The development of VegEze: A mobile phone application to increase vegetable consumption in Australian adults.

Authors

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Keywords

mHealth; Mobile; Vegetables; User-centered design; IDEAS framework; Behaviour change techniques; Digital intervention
Abstract

Background

Changing dietary behaviour is difficult and although it is often clear what needs to change, how to action change is more difficult. Mobile phones have characteristics which may support the complexity of changing dietary behaviour.

Objective

This paper describes the iterative development process to build and test a mobile app called VegEze that aims to increase vegetable consumption.

Method

In order to upscale, reach target users and create a user-friendly end product, a collaborative research-industry partnership was formed to build the app over a 20-week build phase. The IDEAS framework was used as a scientific basis to guide the development. The Behaviour Change Wheel was also used as a theoretical grounding in combination with other theory-based strategies, such as self-monitoring, social comparison and gamification – which have all been shown to be successful in dietary change or digital health interventions. One consumer survey (n=1068), one usability testing session (n=11), and a pilot efficacy and usability trial (n=283) were conducted to inform the design of the app. The samples for the consumer survey and pilot trial were recruited via email from a database of individuals who had previously expressed an interest in participating in online health-related programs.

Results

The target behaviour for the app was defined as “having 3 different types of vegetables at dinner”. The perceived achievability of this target behaviour was high; 93% of respondents felt they were ‘likely’ or ‘very likely’ to be able to regularly achieve the behaviour. App features that users reported to want included recipes and meal ideas (82% of users), functionality to track their intake (62%), and information on how to prepare vegetables. Based on the importance of self-monitoring as a behaviour change technique and its rating by users, the vegetable tracker was a core feature of the app, and was designed to be quick and simple to use and highly applicable to a range of users. Daily feedback messages for logging intake and communicating progress were designed to be engaging and fun using friendly and positive language and emoji icons. Daily and weekly feedback on vegetables consumption was designed to be simple and informative and reinforce monitoring. A creative team were engaged to assist in the branding of the app to ensure it had an identity that reflected the fun and simple nature of the underlying behaviour. The app included 16 behaviour change techniques, most of which were from the goals and planning subsection of the taxonomy.

Conclusions

Combining a theoretical framework with an industry perspective and input resulted in an app that was developed in a timely manner while retaining its’ evidence-base and the process of scientific evaluation. VegEze is currently available in the App store, and the overall impact of the VegEze app will be evaluated using the RE-AIM framework in an uncontrolled, quantitative study.

Trial Registration: Australian New Zealand Clinical Trials Registry ACTRN12618000481279
Introduction

Poor diet quality is one of the most important modifiable risk factors for chronic disease [1]. Poor quality diets are generally characterised by inadequate consumption of fruit and vegetables, and over consumption of unhealthy, energy dense, discretionary foods [2]. Population level nutrition and obesity prevention interventions have had small to modest success in improving diet quality [3-5] – most likely because dietary behaviour change is difficult and multifaceted. Although, it is often clear what needs to change, for example eat more vegetables, how to action changes is more difficult [6]. The interplay between individual level (e.g. willpower, motivation), household level (e.g. availability, finances), and community level factors (e.g. accessibility to fresh food, social norms) are all likely to affect dietary change [7].

Mobile phones have characteristics which may support the complexity of changing dietary behaviour. For example, mobile phones are increasingly ubiquitous; have the ability to reach individuals at nearly any time or place; can be highly interactive; can deliver information in a way that is engaging and rewarding; and provide timely feedback [8]. Tailored feedback can also grow with user inputs [9], creating a personalised experience, which may encourage extended engagement and success with an intervention [10]. Therefore, mobile phone-based behaviour change interventions have the potential to be effective and also accepted by individuals. They may also serve as a cost-effective and scalable way to deliver behavioural nutrition interventions to a large audience. However, to have the greatest likelihood of success, these interventions also need to utilise existing scientific knowledge and theory [9].

