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A mobile monitoring application to support sustainable behavioural change towards healthy lifestyle


ABSTRACT

We describe the development of Body Area Networks (BANs) incorporating sensors and other devices to provide intelligent mobile services in healthcare and wellbeing. The first BAN applications were designed to simply transmit biosignals and display them remotely. Further developments include analysis and interpretation of biosignals in the light of context data. By including feedback loops, BAN telemonitoring was also augmented with teletreatment services. Recent developments include incorporation of Clinical Decision Support by applying techniques from Artificial Intelligence. These developments represent a movement towards smart healthcare, making health BAN applications more intelligent by incorporating feedback, context awareness, personalization and Decision Support.

The element of Decision Support was first introduced into the BAN health and wellbeing applications in the FOVEA project. Obesity and overweight represent a growing threat to health and wellbeing in modern society. Physical inactivity has been shown to contribute significantly to morbidity and mortality rates and this is now a global trend bringing huge costs in terms of human suffering and reduction in life expectancy as well as uncontrolled growth in demand on healthcare services. Part of the solution is to foster healthier lifestyle. A major challenge however is that exercise and dietary programmes may work for the individual in the short term, but adherence in the medium and long term is difficult to sustain, making weight management a continuing struggle for individuals and a growing problem for society, governments and health services. Using ICT to support sustainable behavioural change in relation to healthy exercise and diet is the goal of the FOVEA monitoring and feedback application. We strive to design and develop intelligent BAN-based applications that support motivation and adherence in the long term. We present this healthy lifestyle application and report results of an evaluation conducted by surveying professionals in related disciplines.

KEY WORDS: Telemonitoring, mobile health, Body Area Networks, biosignals, Decision Support, Context Awareness, personalization, primary prevention.

1.1 Introduction

This chapter outlines work on design and development of mobile monitoring systems based on Body Area Networks (BANs) and their application in the healthcare and wellbeing domains. We focus on a particular mobile application designed to support sustainable lifestyle change towards healthier living. Obesity and overweight represent a growing threat to health and wellbeing in modern society. Physical inactivity has been shown to contribute significantly to morbidity and mortality rates and this trend affects not only in the west but now is apparent worldwide, bringing huge costs in terms of human suffering and loss of life expectancy as well as uncontrolled growth in demand on healthcare services. Part of the solution is to foster healthier lifestyle in the population in order to avoid or at least reduce the health consequences of physical inactivity and unhealthy diet for individuals and society at large. However a drawback of exercise and dietary programmes is that they may work for the individual in the short term, but adherence in the medium and long term is difficult to sustain, making weight management a continuing struggle for individuals and a growing problem for society, governments and health services.
The focus of this chapter is a mobile application designed to support users in following and maintaining healthy dietary and exercise programmes. The programme is framed in consultation with professionals such as dieticians, nutritionists and physical therapists and is personalized to the individual’s needs and preferences. The intention is to aid maintenance of the intervention and promote continuing healthy living habits over time.

The first version of the application was developed during the FOVEA project and work continues under the EIT ICT Labs Healthy Consumption programme. The work of the FOVEA and EIT Healthy Consumption projects builds on work on remote monitoring and treatment teleservices using Body Area Networks (BANs) conducted by the Telemedicine Group at the University of Twente since 2001 [1]. Later in the chapter we present the results of a market survey which was designed to elicit professional attitudes to the FOVEA mobile weight management application.

Section 1.2 below describes the design, implementation and main results of the FOVEA market survey. Section 1.3 summarises the findings and Section 1.4 presents discussion and conclusions based on analysis of the results. First we explain the context in terms of successive developments in BANs for smart healthcare.

1.1.1 Body Area Networks for smart healthcare

The mobile weight management application represents an extension of previous work on health BANs, used for monitoring of chronic and acute health conditions, in the direction of health and wellbeing applications, namely in the direction of primary prevention. Here we describe the development of health BANs for telemonitoring/teletreatment at the University of Twente since 2002, and their evolution towards provision of more advanced intelligent services and applications.

We define a health BAN as a network of communicating devices worn on, around or in the body which provides mobile health services to the user. In our generic architecture a BAN consists of an MBU (Mobile Base Unit, handling communication, storage and local processing) and a set of devices which may include a number of sensors, actuators and other devices. So the concept is broader than a sensor network since sensors and possibly also other devices are integrated together with a processing platform/communications gateway (the MBU). The MBU has been implemented on a range of mobile platforms (PDAs and smartphones) and a variety of mobile operating systems.

The BANs are supported by a BAN server (back-end system) which provides persistent storage and other BAN support services. Fig. 1 shows the Generic Architecture of the BAN developed during the MobiHealth project and extended subsequently in other projects.

Fig. 1. Generic Architecture of the MobiHealth BAN system
Sensor data is collected by the BAN, processed and transmitted to a remote (healthcare) location via the MBU and the BAN Back End. The generic architecture, a first prototype health BAN and a number of variants of the BAN for different clinical applications were prototyped and trialled during IST MobiHealth [2-3] which demonstrated that physiological measurements could be collected by sensors connected to a PDA or mobile phone and transmitted over GPRS and UMTS to a remote location (e.g., a hospital or health call centre). Trials were conducted on nine patient groups between 2002 and 2004; trials included telemonitoring of patients with cardiac arrhythmias, COPD patients, pregnant women and casualties in trauma care.

Later variants of the BAN for different clinical applications including monitoring of epilepsy and chronic pain were developed in the Dutch Freeband Awareness project [4-5], the European eTen project HealthService24 [6], the European eTen project MYOTEL [7-8]. In the Dutch project FOVEA we extended the scope to include primary prevention in the wellbeing domain by addressing healthy lifestyle issues in the population at large.

