Measurements of engagement in mobile behavioural interventions?

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ABSTRACT
Mobile digital behaviour changes interventions (mDBCIs) are becoming increasingly useful and necessary within healthcare and wellbeing. Health interventions need to close the gap between intention to behave and the behaviour itself. If apps fail to engage users, the behavioural content is never seen. This paper investigates the measurements of engagement using a health based quiz app. Quiz questions were created using the NHS website and fell into the following six categories: "healthy eating", "losing weight", "sleep", "fitness", and "smoking". Gamification features such as count down timers were used to encourage user participation. Notifications, with individual goals, were sent out to nudge the users to play the quiz.

Engagement was measured in two ways. Firstly, a count of completed quiz questions illustrated app engagement. Secondly, a participants learning was evaluated using a learning curve. This measured whether a participant learnt the health material illustrated by an improvement in their answers over time. A comparison between two participants, who answered the same number of questions, showed a different level of learning. One participant improved producing a learning curve as expected. The other participant consistently answered questions wrong, showing a lack of engagement with the intervention material. This paper shows the importance of measuring these two types of engagement, app and intervention material, separately to improve the designs and effectiveness of mDBCIs.

Categories and Subject Descriptors
H.5.m [Information interfaces and presentation (e.g. HCI)]: Miscellaneous

General Terms
Human Factors, Design, Measurement.

Keywords
Engagement, Mobile health, Mobile Applications, Gamification, Design, Digital Behaviour Change Interventions.

1. INTRODUCTION
For mobile Digital Behaviour Change Interventions (mDBCIs) to be successful, they need to pass several hurdles. For example, an app to help people try to lose weight firstly needs to attract users to download it. It has to compete with a vast array of weight-loss apps in the app store. Secondly, the app needs to be appealing and functional to the user to ensure continued use. An entertaining interface or creating curiosity within the app, can achieve such engagement. This engagement may be important for developing required skills needed in the next stage. Thirdly, the app needs to provide the behavioural intervention, either by educating or directing the user in some way. App design can aid the user by providing the required knowledge, or forming a scaffolding exercise, which enables the user to eventually maintain new behaviours without the app. Often, especially with an app of this kind, material needs to be provided in an engaging way to promote the intended message such as "how to make sensible food choices". The final challenge is to bring about a behaviour change and sometimes this behaviour does not occur in conjunction with the app use. There are therefore significant barriers to an mDBCIs success.

As rational agents this would not be an issue; humans would make selections based on their preferences and beliefs [40]. For example, individuals would choose healthy foods if they were trying to lose weight. However, a person's desires and impulses can override their rational intentions.

There can be numerous barriers to carrying out desired behaviours, often referred to as the Intention-Behaviour Gap [41]. There is a significant gap between a person's intentions (created from their personal goals) and the actual behaviour act. In addition, other factors can impact behaviour. For example, optimism bias explains why individuals carry out risky behaviours. Studies have shown that people disregard pre-known risks as irrelevant to them [22]. Unless an individual has a personal experience with health-related conditions (e.g. a heart attack caused by excessive consumption of saturated fats) they are unlikely to change their eating habits, even if presented with this factual correlation. Therefore warnings alone are not always very successful in bringing about behaviour change. Factors such as lack of ability, motivation or a well timed trigger can impede a behaviour [19]. This disparity between intention and action highlights the importance of mDBCIs. All these barriers to intended healthy behaviour and behavioural interventions further emphasise the importance for creating engaging and successful app.

Several aspects can affect how engaging an app can be and furthermore engagement can be defined in various ways. As our starting point we will use Carroll and Lewis' [6] definition of an engaged interaction, which explains that engagement occurs when a user is more than a "passive spectator". A user becomes engaged when they become an "active and perceptually hardworking participant in control of their own 'engaging' experiences"[6].

2. ENGAGEMENT

Several fields of study, such as UX (user experience), behavioural health interventions, and education use the term engagement. However, the term is frequently loosely defined and different fields have utilised different and sometimes inconsistent definitions.

