1   **AN INTERACTIVE MOBILE PHONE APPLICATION, SMART 5-A-DAY, FOR INCREASING KNOWLEDGE**

2   **OF AND ADHERNCE TO FRUIT AND VEGETABLE RECOMMENDATIONS: DEVELOPMENT AND**

3   **RANDOMIZED CONTROLLED TEST**

4

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17   **Short title: SMART 5-A-DAY: Development and initial test**

18

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20 **ABSTRACT**

21 Background: Fruit and vegetable (FV) consumption is important for health, but many individuals fail

22 to consume adequate FV for health benefits. While many individuals are aware of current FV

23 consumption recommendations, research suggests that adherence to these recommendations is

24 hampered by low knowledge of the details of these recommendations.

25 Purpose: This paper reports the development and details of a pilot randomized controlled test of a

26 novel interactive mobile phone application (app) for addressing low knowledge of the UK 5 a day FV

27 recommendations.

28 Methods: Requirements for the app were first defined by researchers and potential end users, and

29 prioritised using the MoSCoW method. A prototype smart phone app was then developed using an

30 agile approach. Third, the prototype app was tested in a randomized controlled pilot trial, for

31 impacts on FV knowledge and FV intakes. Volunteers were randomized to either receive (N=50) or

32 not receive the app (N=44) for two or four weeks, and FV knowledge, FV intakes, and FV behaviour

33 were assessed at study start and after 1, 2, and/or 4 weeks. App usage and qualitative feedback

34 were also investigated. All findings then informed the development of a final app.

35 Results: Low knowledge of the FV recommendations centred around portion sizes and the need for

36 variety, and an interactive mobile phone app was considered a suitable tool for improving this

37 knowledge in a practical manner, that would be available both at time of consumption and outside

38 of these times. The pilot test revealed improved FV behaviour after two weeks compared to baseline

39 in volunteers who received the app, but improvements in FV knowledge were found in both groups,

40 and no improvements in FV intake were found in formal measures. Patterns of app usage and

41 qualitative feedback also suggested a number of modifications. The resultant final app incorporates

42 several behaviour change techniques (goal-setting, self-monitoring, personalised feedback), as well

43 as aiming to improve knowledge.

44 Conclusions: A novel interactive mobile phone app was successfully developed based on

45 requirements, and when tested in a pilot randomized controlled trial, this app was found to have

46 some impacts on FV outcomes. While benefits from the app were small, impacts will likely increase

47 as a result of recent modifications. The final SMART 5-A-DAY app is available in the Google Play Store

48 and now needs testing in the target population.

49 Trial registration: www.clinicaltrials.gov (ID NCT02779491).

50

51 **Keywords**: fruit and vegetables, 5-a-day message, knowledge, questionnaires, portion sizes, variety

52

INTRODUCTION

A high consumption of fruits and vegetables (FV) is associated with reduced risk of a number of global health concerns [1-10]). Resulting from these health benefits, the World Health Organisation currently recommends consumption of at least 400g FV/day [3-6], and governments around the world have operationalised these recommendations as recommended consumption of a number of portions of FV per day. Campaigns promoting these FV recommendations are easily available, but despite the campaigns, population FV intakes in Europe, the US and across the world, remain low [11-14].

Populations do seem largely aware of the FV consumption recommendations [15-21], and awareness of the recommendations has been associated with improved FV consumption [15,16,18,22,23]. Difficulties are reported, however, with the details of the recommendations. Consumers report confusion and poor knowledge around the foods that can be included as FV [24,25], the amount of FV required in portion sizes [24-28], or contributing to portion sizes, when portion sizes may be small, e.g. for small fruits or in composite dishes [25], the number of portions needed per day [28], the need for a variety of FV [24,25] and the benefits of a high FV consumption [26,27]. Furthermore, recent work of ours reported not only low knowledge of the details of the recommendations, but also a direct association between low knowledge of these details and low FV consumption [15]. These findings suggest that FV consumption would benefit from increasing knowledge of the details of FV recommendations.

Nutrition-related knowledge has previously been related to FV consumption [29-31], and is traditionally increased through educational campaigns and classes [e.g. 1,31-33]. Educational campaigns however can be limited in scope and classes can be limited in reach [32,33]. Educational campaigns furthermore, typically demonstrate success for improving very limited knowledge, while educational classes can achieve increases in knowledge, and can be particularly valuable for teaching practical knowledge and for encouraging engagement, knowledge retention and future use, but these are impractical for population-wide change [32,33].

This work sought to increase knowledge of the details of the UK FV recommendations both in a practical sense by providing details of the FV recommendations at the time of consumption to aid appropriate FV intakes, and by providing these details in an engaging, useful and personally relevant manner, such that individuals would remember and benefit from those details also at a later time point [31-33]. To fulfil this aim, a mobile phone application was developed. Mobile phone

87 applications (apps) can provide information to consumers at the time of food purchase and

88 consumption, as well as outside of these times, and can offer an interactive platform encouraging

89 practical use, personal relevance and practical benefit to encourage information retention and

90 future use. Of specific relevance to this work, an app was initially considered suitable for developing

91 knowledge on FV recommendations, because an app could: allow users to input FV and receive

92 immediate feedback on inclusion or not in the FV recommendations; allow users to input any

93 amount of FV, regardless of contribution to an official portion, and receive immediate feedback on

94 portion sizes; store and add inputted FV to provide a running total; relate this total to

95 recommendations; incorporate the need for variety as part of the portion size and running total

96 function; provide all information quickly, with minimal effort for the user; utilise attractive and

97 colourful visual displays; and an app could be mobile and so could address concerns at time of

98 purchase and at time of consumption, as well as outside of these times. The potential value of smart

99 phone apps is also aided by rapidly growing numbers of smart phone users with penetration rates of

100 68.4% in North America and 64.7% in Western Europe and estimations of use by over a third of the

101 world's population [34].

102

103 Mobile phone apps for encouraging healthy eating are widely available, and some also focus

104 specifically on encouraging FV, fruit or vegetable intakes [35-40]. While these existing FV apps

105 largely focus on encouraging intakes and changing behaviour [35-40], the focus of our work was to

106 facilitate knowledge of FV consumption recommendations, such that this would result in increased

107 adherence to recommendations and intakes. Previous work demonstrates particular confusions with

108 FV recommendations and suggests that clarification of this knowledge may encourage FV

109 consumption. Our aim was primarily to teach knowledge and facilitate retention and future use of

110 that knowledge, such that FV intakes would benefit both at the time of app use and in the future

111 without the need for ongoing app use.

112

113 This paper reports the development of a prototype app, the results of a subsequent pilot trial to test

114 the app for improvements in FV recommendation knowledge and intake, and suggested

115 improvements. First, the requirements for the app were defined from the literature and potential

116 end users, and prioritised using the MoSCoW method [41]. Then a prototype app was designed and

117 developed using an agile approach based on Google's Material Design Guidelines and best industrial

118 practice [42]. The prototype app was then tested in a randomized controlled trial, where end users

119 also provided qualitative feedback, and lastly an amended version of the app was developed. The

120 app was developed specifically for a UK audience, thus current UK FV recommendations were used.

