



PhD thesis

Gamification for a healthier lifestyle – user adherence

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Gamification for a Healthier Lifestyle

– User Adherence

A thesis submitted to Middlesex University in partial fulfilment of the
requirements for the degree of Doctor of Philosophy

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Abstract

Numerous applications have been developed using gamification- in the field of health and well-being to help modify lifestyle factors associated with various diseases such as cancer, diabetes and many more. To improve well-being, an individual needs motivation, and this motivation is one of the key driving factors responsible for user engagement. This research aims to investigate strategies to encourage people to adopt a healthy lifestyle using gamification and identify the key factors responsible for retaining users. The study was not limited to certain activities such as the gym or sports but also motivated people to engage in small activities, for example, doing household work, walking and many others. Some physical activity gamification applications focus on elements such as rewards, leaderboards and competition, while very few investigate various motivational elements using motivational techniques. The application was developed using Unity and C# supported by iOS, Harmony OS and Android. The main aspect of the research focused on motivational techniques such as Behavior Change Techniques (BCTs) and Self-Determination Theory (SDT) to tackle the issue of behavior change and user adherence. BCTs are techniques to help individuals change their behavior to adapt to a healthy lifestyle, and SDT is a theory in which individuals motivate themselves. The pilots were conducted to measure the impact of BCTs and SDTs with organizations such as Middlesex University, Unitas and Hendon School. The participants were of different age groups. The strategy used is to gather feedback using questionnaires and collect data used in Performance Functions to measure the effectiveness of BCTs and SDT. Using Performance Functions, we measured each component of SDT and BCT, which is one of the contributions of this research. The ‘Purpose’ component of SDT motivates participants of all age groups to be physically active compared to other SDT components. The results show that certain age group participants like certain features; for instance, the Daily Streak was popular among adults, while Active Travel was mostly used by teenagers and children in the Habit Formation category of BCT, which helped them to stay engaged for longer.

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Chapter 1

Introduction

A sedentary lifestyle has become a major issue and is a worldwide problem. According to the World Health Organization [1], 39% of adults are overweight, and 13% are obese, i.e., 650 million adopted unhealthy lifestyles in 2016. A key reason for this is owing to minimal mobility and exercise, causing an adverse effect on human well-being and leading to incurable ailments such as diabetes and cardiac issues.

Despite having gyms and fitness courses, people are more inclined towards a sedentary lifestyle. There are various reasons for adopting an unhealthy lifestyle. Firstly, being physically active is difficult due to long working hours and insufficient time to exercise. Furthermore, desk jobs have an adverse impact on individuals' health, leading to less physical activity, which causes inactivity and immobility in lifestyle. Secondly, many people spend time on digital leisure activities such as TV, smartphones, etc., which tend to encourage continuous seating for a long time, causing health issues such as spine disorders [2], pain and discomfort in upper limbs [3] and many more. Finally, shopping has become easy. More people are using online services for shopping or buying groceries. Sitting in one place and with a single click, the items are delivered to their doorsteps, leading to an increase in static behavior.

Consequently, people are adopting unhealthy lifestyles, which cause health problems. One of the important causes of sedentary behavior is a lack of motivation to be physically active, leading to an inactive lifestyle. The contemporary lifestyle health risks are increasing due to people's individual behavior. Thus, a change in behavior can significantly improve well-being. However, behaviors such as physical activity, exercise and diet require motivation to achieve behavior change. In the area of health and well-being, gamification has been increasing in importance [4]. Gamification is defined as “the use of game design elements within non-game contexts” [5]. The advantage of gamification is to enhance user engagement and user experience. Gamification is used in various industries, such as the health sector [6], social media [5], education [7] and many more. Game-based technology, also known as gamification,

is used to promote motivation. It increases the level of involvement and motivation. Gamification helps participants to accomplish their goals [8].

According to Kasurinen and Knutas [9], Crowdsourcing and Games for Health are used in the context of gamification. Crowdsourcing is an online task to socially interact, where a group of people participate in a task of different levels to gain a mutual advantage. On the other hand, Games for Health are to enhance the health or fitness level of the user by motivating users to engage in health-based activity. It is designed to train the user to be physically active while playing games. It promotes exercise gaming to improve the user's way of living.

Therefore, user adherence is a key factor in the domain of gamification. More insight is required into the driving factors responsible for user adherence [10]. The goal of this study is to focus on understanding user adherence and motivating individuals to lead more physically active lives.

1.1. Initial Problem Definition, Aim, and Objectives

Due to the historical context described in the previous section, it was identified that gamification has a good potential for addressing some health issues, particularly in terms of motivating people to be physically active. However, it is still not clear which things work well to motivate people to move more. It was worth investigating more deeply the role of gamification in well-being. Therefore, the initial aim and objectives of this research are as follows:

A1 – To identify the advantages and challenges of using gamification for well-being.

A1- O1: To identify the challenges in the existing gamification applications for well-being.

A1- O2: To identify the factors encouraging the uptake of gamification for well-being.

These aims and objectives will be expanded with other aims and objectives after the Related Work. The extended aims and objectives will be refined after the literature review. The initial question is not changed, but it will be refined.

The main challenge is to encourage individuals to prioritize their well-being by engaging in physical activity and avoiding a sedentary lifestyle. Advanced technologies, such as gamification, can help people to change their habits [9]. However, as the next chapter will explain in detail, existing gamification applications primarily focus on more superficial

elements such as points, badges, and leaderboards. Only a few of them investigate various motivational components using techniques such as BCT and SDT.

After conducting a comprehensive review of these studies, the outcome suggests a gap in the research, indicating the need for further investigation into the factors responsible for motivation. Therefore, to address this research gap and provide an improved solution, this research proposes a methodology that combines a user-centered development approach with motivational techniques. To support our research, it was identified that a gamification application better equipped with motivating factors such as BCTs and SDTs could prove useful as an experimental tool. We named this gamification app: “OnTheMove!” selected through a process by which a number of possible names were proposed by stakeholders and voted on. We supplemented the OnTheMove! app with the definition of Performance Functions. These functions enable the measurement of which motivating factors effectively encourage users of certain age groups to sustain their physical activity over the long term.

1.2. Key Research Contributions

At the initial stage, a literature review and a workshop with colleagues were conducted to examine different existing gamification technologies and motivational techniques used to motivate people to be physically active. The outcome of the literature review indicates that a better development of the system mentioned above is required that focuses on identifying driving factors responsible for user adherence that keep users sticking to a healthy lifestyle for the long term. Therefore, the key contributions of this research are as follows:

- Applying a methodology using a user-centered development methodology supplemented with motivational techniques.
- Developing a user-friendly gamification application to collect data and identify the effectiveness of various elements of motivational techniques.
- Assessing the proposed innovation with people from different sectors of society and different age groups through several pilots¹. We systematically gathered feedback from

¹ Throughout this document, the term 'pilot' refers to the validation phase involving the use of the application by external users. In contrast, the term 'study' refers to this overall research project and research conducted by other scholars. More detailed information is provided in Section Appendix A - Pilot and Ethical Approval Process.

the participants through competition and questionnaires, which we used to expand the offer of motivational techniques offered.