2.1 Engaging Technologies

Chapman et al [8] define engagement, focusing on multimedia training systems, as "attention focus, curiosity, and intrinsic interest". O'Brien and Toms define engagement using attributes which assess the quality of the user's experience, when using a technology [36]. Other researchers, have analysed engagement using theories such as "human attitude" to explain user's behaviour [25]. More recently, "stickiness" has been used to describe engagement and long-term retention. Although there is a disparity in terms, and subtle distinctions here, the majority of definitions focus on the user's impact or interpretation of a system. In contrast, engagement in health is more commonly used as a quantifiable measure.

2.2 Engagement in Health Interventions

Papers investigating engagement with mobile health apps often use the term engagement to refer to counts of interaction e.g. "number of section of the Web-based smoking cessation program opened" [42]. Engagement in this field of research can also be referred to as 'exposure' [13], which signifies an important difference between this type of engagement and other forms. Measuring exposure normally focuses on contact with intervention content [14].

Investigating engagement within mDBCIs can be thought of as a two-step process, engaging with the app and engaging with the intervention content. It is important to understand what the user is focusing on [39]. This is challenging, as there may not be an easily measurable metric to gauge this. For example, engagement could require reading a document; and therefore clicking through to the next screen does not necessarily signify active participation. In some cases such as the watching of a video, more fine grained measures can be utilised, and if a participant is on the page showing the video for less time than the video runs they have not fully engaged with that content. However, the reverse assumption cannot be made, as it cannot be guaranteed that a participant watched the whole video even if it played in its entirety.

2.3 Engagement in Educational Health Interventions

Education can play a key role in self-management for both chronic illnesses and general health and wellbeing. Furthermore, educational health interventions need to provide the material for patients to become "engaged" and "informed". Active or engaged participation requires patients to learn about their illnesses and take more responsibility for care decisions [12]. This needs an active prevention approach rather than a passive reactionary approach [1]; aligning with this papers initial definition of engagement. Measuring how engaged a participant has been in these cases can be carried out through assessment of their learning as a result of using an app or web-based material.

3. CASE STUDY: A HEALTH-BASED QUIZ APP

It is possible to promote and measure engagement within a health-based app-like quiz. There are multiple factors which affect engagement and behaviour change. Using a health-based interactive quiz, this research demonstrates the importance of measuring engagement as a multidimensional concept. As a basic level of engagement the app will explore a count of questions to illustrate participation. An assessment of learning will show an active engagement with the intervention health material.

3.1 Technical Design

The "HealthQuest" app was developed using AngularJs, a JavaScript framework, which allowed a fairly rapid development lifecycle and release. A randomization function in the code automatically allocated participants to either the control or experimental group. The control group took part in baseline and final assessment but did not have access to the quiz content.

The app used BackboneJs to locally store values on the phone so users did not have to re-login with each new session. It was important that it had an app 'feel', using touch screen interaction and a simple design and interface.

Due to time constraints the app was released as a web app rather than through the official app stores. This made it easier to distribute and provide access for participants. All participants were informed that the app was to be used on a mobile device.

3.1.1 Gamification

To engage the participants in a fun and enticing way, the health information was presented within an interactive quiz. Gamification, adding game-like features to a non-gaming behaviour [29], was used to enhance user engagement [5]. In this instance, by converting health facts into a timed quiz.

In previous studies investigating interface design features several elements were identified to increase the enjoyability of a system. Malone [30] found that challenge, in the form of a goal, increases enjoyment but needs to be accompanied by prompt feedback. For this reason a timer counting down from 30 seconds was intended to gamify the question page interface. This type of challenge should increase the users enjoyment of answering questions [44].

Feedback was also provided on the "your stats" page which included: success rate (%), total number of questions answered, fastest correct answer time, and longest correct answer streak. These were calculated using the locally stored values from the user's gameplay, which were also synced with the main database. Score keeping, another promoting factor in enjoyment of a system [44], was provided through a leader board presented as current percentile position within the email prompts sent to participants.