Each clinical application requires a specific set of sensors as well as development of application-specific software and user interfaces. Sensors which have been integrated into the BAN to date include electrodes for measuring ECG and EMG, pulse oxymeter, motion sensors (step counters, 3D accelerometers), temperature and respiration sensors. Apart from sensors, other devices which have been incorporated into different variants of the BAN include positioning devices, alarm buttons and a multi-modal biofeedback device.

Figure 2 shows the physical components of the epilepsy monitoring BAN developed during the Awareness project. The epilepsy BAN incorporates an Xsens MT9-B inertial sensor sensing 3D acceleration, three electrodes (Ag/AgCl contact electrodes) to measure ECG and the Mobi8-MT9 sensor system. 3D accelerometer data is sampled at 128 Hz and the ECG signal is sampled at 1024 Hz.

In this case the MBU is implemented on a PDA (HTC P3600). Simple rule-based decisions are made on the basis of analysis of the biosignal data and data fusion. If measured activity level is low and heart rate increase reaches a predefined threshold, the event is labelled as a possible seizure. If posture is lying, or changes to lying, the probability that the patient is having a seizure is revised upwards. Heart rate is derived from the ECG signal by RR interval analysis. The beat to beat heart rate is
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converted to heart rate change by calculating the difference between mean heart rate in two moving time windows of 10 and 120 seconds. Activity level and posture (lying or not, detected by reference to the earth’s gravitational field) are calculated every 10 seconds. The internal GPS device of the PDA, together with cell-ID information of the mobile network service provider, is used for location determination so that appropriate assistance can be dispatched to the patient if a seizure is detected. The specialist is notified in case of a detected seizure and can view the patient’s biosignals and location on a health professional portal. This BAN uses a combination of external sensors and sensors onboard the PDA.

The first BAN applications in the MobiHealth project were designed to simply transmit biosignals and display them remotely, in order to investigate the feasibility of the use of 3G networks to support useful and usable applications and services related to telemonitoring. In later projects we introduced analysis and interpretation of biosignals in the light of context data and, by including feedback loops, BAN telemonitoring services were augmented with teletreatment services which for example provide information, advice, coaching and/or (bio)feedback to patients. In FOVEA we introduced the element of Decision Support for the BAN user. FOVEA is discussed in more detail in the following section.

In the European FP7 project MobiGuide we are developing the smart health BAN further, focusing on implementing mobile and distributed Clinical Decision Support using Knowledge Based Systems (KBS) techniques from the field of Artificial Intelligence, including inferencing techniques applied to declarative and procedural knowledge bases. The work of the University of Twente in MobiGuide is focused on design, development and implementation of evidence-based decision support on the MobiGuide BANs, with formalised Clinical Guidelines forming the core of the knowledge bases. Focus applications of the project are patient guidance services for patients with atrial fibrillation, gestational diabetes and gestational hypertension, hence specific variants of the patient BAN including (clinical) application specific sensors and software components are under development. However the MobiGuide system is intended to be generic and extensible to serve other chronic conditions.

In MobiGuide the patients use variants of the patient BAN with the appropriate sensor sets to monitor biosignals (e.g., heart rate, blood pressure, blood glucose levels). Measurements are transmitted to a smartphone running Android and from there to a powerful fixed back end system which includes the MobiHealth Back End System together with a set of specialised servers hosting for example declarative and procedural knowledge bases, guideline libraries, inferencing engines, EMRs and PHRs (personal health records). The MobiGuide decision support components, which have access to the patient's historical clinical data, including hospital records, analyse the data, alert the patient about actions that should be taken, ask the patient questions, in the case that additional information is needed, and make recommendations regarding lifestyle changes or advise the patient to contact a care provider. The knowledge bases are evidence-based, incorporating computer-interpretable versions of the relevant Clinical Guidelines, and are distributed between the smartphone and the backend. Inferencing as well as knowledge is also distributed between the BAN and the back end such that the BAN can perform autonomous reasoning if connection with the back end is lost, otherwise the mobile and fixed parts of the distributed Clinical Decision Support System collaborate together to give best advice to the patient. Fig. 3 shows the major health BAN projects of the Telemedicine Group at the University of Twente and how successive generations of projects introduced smarter processing and interpretation of sensor data in order to provide more intelligent teleservices in healthcare.

Over the years these developments represent an evolution towards smart healthcare, making health BAN applications more intelligent by incorporating feedback, context awareness, personalization and Clinical Decision Support. As well as improving the intelligence of mobile services to patients, the use of (distributed and real time) clinical decision support which accepts real-time streaming biosignals as input can also provide a basis for machine learning, enabling adaptive clinical decision support by personalising and adapting strategies to individuals and their changing needs, aiding compliance and potentially supporting sustainable behavioural change.
1.1.2 A mobile application for weight management

The objective of the FOVEA project is to change consumer behaviour in the direction of a healthier lifestyle by applying behavioural theory with support from ICT, including ambulatory monitoring technology based on our experience of developing health BANs. The aim is to support sustainable behavioural change with respect to food and drink consumption and exercise in order to improve health and wellbeing and prevent chronic illness. The approach is to provide real-time personalised feedback and advice at the point of decision making. In the weight management application the advice is tailored to the individual's weight management goals and stage of change. We target the inclined abstainer who is an external eater in the Action stage of the Stages of Change model [9-10]. The Restaurant of the Future (RoF) [11] in Wageningen, The Netherlands, provides an instrumented environment which was used in FOVEA and later in EIT Health Consumptions as a test bed for interactive research in a real-life setting. The RoF infrastructure includes video cameras for behavioural observation, weight-scales at the checkouts and automatic registration of individuals’ food and drink consumption at the point of sale terminals. It also offers possibilities for altering the ambient environment in order to investigate effects on physiology and behaviour of subtle changes in environmental factors.