- Defining Performance Functions to examine each element of motivational techniques and identify which works best for user motivation.

In this section, I provide a comprehensive overview of the research contribution. The following section will explore the specific details of my involvement, giving a detailed account of the insights, methodologies, and innovations that characterize my distinctive contribution to the overall research.

1.3. My Contribution to the Project

The project originally started from an M.Res. project published by Bene [11], which laid the foundation by introducing basic point-based incentives and QR code bonuses. Subsequently, another M.Res. project expanded the avatars with additional personalization features developed by Povilas Urbonas. However, there was a noticeable gap in incentivizing users beyond these features which seemed worth investigating and offered possibilities to try various ideas and had potential for improving the state of the art. Recognizing this opportunity for improvement in the field, I decided to focus my research on user adherence.

During the project's initial stages, I conducted a comprehensive literature review to gain insight into the research topic. I organized and led a workshop with colleagues and stakeholders, which was centered on user adherence and is detailed in sections 3.1.1 and 3.1.2. The requirements identified during this workshop were later linked with motivational techniques followed by a user-centered development methodology.

The workshop provided essential requirements for motivational techniques, which I continuously revised and expanded in various directions following each pilot and survey. I proposed various methods for implementing BCTs and SDT principles in the app, engaging in discussions with stakeholders to enhance their effectiveness and user acceptance. Each interaction with stakeholders' groups received ethical clearance from the university ethics committee.

I successfully deployed the app on three popular platforms, i.e. Android, iOS and Harmony OS, navigating the processes required for them to be available in their respective stores. Additionally, I incorporated feedback from various stakeholders to enhance the app's overall look and feel.

Motivational techniques played a significant role in implementing adherence features such as daily streaks, personal best, and bonus rewards. To assess the effectiveness of these techniques, I organized pilot tests and introduced measurement functions known as Performance Functions. Furthermore, I identified and implemented avatar packages for different age ranges within the OnTheMove! App.

1.4. Thesis Structure

This section outlines the structure of the following chapters of the thesis.

Chapter 2 discusses the related work conducted by other researchers. It emphasizes relevant gamification applications used for well-being and investigates the driving factor behind user engagement.

Chapter 3 presents the methodology (UCIEDP) used in this research, which has four stages: Interaction with Stakeholders, Initial Scoping, Main Development, and IE Installation. The development methodology was linked with motivational techniques (Behavior Change Techniques and Self-Determination Theory). This part of the chapter explains the UCIEDP and elaborates on the workshops conducted with colleagues and stakeholders, focusing on system design.

Chapter 4 focuses on the development of the application and the techniques used in this study. It also establishes a connection between traditional methodology and motivational techniques.

The validation and results of the pilots are explained in detail in Chapter 5. Entry and exit questionnaires were used in all the pilots to gather general information and feedback from the users. This feedback helped to make improvements in the application. Quantitative metrics (called Performance Functions) were also introduced in this chapter, which are complementary to the questionnaires and were used to measure the effectiveness of techniques such as BCTs and SDTs.

Chapter 6 covers the discussion, presents the conclusion, and outlines future work in this research.

Chapter 2

Related Work

This chapter closely examines research on motivation, user engagement, user adherence, and the use of gamified applications for well-being. It discusses the advantages and challenges of gamification, along with potential solutions discussed in Section 2.6, aimed at addressing challenges such as User Privacy, Lack of standardization, Lack of interest in the long run and Cheating to obtain reward. Furthermore, the chapter aims to identify gaps in previous research conducted by other scholars and outline the problem statement, research aims, and objectives of this study.

2.1. Motivation

Physical Activities such as walking, running, jogging and cycling have significant health benefits. It helps improve health issues such as mental health, anxiety, stress, obesity, etc. To adopt these activities, a person must change their lifestyle. Sustaining and making it a habit requires motivation [4].

Motivation is one of the key factors in gamification. It helps in user adherence in the long term. It increases the commitment to the task and performance of an individual [12]. Moreover, it helps in health behavior changes [4]. There is a correlation between the level of engagement and motivation. Vallerand and Thill [13] defined motivation as “the hypothetical construct used to describe the internal and/or external forces that produce the initiation, direction, intensity, and persistence of behavior”.

The term motivation is widely used in the field of psychology and gamification. Johnson et al. [4] describe two types of motivation: intrinsic motivation rises from doing things ‘for their own sake’, whereas extrinsic motivation rises from external factors. Extrinsic motivation includes feedback such as money or verbal praise, while intrinsic motivation includes group quests [8]. Group quests refer to in-game activities or tasks that require users to collaborate with others, giving a sense of relatedness and teamwork. This raises intrinsic motivation, as the desire for

social connection and the satisfaction of achieving common objectives can increase internal motivation to engage in these quests.

However, Alsawaier [14] discusses five motivation components: *intrinsic and extrinsic motivation, task value, Ability belief, and expectancies for success*. Intrinsic motivation arises from the individual needs to mastery, conquering challenges, and nurturing curiosity. Extrinsic motivation arises from factors external to the task's inherent worth, such as incentives and performance rewards. Task value is defined as the insight and value of task completion by the participant and decision-making whether it is favorable for the participant or not. Ability belief is a participant's confidence that their efforts will lead to favorable outcomes, while expectancies for success involve anticipating how the participant will execute a specific task in the future.

Many studies show that intrinsic motivation helps improve health behavior compared to extrinsic motivation, and it also helps in the mental and social well-being of the individual [12, 15, 16, 17, 18]. The study conducted by Kilpatrick et al. [19] suggests that intrinsic motivation helps maintain behavior change and adherence over extrinsic motivation. According to Deci [20], the intrinsically motivated task is performed out of interest instead of worrying about the possible outcome. Intrinsic motivation is closely linked with emotional attributes of subjective well-being such as fun, enjoyment and feeling of efficiency [21, 22, 23].

On the other hand, extrinsic motivation is not for its own sake but for external factors such as reward. A task can be performed without pleasure or interest in extrinsic motivation, and it causes the desire for the outcome of the activity. This desire is not to engage in the activity performed for its own sake but for external factors. The task performed for extrinsic motivation is established in the environment instead of within themselves [24].

Ryan and Deci [25] described extrinsic motivation as "Extrinsic motivation can be a powerful driver of behavior, but it is most effective when the extrinsic incentives are aligned with an individual's own self-determined values, identity, and personal goals". It is to be involved in a task to get rewards or avoid punishments.

Motivation is linked with user adherence and user engagement. Martin et al.'s [26] study discusses the link between motivation and engagement. Moreover, gamification plays a significant role in understanding adherence and engagement. The gamification improves user adherence and user engagement.