3.1.2 Email Notifications

Prompts, such as emails or texts, can encourage a behaviour, e.g. by nudging or reminding the participant to interact with the app [26]. To mimic a real-world app set-up, users were given the option to opt-out of email notifications. Desired options should be set as default to persuade users to accept this choice [21]. Therefore, the default was to accept notifications.

Those that agreed to the notifications received 3 emails over the course of the study. Emails were personalised using the user's chosen game-name and individual values specific to their game play. This personalisation leads to a more compelling persuasive message [17]. Each email also used slightly different behavioural economic methods to encourage engagement.

3.1.2.1 Goal Setting

Goal setting has been highlighted as an important part of behaviour change. Goals are a good way to encourage motivation but it is imperative that large targets are broken down into smaller more attainable sub-goals [34]. Goal-setting Theory states that specific measurable goals which are challenging but realistic are the most effective [45].

For this reason, the first and third email focused on setting a target number of correct questions to aim for. The first email was sent a couple of days into the study to encourage continued use.

Individual feedback provided users with personal goals [17]. If the participant had answered less than 10 questions they were encouraged to aim for this achievable goal. The third email explained that the study was nearing its conclusion and therefore set a new final target.

3.1.2.2 Competition

Shifting an individual's behaviour can be as simple as telling them what other people are doing [18].

However, it is important not to draw attention to any desired behaviour which exceeds expectations [43]. This can lead to the "boomerang effect", where individuals relapse into previous, undesired behaviour. This effect is counteracted when a social nudge is accompanied by an emotional nudge, e.g. in the form of a smiley face, indeed unhappy faces can sometimes prompt underachievers to greater behavioural change [43]. Therefore, the second email categorised participants as either inside the top 10% of gamers or not. Sad and happy faces were also included to encourage underachievers and continued participation in the study.

3.2 Content Design

This study required a database of health facts to quiz users on. All questions were created using the NHS website[1], selected as a reputable information source.

3.2.1 Question Topics

Six categories were selected from the "Live Well" drop-down list on the NHS home page. Each of these topics – specifically "healthy eating", "losing weight", "sleep", "fitness", and "smoking" – had several NHS help and advice pages. This content was analysed and used to form the questions for the quiz.

Rather than collating all 120 questions into one pool, questions were separated into categories, each containing 20 questions. A large question pool would have resulted in a lower repetition of question which could lead to less effective learning [20].

3.2.2 Question Format

Several considerations were made about the format of the questions. All questions were written with a personal pronoun "you" as studies have shown that this helps to engage the reader [38]. Questions were written in a multiple-choice format to try and draw the attention of the gamer to the content, see Figure 1.

[1] http://www.nhs.uk/Pages/HomePage.aspx

Furthermore, messages were written in a gain-framed format to encourage preventive health behaviour change [32]. A gain-framed message can either emphasis the receiving of a positive or the avoiding of a negative outcome [37]. If health information is framed in the wrong way, it could be undervalued due to the optimism bias or ignored altogether due to the "Ostrich Effect" [34]. This effect occurs when a person emotionally reacts to information that they do not like and choose to disregard it altogether [23]. Therefore feedback attempted to explain gains in the here-and-now (e.g. "When you quit smoking, lungs start to clear after 24 hours …").

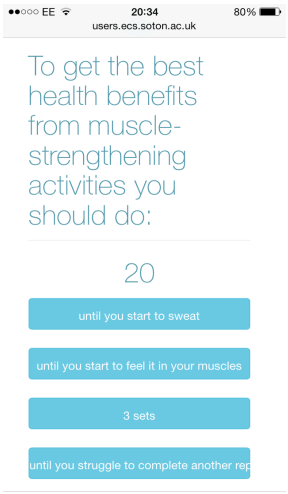

Figure 1. Question Interface

Figure 2. Category Interface

3.2.3 Question Selection

Rather than allocating participants to different categories of questions, individuals selected their own interest topics, see Figure 2. Once the category was selected, questions were randomly chosen from within that topic pool.