A prototype of the entire FOVEA system, integrating components from the RoF infrastructure with the food database of the restaurant supplier, was developed and a study was conducted in 2011 at the RoF involving 30 users selected from regular visitors to the RoF who have BMI 25.00-29.99 (WHO classification “overweight, pre-obese” [12]). A dietician formulated a plan with each user, including up to five lunch compositions (each with up to five food items) to match the user’s personal goals and preferences. These trial users were surveyed after the experiment in the ROF and the results of that survey are reported elsewhere.
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The mobile part, the FOVEA BAN, is a small part of a larger distributed FOVEA system. The mobile system designed is to give real-time monitoring and personalized feedback. The FOVEA mobile system conforms to our BAN architecture; in this case the BAN consists of a smartphone and a single sensor: the smartphone’s on board accelerometer. The FOVEA BAN was implemented as a smartphone application on a Samsung Galaxy S running Android. Food and drink consumption is registered on the smartphone, physical activity is monitored and feedback is given in real time. The mobile application detects the different self service buffets in the RoF. By means of indoor positioning, a map of the layout of the RoF, connection with the food database and knowledge of the individual’s targets, the mobile application is able to guide the user away from less healthy options (using a cue avoidance strategy) and towards healthier options and balanced meal compositions.

The FOVEA BAN stores the user’s profile and keeps track of their energy balance throughout the day. In the RoF the BAN can be used to display the food and beverage selections on offer, allowing the user to check an item before making a selection. “Good” and “bad” selections are highlighted to help the user make healthy consumption decisions. Energy values of food and beverage items on offer are stored in a food database and are used to track total kilocalories of items selected. Registration of food and beverage consumption on the smartphone enables real time estimation of energy intake and helps the user to manage their daily energy budget.

Once the user enters the restaurant, the BAN begins to discover the buffets, which are identified by Bluetooth beacons. The floor plan of the restaurant is displayed on the smartphone screen together with a description of the buffets where the items recommended by the nutritionist can be found. When the user selects one of the discovered buffets, information about those food items is retrieved from the restaurant's database and presented to the user. When a food selection (and confirmation) is made, it is added to the smartphone's database and its calories are added to the user's daily energy intake.

In addition to calculating energy intake, real-time measurement of physical activity (using the smartphone’s on-board tri-axial accelerometer) is used to estimate energy expenditure (EE) in real time. Energy Expenditure estimation is based on a step counting application from MobiHealth B.V. The algorithm has been validated against the OMRON Walking Style Pro. The step count is input to an EE algorithm which was developed during the FOVEA project. The algorithm uses the Harris Benedict method of calculating basal metabolic rate (BMR).

Fig. 4 shows four of the screen displays: the restaurant floor plan, the list of buffets, the energy screen, and the impact of consuming one item (in this case a can of Coca Cola) on energy balance on the right. The last screen shows that consumption of a certain soft drink is not compliant with the current lunch composition (selected by the user on the basis of advice from the dietician adapted to user preferences) and would send their Temporary Energy Balance negative. Thus the user can do a what-if analysis before finalising his selection.
In the following section we describe a survey of 95 potential stakeholders/users of FOVEA. This survey is designed primarily to elicit professional attitudes to and feedback on the weight management application and on the wider applicability of the FOVEA system in general.
1.2. The survey

The objective of the survey is to research the business case for FOVEA by surveying a range of stakeholders including users, developers, industry and researchers in relevant fields in order to establish stakeholder requirements needed to arrive at a FOVEA service that can be deployed full scale. Stakeholders are offered different usage scenarios and revenue models. Section 1.2.1 describes the methodology used. Section 1.2.2 characterizes the sample and Section 1.2.3 presents the results. The results have many implications for the evolving design, including issues relating to long term adherence and hence sustainability.

1.2.1 Methodology

The online survey was aimed at professionals from fields relevant to the FOVEA system in general and to weight management application in particular. The online questionnaire was developed by Val Jones with help from members of the FOVEA project and was administered by Noldus Information Technology BV using Formsite. An invitation to participate was sent by email. Below is an extract from the invitation:

As part of the FOVEA system for monitoring, reasoning and feedback we have developed a personalised application to support health and wellbeing. One application of the FOVEA system is designed to achieve a healthy balance between eating behaviour and exercise.... The aim is to support sustainable behavioural change with respect to healthy living.

Respondents were presented with a description of the FOVEA system and the weight management application. The questionnaire elicits the stakeholders’ attitudes and feedback as follows:

- General attitudes towards healthy lifestyle
- Specific feedback on the FOVEA system and weight management application
- Perceived economic value (using Willingness To Pay (WTP) under different revenue models and different usage scenarios)
- Privacy and data ownership
- Potential extension to other (lifestyle or health) applications

In addition the survey invites these professionals, if interested, to answer some user-oriented questions relating to their interest or otherwise as potential end users of the weight management application. The survey includes multiple choice questions and free text responses. A small pilot of 13 test subjects was conducted during June 2011 and the comments and feedback of the pilot subjects were used to improve the survey. The full survey was launched on 28th June. The survey was closed on August 1st 2011. The results were analysed by Jantine Duit of Noldus Information Technology BV using the Formsite analysis software, which produces the coloured histograms seen in the following section.

1.2.2 The sample

The invitation to participate was sent to 554 individuals drawn from: a selection of 523 contacts from the database of Noldus Information Technology BV, selected on grounds of relevant profession/research area; plus the FOVEA Stakeholders Group (12); selected participants at the Artificial Intelligence in Medicine (AIME) 2011 conference (15); and colleagues of a related project (4). 94 email invitations bounced with a failed delivery message, 22 produced an out-of-office response, hence 116 invitations that we know of were not delivered or not delivered in time. When the survey closed there were 95 responses. Assuming that the remaining 438 were delivered, this gives a response rate of 95/438 * 100 = 22%, quite high for this type of survey, especially considering the time of year (summer vacation).
Responses were received from 23 countries; the majority of respondents are currently living in Europe (with The Netherlands and Germany most numerous), followed by the USA. The remainder are living in United Arab Emirates, South Africa, the Russian Federation, China, Canada, Australia and Argentina.