2.2. User Adherence and User Engagement

Health and fitness mobile applications, commonly used today, are designed with gamification features to enhance user engagement and adherence. These applications use various gamified elements to motivate users to maintain healthier lifestyles, engage in regular exercise, and achieve their wellness goals. The outcome of the study conducted by Bitrian et al. [27] suggests that gamification raises user engagement through satisfaction using three components: *relatedness*, *autonomy* and *competence*. Other studies [28, 29] indicate that gamification helps to improve user adherence. The definition of user engagement and user adherence is as follows:

- **User Adherence** - The term '*adherence*' is defined as *how the individual's action correlates with the accepted exercise program plan* [30]. The concept of adherence to exercise is not solely about the number of participants quitting or attending a session; it is more about the participant's behavior. User adherence to a physical activity app measures both the user's intention to continue using the app [31, 32] and the user's behavior in using the app [33, 34, 29]. An example of user adherence is seen in the MyDiabetes application [28], where the incorporation of gamification elements increased user adherence. This study conducted a survey at S. João's Hospital's endocrinology service, involving 23 participants with Type I diabetes. Although the results appear promising and the gamification elements help to improve the blood sugar level, the long-term effectiveness of the gamification implementation could not be determined. Further investigation was required to assess the impact of gamification on user adherence over a long period.

User adherence is measured based on four parameters [29]: the frequency of app usage [35], motivation to continue using the app [36], the functions of the app that are utilized [37], and the number of days the application is used by the user [38]. However, further investigation is needed for long-term user adherence. These parameters are employed within this study in the 'Performance Functions' section 5.2.

- **User Engagement** - It is defined as "*a quality of user experience characterized by the depth of an actor's cognitive, temporal, affective and behavioral investment when interacting with a digital system*" [39, 40]. A successful digital system keeps users engaged [41]. Quesenbery [42] describes engagement as a dimension of usability impacted by user's initial impression of the app and the fun or pleasure they get while using it. An example of a user engagement application is e-LifeStyle [27, 43]. The

incorporation of gamification elements is shown to boost user engagement. The research focused on developing two types of mobile health (mHealth) applications for hypertension monitoring. These applications had distinct features: one incorporated game-like elements, while the other did not. The main goal was to determine the level of user engagement for well-being using these two different types of mHealth applications. The study's outcome suggests that the gamification elements in the mHealth applications led to increased user engagement and boosted motivation. The group that used the application with gamification elements showed better control of their health compared to those who did not have gamification elements. Nevertheless, the study highlights the need for further investigation into long-term user adherence to these applications.

2.3. Gamification Application for the Well-being

Many applications have been developed for individual well-being using gamification, and we explore some of these below. Studies discussing the importance of gamification in the area of well-being suggest that gamification shows positive results in improving health. Some of the previous research are as follows:

The research conducted by Rose et al. [44] designed a gamified mobile health application known as '*MYSUGR*' to examine the behavior of a group of diabetic patients over 12 weeks (about three months). The outcome of this research was positive, and improvement in blood sugar levels was observed. However, the challenge faced by them was to keep users engaged. The adherence rate of the app users was 88% but dropped after 28 weeks (about six and a half months) to 70%. Hence, further investigation is required on factors contributing to user adherence.

Findings reported by Stinson et al. [10] suggest that the 'mHealth' pain assessment tool has positive outcomes for cancer patients. The quality of life and user participation were improved in teenagers aged between 9 and 18 over a 2-week observation period. The tool helped teenagers with pain management. Although the outcome was positive, it still has some drawbacks. The limitation of this study was that more analysis was required to understand the fundamental factors behind user engagement, for instance, rewarding systems.

Cechetti et al. [43] research developed two types of mHealth applications for hypertension monitoring: one with the game mechanics and the other without. Fourteen patients with

hypertension were categorized in the evaluation stage into four groups, i.e., no gamification with assistance, no gamification and no assistance, gamification with assistance and gamification with no assistance to verify user engagement in health care. The results show that gamification favored engagement and promoted intrinsic motivation in the users. The group with gamification elements managed to control their health compared to those without gamification. However, further study is required for user adherence.

Torrado et al. [45] developed an application called '*HikePal*', which is used to encourage people with intellectual disabilities to be physically active. This application uses gamification elements such as a story and reward systems to keep users engaged. This study used three research strategies: semi-structured interview, focused group and pilot user. The five interviews were conducted with experts on physical activity, disability, and digital systems. The focus group was carried out on six participants to get expert feedback, and the pilot user was carried out on end users. The authors suggested that social interaction is the key factor for motivation as compared to the medal reward system in the application. The main drawback of the system is that it needs to be simplified, and more customization features are required. It's possible that the difficulties users encountered, such as forgetting to click on the next button or finding the story too demanding, may have arisen due to the complexity of managing navigation, technology use, and physical activity all at once. This complexity could negatively impact user adherence, particularly for individuals with intellectual disabilities, who might find navigating such a complex system difficult and may tend to stop using it.

Alsaleh et al. [46] developed a gaming application for Children with Diabetes Mellitus. Six- to twelve-year-old children with diabetes participated in a two-week experiment. They were divided into two groups: a) a control group with ten children and b) a treatment group with ten children. The treatment group children watched the educational video with information about the proper nutrients and food to eat before playing the game. The game mechanics used were badges, points and time. However, the control group played the game without watching the video. Despite the task given to both groups being the same, the treatment group performed better than the control group. The authors suggest that gamification positively affects children's behavior and encourages them to eat healthy foods.

Cafazzo et al. [47] developed and designed an application known as '*Bant*' for adolescents with type 1 diabetes. The adapter automatically transferred blood glucose readings to the bant app running on the devices, allowing users to get the feedback in real-time. The twelve-week pilot was conducted with twenty youths aged twelve to sixteen. Each participant was provided with

a LifeScan glucometer, iPhone or iPod Touch during this pilot. At the initial stage of the pilot, an interview was conducted with patients and their parents. At the end of the pilot, a survey form was provided to the participants. The outcome of the pilot was positive. Points and reward game mechanics help in health improvement. There was a 50% improvement in the daily average frequency of blood glucose.

Ilhan et al. [48] proposed the '*Sleepy Bird*' application to improve sleep-wake-up behavior. Sleepy Bird was designed to address sleep-related problems and encourage individuals to change their daily habits and improve their health. The gamification elements used in this app were notifications, leaderboards, scores, lives, and visual elements. There was gamified and non-gamified versions of the application. Twenty-six people participated in this experiment, thirteen in group A and thirteen in group B. The result of using Sleepy Bird shows that the gamified version successfully motivated the users to change their sleeping patterns compared to the non-gamified version. The users who used the non-gamified version needed more motivation. Thus, the application can be improved by adding more motivating elements and gamified features.

Navarro-Alamán et al. [49] designed an application known as '*Close2U*' for cancer patients. This app includes gamification elements such as rewards and points. Fifteen older age groups with cancer participated in the study - eight females and seven males. The System Usability Scale was used to measure usability along with a questionnaire with ten items. Also, Usefulness, Satisfaction and Ease of Use were used with four elements: a) Satisfaction, b) Usefulness, c) Ease of learning, and d) Ease of use. These elements were used to measure ease of use. This approach's outcome was positive, increasing the participants' motivation. Table 2.1 shows the existing applications, the methods used in the research, the author's comments and the research's limitations.