121 These recommendations specify the consumption of five 80g portions of different FV per day - the 5-

122 a-day FV recommendations [43,44].

123

124 **METHODS**

125 **STAGE 1: DEFINING AND PRIORITIZING THE APP REQUIREMENTS**

126 **Defining the app requirements**

127 App requirements were defined based on previous published research and engagement with

128 potential end-users. Previous published work by ourselves and others has investigated the confusion

129 and concerns of individuals regarding FV recommendations [15-20,23-28].

130

131 Further engagement with potential end-users was also undertaken at four public engagement

132 workshops in Bournemouth, UK, in July 2014 and July 2015. These workshops were undertaken as

133 part of Bournemouth University's Festival of Learning 2014 and 2015, were entitled 'The 5-a-day

134 fruit and vegetable message' and marketed for the general public. The workshops detailed current

135 FV recommendations for the UK, asked consumers for their knowledge and confusions, addressed

136 these confusions and provided advice for increasing intakes. Finally, participants were asked for the

137 appropriateness of an app to help solve their confusions and encourage intakes. Four workshops

138 were held at a number of different times in the day to allow attendance by a range of different

139 individuals. Each workshop was run by the project PI (KMA) and either audio-recorded and

140 transcribed or notes of all suggestions were taken at the time by an additional researcher. Each

141 workshop followed the same format. All transcriptions and notes were subsequently analysed using

142 thematic analysis.

143

144 **Prioritizing the app requirements**

145 Suggested requirements for the app from both the literature and the public engagement workshops

146 were then discussed and prioritised by the principal researchers (KMA, NJ) using MoSCoW principles.

147 The MoSCoW method [41] is a technique used in software development to prioritize the importance

148 of the delivery of all identified requirements. Requirements are categorized as 'Must have', 'Should

149 have', 'Could have', and 'Won't have', based on importance, and then prioritized during the

150 development process in this order. Requirements identified as 'must have' are considered central to

151 project success; those identified as 'should have' are considered important, but not necessary; those

152 identified as 'could have' are considered desirable but not necessary; and those identified as 'won't

153 have' are considered least important [41]. Consideration was also given to the UK FV

154 recommendations. For example, the UK recommendations stipulate that five different FV must be

155 consumed per day, thus additional consumption of eaten FV would not contribute to the 5-a-day

156 total, and that fruit juices / smoothies can contribute to total FV consumption, but can only count as

157 one portion regardless of variety and quantity consumed [43,44].

158

159 **STAGE 2: DESIGNING AND DEVELOPING THE APP**

160 A prototype app was developed to include all requirements identified as 'must have' and 'should

161 have' and avoid requirements identified as 'won't have'. The app was developed for android smart

162 phones following Google's Material Design Guidelines and industrial best practices, with reference

163 to the adapted Technology Acceptance Model (TAM) [45-47]. The adapted TAM proposes that

164 technology usage is positively predicted by 'perceived usefulness' ("the degree to which a person

165 believes that using a particular system would enhance his or her … performance") [45, pg. 320],

166 'perceived ease-of-use' ("the degree to which a person believes that using a particular system would

167 be free of effort") [45, pg. 320], 'perceived enjoyment' ("the extent to which the activity of using the

168 [technology] is perceived to be enjoyable in its own right, apart from any performance

169 consequences that may be anticipated") [46, pg. 1113], and 'perceived visual attractiveness' (the

170 degree to which a person believes that the [technology] is aesthetically pleasing to the eye) [47].

171

172 **STAGE 3: TESTING OF THE PROTOTYPE APP**

173 Evaluation of the app was undertaken using a randomized controlled pilot trial, where volunteers

174 were randomized to receive or not receive the app for either two weeks or four weeks and FV

175 knowledge, FV intake and FV behaviour were assessed and compared at baseline and after 1, 2

176 and/or 4 weeks.

177

178 **Volunteers**

179 Volunteers to test the app were recruited from the staff and students of Bournemouth University,

180 UK, from Nov. 2015 - March 2016, June 2016 - August 2016, and from Nov. 2016 - March 2017. We

181 aimed to recruit 100 volunteers in total - 50 to test the app and 50 to act as controls. No earlier

182 research was available to allow power calculations, thus 50 volunteers were considered sufficient to

183 gain feedback and assess potential impacts of the app, while ensuring the work would remain ethical

184 should few impacts be found. Adult volunteers (aged 18 years and over) were required to own an

185 Android smart phone (as the app was only developed for Android platforms), and there were no

186 other inclusion / exclusion criteria to maximise the generalisability of the study. Volunteers were

187 recruited for a study to 'test a novel mobile phone app for encouraging healthy behaviours'.

188 Volunteers were thus aware at the study start, that they may or may not receive an app to test, but

189   they were informed that that the app may target one of a number of health behaviours, such as

190   healthy eating, stress reduction or exercising.

191

Intervention / Control

193   Volunteers were randomized to receive the app (intervention) or not receive the app (control).

194   Randomization was undertaken on study entry by drawing lots (participants selected one of two

195   coloured dice from a bag), and recruitment stopped once 50 individuals had been randomized to

196   test the app. All volunteers who received the app were asked to download the app onto their

197   phones, to register with the app to set-up a user profile, and to use the app as often as they wished

198   for either a two week or a four week period. Duration of the test period for two or four weeks was

199   undertaken to estimate effects following very short and longer term use. Various evidence suggests

200   apps can have limited effects on behaviour because an initial high use typically fades [38,39]. Initial

201   download and access to the app was undertaken in the presence of the researcher where possible to

202   ensure correct download. No additional information on the FV recommendations or on FV intakes

203   was provided as part of the study to either group. The only difference between the intervention and

204   control group was the receipt of the app (intervention group) or not (control group). The app was

205   tested for two weeks from Nov. 2015 - March 2016 and from Nov. 2016 - March 2017, and for four

206   weeks from June 2016 - August 2016.

207

Outcomes

209   Awareness of the 5-a-day FV recommendations, FV knowledge, FV intake and FV behaviour were

210   assessed as outcomes. Awareness of the recommendations, FV knowledge and self-reported FV

211   intakes were assessed using a questionnaire previously developed by ourselves [15]. The

212   questionnaire consists of two questions on awareness of the 5-a-day message, four questions on

213   knowledge of the details of the message (which foods are included, portion sizes, the need for

214   variety, reasons for consumption), and two questions on FV intake. Self-reported FV intake was also

215   assessed using a validated FFQ – the Leeds Food and Nutrition Survey [48]. FV behaviour was

216   assessed using a behavioural measure of complementary drink choice. Demographic and lifestyle

217   characteristics that have previously been associated with FV consumption and dietary knowledge

218   [11,15-17,21-24,28] were also assessed as potential confounders. All volunteers (intervention and

219   control) completed all outcome assessments in the same manner. To maximise the data collected in

220   the study period, data was collected from those in the two week study at baseline, week 1 and week

221   2, and from those in the four week study at baseline, week 2 and week 4. The two self-report

222   questionnaires used [15,48] are discussed briefly below and provided in the Supplementary

223   Materials.

224

225   **Awareness of the recommendations:** Awareness of the recommendations were assessed using two

226   open-response questions: 'Are you aware of the 5-a-day fruit and vegetable message?' and 'What do

227   you think it means?'