Responses were evenly split between male and female (46:47) indicating that (at least in this self-selected sub-sample of the sample) males are equally interested in lifestyle and weight management as females. This may simply reflect professional interest rather than personal interest since the survey was targeted at relevant professional groups.

Age bands 21-30 to 61-70 were represented, with the majority falling into age range 31-50. As can be expected, given the target population, the respondents were almost exclusively highly educated (university/college degree or higher degree) and/or professionally qualified.

In Section 1.2.3 below a sample of questions and responses are presented.

1.2.3 Survey Results

In this section we present the results of the survey. For reasons of space we omit some questions and many of the histograms, showing the result summary only.

1.2.3.1 General attitudes towards healthy lifestyle in terms of importance of diet and exercise.

Questions 1-4, relating to attitude towards healthy lifestyle in terms of importance of diet and exercise, show that a majority (83/95) are interested in healthy lifestyle and/or weight management. The majority of those were interested in healthy lifestyle and/or weight management as private individuals (54/83) as well as from a professional viewpoint (49/83). Almost all (93/95) agreed that a healthy diet is important or very important and that regular exercise is important or very important (94/95). The conclusion, not surprisingly, is that these respondents have a positive belief in the importance of healthy lifestyle.

1.2.3.2 Reactions to the FOVEA weight management application in particular

Questions 5-14 sought reactions to the FOVEA weight management application in particular. Before these questions were presented, a series of informative screens were displayed which explain the application in some detail illustrated by some of the smartphone screenshots from the weight management app.

**Q5. How do you rate the FOVEA smartphone application as a helpful diet and exercise aid? (N = 95)**

73/95 judged the FOVEA smartphone application as very good or good as a helpful diet and exercise aid. 17 replied neutral, 5 judged it as bad or very bad.
A similar pattern was observed for the usefulness of the FOVEA application for supporting healthy eating choices. (Q6. How do you see the usefulness of the FOVEA application for supporting healthy eating choices?)

Q7. Would you be interested in using the FOVEA application? *

The respondents were more evenly split on the question of whether they were interested in using the FOVEA application: Yes: 44/95, No: 34, I don’t know: 17. The 44 who answered Q7 positively were asked (Q8) on whose behalf they were interested in using the FOVEA application. Multiple responses were allowed (and used). 24/44 were interested in the application themselves as a professional, three for their patients or clients; 30 were interested themselves as private individuals; and ten were interested on behalf of family or friends. So to summarise, more than half were interested in their capacity as private individuals as well as in a professional capacity.

Q9. What kinds of feedback on diet and exercise would you like to see? [free text response]

Out of N=95, 35 responded. Several responses were negative; the criticisms included the opinion that the system was too complicated, or overambitious. Another criticized the imbalance between diet and exercise and highlighted some shortcomings of accelerometry for energy expenditure estimation. Another suggests that GPS monitors would be a better choice for exercise monitoring. However current GPS solutions would miss out all indoor exercise. Indeed accurate estimation of total energy expenditure (indoors as well as outdoors) does remain a challenge.

Further, respondents wanted positive feedback when they make good choices and warnings when they make poor choices, with warnings possibly including likely consequences of poor choices on body weight; tracking of progress in diet and exercise including longitudinal information; better balance between diet and exercise information and relating the two; more feedback relating to exercise; menu or food suggestions; special diet information; nutritional profile and value of food options and more visuals.

Q10. What positive aspects of the FOVEA application do you see? [free text response] R=74/95

Most responses were positive. The features mentioned as positive aspects fall into the following categories: Awareness raising at point of purchase and consumption; Tracking (of physical activity, of food intake); Linking of eating behaviour with physical activity and health implications; Daily and real time checking (of food intake and activity); User friendliness, attractiveness, ease of use, convenience, simplicity; Easy for consumers to understand; Ability to check out food choices and meal options; Good Real time feedback which can have immediate effects on behavior; Objective information and advice; Implications of choices are visible; Personalization of feedback; Support of planning, goal setting, record keeping; Information enables informed decision making to achieve balance; Automated calorie counting and warnings; Use of positive and negative reinforcement; User has a chance to override the system, teaching self-control; usable at all times; Targeting behavioural change.

Some respondents were skeptical: one replied to the effect that if the system worked it would provide very good feedback, but was doubtful whether the system would meet its claims. Another respondents saw no positive aspects whatever.

Q11. What negative aspects of the FOVEA application do you see? [free text response] R= 74/95

6/74 respondents replied that they saw no negative aspects to the FOVEA application. Others saw a number of negative aspects. One felt cheated, seeing the survey as a marketing exercise. The other responses are summarised below: limited environment of use [of the current prototype – one
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restaurant only]; cost and effort of building and maintaining food databases in all relevant settings (and doubts about likelihood of honesty and accuracy for some food suppliers); lack of inclusion: not everyone has (can afford, wants to use) a smartphone, may exclude older people or those with lower literacy; doubts about compliance, privacy, intrusiveness, data security; too complicated, too cumbersome to use; taking enjoyment away from eating; locus of control: warnings too strong, too controlling, Big Brother effect, perceived limitation of freedom could lead to reactance effects in some individuals; doubts about the utility and added value of the information/app (motivated people are usually already well-informed about calorific values and energy expenditure, non-motivated people won't use it, will ignore advice or will cheat); doubts about accuracy of energy intake and expenditure estimation, especially in circumstances such as high intensity workouts or training with weights.