An explosion of healthy eating mobile phone applications (apps) has occurred in recent years (eg, MyFitnessPal, Lifesum, Lose It!, Easy Diet Diary). However, many commercial apps are not scientifically developed based on behavioural theory or evidence, and have yet to undergo rigorous evaluation [8]. Regardless of this, high and consistent downloads suggest they have significant reach and appeal, at least in the short term [11]. Apps are also being developed and used by the research community, but unfortunately the pace of development and evaluation in research means the temporal lag limits their potential impact [12]. Despite contrasting times from conceptualisation to market, both scientific and commercial entities want to develop engaging and effective apps and working together could result in better end-products.

This paper describes the iterative development process to build and test a mobile app that considers both the scientific and commercial validity, and that targets a complex and critically important dietary behaviour – increasing vegetable consumption. The IDEAS framework was used as a scientific basis to guide the development of the app, and is used here to provide a detailed description of the journey of building VegEze – an app to increase vegetable variety and consumption.
Method and Results

The IDEAS framework (Integrate, Design, Assess and Share) is a flexible guide to the development of digital interventions, and while depicted as a linear process, is intended to be iterative and stages revisited as required during the development process [13]. The framework draws on behavioural theory, design thinking, user-centered design, rigorous evaluation and dissemination – which have all been shown to be important for digital health interventions [13]. Figure 1 is an adaptation of the IDEAS framework flowchart [13] reflecting the order and process that was used in the development of the VegEze app.

Part 1: Integrate insights from users and theory

The first three phases of the framework are designed to gather insights from users and behavioural theory to focus the intervention process around a specific and measureable target behaviour.

Phase 1: Specify target behaviour

Specifying the target behaviour was, in the first instance, an evidence-based decision drawing on existing literature which was later tested with potential users before proceeding with the app development. Data from the latest Australian National Nutrition survey suggests that less than 4% of adults consume enough vegetables to meet the Australian Dietary Guidelines [14]. Adequate consumption may reduce the risk of chronic diseases such as heart disease, diabetes and some cancers, as well as help to maintain a healthy weight [14]. The Australian Dietary Guidelines and Go for 2 & 5™ campaigns encouraged the population to ”enjoy plenty of vegetables”, ”increase consumption”, and include ”different types and colours” with a prescription for total daily recommended servings. These population level campaigns have had some success in increasing vegetable consumption [4]. However, in the context of behaviour change their advice broadly addresses the problem of inadequate vegetable consumption, without identifying a highly specific target behaviour. In order to more precisely refine these public health messages to a specific target behaviour, secondary data analysis of the CSIRO Healthy Diet Score survey was performed.

The CSIRO Healthy Diet Score is a large, national short food survey in Australia with over 198,000 responses [2]. Respondents reporting “always” having 3 different types of vegetables at their evening meal had higher overall vegetable consumption relative to other frequencies. These people were also more likely to meet the recommended daily intakes [15]. Other research also suggests that serving a variety of vegetables can help in selecting a healthier meal [16] and is an effective strategy to increase vegetable consumption in a single meal [17]. Based on the CSIRO Healthy Diet Score data and other acute studies, the target behaviour for the app was defined as “having 3 different types of vegetables at dinner”. This is a novel, specific and an actionable behaviour that is associated with an increased likelihood of the desired outcome – that is increased vegetable consumption. In addition, it is measurable, easy to self-monitor, and has the potential to produce a cascade benefit, that is improving vegetable consumption at other meal times. Therefore, the initial target behaviour was to “eat 3 different vegetables at dinner”.

Figure 1. The application of the IDEAS framework* to the development of the VegEze mobile phone app. *Due to project requirements the first three phases of Part 1 of this study took place in a different order to original IDEAS framework.
Phase 2: Ground in behavioural theory

As well as scientific literature, the development of the app drew on the Behaviour Change Wheel (BCW) as a theoretical grounding in combination with other theory-based strategies, such as self-monitoring, social comparison and gamification – which have all been shown to be successful in either dietary change or digital health interventions [18-23]. The BCW is an integrative guide for understanding behaviour change, and is a synthesis of many previously published theoretical frameworks from this field. Central to the BCW is the COM-B model which recognises that for a behaviour to occur an individual must have the Capability, Opportunity and Motivation to engage in the Behaviour (COM-B). The first step of the BCW process is to specify the target behaviour (similar to Phase 1 described here). Then, subsequent steps identify what needs to change in order to perform this target behaviour. To help quantify this and prioritise features of the app, we administered the COM-B Self-Evaluation Questionnaire in a sample of potential users (described below).