228

229   **FV knowledge:** FV knowledge was assessed using four structured closed-response questions on: 1)

230   the FV that are included in the UK recommendations; 2) the portion sizes that are required for the

231   recommendations; 3) the variety of FV that is required for the UK recommendations; and 4) the

232   reasons for FV consumption. These questions include: 1) a number of foods; 2) a number of different

233   portions of FV; 3) a number of combinations of FV to be consumed in a day; and 4) a number of

234   different health conditions, respectively, and respondents were asked to report: 1) inclusion in the

235   recommendations or not; 2) contribution to the recommendations based on portion sizes; 3)

236   number of FV portions consumed in the day; and 4) impact of FV on each health condition,

237   respectively. For all questions, a correct response, based on current recommendations from the UK

238   Government [44] is scored +1, an incorrect response is scored -1, and 'don't know / not sure' is

239   scored 0.

240

241   **Self-report FV intake:** FV intake was assessed using one single open-response question, one

242   structured open-response question, and a validated FFQ [48]. The open-response question asked for

243   estimated number of portions of FV consumed per day, to provide a measure of 'Estimated FV'. The

244   structured open-response question requested household amounts (e.g. tablespoons) of all FV

245   consumed at various time points (before breakfast, breakfast, morning, lunch, afternoon, evening

246   meal, evening) on a typical weekday and on a typical weekend day. This questionnaire was used to

247   calculate portions of FV consumed per day, to provide a measure of 'Calculated FV'. The validated

248   FFQ [48] requests frequency of consumption for 65 different foods using the response format 'two

249   or more times a day', 'every day', '3-5 times a week', '1-2 times a week', '1-3 times a month', and

250   'rarely/never', which are subsequently scored '2', '1', '0.5', '0.21', '0.07', and '0' respectively, to

251   provide a measure of frequency of consumption per day. The questionnaire was validated in adults

252   at the time of development. Ten questions on FV are provided, and responses to these ten questions

253   were then converted to consumption per day and summed, to give a measure of 'FFQ FV'.

254

FV Behaviour: FV intake was also assessed using a behavioural measure. Volunteers were offered a drink while completing all questionnaires, and given the choice of a tea, coffee, water or fruit smoothie. The UK 5-a-day recommendations include fruit juice and fruit smoothies as FV [43,44], thus selections of the fruit smoothie were considered an FV choice, while all other drinks were considered a non-FV choice. No drink was also a permitted option.

Demographic and Lifestyle Characteristics: Demographic and lifestyle characteristics also assessed were: gender, age, marital status, living status, number of years of education, smoking habits, alcoholic drinking habits, dietary supplement taking habits, and height and weight (to calculate BMI).

App Feedback

Number of uses were requested from volunteers who received the app, and downloaded from the app itself. Volunteers who received the app were also asked to feedback on their experiences and offer suggestions for the app. This feedback was requested as part of the study debrief. Participants were free to offer as many or as few comments as they wished in written or verbal form.

Additional Measures

To encourage a perception that the study was investigating the impacts of a number of apps for a variety of health behaviours, some additional measures, e.g. questions on physical activity and stress, were also undertaken. These data were not analysed.

Procedure

Volunteers undertook all outcome assessments at the Eating Behaviours Laboratory, Bournemouth University, UK. On each assessment occasion, volunteers completed all questionnaires using an online platform (Qualtrics), were offered a drink, and had every opportunity to ask questions. One researcher randomized all volunteers and dealt with all queries, while another researcher oversaw all outcome assessments, thus this researcher was blind to treatment (intervention / control).

The study was given ethical approval by the Research Ethics Committee of Bournemouth University, prior to commencement, and was registered as a clinical trial on www.clinicaltrials.gov (ID NCT02779491). Methods were undertaken as detailed in the trial registration with the exception that a behavioural measure of FV intake was added to the study prior to commencement, and a measure of FV attitudes was cut. The original study proposal included a measure of attitudes towards FV, but these were decided against prior to the study start to reduce demand characteristics

289 given the extensive FV knowledge questionnaire. All participants provided written informed consent

290 prior to starting the study.

291

292 **Analysis**

293 Quantitative data were analysed on an Intention-to-Treat basis, where missing data were completed

294 using multiple imputation [50], based on gender, age, study period, and baseline measures.

295 Demographic and lifestyle variables and all measures at baseline were first described and compared

296 using t-tests, based on study duration and intervention / control grouping. To investigate impacts of

297 the app with time, all FV knowledge and intake outcomes were analysed using ANOVA for

298 differences between baseline and week 2, and baseline and week 4. A covariate of study duration

299 was also added to the ANOVA for the two week data, to accommodate differences between those

300 studied for two weeks and those studied for four weeks. Thus effects at week 2 were investigated

301 using a 2 (intervention / control) x 2 (baseline / week 2) mixed ANCOVA, and effects at week four

302 were investigated using a 2 (intervention / control) x 2 (baseline / week 4) mixed ANOVA. Our

303 behavioural measure of FV intake – choice of fruit drink or non-fruit drink was analysed using Chi-

304 squared tests. All data are reported as means and standard deviations. Significance was set at

305 $p < 0.05$. Qualitative comments were analysed using thematic analysis.

306

307 **STAGE 4: DEVELOPMENT OF THE FINAL APP**

308 Finally, the results and feedback from the users of the pilot randomized controlled trial were used to

309 suggest amendments to create a final version of the app.

310

311 **RESULTS**

312 **STAGE 1: DEFINING AND PRIORITIZING THE APP REQUIREMENTS**

313 **App requirements**

314 Previous published work reveals confusion around: the foods that are included in the

315 recommendations; the amount of FV required for a portion, particularly where large items, small

316 items and composite dishes do not always contribute complete portions; the number of portions

317 needed per day; and the need for a variety of FV [15-20,23-28].

318

319 The four workshops were attended by 32 members of the population of Bournemouth. We did not

320 measure any demographic variables, but individuals were noticeably of both genders, aged from 18

321 years to old age, and based on their questions or self-disclosures were students, mothers of young

322 children, working professionals and retired individuals.