Q12. Are there any additional features you would like to have? [free text response] R=49/95

Out of 49/95 responses, 13 answered with variants of No: (eg. No, None, is enough, can’t think of any).

One respondent pointed out that purchase doesn’t imply consumption (this is a constant challenge in this kind of research).

Other additional features suggested were: More nutritional information, including sugar (for diabetics), lactose, gluten for intolerances; function for scanning products in the supermarket or at home for calorific value; Planning function (for meals, shopping, exercise…); More physiological measures (absorption of eg sugar or fat aliments, pulse rate, heart rate variability, % body fat, hydration levels based on consumption); suggestions for more healthy meal options and sustainable options, recipe creation; better activity measurement eg based on MET tables or GPS; feedback from an exercise professional preferably someone with ACSM certification; alarms; sleep monitoring; Suggestion of extra exercise to offset over consumption of calories; Social reinforcement: buddy system, reward system for good choices, competition among friends.

Q13. Where do you think that FOVEA would be most useful? #

Reponses to this multiple response question shows that roughly a third of the respondents recognized the usefulness of FOVEA in each of: restaurants, supermarkets, at home; slightly fewer selected at work (21/95) and at the gym (16/95). 27/95 selected everywhere. Seven selected other and made further comments; responses under Other included views that the application needs to be ubiquitously available to be effective and that it should be on a personal device.
Q14. Who do you think would benefit most from FOVEA? #

N = 95

23/95 thought everybody would benefit, people who eat too much (21) or exercise too little (12), 47/95 mentioned people who want to live healthily and 29 – mentioned people with specific illnesses.

1.2.3.3 Willingness To Pay
Q15-16 relate to Willingness To Pay (WTP) [13] using two business models: one off payment for a smartphone application, and monthly subscription to a smartphone service respectively. Any currency is accepted; responses were converted to Euros before the graphs were produced.
Q15. If you could buy the FOVEA application for your phone, how much would you be willing to pay for it? Please indicate which currency you are using.

Respondents’ WTP as a one-off payment for a phone app, based on the description given, ranged from €0 to €150, with Mean €22.1, SD 34.
Q16. If the FOVEA application was available by monthly subscription, how much would you be willing to pay for the service per month? Please indicate which currency you are using.

N=68

Respondents’ WTP as a monthly subscription for a phone app, based on the description given, ranged from €0 to €50, with Mean €5.1, SD 8.6.

The respondents are then presented with the possibility of extending the current FOVEA service beyond the limited setting of the experimental prototype (one restaurant) as described in the informative screens, to (potentially) a scenario where the service is available at all times and places where food and drink purchasing decisions are made.
Q17. Would you like to see the FOVEA application extended to link to the product databases in other restaurants/food shops/supermarkets? This way it could assist food purchasing decisions in other places and at other times of the day. *

N = 95
73% (70/95) said they would like to see this extended service.

Q18. Would this increase your desire to buy the application? *

N = 70
61% of respondents to Q18 (43/70) said this would increase their desire to buy the application.

The WTP questions are then repeated in relation to this new scenario in Qs19-20.

Q19. If the FOVEA application could link to all the shops and restaurants where you shop and eat, how much would you be willing to pay for it as a one off payment? Please indicate which currency you are using. N=32

Respondents’ WTP as a one off payment for a phone app, based on the extended scenario, ranged from €1.5 to €175, with Mean €35, SD 37.

The extended scenario saw a rise in mean WTP from €22.1 to €35 for one-off payment.
Q20. If the FOVEA application could link to all the shops and restaurants where you shop and eat, how much would you be willing to pay for it per month? Please indicate which currency you are using. N=33

Respondents’ WTP as a monthly subscription for a phone app, based on the extended scenario, ranged from €2 to €20, with Mean €7.6, SD 17.

The extended scenario saw a rise in mean WTP from € 5.1 to €7.6 for monthly subscription.

1.2.3.4 Privacy issues.

Q21-23 elicit opinions on privacy issues.

Q21. Do you see the FOVEA application as intrusive or not?

![Graph showing opinions on application intrusiveness]

N = 95

Just over half of respondents (48/95, 50.4%) saw the application as quite intrusive or very intrusive.

Q22. Who do you think should be responsible for holding the personal information of the user?

![Graph showing who should hold personal information]

N = 95

The majority of respondents considered that personal information should be held by the user (80/95, 84.2%).
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Under Other one response was blank, the other two were:

Other: the user (so we revise the above result to 81/95)
Other: the smartphone/computer system

Q23. Please comment on your answer, if you wish:

Free text responses showed broad agreement that the data belonged to the user and should only be seen by the user, except where the user grants access to certain professionals to classes of data relevant to their care function. Several responses related motivation to sustainability.

The FOVEA system is a general real-time measurement, reasoning and feedback system for lifestyle applications and hence is much more generic than the single application described here (weight management). Q24 explains this context and elicits ideas about other potential applications.

Q24. The system can in principle be augmented with any body-worn sensors which have a (wireless) communication interface. In addition, new software applications can be implemented to provide all kinds of services involving real time monitoring, processing of biosignals and context data, and user feedback and/or e-coaching. Assuming availability of the necessary sensors, what other applications of the FOVEA real-time measurement, reasoning and feedback system might be of interest to you?

Of the 47 respondents who filled in this question, 12 responded some variant of No or Don’t know. A further five simply answered with a variant of Y, without specifying an application. The suggestions of alternative applications were: research; monitoring sleepiness vs. alertness; stress monitoring; healthcare/wellbeing applications (chronic disease management (diabetes, high cholesterol, hypertension), Children's health & exercise, Rehabilitation); e coaching; Monitoring athletes during training; control household devices.