Phase 3: Empathise with target users

In order to upscale, reach target users and create a user-friendly end product, a collaborative research-industry partnership was formed which brought a multidisciplinary team together to build the app over a 20-week build phase. The team was led by a product development manager (from industry) and nutrition scientist (researcher), and included research dietitians, behavioural scientists, product developers, and software engineers.

To understand how the target behaviour (eat 3 different vegetables at dinner) was received by potential users, and to elicit perceptions about performing this behaviour, we conducted an online consumer survey with target users. The sample was recruited via email from a database of individuals who had previously participated or expressed an interest in participating in online nutrition and health-related surveys or programs. An email was sent 9900 individuals and 1068 individuals completed the survey within 24 hours. The majority of this sample were female (84%), with an average age of 56 years. They were generally health conscious and health literate, with 94-99% reporting they felt it was ‘important’ or ‘very important’ to eat enough and a wide variety of vegetables each day, and 71% correctly identifying the daily recommended number of vegetable serves. However, 66% of this sample still believed they would like to eat more vegetables and this was largely for health-related reasons (Figure 2).
When asked what they thought it would take to increase vegetable intake, 37% of responses from users were reasons associated with their capability (e.g. have better planning skills, cooking skills and knowing how to eat more vegetables), 33% were for reasons associated with motivation (e.g. developing better plans and a habit of eating more vegetables, feeling like I want to eat more vegetables), and 30% were reasons associated with opportunity (e.g. having more time, triggers to prompt me to eat more vegetables). Therefore, respondents reported needing help in all areas of behaviour change according to the COM-B theory (Figure 3).

56% of respondents were ‘interested’ or ‘very interested’ in an app to specifically help with achieving the target behaviour of eating 3 types of vegetables at dinner (Table 1). Interestingly, this was similar to those interested in the more traditional intervention target of ‘increasing vegetable intake’ (55%). In the context of the app and perceived achievability of this target behaviour, 93% of respondents felt they were ‘likely’ or ‘very likely’ to be able to regularly achieve the behaviour, and most (68%) thought they would be able to do it for 30 days or more (Table 1).

As well as administering the COM-B Self-Evaluation questionnaire the 1068 survey respondents indicated their preferences for features in an app and their current vegetable eating behaviours. App features that users reported to want included recipes and meal ideas (82% of users), functionality to track their intake (62%), and information on how to prepare vegetables (51%, Table 1).

Most people reported to consume vegetables at their dinner meal (98% of respondents), but many also included vegetables with lunch (85%). Consuming vegetables at breakfast (11%) or as a snack (19%) was less common. The most common ways participants indicated eating vegetables in their meals were by including vegetables in dishes such as stir fries (48%), salads (39% as a side salad and 38% as a main), and 32% reported “hidden” within a dish such as spaghetti bolognaise. In addition, 66% of respondents reported that they “mix it up” and consume vegetables in a variety of ways. This information was used to guide the development of recipes and meal ideas.
Table 1. Evaluation questions about the proposed app from the consumer survey (n=1068).