3.2.4 Feedback

A feedback screen was presented to the user after every completed question, during gameplay. This screen clearly fed back the status of their answer, the correct answer, and an in-depth health-based explanation. Feedback is an important element of learning. Players are curious and enjoy knowing information so prompt feedback either confirms their knowledge base or corrects their incomplete comprehension [30]. Lee and Dey found that real-time feedback both improved consistency, reduced errors and reinforced healthy behaviour [12]. Previous research has found that the repetition of content further adds to the users learning [33].

3.2.5 Health Assessment

The secondary aim of the research was to bring about behaviour change. Participants were asked at the end of the study whether they felt their attitudes had changed. However, this change can be subtle. In an attempt to gather as much data as possible (including conscious or subconsciously behaviour change), the study included a health assessment form. This was a digital version of the East Midland Public Health Observatory's "Workplace Health Needs Assessment" [37] which was incorporated into the app. This document was also produced by the NHS and selected because it asked questions relevant to the question categories. All

participants completed this health assessment at the beginning and end of the study.

4. STUDY DESIGN

Participants were recruited through a social media site. They included 12 males and 17 females ranging from 21 to 56 years old. All participants were informed that the study would require a mobile device and access to the Internet.

4.1 Procedure

All participants carried out the baseline health assessment on the App. Participants were then presented with 20 random test questions from any of the six categories. No feedback was provided on these questions. These questions were not intended to educate users, but purely used to assess the current level of participant's knowledge.

Participants allocated to the experimental group, by the system, could then select a question category and start to play the quiz. Participants were encouraged to use the app whenever they wanted to and feedback was always provided on completion of a question. The control group could not access quizzes during the trial period. At the end of the trial period all participants in both groups were given a second test comprised of 20 random test questions and then asked to complete a health assessment on the App.

4.2 Data Collection

The registration form asked participants to state their gender, age and contact details. The app sent updates to the server after each question. This data included the question id, user's answer, time of day, time taken to answer the question, and longest correct answer streak. To protect against random clicking, the answer time was calculated and saved with each question. If a user had a high fail rate, times could be checked to see if the nature of interaction with the content seemed realistic for someone engaging with the material. This record also allowed the researchers to confirm that a question had timed out, exceeded the 30-second limit, in gameplay. The fastest correct answer time was also recorded and updated after each question in order to provide a further target goal for the user when they viewed their stats page.

5. RESULTS

5.1 Learning

A comparison between the pre- and post-tests results (20 random questions) showed little significance between the control and experimental group. This is probably because the tests used *all* questions rather than focusing on the specific categories the user chose to learn about. However, learning was also evaluated on an individual basis, looking at their responses to the quiz questions during the study.

Engagement with the material, demonstrated as learning, did occur through repetition and extended periods of gameplay. Figure 3. displays a standard learning curve [31], where performance is illustrated as the error rate plotted against the number of questions answered. The error rate was calculated using the number of incorrect answers divided by the number of completed questions. Figure 4. also shows the expected learning curve, i.e. as the participant answered more questions their error rate reduced. There are some spikes in the curve but this could be due to a number of reasons such as an unseen question or lack of concentration. This shaped graph was a common occurrence within the experimental group.