The remainder did not suggest alternative applications as such but rather suggested extensions to the current application (eg. monitoring blood glucose and hormones in relation to nutrient intake, measure time and distance covered during exercise) or additional individual parameters to be monitored (eg heart rate, temperature, BP, lung capacity, body fat percentage, biomarkers of health status, fluids), additional sensors (eg step counter, movement recorder) or extra features (eg. graphing, transmission of data, ability to combine group data).

1.2.3.5 Other comments

Q25. If you have any other comments on FOVEA please add them here.

Responses to Q25 were mainly positive, mentioning for example a good application concept, usefulness and convenience. Some questioned whether motivation would be sustained and whether sufficient feedback was given. Another issue was the complexity of providing adequate coverage of the huge range of food items available. One responder felt the product was not viable.
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1.2.3.6 The professionals as potential end users

27-34 are directed at end users of the weight management application. Before Q26 a screen invites the respondent, if interested, to adopt the role of potential user and answer the user-oriented questions. They are given the option to skip this section. 28/95 (29.4%) of respondents exercised the option to answer the user-oriented section. Therefore for Qs27-34, max. N is 28.

Q27. Are you happy with your weight at present?

N = 28

64.2% of the respondents (18/28) claimed to be happy with their present weight (although responses to the following question (Q28) show that nearly half considered themselves to be overweight); the remainder consider themselves to be the right weight. None considered themselves underweight, very underweight or very overweight.

Q28. Do you consider yourself to be:

N = 28
Q29. Do you want to make changes to your diet?

N = 28

Q29 shows that 57.1% (16/28) stated that they wanted to make changes to their diet and Q30 shows that 64.2% (18/28) stated that they wanted to make changes to their exercise habits. 67.8% (19/28) say they have tried to change their weight by means of diet and/or exercise in the past (Q31) reporting this was very successful (26.3%: 5/19), quite successful (63.1%: 12/19) and not at all successful (10.5%: 2/19) (Q32).

Q30. Do you want to make changes to your exercise habits?

N = 28

18/28 said they wanted to change their exercise habits, 7 do not and 2 don’t know.
Q31. Have you tried in the past to change your diet and/or exercise pattern in order to lose weight or increase in weight? * 

19/28 have tried in the past to change their diet and/or exercise pattern in order to lose weight or increase weight.

Q32. How successful were you in losing weight or increasing in weight? * 

Q32 was only presented to respondents who answered “Yes” to the previous question, hence N=19, despite this being a mandatory question.
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Q33. How long did you maintain your new weight?

N = 17

64.7% (11/17) reported success in maintaining their new weight over a period of months, and 29.4% (5/17) over years.

Q34. Has a health professional ever told you that you were: #

N = 28

7/28 reported being told they were overweight, and 1/28 obese, by a health professional. Compare with 13/28 self-reported overweight (Q28).

The remaining questions related to demographics and are summarized above in the description of the sample.

Q40. Please describe the kind of organization that you work for as precisely as possible.

The responses describing the organisations respondents work for (sometimes multiple organisations per respondent) are classified below:

- Research Institute/University (41) with some specifying further as: medicine, nutrition, food and drink research organizations, exercise science, rehabilitation, Emotion research;
- Food Industry (10): fragrance & flavor supplier, Manufacturer of healthy foods, Dairy company, food company, project development in food and health, Research lab of dairy company, Research center in large food company, Wageningen University Restaurant of the Future, Spice and seasoning manufacturers, food manufacturer in CPG (frozen foods, condiments, sauces) and Foodservice (condiments, sauces);
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- Healthcare (7): child rehabilitation, Healthcare company, hospital, Research Association, Obesity clinic/care (3);
- Other Industry (6): SAP AG, IT hardware, software and services provider, Cosmetic company, Consumer Product Goods, Fast Moving Consumer Goods Industry, telecommunications;
- Government (2): public government, Government Research Agency;
- R&D (2): R&D, Fortune 100 company in corporate R&D;
- Press and Media (1);
- Sport (1);
- Miscellaneous: Agency, consultant on various funded grants, user centred design, top support and innovation lab, independent, market research agency.

A small minority of the professionals surveyed belonged to consumer groups (6/94), patient groups (4/94) or other relevant groups (11/94).

Most questions were optional and therefore could be skipped. 94/95 respondents stayed with the survey and answered all up to the final question.

1.3. Summary of findings

This section summarises the findings from the market survey, according to the different sections of the questionnaire.

1.3.1 General attitudes towards healthy lifestyle

Results relating to attitude towards healthy lifestyle in terms of importance of diet and exercise (Q1-4) show that a majority (83/95) are interested in healthy lifestyle and/or weight management. The majority of those were interested in healthy lifestyle and/or weight management as private individuals (54/83) as well as from a professional viewpoint (49/83). Almost all (93/95) agreed that a healthy diet is important or very important and that regular exercise is important or very important (94/95).

1.3.2 Specific feedback on the FOVEA system and weight management application

(Qs5-14) invite opinions on the FOVEA weight management application. 73/95 respondents judged the FOVEA smartphone application as a helpful diet and exercise aid as very good or good. 17 replies were neutral, 5 judged it as bad or very bad. A similar pattern was observed for the usefulness of the FOVEA application for supporting healthy eating choices. Respondents were more or less evenly split on the question of whether they were interested in using the FOVEA application.

Of those who were interested, 24/44 said they were interested in the application themselves as a professional, three for their patients or clients; 30 were interested themselves as private individuals; and ten were interested on behalf of family or friends. So, more than half were interested in their capacity as private individuals as well as the (overlapping) interest in a professional capacity.

Q9 (What kinds of feedback on diet and exercise would you like to see) produced many positive suggestions and also some criticisms. Critical points included: an imbalance in the application between diet and exercise (focus on diet, not enough focus on exercise); the shortcomings of accelerometry for accurate measurement of exercise intensity; and a plea for inclusion of expertise from exercise professionals.