<table>
<thead>
<tr>
<th>How interested are you in an app to help you to eat 3 types of vegetables at dinner?</th>
<th>Percentage of users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very interested</td>
<td>28%</td>
</tr>
<tr>
<td>Interested</td>
<td>28%</td>
</tr>
<tr>
<td>Neutral</td>
<td>21%</td>
</tr>
<tr>
<td>Not interested</td>
<td>9%</td>
</tr>
<tr>
<td>Not at all interested</td>
<td>11%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How long do you think you could do this for?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 7 days</td>
<td>5%</td>
</tr>
<tr>
<td>7 days</td>
<td>9%</td>
</tr>
<tr>
<td>14 days</td>
<td>10%</td>
</tr>
<tr>
<td>21 days</td>
<td>8%</td>
</tr>
<tr>
<td>30 days or more</td>
<td>68%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What features would you like to see in an app to increase vegetable intake?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Recipes</td>
<td>82%</td>
</tr>
<tr>
<td>Tracker</td>
<td>62%</td>
</tr>
<tr>
<td>How to info</td>
<td>51%</td>
</tr>
<tr>
<td>Weekly reports</td>
<td>43%</td>
</tr>
<tr>
<td>Info on guidelines</td>
<td>39%</td>
</tr>
<tr>
<td>Health info</td>
<td>32%</td>
</tr>
<tr>
<td>Challenges</td>
<td>29%</td>
</tr>
<tr>
<td>Rewards</td>
<td>22%</td>
</tr>
<tr>
<td>Engage family</td>
<td>14%</td>
</tr>
<tr>
<td>Photo gallery</td>
<td>9%</td>
</tr>
<tr>
<td>Social sharing</td>
<td>6%</td>
</tr>
<tr>
<td>Leader board</td>
<td>4%</td>
</tr>
</tbody>
</table>

Part 2: Design iteratively and rapidly with user feedback

Phase 4: Ideate creative implementation strategies

This phase focuses on translating insights from users and theory into features of the app. The process of brainstorming ideas for the app was highly iterative and incremental. The multidisciplinary project team met twice per week throughout the development process which allowed us to generate and refine ideas, and implement behaviour change strategies within features users expected from the app. This was done collaboratively in order to retain the scientific evidence-base while also maximising the user experience.

Phase 5: Prototype a potential product

The build started by prototyping different ways to track vegetable intake. Based on the importance of self-monitoring as a behaviour change technique and its rating by potential users in the consumer survey (a tracker for vegetable intake was the second highest rated feature that users expected, and highest in terms of a functionality feature) this feature was going to be a core component of the app. As well as communicating progress, a tracker can be used to communicate and reinforce the specific target behaviour. Consumer feedback indicated that a large proportion of users consumed vegetables at lunch as well as dinner, so the project team decided that the tracker would allow vegetables to tracked at all meals across the day.
In order to empathise with users, this vegetable tracker feature needed to be quick and simple to use; highly applicable to a range of users by including a large variety of different vegetables; and, accommodating of users from across the health and motivation spectrums. Unlike traditional scientific methods, emphasis was therefore placed on simplicity and intuitiveness of this dietary intake recording tool. Its core functionality was to record variety of vegetables consumed (i.e. the types) as well as servings (i.e. the amount). A vegetable list of 125 vegetables was created and a prototype vegetable tracker allowed users to scroll the vegetable list, and click through to record the type and amount of vegetables consumed at each meal of the day. The prototype featured only the core component to ensure the app reached the target behaviour as effectively as possible (Figure 4).

Figure 4. Early low resolution wireframes used in iterating the prototype for the vegetable tracker functionality of the app.

Phase 6: Gather user feedback on the prototype

User testing was conducted with 11 people who were approached in a local café, were not known to the project team, and perceived to be aged between 25-45 years (demographic information was not asked by way maintaining anonymity). Members of the development team observed individuals using the prototype app as they were asked to do 4 tasks: add cauliflower, sweet potato and corn to dinner; add capsicum to breakfast; add salad for lunch; and add carrots for a snack. This resulted in
user feedback on the prototype and assessment of the functionality of navigating the vegetable list and logging vegetables consumed in meals. The key observations were that all participants were able to complete all tasks in minimal time and the flow of entering items was reasonably easily learnt. The meal icons for breakfast, lunch, dinner and snacks appeared to be confusing, as users were not able to easily differentiate meals. Using circles for the meal icons also appeared to be confusing as users seemed to require more context in terms of what they were aiming for and how to fill them in. The recommendations for refinement from the development team included (i) further iteration on the design of meal icons, (ii) creation of on-boarding screens to help the user navigate, (iii) more focus on the development of “progress indication”, and (iv) to continue testing and iterating the dashboard design for further testing in the pilot trial. This feedback was included into the next iterations of the app.