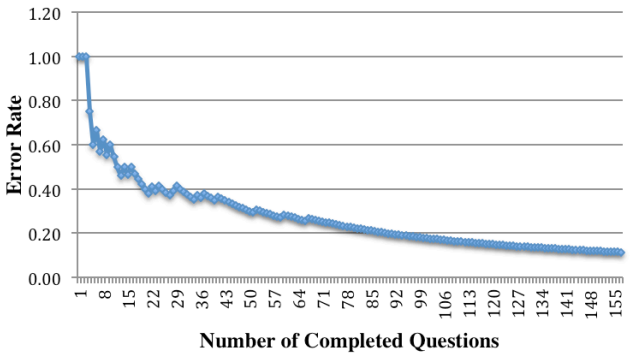

Figure 3. Graph Showing the Learning Curve of Participant X Whilst Using the App

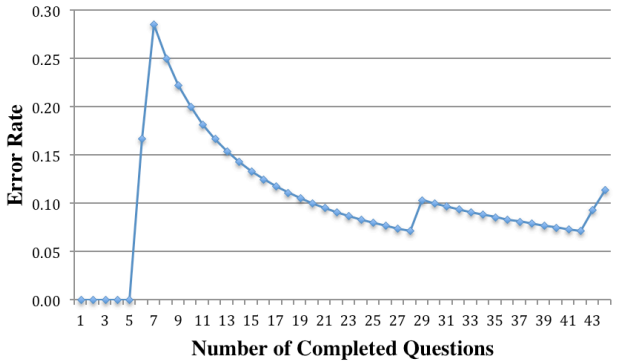

Figure 4. Graph Showing the Learning Curve of Participant Y Whilst Using the App

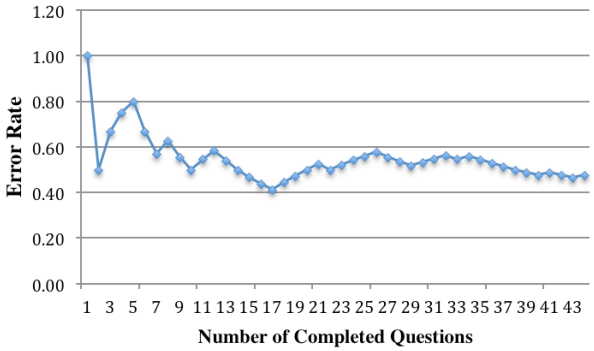

Figure 5. Graph Showing the Learning Curve of Participant Z Whilst Using the App

Figure 5. shows that participant Z completed an identical number of questions to participant Y. This illustrates the same level of engagement with the app. However, participant Z failed to show the normal rate of learning, illustrated in the previous two figures. Therefore participant Z failed to show the same engagement with the intervention, never successfully passing below an error rate of 0.4 compared to the 0.1 seen in the other graphs. .

5.2 Feedback

During the initial test participant 19 was concurrently asked the same question. Even though the first attempt was correct, the user doubted their answer seconds later, potential due to this repetition. However, when the same question was presented a further two

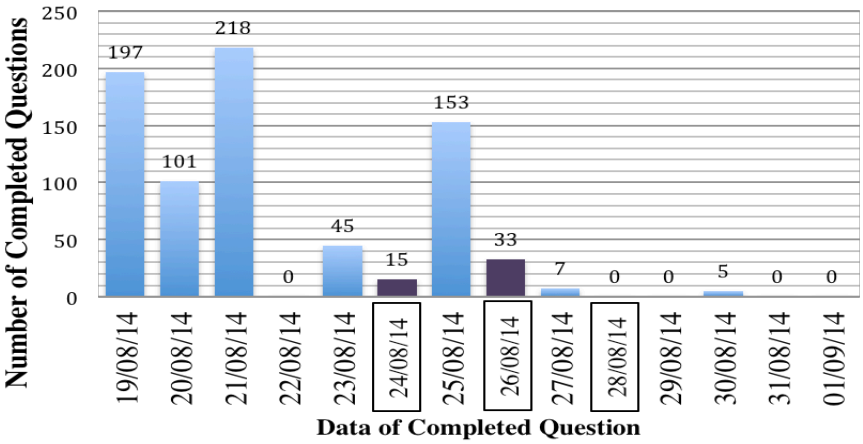

Figure 6. Number of Completed Questions vs. Date

times in gameplay, the user answered correctly both times. This shows that the user potentially thought question repetition was a sign of negative feedback. However, once in game play and provided with positive feedback, this situation did not reoccur.