Research	App	Observation Period	Comments	Limitation
Rose et al. [44]	MySugr	12 weeks	Positive Outcome and improvement in blood results.	More research is required for user engagement.
Torrado et al. [45]	HikePal	—	The gamification elements used in this app are the story and reward system.	Overly complex with more customization of features required.
Cafazzo et al. [47]	Bant	12 weeks	Points and reward game mechanics help in health improvement. The result shows a fifty percent improvement in the frequency of blood glucose.	Experiments are needed on nontangible, virtual rewards as a substitute.
Ilhan et al. [48]	Sleepy Bird	2 weeks	Elements used in this app were notifications, leaderboards, scores, lives, and visual elements.	More motivating elements and gamified features are needed.
Navarro-Alamán et al. [49]	Close2U	—	Gamification elements used are rewards and points.	Improvement is needed in the ranking and point system.

Table 2. 1: Existing gamification applications.

In the table above, the main limitation of these research studies is that further investigation is required to understand the motivating elements for user engagement.

2.4. Traditional Gamification Element

As stated above, more research into the gamification element is required. Therefore, this section lists some of the traditional gamification elements and the comments on each element

by the authors to get insight into each element. Motivational Factors / Gamification Elements discussed by other researchers are as follows:

- **Competition-** Competition caused by leaderboards increases the player's level of engagement and sense of not being alone [5].
- **Setting Goals-** Munson et al. [50] designed an application to promote physical activity. The user sets the goals from Sunday to Saturday. The goals are broken down based on physical activities such as walking, cardio, etc. Two goals were introduced: Primary and Secondary. They are also known as main and backup goals. If one goal becomes unachievable, the other may still be a realistic goal. If app users have a good week, they may push themselves to achieve one of the goals. The outcome of this research indicates that setting primary and secondary goals has a positive impact on the application users. Strecher et al.'s [51] research suggests that a challenging goal has a positive linear relationship with the level of performance. Setting specific challenging goals leads to increased performance.

A study by Lynch et al. [52] suggests that goal-setting outcomes increase intrinsic motivation, which, in turn, enhances engagement by providing participants with a purpose behind these goals. Intrinsic motivation raises long-term engagement and helps individuals develop a habit of physical activity. This study mainly focuses on older adults to encourage them to maintain an active lifestyle. These activities are beneficial for improving their health, especially in light of age-related issues such as mental health, dementia and osteoporosis. The research methodology used was a qualitative online survey with 24 participants aged 60 and above.

- **Online trophies-** Munson et al.'s [50] research investigate how rewards, goal-setting and self-monitoring behavior help to encourage physical activity. A gamification application was developed and tested for 4- weeks of the experiment. Twenty-three people participated in this experiment. Six participants felt that the trophies were lame and unnecessary; however, three participants found they were motivated by the trophies. This research suggests that Online trophies and ribbons are the least motivating features.
- **Liking-** A study conducted by Ozanne et al. [53] aimed to investigate the use of the 'like' feature on Facebook and the motivations behind it. The participants interviewed were from the United States and Ecuador. Liking behavior can be used for several reasons. One of them is gratified usage motivation. The gratified usage motivation

includes bonding, entertainment, information/discovery, and self-identification. Bonding is used for congratulating or showing support to others by liking. Bonding was a common motive among US participants, whereas 'information' was the primary reason for Ecuadorian participants to 'like' posts. 'Liking' increases motivation, which is a key element in gamification.

Table 2.2 summarizes the traditional gamification elements used in previous research and their respective research focuses.

Research	Gamification Element	Research Focus
Drza-Grabiec et al. [3]	Competition	Physical Activities
Munson et al. [50] Strecher et al. [51] Lynch et al. [52]	Setting Goals	Physical Activities
Munson et al. [50]	Online Trophies	Physical Activities
Ozanne et al. [53]	Liking	Facebook

Table 2. 2: Traditional Gamification Elements

2.5. Advantages of gamification for the well-being

Gamification is increasingly gaining attention for enhancing user engagement [27]. It is used to motivate users, engage and provide satisfaction, and is helpful in various ways. Some of the advantages of gamification are as follows:

- **Change of behavior** – An individual's desire can change an unhealthy lifestyle and behavior. Behavior change is a complex process and is sustainable for the long term. The developer of the apps must implement the features in the app that keep the user engaged and motivated for the longer term. This can be achieved by implementing gamification [54]. Gamification is implemented to encourage positive behavior. As it helps to encourage and motivate users to use gaming elements that make the activities fun, it can break poor habits and lifestyles [55].

Enhance User Experience- Partala and Saari [56] describe user experience as comprising all components that impact user interaction with the system. Some

researchers have concluded that emotions play a significant role in understanding user experience and are linked to the actions performed [57, 58]. Making activities entertaining using gaming elements keeps users engaged.

- **Improve Health** – Several studies conclude that gamification helps improve health and well-being, addressing issues such as depression [59, 60, 61, 62] and anxiety [59, 62, 63], diabetes [44, 46, 47] and cancer [10, 49]. For instance, in the area of mental health, gamification has been found to offer effective measures for individuals struggling with depression and anxiety. These gamified approaches often include engaging activities or challenges that help users manage their symptoms and build coping strategies. The interactive and rewarding nature of gamification can contribute to improved mental health issues.

Gamification is effective in improving health, particularly in promoting behavioral changes such as increased physical activity. It has been used to encourage increased physical activity, which is significant in managing conditions like diabetes and supporting individuals dealing with cancer. Gamified apps and platforms often incorporate elements like challenges, rewards, and progress tracking, all of which motivate users to adopt healthier lifestyles.

Provide fun and enjoyment – Gamification applications have gaming features which make the activity fun and interesting. Fun and enjoyment are correlated with engagement, meaning that when users find a task enjoyable, they are more likely to stay engaged.

Increases User Satisfaction – Engaging and satisfying users have become a critical task [54]. Previous research has shown that gamification creates a game-like experience, increasing intrinsic motivation and user satisfaction, and potentially leading to behavior change [64].

2.6. Challenges of gamification in the area of well-being.

Gamification offers several advantages, including the ability to sustain behavior for the longer term [54]. However, there are some challenges of using gamification that need to be addressed. This section explores the challenges of gamification and possible solutions. The challenges of gamification are as follows:

User Privacy – One of the major challenges of gamification is to ensure that the user's privacy is not violated [65, 66]. Some game elements, such as leaderboards and challenges linked to a user's identity, can violate user privacy by revealing personal information to the audience. For example, leaderboards may display a user's name or username along with their performance rankings, making their identity easily identifiable. Similarly, challenges linked to user identities may share personal data or achievements publicly, which can be an issue if it is not protected.

In some applications where profile creation is mandatory, users may be required to share their personal information, like their name, email address, or other identifying details. This raises concerns about data security and the misuse of such information. On the other hand, in applications where profile creation is optional, users have the choice to remain more anonymous, reducing the risk of privacy violations.

However, not all game features pose the same risk. Rewards and badges, for instance, do not violate privacy if they are designed to be anonymous and not linked to an individual's identity [67]. This means that users can enjoy the benefits of gamification without revealing their personal information to others.

Protecting user's information and providing a platform that ensures user privacy increases trust among users. Research has shown that protecting privacy increases user engagement by establishing trust between the user and the application [68]. Providing privacy settings and transparency about data storage, retention duration, and data access can further enhance trust between users and the service [69].