Phase 7: Build minimum viable product

The beta version of the app was developed with fully functional versions released and tested iteratively by the project team, with feedback provided to the project lead of the development team at regular intervals. The beta version of the app focussed the on-boarding process, refining the vegetable tracker and user experience, developing a framework for providing feedback, and the visual branding.

To ensure the effectiveness and usability of the app could be assessed rigorously, evaluation surveys were designed to be embedded into the app using Apple® ResearchKit® software (Figure 5). The on-boarding process included ethics documentation and consent as well as the baseline evaluation survey. The survey questions drew on previously validated questionnaires to assess amount and variety of vegetables (as the primary outcome)[24] and psychological predictors of intake (as possible covariates of behaviour change) such as attitudes, intentions and nutrition related self-efficacy [25-27]. The baseline evaluation survey was initially designed by researchers, and then refined for length and readability based on feedback from developers and the broader project team. Although it extends the registration process, inclusion of the survey is considered essential to allow for thorough evaluation of the app. Google Analytics was used to collect app usage data to allow us to understand the interactions between patterns of use and successful behaviour change.

Figure 5. A sample of screenshots of the consent process which was embedded in the app using Apple® ResearchKit® software.

The user experience for the early versions of the app centred on perceived ease of logging intake and usability of the vegetable list. In the prototype, the vegetable list was ordered by frequency of
consumption per meal based on population intake data from the Australian National Nutrition Survey [28], and then over time ordered with user’s inputted data. Each vegetable item in the list had a name, image and an information button which clicked through to details on standard serve size information. Serves could be added with a tap of the ‘+’ and ‘-’ icons for each vegetable in the list.

The framework for the frequency and content of feedback messages sent via push notifications were developed by the project team. Three types of notification messages would be sent including daily feedback for logging, as well as content and recipe notifications which were sent on a random schedule 3-4 times per week. Daily feedback messages for logging intake and communicating progress was designed to be engaging and fun using friendly and positive language and emoji icons. Daily and weekly feedback and graphs on the variety and serves of vegetables logged was designed to be simple and informative and reinforce monitoring.

Finally, a creative team were engaged to assist in the branding of the app to ensure it had an identity that reflected the fun and simple nature of the underlying behaviour. Various names and logos were tested in the pilot study, and the name “VegEze” with the by-line “Do 3 at dinner” received the most positive response from potential users and it was agreed by the project team to use this branding for the app.

Part 3: Assess rigorously

Phase 8: Pilot potential efficacy and usability

A new sample of potential target users, recruited through the same database described above, were invited to download the beta version of the app and try it for a few days and provide feedback via three evaluation surveys. Of the 553 participants that registered their interest, 311 downloaded the app (56% of those interested) and 283 completed the baseline survey (91% of those who downloaded the app). Participants used the app for about 24 hours and were asked to complete a second survey (post download survey n=146), followed by a final survey about 3 days after download (post pilot survey n=103).

The sample that completed the baseline survey were largely female (84%), mean age 48 years, and 46% were overweight or obese. The majority of the participants that registered (89%) reported they thought they would like to use the app at least once a day, and 87% felt they would use the app for 2-3 minutes per day or more. When asked how long they thought they could maintain the challenge of eating 3 different types of vegetables at dinner, 67% of users at baseline felt they could maintain it for 21 days or more.

App usage

During the testing period (7 days), 265 of 283 (94%) users who completed the baseline survey logged their vegetable intake at least once. Users averaged 5 sessions in the app during this period, with an average daily engagement time of 3m 54s. There were 1419 vegetable logs recorded, an average of 5.4 logs per user. The majority of these logs were for the evening meal (1042/1419=73%).