Many constructive suggestions were made, such as inclusion of: positive feedback for good choices and warnings for poor choices that include likely consequences for effect of poor choices on body
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Weight; Progress over time, weight tracking and correlation to progress; Plan vs. reality = balance; and guidelines and suggestions for exercise.

Other ideas were: suggestions for food alternatives and suggestions for healthy food in the restaurant; and assistance on healthy choices. Several respondents asked for more or more specialised nutritional advice on healthy food in the restaurant; and nutritional profile and value of food options.

Main positive aspects of the FOVEA application reported were: information/raised awareness at point of purchase and consumption; real time personalized feedback; tracking (of physical activity, of food intake) enabling informed decision making to help achieve a balance; automation (of calorie counting, of warnings); targeting of behavioural change; and use of positive and negative reinforcement. Respondents also mentioned user friendliness, attractiveness, ease of use, convenience, and simplicity as positive features.

When asked about negative aspects of the FOVEA application, notable points related to: the cost and effort of building and maintaining food databases in all relevant settings; (and also doubt was expressed on the likelihood of honesty and accuracy in case of some food suppliers); lack of inclusion (not everyone has, or can afford, or wants to use) a smartphone, so the application may exclude older people or those with lower (computer) literacy; likelihood of compliance; issues relating to privacy, intrusiveness, data security and locus of control (too controlling, Big Brother effect). Further doubts were expressed about the utility and added value of the information/app (balance is too much towards diet and not enough towards physical activity; doubts about accuracy of energy intake and expenditure estimation, especially in circumstances such as high intensity workouts or training with weights).

When asked about where you think that FOVEA would be most useful? roughly a third of respondents recognized the usefulness of FOVEA in: restaurants, supermarkets, and at home; slightly fewer selected at work (21/95) and the gym (16/95). 27/95 selected everywhere.

When asked about who would benefit most from FOVEA, 23/95 thought that everyone would benefit, 21 ticked people who eat too much; 12 ticked people who exercise too little; 47 mentioned people who want to live healthily and 29 mentioned people with specific illnesses.

1.3.3 Perceived economic value

Q15-16 relate to Willingness To Pay (WTP) [13] using two payment models: one off payment for a (smart)phone application, and monthly subscription to a (smart)phone service respectively. Respondents’ WTP as a one-off payment for a phone app, based on the description given in the questionnaire, ranged from €0 to €150, with Mean €22.1, SD 34. Respondents’ WTP as a monthly
subscription for a phone app, based on the description given, ranged from €0 to €50, with Mean €5.1, SD 8.6.

The respondents were then presented with the possibility of extending the current FOVEA service beyond the limited setting of the experimental prototype (one restaurant) as described in the informative screens, to (potentially) a scenario where the service is available at all times and places where food and drink purchasing decisions are made. The majority (70/95)said they would like to see the FOVEA application extended to link to the product databases in other restaurants/food shops/supermarkets to assist food purchasing decisions in other places and at other times of the day. 43/70 said this would increase their desire to buy the application. The Willingness to Pay questions were then repeated with the proviso that “the FOVEA application was linked to all the shops and restaurants where you shop and eat”. Respondents’ WTP as a one off payment for a phone app, based on this extended scenario, ranged from €1.5 to €175, with Mean €35, SD 37. The extended scenario saw a rise in mean WTP from €22.1 to €35 for one-off payment. Respondents’ WTP as a monthly subscription for a phone app, based on this extended scenario, ranged from €2 to €20, with Mean €7.6, SD 17. The extended scenario saw a rise in mean WTP from € 5.1 to €7.6 for monthly subscription.

1.3.4 Privacy and data ownership

Q21-22 elicit opinions on privacy issues. 48/95 respondents (50.4%) saw the application as quite intrusive or very intrusive. The majority considered that personal information should be held by the user (80/95, 84.2%).

In summary we can say that there was broad agreement that the data belonged to the user and should only be seen by the user, except when the user grants access to certain professionals to classes of data relevant to their (care) function.

1.3.5 Potential extension to other (lifestyle or health) applications

Q24 ( …Assuming availability of the necessary sensors, what other applications of the FOVEA real-time measurement, reasoning and feedback system might be of interest to you?) produced a number of suggestions of alternative applications as follows: Research: monitoring sleepiness vs. alertness; stress monitoring; healthcare/wellbeing applications (chronic disease management (diabetes, high cholesterol, hypertension); Children's health & exercise, Rehabilitation); e coaching: Monitoring athletes during training , control household devices.

3.6 User-oriented questions

Q27-34 are directed at end users of the weight management application. Before Q26 a screen invites the respondent, if they are interested, to adopt the role of potential user and answer the user-oriented questions, but also giving the option to skip this section. 28/95 (29.4%) of respondents exercised the option to answer the user-oriented section.

A total of 18 of the 28 respondents to the user-oriented section claimed to be happy with their present weight (although responses to the following question (Q28) show that nearly half considered themselves to be overweight); the remainder consider themselves to be the right weight. None considered themselves underweight, very underweight or very overweight.

A total of 16/28 stated that they wanted to make changes to their diet and 18 stated that they wanted to make changes to their exercise habits. 19/28 say they have tried to change their weight by means of diet and/or exercise in the past; 5/19 reported this was very successful, 12/19 quite successful and 2/19 not at all successful. 18/28 want to change their exercise habits, 7 do not want to change their exercise habits and 2 answered don’t know.

19/28 have tried in the past to change their diet and/or exercise pattern in order to lose weight or increase weight. Of these 19, a total of 5 reported that this was very successful, 12 quite successful and 2 not at all successful. 11/17 reported success in maintaining their new weight over a period of months, and 5/17 over a period of years.