323

324 These participants voiced similar confusions to those found in the literature, and suggested that an

325 app would potentially be appropriate to aid with these concerns. Five key themes emerged from

326 analysis of the workshop discussions:

327 Useful for portion sizes: Participants expressed particular difficulties over the differing portion sizes

328 required for differing FV, and valued an idea that amount consumed could be entered into an app

329 using household measures, e.g. spoonfuls, and converted into portion sizes for them: '*Oh yeah, that*

330 *would be cool, so I can type in like 10 grapes and it tells me, yeah, that's one portion, …, or that's only*

331 *half a portion, or whatever, …, yeah, that would be handy'; 'If it could tell me my stew gives me two*

332 *portions, when I have loads of veggies in it, just all in pieces, … then that would be handy'.*

333 Useful Monitor: The app was considered likely to be useful for keeping track of FV consumption,

334 particularly for small amounts of FV, e.g. in composite dishes: '*I like the idea that I might be getting 5*

335 *a day already but I just don't know it, …, but to have a little machine to keep track of it in the day for*

336 *me, and then I can check at the end, that would be helpful.'*

337 Useful Target: The calculator function was also considered useful for telling users how close they

338 were to a daily target: '*If you could have some sort of bar to tell you how close you were to the 5 a*

339 *day, that would be useful, …, you know, a man who gradually fills up, or something similar.'*

340 Useful to have it Mobile: Potential users also liked the idea that the app would be with them

341 whenever they needed it, thus they could use it in the evening to recap at the end of a day, but they

342 could use it also, at point of purchase or point of consumption: '*So you could use it in the shop or in*

343 *the canteen and just try, you know, if I had the salad I would have 3 half portions, but if I have the*

344 *hot meal and two veg [portions] instead of the chips, that would be two portions – that would be*

345 *better. I would never think like that normally.'*

346 Possible Negative Monitor: A few reservations were also expressed around the feedback that users

347 may receive following their use of the app and the possibility that this may be negative - '*I think it's a*

348 *neat idea, but I wouldn't want anything telling me I was bad, or not eating well enough. … I wouldn't*

349 *use it in that case – it needs to be nice to me!'*

350

351 **Requirement Priorities**

352 The priorities for the app based on MoSCoW principles are presented in Table 1.

353

354 Table 1: MoSCoW requirements for the app

	Requirements
Must	1. Allow users to input FV consumed at any time and using household

have		amounts, e.g. number of items, number of spoonfuls
	2.	Provide users with a list of all FV for selection, as opposed to requiring manual input
	3.	Categorise FV (e.g. as fruits, vegetables, salad items) to avoid overly long lists of FV items for inputting
	4.	Allow users to input part items / units, where only part items have been consumed, e.g. in composite dishes
	5.	Provide immediate feedback on inclusion or not of the FV in the UK 5-a-day recommendations
	6.	Calculate contribution to a portion for the UK 5-a-day recommendations based on amount consumed
	7.	Allow fractions of portions in these calculations, but do not allow multiple portions of the same FV in any one day
	8.	Provide immediate feedback on contribution of the portion to the UK 5-a-day recommendations
	9.	Sum contributions of portions to provide a running daily FV total
	10.	Relate this running daily total to the recommendations of 5 FV per day
	11.	Provide immediate feedback on the daily FV consumption per day
	12.	Require users to set up an account to allow FV to be tracked on a personal basis.
	13.	Ensure users data is retained on their own device, to ensure data protection and privacy.
Should have	14.	Provide FV items using coloured picture icons as well as FV names
	15.	Display total daily FV consumed in a graphical manner allowing representation also of the target, e.g. using a filled bar
	16.	Provide constructive feedback to highlight if the amount consumed is insufficient to amount to a whole portion, e.g. 'an additional spoonful of xxx would provide a full portion'
Could have	17.	Store daily running totals over time to allow users to view their history
	18.	Provide a signal when the 5-a-day target was met, e.g. applause sound
	19.	Provide a reward when the 5-a-day target was met, e.g. a token to be traded for material gain
Won't have	20.	Provide instructive advice based on user inputs, e.g. 'you need to eat more of xx'

| | 21. Require users to input additional information, e.g. time and place |
| | 22. Allow users to amend FV consumption in the past |

355

356

357 **STAGE 2: DESIGNING AND DEVELOPING THE APP**

358 The app was developed using an agile approach as described by Google's Material Design Guidelines

359 and industrial best practices [42]. A user journey map was first created to visualise the timeline of

360 interactions with the potential app from the landing page. Wireframes of each app screen were then

361 produced using Balsamiq. These wireframes focused on app screen layout and content structure and

362 were organised to reflect the user journey map. These wireframes were then mapped to mockups

363 showing the actual visual designs for each screen. An interactive prototype was created using

364 InVision, and from this an android app was developed using native Android Studio. Primary

365 researchers (KMA, NJ) were consulted at each step for feedback.

366

367 The prototype app consisted of a series of screens allowing consumers to input and view their daily

368 FV intake in comparison to the UK 5-a-day recommendations. All requirements identified as 'must

369 have' and 'should have' were included with the exception that picture icons were not provided for

370 some FV items (Table 1, requirement 14). Icons were not easily available for all FV items, and while

371 desirable, icons for all FV items were considered not necessary at the prototype stage. Names were

372 provided for all FV. All 'won't have' requirements were also avoided. Details of the app, per screen,

373 are given in Table 2. Screenshots of screens 4, 5, 6, and 7 are given in Figure 1.

374

375 Table 2: Details of the prototype app.

Feature	Detail	Supported user actions	Requirements addressed
1 – Welcome	The app name and app logo	Swipe to continue	
2 - Registration	Request to login or register for an account	Provide a username to allow data to be tracked	12,13
3 – Daily summary	Total FV inputted in the current day	Options to add (more) FV	11,15
4 – Input Categories	Lists of FV, categorised as 'fruit', 'vegetables', 'salad' and 'drink'	Select relevant FV category	1,2,3
5 – Input Item	Individual FV items per category, displayed	Select relevant FV	1,2,4,5,14

	by name and icon (where available)	item	
6 – Input Amount	Arrows to select amount consumed, provided as items or spoons, as most commonly used	Select amount	1,4
7 – Updated summary	Amount consumed provided in portions based on recommendations. Details of amount required for a full portion if less than one portion. Total FV inputted for the current day updated and displayed. Motivational or congratulatory message also displayed.	Options to add (more) FV	6,7,8,9,10,11, 15,16

376

377

378 Figure 1 about here

379

380 **STAGE 3: INITIAL TESTING OF THE PROTOTYPE APP**

381 **Volunteers**

382 Ninety-four volunteers took part in the randomized controlled test – 50 who received and tested the

383 app, and 44 who acted as controls. Of these, 32 volunteers received the app for two weeks, 27

384 volunteers acted as controls, and 18 volunteers received the app for four weeks, 17 volunteers acted

385 as controls. Demographic and lifestyle characteristics of all participants are given in Table 3.