Questionnaire results

After downloading the app, at least 80% of users ‘agreed’ or ‘strongly agreed’ that the set up process of the app, including completing the baseline evaluation survey, was clear and relatively easy to complete. After using the app for a few days, 85% of users reported to like the tracking feature to record type of vegetables, and 79% liked the tracking feature to record serves consumed. Importantly 75% of users felt the vegetable logging feature was easy to use, and 69% found it was useful.
“A powerful motivator - more than I expected. I liked the quality of the images of vegetables and the search function.”

“I find the information about how much a serving size is for each vegetable is really useful. I would probably just assume I’m eating enough by having a few beans, pieces of carrot and broccoli florets for dinner - but know I know exactly how much I need to eat.”

“I like the scroll and search option to find veges and the incremental steps to measure vege intake. REALLY liked the option to click on the vege to show what a serving actually is AND the photo of the vege - great; ease of use, thumbs up.”

Immediately following download, 75% of users felt their overall experience of using the app was positive, and after a few days of using the app 81% of users felt their experience was positive. Immediately following download 86% of users reported they would use the app at least once a day, and this remained high at the end of the pilot trial (78% of users). Post download and post pilot 80% and 87% of users respectively felt they would use the app for 2-3 minutes. About one third of users felt they would use the app for 1-3 months, and another third for more than 3 months. Finally, 63% of users who completed the post pilot survey (n=103) felt the app was easier or much easier than other health apps and 69% indicated they would give the app 4 out 5 stars.

“Enjoying using the app so far and it’s definitely challenged me to increase my veg intake at dinner.”

“Yes, I’m very impressed with how many veggies there are to choose from. Being a creature of habit it certainly opens your eyes to what you can eat.”

**Final intervention and theoretical grounding**

Based on the pilot evaluation, a few issues were identified by users in regards to the vegetable list and logging of vegetables that were addressed in the final build of the app. For example, the development team further refined the process for adding and deleting vegetables at different meal times to make it easier for users; the order of the vegetable list was revisited; and finally users wanted more visual feedback of their total vegetable servings in addition to total types.

The final build also focused on the gamification elements of the app and the content which were not part of the beta version. Gamification has the potential to facilitate behaviour change by increasing motivation, and making an everyday task more fun to achieve [21]. The release version of the app invites users to participate in a 21 day challenge to have 3 different types of vegetables at dinner (Figure 6a). To encourage autonomy, challenges can be reset and restarted at any time by the user. In addition to the challenge, other gamification features include rewards and a form of leaderboard (Figure 6e and g). A rewards based scheme was built into the challenge whereby individuals achieved different levels/awards depending on their intake. A leader board displays the different awards and the percentage of individuals using the app who are striving for each award – a de-identified form of social comparison. These gamification elements in the app were developed with the behavioural scientists, and then further fleshed out by the project leaders to achieve features that were fun and motivating but also realistic within the project constraints.

The consumer survey described in Phase 3 suggested that 82% of respondents expected recipe and meal ideas in the app, as well as information on how to prepare vegetables (51% of respondents). The content framework divided articles into three categories: (1) evidenced based fun facts on vegetables, (2) recipe and meal ideas all containing 3 different vegetables, and (3) tips and tricks on how to prepare and include vegetables in meals (Figure 6h, i, j). The recipe and meal ideas covered stir fires, mixed dishes, main and side salads, as well as meals with “hidden” vegetables given the
consumer survey suggested respondents were eating vegetables in a variety of ways. Two research dietitians worked together to develop 74 short articles and 57 recipes and meal ideas for inclusion in the app.

Two-way user feedback was central to the app (Figure 6b, e, f). The home screen became the place where users can review their progress of the day with carrot icons representing the number of types consumed in each meal for the current day. With a bar slider at the top of the screen users can review previous days at a glance with a ‘tick’ indicating that the goal was met (Figure 6b) or across the challenge period in a calendar format (Figure 6e). With a swipe from the home screen, users can also review their progress towards reaching the recommended number of serves per day, as well as review the past progress on reaching this target with a simple visual bar chart (Figure 6f).