Users using gamified applications are likely to share their private information with companies, risking their personal information privacy. Information Privacy [70] is defined as user's control over their personal information, including how the data is collected, stored and used [71]. In other words, users should have the right to be informed about the data used, the duration and the location where the data is stored and the person who has access to the user's data [67]. Furthermore, users must have the ability to retract the right to store their data or request secure deletion when they see fit. This level of control gives users authority to safeguard their personal information, ensuring that their data remains private and protected.

Loss of information privacy can result in discrimination, unsubscribing from advertising and sharing information with third parties [72, 73, 74]. Safeguarding user information is not only a legal requirement but a moral obligation. It is a responsibility of organizations, policymakers,

and individuals. Therefore, a possible solution to this challenge is the development of gamified applications with a strong focus on user privacy [65].

Lack of standardization - There are currently no guidelines for developing gamification applications [66], and some research [75, 76] suggests a lack of standardization in this area. For instance, the study conducted by Ambros-Antemate et al. [77], which focused on the rehabilitation of patients with disabilities, highlights that many applications are not developed using a software engineering framework, i.e., it is not designed to consider the patient's needs.

Lack of interest in the long run - Users may experience diminishing interest over time and require additional motivation. They might find the activity interesting at first, but they may lose interest after a while. When users lose interest, they need extra incentives or motivation to continue engaging with the activity or application. This includes rewards or challenges that make the activity more enjoyable. Users are more likely to stay motivated if they clearly understand what they need to achieve, i.e., clear goals and if they feel that the choices they make within the task have a meaningful impact on the outcome. In other words, users are more likely to stay motivated when they see a purpose in their actions.

Another key aspect that can help retain user interest is the continuous development of the application. This strategy is often observed in subscription-based apps where regular updates with new features keep the app 'fresh' and exciting, capturing users' interest and encouraging them to stay engaged.

Users with clear goals and meaningful choices are more likely to see the task as positive, which increases motivation. The incorporation of purposeful games can be particularly encouraging [78]. 'Meaningful choices' that are of value to the user relate to choices within an application or activity that directly link to the user's goals or preferences. These choices are directly connected to what matters most to the user, making them more engaging and motivating. Implementing games within the application can be an effective way to maintain user motivation. Gaming elements often provide clear goals, significant choices, and a sense of fun, keeping participants engaged, encouraged, and motivated.

Cheating to obtain reward – Cheating is defined as a player achieving the desired outcome while violating the game rules, which is unfair according to the game rules [79, 80]. Such behavior can lead users to give up the game as it damages the fairness of the game [81, 82]. In some cases, the unfairness can become intolerable for genuine users who are committed to

achieving their goals from the application [83]. The reasons for cheating are varied and may include:

- Excessive focus on winning the competition
- Avoiding Failure
- Obtaining rewards
- Cheating to avoid losing streaks
- Cheating out of boredom

In gamified physical activity applications, cheating is often done among users who prioritize rewards over actual physical activity. They have a stronger desire for rewards and incentives, which may lead to cheating. People cheat to achieve desired results or to get rewards [84, 85, 86]. Some studies [87, 88, 89, 90] suggest that the misuse of gamification is due to the loss of intrinsic motivation over extrinsic motivation.

Within fitness applications, unfair play can occur when users fake the detection of physical activity, undermining the integrity and fairness of the game. Encouraging fairness within the game is essential [91]. Measures to prevent cheating can be implemented, such as using an algorithm to differentiate between the actual activity and shaking the phone with hands [79].

The content above makes it clear that these are the following challenges. Fig 2.1. illustrates the summary of four challenges of gamification.

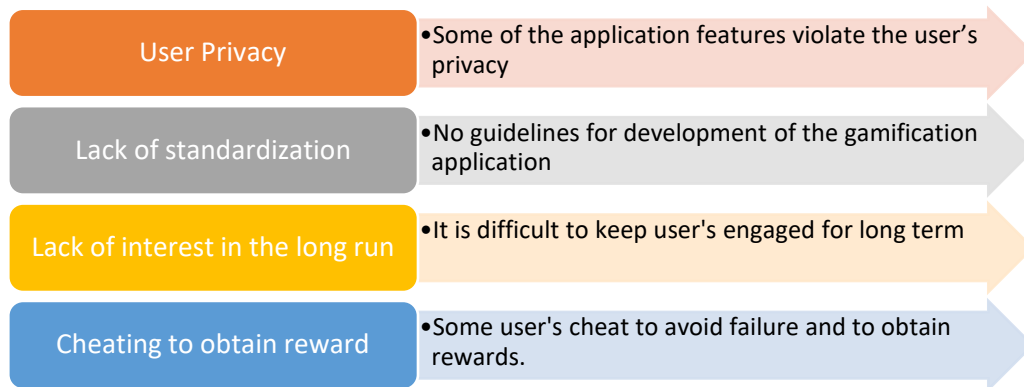


Figure 2. 1: Challenges of Gamification

Table 2.3 discusses the challenges of gamification, with possible solutions used in this research. Some of the issues below were not a high priority because we focused more on developing positive features such as user adherence. Although this was not our priority because we were more focused on positive features, we still put some effort into addressing these issues.

Challenges of gamification	Possible Solutions used in this research
User Privacy	The data is stored in the database with only access to people working on this project. Also, the data privacy document was shared with the participants, having information about how the data is used and stored.
Lack of standardization	The improvement was made after every iteration according to stakeholder's and user's needs. This project uses UCIEDP, requirement list, testing and validation methodology. UCIEDP prioritizes stakeholder requirements and preferences, ensuring the project's design and functionality meet their expectations. The requirement list documents and tracks project specifications, ensuring all project components meet established standards. Additionally, a testing and validation methodology provides regular quality assurance checks, usability testing, and validation to maintain consistency and alignment with established standards, all while continuously improving the project based on stakeholder and user feedback and needs.
Lack of interest in the long run	Features such as Daily Streak, Personal Best, Real Rewards, QR codes and more are used to motivate and encourage people to use them in the long run.
Cheating to obtain reward	This study ensures that the system is safe. We asked for ID documents such as Passports, Driving Licenses or BRP from the teams to check the people joining the competition were genuine. We took some measures through features to encourage participants to use the app more healthily, like Daily Streak, Personal Best, and Age Band, which are discussed in detail in Section 4. Furthermore, app usage is restricted to one user per account to prevent unauthorized participation.

Table 2. 3: Challenges of Gamification and possible solutions used in this research.

2.7. Problem Definition, Aims, and Objectives

Several options were considered to increase motivation. However, these are not necessarily used in the mainstream applications currently available in the market. For example, many applications such as MyFitnessPal, FitBit and Runkeeper [92] have been developed to improve health and well-being, but user adherence is a major challenge and needs more research. According to Rasche et al. [93], the main reason to quit Pokémon Go was due to boredom and reaching a high goal was too challenging. Fifty-seven percent of users left the app due to boredom, and 29% due to not being able to reach a high goal.