On the other hand, when a similar situation occurred for a different user, they did not change their answer. Instead this participant consistently answered correctly. More complex quiz construction algorithms could help avoid such issues although they do provide useful information about the way participants may learn through such quizzes.

5.3 Nudges

Figure 6. shows the number of completed questions in relation to the date of the study. The boxed dates represent when the email notifications were sent out. The first email nudge (sent at 21.00) was highly successful with a clear peak and activity on the following working day. This email was sent late at night so the subsequent day's results are particularly relevant. The second nudge (sent at 16.00) also could have been successful but the large volume on the previous day makes it difficult to judge which email was responsible for the 33 completed questions on the 26th. The final email (sent at 16.00) intervention was less successful, with no extra questions on either that day or the following day. There was a final peak on the third day, which was a Saturday. However, more investigation is required to understand why this notification was less successful.

6. RELATED WORK

Several studies have investigated different technical features which can affect engagement, behaviour change or even acceptance of an app. Chang et al proposed a framework for user attitudes towards apps [7]. The framework suggests 7 elements: attractiveness, fun and excitement, diffusiveness, social support, trust, perceived ease of use and perceived value. Although this is a good starting point, many of these terms are subjective and further research needs to explore how these can be accomplished.

Bickmore et al carried out an interesting study using "Laura", a virtual agent designed to increase long-term engagement with their intervention system and therefore increase the participant's exercise [4]. Although the system was successful in promoting longer interactions, it didn't transfer into exercise. In fact they found the more engaging Laura was, the less the participants walked [4]. There is therefore a fine line between creating an engaging system for health interventions and creating something that engages users with technology.

Looking at log-data in more detail can lead to further understanding of individual usage to inform designing personalised interventions [35]. Additionally this evaluation can help recognise any design assumptions or identify usability issues [35].

6.1 Gamification

Zombie Division was an educational game which aimed to teach primary school children about arithmetical division [2]. This game seemed to engage students with interesting gameplay and graphics. However, this app is more like a game than a gamified lesson, potentially distracting the children from learning [2]. Baker et al couldn't conclude that learning of the mathematical material had occurred. Students potentially just learnt how to play the game [2].

McDaniel et al investigated the effect of providing additional content to a course of students using an online [33]. In comparison to previous studies of this kind, this research provided a more realistic natural setting to investigate online learning [24]. This study found multiple-choice questions to be just as effective as short-answer formats [33]. Furthermore, providing strong evidence that students can learn using quizzes provided there is informative feedback [33]. This paper provides good grounding for method used by the HealthQuiz app. However, the students in McDaniel et al's study had enrolled on a particular undergraduate course [33]. The HealthQuiz investigates the role of a quiz containing information that isn't being assessed for credit carrying modules.

Fish'n'Steps used a gamified app to encourage exercise by linking daily activity to an animated fish character [28]. UbiFit, a garden based persuasive game, built upon the Fish'n'Steps research [11]. UbiFit used three features: a quick-look display for instant stat updates, an interactive application which kept detailed records of the completed activities, and a device for recording fitness [11]. UbiFit found the animated display was "essential" to success, i.e. extended periods of activity [10] and Fish'n'Steps seemed to provide the motivation to encourage healthy behaviour [28].

Gamification therefore can be effective in motivation and promotion of health behaviour. However, the fitness device, used in UbiFit, required further technical advancements but both studies highlight the important fact that interventions need to fit easily into people's daily lives. As an app based quiz, HealthQuest is easy to use in a spare minute or spare hour, hopefully fitting in to user's general lifestyle. Furthermore, this type of app allows users to further their knowledge, promoting self-management, rather than just prompting a behaviour.

6.2 Feedback

Feedback can also affect the success of an intervention. Significantly, in the Fish'n'Steps study, participants reported occasionally ignoring the game to avoid the negative feedback of the crying fish [28]. Instead of motivating users this led to demotivation and highlights the importance of language in behaviour changing interventions.