386 Volunteers who were studied for two weeks were more likely to be younger (t(92)=2.52, *P*=0.02) and

387 less educated (t(92)=4.08, *P*<0.01), than those who were studied for four weeks, predominantly

388 because volunteers were studied for a two week period when most of the volunteers were

389 Undergraduate students, and for four weeks when most of the volunteers were Postgraduate

390 students or University staff. No differences were found between intervention and control groups in

391 any demographic and lifestyle variable (largest t(57)=1.57, *P*=0.12).

392

393 Adherence to the study was good. Eighty-eight (94%) volunteers took part in all three test sessions, 1

394 volunteer undertook the first two sessions but failed to undertake the final session (control

395 volunteer for four weeks), 3 volunteers undertook the first session but failed to undertake the

396 second two sessions (1 volunteer received the app for four weeks, 1 volunteer was a control for four

397 weeks, and 1 volunteer was a control for two weeks), and 2 volunteers undertook the first and third

398 session, but missed the second session (both volunteers received the app for two weeks). Reasons

399 for drop-out were not recorded.

400

401 Table 3: Number of participants (and relative frequency), or mean (and standard deviations) for all

402 demographic and lifestyle characteristics

	Two week study		Four week study	
	App (N=32)	Control (N=27)	App (N=18)	Control (N=17)
Gender	Male: 10 (31%) Female: 22 (69%)	Male: 10 (37%) Female: 17 (63%)	Male: 6 (33%) Female: 12 (67%)	Male: 5 (29%) Female: 12 (71%)
Age (years)	22.3 (7.7)	21.4 (5.3)	25.9 (7.9)	25.9 (7.9)
Married	Married: 0 (0%) Not Married: 32 (100%)	Married: 0 (0%) Not Married: 27 (100%)	Married: 1 (6%) Not Married: 17 (94%)	Married: 2 (12%) Not Married: 15 (88%)
Living	Alone: 2 (6%) With others: 30 (94%)	Alone: 3 (11%) With others: 24 (89%)	Alone: 2 (11%) With others: 16 (89%)	Alone: 2 (12%) With others: 15 (88%)
Education (years)	14.9 (1.7)	15.0 (1.5)	16.9 (2.8)	16.9 (2.8)
Smoking	Non-smoker: 27 (85%) Light (0-2/day): 2 (6%) Moderate (2-10/day): 3 (9%) Heavy (10-20/day): 0	Non-smoker: 21 (78%) Light (0-2/day): 3 (11%) Moderate (2-10/day): 2 (7%) Heavy (10-20/day): 1 (4%)	Non-smoker: 16 (89%) Light (0-2/day): 2 (11%) Moderate (2-10/day): 0 (0%) Heavy (10-20/day): 0 (0%)	Non-smoker: 13 (18%) Light (0-2/day): 2 (12%) Moderate (2-10/day): 1 (6%) Heavy (10-20/day): 1 (6%)
Supplements	Never: 18 (56%) Occasionally: 7 (22%) Regularly: 7 (22%)	Never: 14 (52%) Occasionally: 11 (41%) Regularly: 2 (7%)	Never: 5 (28%) Occasionally: 11 (61%) Regularly: 2 (11%)	Never: 8 (47%) Occasionally: 7 (41%) Regularly: 2 (12%)
Alcohol	Never: 4 (13%) Light: 20 (62%) Moderate: 7 (22%)	Never: 2 (7%) Light: 19 (70%) Moderate: 9 (33%)	Never: 6 (33%) Light: 7 (39%) Moderate: 4 (22%)	Never: 3 (18%) Light: 9 (53%) Moderate: 4 (23%)

	Heavy: 1 (3%)	Heavy: 0 (0%)	Heavy: 1 (6%)	Heavy: 1 (6%)
BMI	21.6 (8.4)	24.0 (5.5)	25.0 (4.4)	25.1 (4.3)
Activity	None: 1 (3%) Standing all day: 3 (9%) Light: 4 (13%) Moderate: 10 (31%) Heavy: 12 (38%) Very heavy: 2 (6%)	None: 1 (4%) Standing all day: 6 (22%) Light: 3 (11%) Moderate: 7 (26%) Heavy: 7 (26%) Very heavy: 3 (11%)	None: 0 (0%) Standing all day: 0 (0%) Light: 3 (17%) Moderate: 4 (22%) Heavy: 10 (55%) Very heavy: 1 (6%)	None: 0 (0%) Standing all day: 2 (12%) Light: 2 (12%) Moderate: 6 (35%) Heavy: 6 (35%) Very heavy: 1 (6%)

403

FV Outcomes

Details of all FV outcomes are given in Table 4. Analyses of FV outcomes at baseline again revealed significant differences between volunteers studied for two weeks and those studied for four weeks in estimated FV consumption (t(92)=3.46, *P*<0.01) and FFQ FV intakes (t(92)=2.49, *P*=0.02). Volunteers studied for four weeks estimated and reported higher FV intakes. No differences were found in FV knowledge (largest t(92)=1.63, *P*=0.11). No differences were found between intervention and control groups at baseline (largest t(92)=1.10, *P*=0.28).

FV awareness: All volunteers with the exception of 2 volunteers in the four week study (one who received the app, and one who was a control) were aware of the 5-a-day FV recommendations at baseline, and at sessions 2 and 3, all volunteers were aware of the recommendations.

FV knowledge: Significant increases by week 2 were found for the questions on foods included in the recommendations (F(1,91)=5.11, *P*<0.01) and portion sizes (F(1,91)=5.69, *P*=0.02), and by week 4 for all FV knowledge questions (smallest F(1,33)=4.65, *P*=0.04). No differences were found between intervention and control groups with time (largest F(1,33)=1.03, *P*=0.32).

FV intake: No differences were found between intervention and control groups over time (largest F(1,91)=0.44, *P*=0.51). Significant differences based on study duration were retained in estimated FV and FV intakes assessed by FFQ (smallest F(1,91)=7.83, *P*=0.01). Correlations between all three FV intake measures also demonstrate comparability (smallest r=0.41, *P*<0.01). No effects of time were found (largest F(1,91)=1.73, *P*=0.19).

426

427 **FV Behaviour:** No significant differences between groups were found at baseline (Chi-

428 squared(1)=0.17, *P*=0.68). By week 2, significantly more fruit smoothies were chosen by those in the

429 intervention group compared to controls (Chi-squared(1)=5.96. *P*=0.02), but no effects were found

430 at week 4 (Chi-squared(1)=1.17, *P*=0.28).

431

432 Table 4 about here

433

434 **App usage**

435 Self-reported usage of the app was high - most participants reported using the app on most days or

436 every other day. Recorded use of the app also suggested almost daily usage or usage every other

437 day. Following initial access, volunteers in the 2 week study used the app a mean 11.4 (7.2) times,

438 ranging from 0 - 27 times, and volunteers in the four week study used the app a mean 13.7 (9.2)

439 times, ranging from 2 - 34 times. App usage was greater in the earlier part of each test period.