It has been recognized that motivational techniques play a crucial role in keeping users engaged. The above text helped to identify the motivational techniques and technologies used by other researchers. However, further research is needed to sustain long-term user motivation through these techniques. This emphasis on sustaining motivation aligns with the focus on Aim **A2** as follows:

A2 – To propose a method to develop a gamification application using motivational techniques.

To achieve this aim, two objectives, **A2-O1** and **A2-O2**, have been proposed:

A2 – O1: To identify how motivational techniques work on different age groups.

A2 – O2: To combine traditional development methodologies with motivational techniques.

These objectives aim to deepen our understanding of how motivational techniques function and how they can be integrated into development methodologies. To effectively measure and analyze these motivational techniques, aim **A3** was introduced.

A3 – To develop a gamification system and to examine user adherence by conducting pilot studies with different organizations.

This aim is essential for a comprehensive examination of these techniques. To attain Aim **A3**, three corresponding objectives, **A3-O1**, **A3-O2**, and **A3-O3** have been established. The main extended objectives to realize these aims are as follows:

A3 – O1: To implement motivational techniques in the proposed system.

A3 – O2: To design questionnaires to gather feedback from the users for general information on how to develop a suitable gamification application.

A3 – O3: To identify a method to measure the effectiveness of techniques to gain more specific information about which technique works best.

Aim **A2** and **A3** were identified after an analysis of the literature review. However, aim **A1** and objectives **A1-O1** and **A1-O2** were the initial aims and objectives identified before going through the literature review. It was to understand more about gamification and the challenges and advantages of gamification. Also, to explore the existing gamification applications. These initial aims, objectives and problem definition have been introduced in section 1.1.

Therefore, this research addresses the issue of user adherence in the long run by using techniques such as BCTs and SDT, drawing from the valuable experience and insights of colleagues in the Sport and Psychology Department. Their comments and feedback were gathered during a workshop to collect ideas, suggestions, and expertise in the field, details of which are provided in section 3.1.1. During this workshop, colleagues provided valuable input, some of which has been incorporated into the OnTheMove! App. For instance:

- *“Social isolation is one of the biggest problems in modern society, especially for people living in bigger cities and for 50+ people. If this app helps, creating teams and connecting people from a neighborhood together will also improve mental health and motivate people to keep up the activity.”*
- *“Focus on purposeful activity, i.e. not exercise for the sake of it.”*
- *“Although goals become less important when a habit is formed, initially, goals must be specific and realistic, and a small change approach may be useful. Variation in behavior may stave off boredom but may be effortful when trying to form habits. Having contextual cues to elicit behavior, such as forming implementation intentions (i.e. plans), followed by the behavior and rewards (which are already part of the app), is part of the cycle of habit formation.”*

As a summary of this Chapter 2, defines motivation, user engagement and user adherence. It discusses two types of motivations: intrinsic and extrinsic motivations. Also, it compares the research work conducted by other researchers and the gap in the research. The traditional gamification elements, the advantages of using gamification and the challenges of gamification are also discussed in Chapter 2. The problem definition, aims and objectives of this project are identified, and the investigation of existing applications in the area of well-being indicates that further research is required on the driving factors behind user motivation.

In the following chapter, the research explores the concepts introduced in Chapter 2, particularly by elaborating on the connection between the development methodology and motivational techniques. It presents the methodology used in this research, which has four stages: Interaction with Stakeholders, Initial Scoping, Main Development, and IE Installation. Chapter 3 also provides an explanation of the user-centered methodology and discusses the workshops conducted with colleagues and stakeholders, with a specific focus on system design.

Chapter 3

System Design Methodology

The methodology used to achieve the objectives of this research is to follow the User-centered Intelligent Environments Development Process (UCIEDP) [94], which focuses on interaction with the stakeholders for co-designing of solutions and takes several iterations to improve the system as part of the development of the final product. This strategy has been used in the creation of various systems, for example, to assist people with Down's syndrome [94], the system used for cardiac health monitoring [95], a personalized automation system designed to offer users smart home services immediately upon moving into their new house [96] and the development of a context-aware system for managing asthma conditions [97]. There are four stages of UCIEDP: Interviewing the stakeholders, Initial Scoping, Main Development and Intelligent Environment Installation. In the initial stage, system requirements are gathered by engaging stakeholders through interviews or workshops. This phase extends beyond the functional aspects, incorporating a collaborative design process. The focus is on understanding not just the functional requirements but also reaching an agreement with stakeholders regarding the technological platform and infrastructure. This ensures an effective resolution to the identified problem that aligns with stakeholders' preferences and acceptability standards. The third stage involves designing and implementing the system with the active participation of stakeholders, while the final stage includes conducting end-user testing. This involves installing the software on the infrastructure, and various stakeholders conduct functional testing to ensure compliance and adherence to specified requirements. In summary, the UCIEDP is flexible, allowing for the incorporation of essential modifications and enhancements. This flexibility proves crucial in meeting stakeholder expectations while operating within the constraints of available resources. Furthermore, this methodology positions itself between sequential-type and agile-type approaches. It provides a balanced mix of flexibility, iteration processes, and active stakeholder involvement. This stands in contrast to the strict unidirectional sequence of steps found in the Waterfall model and the rapid release pressures characteristic of agile methodologies like Scrum. The approach is designed to navigate a path that allows for adaptability while avoiding the limitations associated with both rigid and highly dynamic project management methodologies.

The UCIEDP is used in this research for iterative improvement and to incorporate novel design ideas. It guides the development of the system. The methodology emphasizes the direct involvement of stakeholders at all stages of the project. Stakeholder engagement activities include workshops and pilots. Fig.3.1 shows how the project evolved from the low maturity level of the app to a higher level through iterations. The four stages of this methodology are Interaction with Stakeholders, Initial Scoping, Main Development and IE Installation. These stages are explained in detail in some of the following sections and chapters.

