disease, cancer and type-2 diabetes mellitus were recorded [(16)]. Furthermore, associations between DQS and both nutrient and biomarker data were determined using the cross-sectional NDNS dataset [(14; 15)] *[unpublished]*. The eNutri DQS provides valuable quantitative assessment of the users' diet (i.e. score out of 100) and enables automated feedback on dietary improvements (i.e. an increase in DQS) when the user repeats the FFQ.

In the eNutri app, following completion of the FFQ, the user's diet is scored according to the *e*Nutri DQS, with a minimum score of '0' and maximum score of '100', reflecting the least and most healthy diets, respectively. (see **Figure 3**). The app then uses an algorithm to determine which foods would have the most beneficial impact on the users' DQS. The foods/drinks selected by the algorithm are presented to the user in 5 advice sections. The first 3 sections are intended to encourage dietary change: 'foods to boost' – 3 foods that the user has reported eating and that would be beneficial to increase, 'foods to try' – 3 foods that the user has not reported eating in the past month and that would be beneficial to add into their diet, and 'foods to reduce' – 5 foods that the user has reported eating and that would be beneficial to cut down on. Each food item in these sections is presented with a 'Tip' that offers suggestions for implementing the suggested dietary change, along with a recommended portion size in user-friendly units (e.g. tablespoons, handfuls). The tips also consider dietary restrictions (e.g. non-meat/fish eaters) and BMI as extra levels of personalisation.

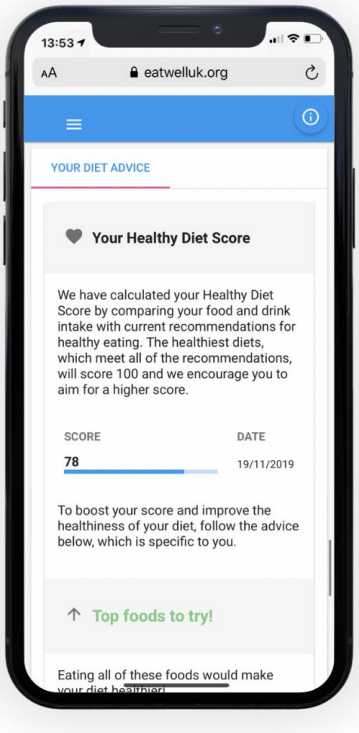

Figure 3. Image of the eNutri personalised nutrition report showing a user's diet quality score

The remaining 2 sections were intended to provide encouragement to maintain existing healthy-eating behaviours: 5 'foods to keep eating' and 5 'foods to keep avoiding'. The estimation of the user's preferences is particularly featured in the 'foods to keep avoiding' whereby the 'keep avoiding' reminder is given for foods that are deemed by the preference model to be the most "tempting" for the user. For each food item(s) presented in these 5 sections, the report also presents an associated education message that explains why increasing/reducing the amount of these foods/drinks in their diet is important to the users' health. The inclusion of the tips, education messages, and goal-setting in the personalised nutrition report constitute important behaviour change techniques, including: 'instruction on how to perform a behaviour', 'action planning', 'information about health consequences', 'perceived benefits' and 'feedback on behaviour' [(17)].

STAKEHOLDER ENGAGEMENT

It is important to involve stakeholders in the design of apps in order to identify areas for improvement and improve the app's likelihood of success and wider utility. Throughout the development of the *e*Nutri app we have

consulted key stakeholders, including users and registered Dietitians and Nutritionists, to ensure the system is user-friendly and that personalised recommendations are clear, understandable, appropriate and relevant [8; 18]. Age-related changes in cognitive, perceptual and motor capabilities affect how people interact with apps [19] and so, in the initial design stages, we also consulted with adults aged 60+ years to check that our core design features were accessible (e.g. that users could easily navigate through the app) [8].

The *e*Nutri app also includes a System Usability Score (SUS) questionnaire which each user is asked to complete after they finish the FFQ. The median SUS in the first version of the eNutri app, used by 322 healthy adults, was 77.5 (IQR 15.0); a score greater than 70 is considered good [8]. As a comparison, a study of popular services and products gave rise to an average SUS of 70.1, including Microsoft Excel (56.5), GPS (70.8) and ATMs (82.3) [20]. Embedding the SUS in the app enables our team to track the impact of updates and modifications on usability.

ESTABLISHING AN EVIDENCE BASE

The ability of the eNutri app to improve users' DQS and hence adherence to nutritional guidelines has been tested in several proof-of-principle dietary intervention studies to date, which have included >300 adult users. Within these studies, we aimed to establish whether the personalised nutrition offered by the app would result in greater beneficial diet change than general population advice. We asked study participants to use the app over a 12-week period. Half received eNutri's personalised food-based recommendations, and the other half standard dietary guidelines based on the UK's Eat Well Guide from Public Health England, delivered via the app [21]. We also wished to gain insights into how users perceived the usability of the app and the advice that they received. Users were asked to rate the app's usability using the SUS and to offer subjective feedback on the app, including, for example, whether it encouraged them to eat more healthily.

Automated delivery of personalised nutrition advice is in its infancy, therefore we considered it important to limit the target population within the eNutri studies to those without specific dietary requirements (e.g. diabetes, allergies/intolerances), in order to mitigate risks where a study participant would receive advice that may conflict with recommendations from healthcare professionals. The trials are registered at clinicaltrials.gov: NCT03250858 and NCT03897972.

At the time of writing, we are still analysing the results from the proof-of-principle studies, however, some of the early user feedback indicates an appetite/market for personalised nutrition services. For example, *e*Nutri users have expressed a likelihood of recommending the eNutri app to family and friends, a willingness to pay to purchase the app, and a perception that the app encouraged them to eat more healthily and made them feel more confident about making positive changes to their diets. Users' comments included "(the advice) made me think what I had eaten, realised I eat too much and portion size is too big" and "Very clear advice. Very specific guidance on a healthy lifestyle. Allows you to assess your own goals" [*unpublished*].

FUTURE OPPORTUNITIES

The *e*Nutri app has undergone significant re-development and optimization since its conception, via engagement with stakeholders, usability assessment and feedback from users. To date, we have conducted several proof-of-principle intervention studies to test the impact of the app on users' diet quality, however we also anticipate that using the app may reduce metabolic risk factors (e.g. total cholesterol), and in the long-term, delay or prevent the onset of chronic diseases, such as diabetes and cardiovascular disease. Apps, such as eNutri, that encourage healthier food intake and can be deployed at low-cost to large population groups have the potential to reduce burdens associated with these diseases.

In the future, we aim to widen the reach of the app to include specific populations such as adults who are 65 years and older and adolescents. With rigorous testing and via engagement with relevant users and healthcare professional groups (e.g. registered Nutritionists and Dietitians), it will also be possible to tailor the app for more clinical applications and to accommodate specific dietary needs (e.g. coeliac disease). The eNutri app has been developed to suit a Western European population and is based on UK data, however it is conceivable that components of the app could be swapped for databases more representative of other regions; for example, the eNutri DQS could be replaced with a Mediterranean diet score to suit a Southern European population. We have already demonstrated the ability of tailoring the app for other languages and local diets, via collaborations with colleagues in Germany and Kuwait.

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