While the app draws on the BCW framework and gamification, it also draws on a range of other theory-driven strategies from the 93 Behaviour Change Techniques (BCTs) taxonomy [29]. The app was independently coded by two trained research assistants, who identified 16 behaviour change techniques used within the app, most of which were from the goals and planning subsection of the BCT taxonomy (Table 2).
Table 2. The VegEze app was coded for the inclusion of 16 behaviour change techniques from the Behaviour Change Techniques taxonomy.

<table>
<thead>
<tr>
<th>Behaviour Change Technique Category</th>
<th>Behaviour Change Technique description</th>
<th>Example of intervention component in the app</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goals and planning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Goal setting (behaviour)</td>
<td>Set or agree a goal defined in terms of the behaviour to be achieved.</td>
<td>Sets a goal to eat 3 types of vegetables at dinner each day for 21 days.</td>
</tr>
<tr>
<td>1.4 Action planning</td>
<td>Prompt detailed planning of performance of the behaviour.</td>
<td>Encourages planning and preparation to eat a variety of vegetables at dinner.</td>
</tr>
<tr>
<td>1.5 Review behaviour goals</td>
<td>Review behaviour goals in light of achievement.</td>
<td>Daily feedback messages and visual displays provided on types of vegetables consumed.</td>
</tr>
<tr>
<td>1.6 Discrepancy between current behaviour and goal</td>
<td>Draw attention to discrepancies between current behaviour and the goal.</td>
<td>Home screen and daily feedback messages point out differences between the number of types of vegetables consumed and target; and feedback screen provides feedback about consumption of serves of vegetables relative to Dietary Guidelines.</td>
</tr>
<tr>
<td>1.7 Review outcome goals</td>
<td>Review the outcome goal in light of achievement.</td>
<td>At the end of the challenge, feedback on achievement is provided and a new goal can be set.</td>
</tr>
<tr>
<td><strong>Feedback and monitoring</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2 Feedback on behaviour</td>
<td>Monitor and provide informative or evaluative feedback on behaviour.</td>
<td>Daily feedback messages and visual displays provided on types of vegetables consumed.</td>
</tr>
<tr>
<td>2.3 Self-monitoring of behaviour</td>
<td>Establish a method for the person to monitor and record their behaviour.</td>
<td>Vegetable log asks participants to record consumption daily.</td>
</tr>
<tr>
<td><strong>Natural consequences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1 Information about health consequences</td>
<td>Provide information about health consequences of behaviour.</td>
<td>Learn section provides information on the health benefits of consuming vegetables.</td>
</tr>
<tr>
<td>5.3 Information about social and environmental consequences</td>
<td>Provide information about social and environmental consequences of behaviour.</td>
<td>Learn section provides information about the benefits to their family, and environmental benefits to consume and not waste vegetables.</td>
</tr>
<tr>
<td>5.6 Information about emotional consequences</td>
<td>Provide information about emotional consequences of behaviour.</td>
<td>Learn section provides information that eating vegetables increases energy and sense of wellbeing.</td>
</tr>
<tr>
<td><strong>Comparison of behaviour</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.2 Social comparison</td>
<td>Draw attention to other people's</td>
<td>A leader board displays the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
performance to allow comparison with own performance. different awards and the percentage of individuals using the app who are striving for each award.

<table>
<thead>
<tr>
<th>Repetition and substitution</th>
<th>8.1 Behavioural practice/rehearsal</th>
<th>Prompt practice of the behaviour in order to increase habit. Prompt rehearsal and repetition of the behaviour in the same context repeatedly.</th>
<th>Daily push notifications to prompt behaviour. Push notification prompt consumption of 3 types at dinner each day.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.3 Habit formation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reward and threat</th>
<th>10.3 Non-specified reward</th>
<th>Arrange delivery of a reward if there has been effort and progress in behaviour.</th>
<th>Virtual rewards received for logging and achieving progress towards 3 vegetables at dinner. Information section informs of virtual rewards for logging and achieving progress towards 3 vegetables at dinner.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.6 Non-specific incentive</td>
<td></td>
<td>Inform that a reward will be delivered if effort and progress in behaviour is made.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scheduled consequences</th>
<th>14.5 Rewarding completion</th>
<th>Build up behaviour by arranging reward following final component of the behaviour.</th>
<th>Participants receive virtual rewards for eating 3 vegetables which is contingent on them buying, cooking and eating vegetables.</th>
</tr>
</thead>
</table>