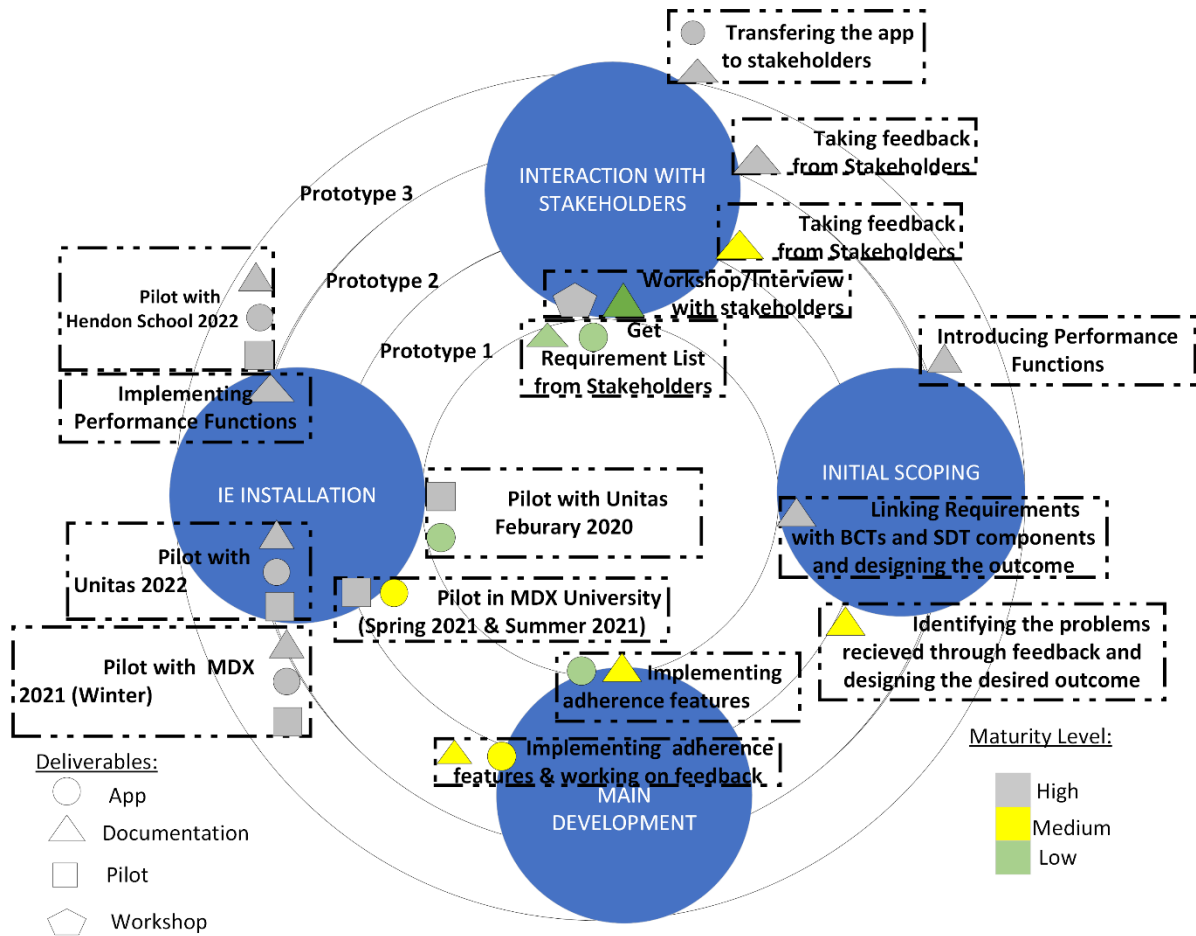


Figure 3. 1: Project evolution using UCIEDP

Each of the blue sections represents one of the stages of UCIEDP. Several iterations can be identified by each circle. The inner circle is the first iteration. Then iterations are two and three going up outwards. Different colors were used to indicate different maturity levels of the output. The green color is a low maturity level, the yellow color is a medium maturity level, and the grey color is a high maturity level. The shapes, i.e. circle, triangle, square and pentagon, were used to indicate the deliverables. The deliverables (left and bottom of figure) are represented by geometrical shapes such as the circle shape which represents the application,

the triangle shape represents several documents, the square shape represents the pilots, and the pentagon shape represents the workshops. In the boxes, the corner of the shapes touches the iteration circles. A box belongs to the iterations where the colored shape is attached. Each shape indicates different maturity levels. As seen in the inner circle, there are more often green deliverables because they are a low level of maturity, but as the iteration is executed in the project, the output of outer iterations is grey as they are more mature.

Some features of the app will mature through many different iterations. In Prototype 1, the outcome of the workshop with the stakeholders was satisfactory and helpful. The conclusions of the workshop were considered reliable. In this workshop, the documentation was an initial draft. Therefore, it was at a low level of maturity. A list of requirements was set to work on in this workshop in the Interaction with Stakeholders stage (top center of Figure), which was also at a low maturity level as it was not linked with motivational techniques and early stage of the project. The app was at a low maturity level as it was not well aligned with the requirements and motivational techniques. These requirements are then linked with the motivational techniques in the Initial Scoping stage (right-hand side of figure), which was a high maturity level. In the Main Development stage (Bottom, center of the figure), the adherence features were implemented where the documentation was medium maturity level as it was an intermediate draft. However, the app was at a low maturity level as it was in the development stage. After implementing features, the pilot with Unitas was conducted in February 2020 to test the features, which was a high maturity level, and the app was at a low maturity level as we got feedback from users to make improvements to the application. The feedback was taken using a questionnaire. This pilot was conducted in the IE Installation stage (left-hand side of the figure).

In Prototype 2, feedback was taken from users and stakeholders in the Interaction with Stakeholders stage after implementing the features. This feedback was taken in the form of documentation which was medium maturity level. In the Initial Scoping stage, the issues were identified in the application using feedback from users and stakeholders, which was medium maturity level. In the Main Development stage, the adherence features were implemented, and improvements were made in the application linking it with motivational techniques. The documentation was medium maturity level as it was an intermediate draft, and the application was also medium maturity level as it was under development, i.e., improvements in the application using the feedback and adding new features in the application. Then this was tested in the IE Installation stage. To test the system, the pilots were conducted at Middlesex

University in Spring 2020 and Summer 2020, which was a high maturity level. However, the app was a medium level maturity as the improvements were required.

Prototype 3 was considered a high maturity level as it was the final stage of the project. In Prototype 3, the process was repeated, and feedback was taken from stakeholders in the form of documents or emails, which was a minor improvement. In the Initial Scoping stage, the Performance Function was introduced (section 5.2). In the Main Development stage, minor changes or modifications were made using feedback from stakeholders. In the IE Installation stage, the pilots were conducted with organizations such as Middlesex University 2021 (winter), Unitas 2022 and Hendon School 2022. App, documentation and pilots were considered as high maturity level as it was the final stage. Performance Functions were implemented in this stage to better understand BCTs and SDTs effectiveness for this project. The questionnaires and Performance Functions were used in these pilots to identify which techniques work best for our research on different age groups. The stakeholders requested a minor improvement. These were minor details but not the bug in the app. Hence, the application and the documentation were a high-level maturity when transferred to the stakeholders after the improvements were made.

This chapter provides an overview of the pilots, with more details in Chapter 5. Table 3.1 summarizes the pilots as follows:

Pilots	Age range of participants	Number of participants
Unitas Pilot (2020)	Teenagers	25
MDX Spring 2021 Pilot	Mature adults and Elder citizens	29
MDX Summer 2021 Pilot	Mature adults and Elder citizens	4
MDX Winter Pilot (2021)	Mature adults and Elder citizens	6
Unitas Pilot (2022)	Teenagers	12
Hendon School Pilot (2022)	Children	17

Table 3. 1: Overview of Pilot details.

The stakeholders determined the recruitment of participants. Contact with potential participants in some pilots with external organizations, including schools and gyms, was established through stakeholder collaborations. Every participant chosen for the study was a resident of

London, known for its exceptional diversity. The participants came from various social, economic, and cultural backgrounds.

3.1. Stakeholder Involvement

The Interaction with Stakeholders stage is one of the stages of UCIEDP, highlighting the significance of continuous engagement with stakeholders throughout the project's development. Workshops, like those conducted with colleagues and external organizations, are an example of these interactions. These external organizations include different organizations such as companies and schools like Greenwich Leisure Limited, Barnet Council and Hendon School. These stakeholders were also representatives of the final user's demographics. Their involvement extended beyond workshops to activities like the pilots, which were organized to identify the effectiveness of these motivational techniques and show strong stakeholder participation and engagement.