440 Percentage of users using the app on each day is shown in Figure 2. On the majority of days on which

441 it was used, the app was used only once. In total, the app was used once a day on 63.6% days on

442 which the app was used in the two week study and 66.0% of days on which the app was used in the

443 four week study; twice a day on 31.8% days and 22.3% days respectively; three times a day on 3.9%

444 days and 9.7% days respectively; four times a day on 0.7% days and 1.0% days respectively; and five

445 times a day on 1.0% days on which the app was used in the four week study.

446

447 Figure 2 about here

448

449 **App feedback**

450 Qualitative feedback on the app was positive – almost all volunteers reported liking the app

451 although many also reported room for improvements. Suggested improvements included: an option

452 to add FV for the previous day because these were possibly simply forgotten; an option for changing

453 the goal from 5 a day to more than this if individuals preferred to aim higher; a need for missing FV

454 to be added, or an option to feedback that FV were missing so that these could be added; a daily

455 notification or option to add these to remind users to interact with the app; and tips or suggestions

456 for how to increase FV consumption.

457

458 The majority of volunteers also reported that the app was useful. Almost all volunteers reported that

459 the app was useful for keeping a record of their consumption and for making them aware of limited

17

460   consumption: *'Made me conscious of what I was eating', 'Good to have a record of how much of 5-a-*

461   *day was eaten and also to know when you're short'.* Volunteers also reported increased FV intakes

462   through a wish to engage with the app: *'I think it made me want to eat more fruit and veg because I*

463   *had to write it down';* and adhere more fully with recommendations: *'I think it was useful in terms of*

464   *realising that I don't eat enough fruit and veg, as it has made me think about it more', 'I would eat*

465   *more at dinner if I noticed I had not eaten enough that day'.*

466

467   A limited number of volunteers, also felt that the app was unnecessary: *'The app was useful, but I*

468   *personally don't need an app to ensure that I get my 5 a day';* or did not help them: *'Did not help as I*

469   *plan meals the week before.'*

470

471   **STAGE 4: DEVELOPMENT OF THE FINAL APP**

472   Based on the outcomes and feedback from the pilot test, a second version of the app is under

473   development. Amendments that have so far been completed are: to include picture icons for all FV

474   items included in the app; to ensure all FV included in NHS recommendations [44] are included on

475   the app; to allow users to return to previous days to add additional items where desired; and to

476   allow users to change the target FV to more than 5 if desired (the default setting is for a target of 5

477   FV per day). The 'history' option allows users to return to a previous day to add additional items. An

478   ability to return to previous days was initially avoided in the prototype app to discourage users from

479   adding false information as a result of faulty recollections. Considering that the app is primarily for

480   the benefit of the user and that false information can be added to the app at any time, requests for

481   access to previous days has been granted, and may be beneficial for some users. The option to

482   change the intake goal is presented to users at registration, and can be amended as desired as part

483   of the user profile settings. The additional screens for the final app are given in Table 5, all screens

484   for the prototype app also remain.

485

486   Table 5: Additional screens of the final app

Feature	Detail	Supported user actions	Requirement addressed
8 – Personal preferences	Options for 'History: to allow inputs for previous days'; 'Reports' to provide an overview for the week; 'Refresh' to request updates; 'Settings' to update goal targets and add notifications.	Select options or return to Summary (page 3)	

9 - History	Calendar display	Select date, input FV as for the current day	Historical input permitted
10 - Reports	Overview of FV intake for the previous week / month (not yet enabled)		
11 - Refresh	Refreshes and updates total	Enabled	
12 - Settings	Options for 'Help' to feedback to the developer; 'User' to access details of the user and amend intake goal; 'Notifications' to set alarms; 'Devices' and 'App'.	Select options or return to Summary (page 3)	
13 - Help	Abilities to contact the development team (not yet enabled)		
14 - User	User details and user setting displayed	Option to amend intake goal	Goal amendment permitted
15 - Notifications	Abilities to set up notifications (not yet enabled)		
16 - Devices	Device details provided		
17 – App	App version details provided		

487

488

489 Amendments that are still under development will: allow users to reduce or delete an FV item once
490 this has been logged (this is currently not possible); allow users access to an overview of FV
491 consumed over the previous week or month; allow users to set up notifications; and allow users to
492 feedback directly to the development team. Consumption totals for previous days can currently be
493 viewed individually, but an historical overview may also be helpful. An interactive notification is
494 intended to demonstrate to users the further consumption required on any one day to meet the
495 recommendations. The default set up will be for no notifications, to avoid negative reactions to the
496 app, but notification set-up will also easy if desired. Other suggestions from app users to include tips
497 and suggestions to increase FV are not currently planned to retain the focus and simplicity of the
498 app.

499

500   The final app is now available for download at no cost from the Google Play Store under the name of

501   SMART 5-A-DAY. Development continues and updated versions of the app will be released as new

502   features are added.

503

504   **DISCUSSION**

505   A novel smart phone application was conceived to increase knowledge of the details of the UK FV

506   recommendations both in a practical sense by providing details of FV recommendations at the time

507   of consumption, and by providing these details in an engaging, useful and personally relevant

508   manner, such that individuals would remember and benefit from those details also at a later time

509   point. A prototype app was developed and tested by 50 users as part of a randomized controlled

510   pilot trial, for either two or four weeks. FV assessments and positive qualitative comments suggested

511   positive impacts of the app, but reported effect sizes were small. Additional features were suggested

512   and a final version of the app is currently under development.

513

514   The early development work confirmed low knowledge of the details of the 5-a-day FV

515   recommendations in consumers, as found in the published literature [15-20,22,23], and reinforced

516   the researchers' suggestions on the suitability of an app for providing increased FV knowledge. App

517   development was then possible as required, to result in a fully functioning interactive mobile phone

518   app. The results of the randomized controlled pilot trial demonstrate limited impacts of the app on

519   the questionnaire measures of FV knowledge and FV intakes, although an impact on FV behaviour

520   was found and qualitative feedback suggested benefits. Improvements in FV knowledge were found

521   across the study (regardless of app receipt) presumably as a result of inclusion in a study on healthy

522   eating and the repeated assessment of FV knowledge and FV intakes, so increased awareness of

523   these issues. The limited findings specific to those who received the app suggest that benefits of the

524   app are small, particularly in addition to the benefits of taking part in the study, although increased

525   FV knowledge in all study volunteers regardless of app / no app provision may have masked impacts

526   of app use.

527

528   An impact on FV behaviour was found. Given a choice of a range of available drinks, use of the app

529   for two weeks resulted directly in increased FV selection and consumption. Behavioural outcomes

530   are important, as it is only behaviour that will impact on health [31-33], and we have previously

531   suggested that spontaneous behavioural outcomes, such as those found here may be particularly

532   valuable in an environment of plenty [50]. Small spontaneous changes in behaviour such as this may

533 also remain largely unnoticed by individuals themselves and so may go largely unreported in self-

534 report measures such as those also used and often included in studies such as these [51-53].