7/28 reported being told they were overweight, and 1/28 obese, by a health professional. (Compare with 13/28 self-reporting as overweight.)
1.4. Discussion and conclusions

Results relating to general attitude towards healthy lifestyle in terms of importance of diet and exercise show that a large majority of the sample reported that they were interested in healthy lifestyle and/or weight management. The majority of those were interested as private individuals as well as from a professional viewpoint. All but two (N=95) agreed that a healthy diet is important or very important and all but one that regular exercise is important or very important.

Regarding feedback on the FOVEA system and weight management application, 73/95 respondents judged the FOVEA smartphone application as a helpful diet and exercise aid. Respondents were evenly split on the question of whether they were interested in using the FOVEA application. Critical points included: focus on diet, not enough emphasis on exercise and the shortcomings of accelerometry for accurate measurement of exercise intensity.

Main positive aspects of the FOVEA application reported were: information/raised awareness at point of purchase and consumption; real time personalized feedback; tracking (of physical activity, of food intake) enabling informed decision making to help achieve a balance; automation (of calorie counting, of warnings); targeting of behavioural change; and use of positive and negative reinforcement. Respondents also mentioned user friendliness, attractiveness, ease of use, convenience, and simplicity as positive features.

Negative aspects of the FOVEA application raised related to: the cost and effort of building and maintaining food databases in all relevant settings; lack of inclusion (not everyone has, or can afford, or wants to use) a smartphone, so the application may exclude older people or those with lower (computer) literacy; likelihood of compliance; issues relating to privacy, intrusiveness, data security and locus of control and Big Brother effect. Some doubts were expressed about the utility and added value of the information/app (eg. doubts about accuracy of energy intake and expenditure estimation, especially in circumstances such as high intensity workouts or training with weights).

Roughly a third of respondents recognized the utility of the FOVEA weight management application in the following settings: restaurants, supermarkets, and at home.

Regarding perceived economic value, questions relating to Willingness To Pay (WTP) used two payment models: one off payment for a (smart)phone application, and monthly subscription to a (smart)phone service respectively. Respondents’ WTP as a one-off payment for a phone app, based on the description given in the questionnaire, with the limited usage scenario of the RoF only, ranged from €0 to €150, with Mean €22.1, SD 34. Respondents’ WTP as a monthly subscription for a phone app, based on the description given in the questionnaire, with the limited usage scenario of the RoF only, ranged from €0 to €50, with Mean €5.1, SD 8.6.

The majority said they would like to see extension of the FOVEA application to link to the product databases in other restaurants/food shops/supermarkets to assist food purchasing decisions in other places and at other times of the day. 43/70 said this extended scenario would increase their desire to buy the application. Respondents’ WTP as a one off payment for a phone app, based on this extended scenario, ranged from €1.5 to €175, with Mean €35, SD 37. The extended scenario saw a rise in mean WTP from €22.1 to €35 for one-off payment. Respondents’ WTP as a monthly subscription for a phone app, based on this extended scenario, ranged from €2 to €20, with Mean €7.6, SD 17. The extended scenario saw a rise in mean WTP from €5.1 to €7.6 for monthly subscription.

Regarding Privacy and data ownership there was broad agreement that the data belonged to the user and should only be seen by the user, except when the user grants access to certain professionals to classes of data relevant to their function.

Regarding Potential extension to other (lifestyle or health) applications, suggested alternative applications were made as follows: research: monitoring sleepiness vs. alertness; stress monitoring; healthcare/wellbeing applications (chronic disease management (diabetes, high cholesterol, hypertension); children's health and exercise, rehabilitation); e coaching; Monitoring athletes during training, control household devices.
Regardless **attitudes as potential users themselves**, a total of 18/28 of these (professional) respondents claimed to be happy with their present weight (although responses to another question show that nearly half considered themselves to be overweight); the remainder consider themselves to be the right weight. None considered themselves underweight, very underweight or very overweight.

A total of 16/28 stated that they wanted to make changes to their diet and 18 stated that they wanted to make changes to their exercise habits. 19/28 say they have tried to change their weight by means of diet and/or exercise in the past; 5/19 reported this was very successful, 12/19 quite successful and 2/19 not at all successful. 18/28 want to change their exercise habits. 19/28 have tried in the past to change their diet and/or exercise pattern in order to lose weight or increase weight. Of these 19, a total of 5 reported that this was very successful, 12 quite successful and 2 not at all successful. 11/17 reported success in maintaining their new weight over a period of months, and 5/17 over a period of years. 7/28 reported being told they were overweight, and 1/28 obese, by a health professional. (Compare with 13/28 self-reporting as overweight.)

In December 2012 a further experiment was conducted at the ROF using the new version of the system developed during EIT Healthy Consumption. Results of that experiment will be reported elsewhere. The results of the FOVEA project including the survey described in this chapter and other FOVEA surveys and experiments feed into the EIT Healthy Consumption project.

According to the World Health Organization more than 1.4 billion adults were overweight worldwide in 2008. Of these adults over 200 million men and nearly 300 million women were obese [14]. In 2012 Lee et al [15] published results in The Lancet showing that physical inactivity caused 9% of premature mortality worldwide in 2008.

Even amongst this well informed and well motivated group of subjects, attempts to maintain health weight were shown to be poor in the long term; less than a third managed to sustain their new weight over a period of years (Q33). In order to support healthy lifestyle in way that sustains motivation and brings long terms results, we need to continue multidisciplinary study in order to evaluate and improve ICT support such as the FOVEA BAN application in order to contribute positively to this burgeoning health problem. If we can be successful the health benefits van be great. Lee et al estimate that if inactivity were decreased by only 10%, more than half a million deaths could be averted every year worldwide. Furthermore if physical inactivity were eliminated completely this would increase the life expectancy of the world`s population by 0.68 years [15].

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