Lee and Dey [27] investigated the role of feedback *after* the desired behaviour, using a "sensor augmented pill-box" and a tablet [27]. However, the behaviour change was not sustained after the feedback was removed [27]. If this feedback is required in the long-term, the system could be designed to work on an individual's phone, providing constant access. This is especially significant for older patients who suffer from multiple chronic conditions and may require this type of intervention for the rest of their lifetime. An app, such as HealthQuest, doesn't require extra hardware to work. Therefore this intervention structure could be applied to several types of intervention.

6.3 Education

DeWalt et al's study into heart failure found an educational intervention benefitted several health behaviour change aspects, including self-management [15]. Using a booklet on self-management processes, this educational intervention appeared to reduce hospitalisation and fatality for patients of all literacy levels [16]

In an e-learning study using outpatients from a hospital, 72.2% of participants found the web-based system to be more effective than traditional educational methods [3]. In addition, 70.8% claimed they would continue to use a similar e-learning system at home [9]. Although these intention percentages are encouraging, intention does not always translate into behaviour change.

7. DISCUSSION

An exploration of individual participants found that learning occurred during gameplay. Similarly to other gamified apps, such as Zombie Division, this could have resulted from users learning the game rather than the content. However, users often had several days between gameplay and the questions were randomised; therefore learning the system might not have been as easy as learning the actual material. Further evaluations of learning could provide more evidence to the success of the app.

The first nudge, which used individual goal targets, seemed highly successful in encouraging participants to return to the app. These findings support the goal-setting theory as a highly motivational tool. The subsequent two nudges, however, were less successful. This could be because participants had recently logged on to the system as a result of the previous nudge. Furthermore, a comment left by a particular user hinted that a count of successful and unsuccessful questions should be included in the app. This signifies that there is an issue with the app design suggesting that some participants may not have found their stats screen. If that is the case, motivation to learn might have been reduced because participants could not see whether they were hitting their goals. A redesign should be considered in future studies.

Some participants in the experimental group only answered a couple of questions and failed to return to the app. This could be the Intention-Behaviour Gap, where participants intended to use the app but failed to plan it into their daily life. Alternatively they might have been adverse to the information provided causing the ostrich effect or potentially they didn't find the app useful. Further qualitative research could help explain this lack of engagement.

On the whole, participants answered an average of 70 questions, minimum 10 and maximum 233. In the final questionnaire, 70% of the experimental group users stated they would use the quiz as part of a health-based app. The app engaged users for the time that they answered questions. In addition, the learning that occurred during these gameplay sessions suggests users engaged with the health material.

This study has recognised that unintended feedback can result in undesired behaviour change. This occurred when a user was shown the same question within one test scenario. As this stage of the experiment lacked feedback, it is presumed that the participant interpreted this as an answer error. This would need further investigation to confirm this finding, but regardless it is something that can be considered during the design of any learning intervention.

Furthermore, some participants found it difficult to locate the "your stats" page. Therefore a more visible "your stats" page would improve the users experience when learning. Other features such as leader boards and controlling the frequency of notifications could add to the overall engagement with the app.

As expected for the majority of participants behaviour change did not occur. One participant did significantly reduce an average weekly smoking count from 60 to 35. Although this is the intended behaviour outcome, further research is required to understand if any external factors may have affected this.

8. CONCLUSIONS

This paper explores 'engagement' within digital behavioural health interventions. Importantly distinguishing between engagement with the app and engagement with the intervention. Many theories of behaviour change and healthy living models emphasise the importance of education and self-management of one's health. Using techniques, such as gamification and notifications, this HealthQuest app design, successfully engaged users in two ways. First, the app successfully encouraged users to participate in the quiz illustrating engagement with the app. Second, many users engaged with the intervention, illustrated by their reduction in error rate during gameplay.

However, significantly two participants with the same number of completed questions had varying levels of improvement over time. This highlights the difference between engagement with the app and intervention. Logs of usage may only present engagement with the app rather than with the intervention. Future studies need to separately measure these two aspects of engagement to ensure users are engaging with both successfully.

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