535

536 The qualitative feedback also suggested potential changes in intake, but again that these changes

537 may be small and may go uncaptured by traditional dietary assessment methods [52]. The

538 qualitative feedback furthermore goes on to suggest that these small changes may have occurred

539 more as a result of volunteers becoming more aware of their intakes than previously, and becoming

540 particularly aware of low intakes. Awareness of a need for change has previously been suggested as

541 an important step towards behaviour change [33,34]. The qualitative feedback also fails to suggest

542 impacts on FV knowledge, and although the app was intended to increase knowledge, it is well

543 recognised that recording food intake can alert consumers to eating patterns, particularly some

544 eating patterns that are not easily recognised over a whole day, and that this realisation can change

545 behaviour [51,54-56]. The importance of increasing awareness of low intakes was not anticipated,

546 but this finding suggests an added benefit from the app.

547

548 The qualitative comments were largely positive. Negative comments centred solely around a lack of

549 personal interest or relevance, because these users were already high FV consumers. High FV

550 consumers are not the target audience for the app.

551

552 Additional findings from the initial test also related to app usage. Around 50% of those who received

553 the app used it initially, these figures dropped throughout the test period, and the majority of users

554 used the app once per day. These data are comparable to those found in studies of similar apps

555 [38,39]. Our app was intended for use as often as volunteers wished – possibly once a day for record

556 keeping or more often to acquire knowledge or encourage good adherence. The pattern of use

557 suggests our testers were using the app more to track intake than to gain knowledge. These findings

558 suggest that for maximum benefit from the app, it may be useful to market the app specifically for

559 gaining knowledge of the recommendations as well as for adherence to these. This would also help

560 distinguish the app from other apps that are intended primarily for tracking and record keeping [35-

561 39]. Increased usage at the start of the usage period is commonly found in app testing studies, and

562 the reduced subsequent usage is frequently cited as a suggestive of poor engagement. Many users

563 also suggested an additional reminder to aid interaction with the app, or requested an ability to

564 return to a previous day to input forgotten items. These findings suggest that motivation to use the

565 app was quite low among our testers, but our trial was not advertised as a study on FV consumption

566 or healthy eating (to avoid demand characteristics), thus our testers are likely to have been less

567 motivated than those who would be more likely to use an app on 5-a-day FV recommendations of

568 their own volition. Importantly furthermore, based also on the qualitative comments, we do not

569 consider this reduced usage to demonstrate poor functionality of the app. The app was intended

570 mainly to encourage users to understand and learn the FV recommendations, thus extended use

571 should not be necessary.

572

573 The work conducted here, further demonstrates the value of the early consultative work and the

574 randomized controlled pilot test. Positive responses to the app overall demonstrate the value of the

575 early research and the initial consultation exercises with potential end users. The increases in FV

576 knowledge and intakes in all trial volunteers, demonstrate the value of a randomized controlled trial

577 for testing the app. Not all apps are tested for impacts on behaviour prior to release, and many that

578 are tested are done so without also involving a control group. Consideration in our study of only the

579 50 app testers would have suggested considerable increases in FV knowledge and intakes as a result

580 of the app, while the inclusion of the control group demonstrates these impacts to probably result

581 more from study inclusion or FV questionnaire completion.

582

583 Our randomized controlled test was limited through the repeated assessment of FV outcomes, and

584 the repeated use of self-report measures. These types of measures have previously been

585 demonstrated as accurate [48,51-53], but very brief measures may have been insensitive to small

586 changes. Our test was also limited through the inclusion of testers who were not our intended target

587 group. The app is intended for those who wish to improve their knowledge of the FV

588 recommendations, probably to aid FV intakes. To avoid demand characteristics in our test, we asked

589 only for those who wished to try a new health-orientated app, and some of these individuals may

590 have been unmotivated, unwilling or unable to improve FV intakes. By comparison, our testers were

591 unsure of the apps being tested in the study, thus were unclear that FV was the focus for all users,

592 and responses to the FV questionnaire in our volunteers did confirm low knowledge of the 5-a-day

593 FV recommendations among the population [15-20,22,23]. Impacts based on age and education

594 have also been found previously [11,22,23]. We could also have measured usability of the app using

595 more formal measures, such as the System Usability Scale [57]. Considering the more

596 comprehensive measures of app usage and app benefit in terms of knowledge and intakes in our

597 trial, we did not collect these usability measures, but information from these measures may have

598 allowed comparison with other apps or technological devices [57].

599

600 The positive responses and potential for changes in behaviour has resulted in continued

601 development of the app to result in an amended version. This version includes clear details of an FV

602 consumption goal, allows uses to input FV consumed and provides detailed and graphical

603 information on how this consumption relates to the FV recommendations, provides clear

604 personalised feedback on distance to the goal, and allows users to change their target FV goal to a

605 goal of their choice as they wish. Our final app thus includes three key aspects of behaviour that

606 have previously been suggested to lead to successful behaviour change, particularly for dietary

607 behaviours, alongside increased knowledge: self-monitoring, goal-setting and feedback in relation to

608 goal attainment [54-56]. Other apps and interventions aiming to improve FV intakes and dietary

609 quality also use similar behaviour change techniques [35-40], and self-monitoring and goal-setting

610 have previously been suggested as particularly important techniques by professionals [54-56] and by

611 consumers [35,39]. It is interesting that although our app initially aimed to increase only knowledge,

612 functions as a result of user feedback now also include established behaviour change techniques.

613

614 The increased FV behaviour and qualitative reports suggest that the app has potential to benefit FV

615 intakes and health, although changes may be small. Small changes on a population-wide level

616 however, will have significant impacts. Increased benefit is also likely from the added features, from

617 highlighting the knowledge component, from tests of the app in our target audience, and from the

618 additional features still under development.

619

620 Our amended app now also needs testing. Further testing will not only demonstrate the improved

621 value of the app, but may also demonstrate the aspects of the app of particular benefit, given our

622 inclusion also of behaviour change techniques as well as knowledge, and the reported value of these

623 [54-56]. Additional functionality also allows direct linkage with additional software allowing direct

624 access to questionnaires or other research materials.