**Phase 9: Evaluate with a trial**

The overall impact of the VegEze app will be evaluated using the RE-AIM framework [30, 31] in an uncontrolled, quantitative study designed to measure its effectiveness in increasing daily vegetable consumption after 21 and 90 days, as well as to determine the associations between user characteristics and outcome measures. VegEze is currently available in the App store as a standalone research app and participants have been recruited to take part in the evaluation study through television, radio and social media. The results of this evaluation will be published and the execution of a communication plan will ensure the results are shared widely at the completion of the trial (Phase 10 of the IDEAS framework).

**Discussion**

Overview

This paper has described the theoretically and commercially derived development of the VegEze app, its features and functionality. Combining a theoretical framework with an industry perspective and input has resulted in an app that was developed in a timely manner while retaining its’ evidence-base and the process of scientific evaluation. It has been suggested that the pace of the development, evaluation and dissemination cycle is too structured and slow in academia, inhibiting the progress in meaningful and engaging mobile phone interventions. However, few have worked closely with industry partners to remedy this. The quick build phase of VegEze is evidence that academic-industry partnerships can work efficiently and effectively to develop products that target important population health issues. The upcoming, large scale evaluation will demonstrate the reach and ability of this app to achieve behaviour change. Reviews of literature suggest interventions in the general adult population can increase consumption of fruit and vegetables by 0.2-0.6 serves per
day or up to 1.4 in more controlled environments [32], but this increase is likely due to changes in fruit intake and to a lesser extent vegetable intake [33]. A more recent review of electronic and mobile health interventions for young adults found of the studies that reported vegetable intake independent of fruit, 4 out of 5 studies increased intake, with reported increases between 0.1-0.4 serves per day [34]. We are expecting that the VegEze app will reach over 5,000 people and achieve an average increase of between a quarter to half a serve, and possibly higher in those who have low vegetable intakes.

Strengths

The VegEze app has at its core the fundamental behavioural techniques of goal setting and self-monitoring. These techniques have been applied in interventions targeting a multitude of behaviours and are consistently identified in various theories as fundamental for the process of behaviour change [19]. However, how these are operationalised is critical to the target behaviour. We have been careful in how these techniques have been applied in a way tailored specifically to the behaviour of interest. We have also been careful in balancing the scientific evidence base, with the fun, engaging and usability elements expected of commercial grade apps – largely the result of an ongoing exchange of ideas between the members of the multidisciplinary project team. Finally, the IDEAS framework helped to focus the priorities of the app development and retain scientific method. The use of Apple’s® ResearchKit® software means that evaluation surveys are embedded into the app and will allow for a robust evaluation phase.

Limitations

While the development of the app was informed by large groups of potential users, they were individuals who had previously registered or participated in health-related initiatives. As a result the majority were women, aged in their late 40s/early 50s, health motivated and all volunteered to help in the development of an app targeting vegetable consumption. It is possible that the resulting app may not appeal as much to other groups of the population, however this will form part of the evaluation trial.

Conclusions

The development of VegEze was the result of a research-industry partnership which brought together scientific evidence and commercial ‘know how’ to develop an app targeting inadequate vegetable consumption among Australian adults. The IDEAS framework involved a number of iterative steps and helped to retain a theoretical foundation without comprising the pace of the pathway to market. The effectiveness of the app is currently being evaluated in a large scale, ‘real world’ trial and the results will be reported using the RE-AIM framework.

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Conflicts of Interest

The authors declare no conflicts of interest.

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