625

626 Further development of the app may also be of value. Notably, our initial discussions with potential

627 end users suggested an interest in both immediate and longer-term rewards for reaching a target

628 goal. Repeated work demonstrates a value for rewards for encouraging healthy food consumption,

629 including fruit and vegetable consumption [58], and rewards have previously formed an integral part

630 of many successful dietary change interventions [36,55,59]. Other studies also suggest only limited

631 benefit from apps for behaviour change, and have suggested a need for strategies to ensure

632 continued use [36,40]. One of the advantages of our app was an intention that users would learn

633 knowledge through the app, thus extended use should not be required. Many apps related to social

634 activities, such as eating, also include a 'share' option to allow others to view the inputs of others, or

635 allow comparisons between users or with an established norm. Feedback options for others to

636 comment on FV inputs, through 'likes', may also facilitate motivation, and so facilitate engagement

637 with and action based on the app. Offline and different versions of the app may also be desirable,

638 e.g. through the use of different formats, different controls or different set-ups, possibly for

639 different population groups. Adolescents and young adults are groups with low FV consumption that

640 may be particularly inclined towards digital interventions [39]. Socially deprived consumers may also

641 benefit from specific aspects of the app, and investigation in different cultures (using local

642 recommendations) would be of interest. Further work discriminating between those who use and do

643 not use the app, and between those who find and do not find the app useful, would be very

644 valuable.

645

646 **Conclusions**

647 In conclusion, this work details the development and early test results of a novel interactive mobile

648 phone application for improving knowledge and implementation of the UK 5-a-day FV

649 recommendations. SMART 5-A-DAY was developed following assessment of the existing literature

650 and consultation with potential end users, and then tested in a randomized controlled pilot trial. The

651 trial demonstrated increased FV behaviour two weeks after app receipt, and resulted in positive

652 feedback, although resultant changes in FV knowledge and intakes were small. Suggestions for

653 amendments were also made. Development of the app is continuing, and further testing is required.

654

658

659 **CONFLICTS OF INTEREST**

660 David Passmore is the founder and CEO of Vers Creative UK, a digital solutions development

661 company, based in Bournemouth, UK. There are no other conflicts of interest.

662

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805   Table 4: Mean (and standard deviation) FV knowledge scores, self-reported intake and drink choice for all volunteers at baseline, week 1, week 2 and week

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	App				Control			
	Baseline (N=50)	1 week (N=32)	2 weeks (N=50)	4 weeks (N=18)	Baseline (N=44)	1 week (N=27)	2 weeks (N=44)	4 weeks (N=17)
Foods (scored -35 to +35)	18.4 (6.8)	22.9 (6.4)	21.5 (8.1)	19.3 (7.9)	17.9 (7.1)	18.1 (8.8)	20.5 (8.3)	21.6 (6.3)
Portion sizes (scored -27 to +27)	-6.4 (6.2)	-5.0 (8.0)	-4.4 (7.8)	-7.6 (9.5)	-7.8 (5.7)	-6.7 (5.7)	-6.4 (7.5)	-5.3 (7.4)
Variety (scored -18 to +18)	-2.8 (5.7)	-0.4 (5.6)	0.1 (6.4)	-3.3 (6.3)	-2.6 (5.5)	-1.4 (6.0)	-1.1 (5.9)	-0.8 (6.9)
Reasons (scored -25 to +25)	0.1 (5.7)	0.8 (5.7)	1.1 (4.8)	1.2 (5.6)	-0.1 (6.5)	-0.6 (5.3)	0.7 (5.2)	1.4 (5.9)
FV estimated (FV portions/day)	3.3 (1.4)	2.9 (1.4)	3.4 (1.5)	4.1 (1.2)	3.2 (1.7)	3.1 (1.5)	3.3 (1.7)	3.6 (2.2)
FV calculated (FV portions/day)	4.1 (1.4)	3.7 (1.5)	4.1 (1.6)	5.3 (1.6)	3.7 (2.0)	3.6 (2.2)	3.8 (1.8)	3.9 (1.6)
FV FFQ (Daily FV intake (portions))	3.5 (1.9)	2.6 (1.1)	3.2 (1.8)	3.5 (1.9)	3.3 (2.2)	2.3 (1.3)	2.9 (2.3)	3.9 (2.9)
Drink choice – Fruit smoothie	13 (21%)		23 (45%)[a]	4 (25%)	11 (36%)		8 (16%)[a]	5 (31%)
Drink choice – Other drink	22 (18%)		8 (16%)[a]	5 (31%)	15 (25%)		12 (23%)[a]	2 (13%)

807   [a] Significant differences between app and control groups (Chi-squared(1)=5.96. P=0.02).
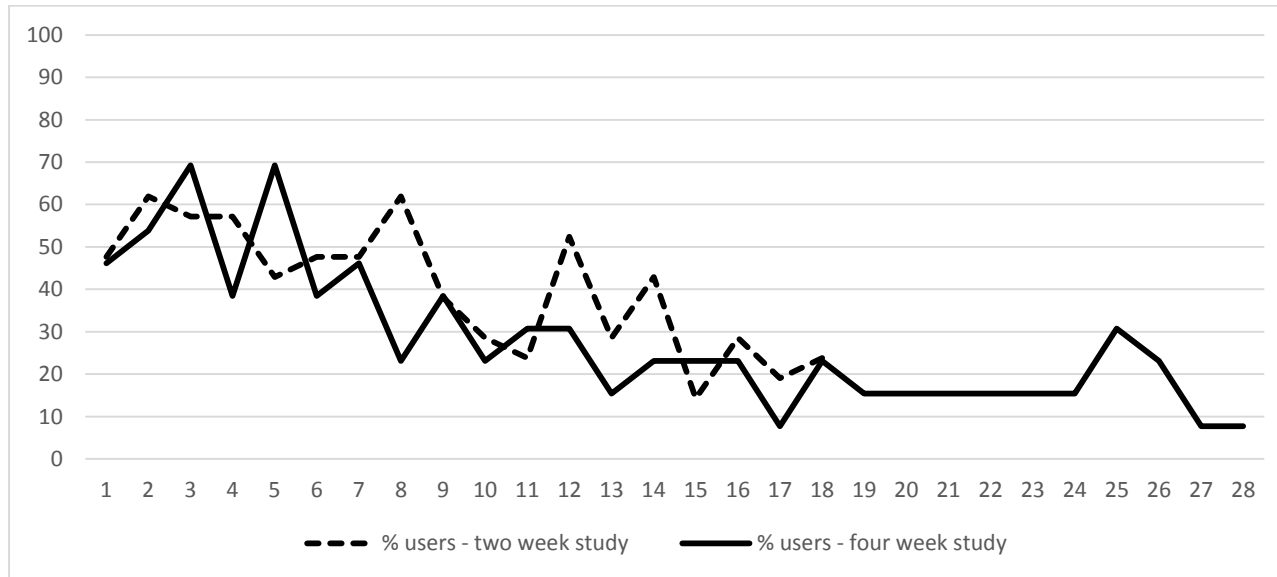
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810   Figure 1: Screenshots of the app: a) Screen 4 – FV categories; b) Screen 5 – Fruit icons; c) Screen 5 – Vegetable icons; d) Screen 6 – FV selection; e) Screen 7

811   – Summary Low; f) Screen 7 – Summary High

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813   Figure 2: Percentage of users using the app on each day of the study in addition to initial access on Day 1.

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