3.1.1. Workshop with Colleagues

At the start of this project, a workshop was conducted at Middlesex University London in November 2019 with Colleagues from the Psychology Department, Management Leadership and Organizations Department and London Sports Institute. The aim of this workshop was to get understanding and feedback from colleagues by sharing knowledge in their areas of expertise. Also, to get an insight into how different theories and concepts, such as Behavior Change Techniques (BCTs) and Self Determination Theory (SDT), work on different age groups. The term '*user adherence*' was adopted in this workshop which is used in this paper and is a part of the internal project terminology, though it is not normally used in the gaming community. The qualitative approach was used in this workshop. This workshop was a focused group workshop where questions were asked regarding user engagement and factors that keep them engaged with the application and to get an insight into which elements may motivate citizens the most.

In the early stage of the workshop, BCTs were identified as a potentially valuable concept, because BCTs are techniques to help individuals change their behavior to adapt to a healthy lifestyle. However, it was a challenge to choose from the BCTs because there is a very high number of them in the technical literature. Michie et al. [98] listed 93 BCTs which are categorized into 16 groups or categories such as Reward and Threat, Feedback and Monitoring,

Social Support, and Goals and Planning. These four categories are some of the most effective BCT categories in gamification interventions for physical activity [99]. Others include Repetition and Substitution, Comparison of Behavior and Natural Consequences. A combination of BCTs helps to increase engagement and motivation. BCTs are useful and can be used for a long time [100]. According to research conducted by Mercer et al. [101], the most attractive BCTs for adults and teenagers are self-monitoring and self-regulation techniques in activity trackers. It was decided in the workshop not to focus on each BCT but to look at the BCT category and its representatives. In this paper, we call them “*Category Representatives*”. Therefore, we only used BCTs from the seven categories listed that are deemed appropriate for the app by prioritizing and selecting based on its benefits in relation to the design complexities.

In addition to BCTs, we also drew on Self-Determination Theory (SDT). SDT is a theory in which individuals motivate themselves. According to Sailer et al. [5] and Shi et al. [102], in SDT, a person motivates themselves through intrinsic and extrinsic motivation. It is through self-engagement that a person feels motivated. In SDT, there are three factors for motivation:

1) Autonomy - freedom of taking decisions of your own choice without any pressure, 2) Competence – a feeling of success and achievement, 3) Relatedness - feeling connected to others. However, Bovermann et al. [103] discuss four factors of SDT: a) Autonomy, b) Competence, c) Relatedness and d) Purpose, which is a desire to make something meaningful. ‘Purpose’ is intrinsic motivation which is perceived to help to do activities willingly and retain them for a longer term. These SDT factors are perceived as important as they give insight into how gamification engagement and motivation work. Therefore, this motivation is a key factor for user adherence. The study conducted using SDT and BCT strategies is to keep users engaged in physical activity using the OnTheMove! App.

3.1.2. Workshop with Stakeholders

The other workshop was conducted with the main organizational stakeholders: Greenwich Leisure Limited and Barnet Council in November 2019. This workshop took place in London with 8 participants, including Greenwich Leisure Limited Managers and Barnet Council Managers. This workshop was focused group, and a qualitative approach was used. The workshop started with the presentation of the app by Bene [11], who was working mainly with a teenage group. Then it was followed by a discussion of how to improve the app and make it available for all the users. This workshop was conducted during the initial stage of our research,

as the project transitioned from targeting a teenage group to participants of all age groups. It became evident that the project needed further improvement, particularly the incorporation of adherence features suitable for all age groups. This research also focuses mainly on adherence features by linking the requirement list with motivational techniques. A list of requirements was set to work on. The aim of this workshop was to gather feedback and get a list of requirements. The requirement list was updated after each iteration, i.e., approximately every month. Finally, 87 requirements were identified (<https://figshare.com/s/6e8d720807cd3984cb77>). Table 3.1 shows a sample of some of the requirements from the stakeholders which we have linked with the BCTs.

BCTs	Requirements
Reward	Reward Effort rather than an absolute result. Measuring how much a person has progressed and rewarding that progress (e.g., a 2% improvement from the previous performance), up to a certain point where the reward could be absolute, for example, best three in each age category.
Goal	Set Primary and Secondary Goals
Information about health consequences	Display useful information on how to be healthier.
Self-monitoring behavior	Be able to see their past history of steps.
Social Support	Be able to like other users steps and see the number of likes.

Table 3. 2: Requirement List Sample with BCTs

3.2. System Architecture

The system architecture was designed using the requirement list from stakeholders, which was linked with BCTs. The requirement categories defining the system architecture are ‘General development and Maintenance’, ‘Gamification’ and ‘Technologies’. This is the Initial Scoping stage of UCIEDP. Fig. 3.2 shows the system architecture. From left to right: users communicate with the application using smartphones. The supported platforms are Android/Harmony OS or iOS devices with the application installed that contains files which establish a connection

between Windows Server 2012 R2 using Web requests (shown in the right-hand side of the figure). The application is developed using Unity version 2019.4.12f1 and C# Script. The C# Script communicates between the application and database using web requests. This is the frontend, the window server 2012 R2 is accessed remotely using Amazon Elastic Compute Cloud (Amazon EC2). The backend consists of server hosting PHP scripts which communicate between MySQL Workbench 8.0 and the application. The request is sent to the MySQL database, and then the response is sent back to the user via PHP script.

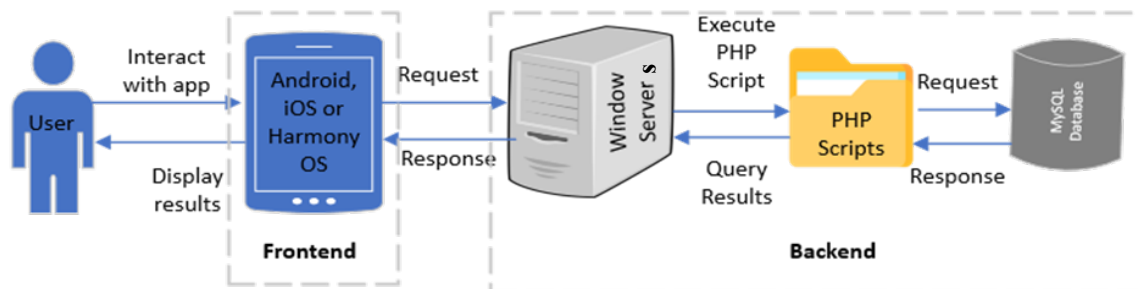


Figure 3. 2: System Architecture

3.3. Intrinsic and Extrinsic Motivation used in OnTheMove! App

Intrinsic motivation arises from psychological needs such as Enjoyment, Satisfaction, Achievement, Interest, Willingness [4], and extrinsic motivation arises from extrinsic reward [8]. Fig.3.3 shows two types of motivations: intrinsic and extrinsic motivations. Also, the features of the app use these motivations.

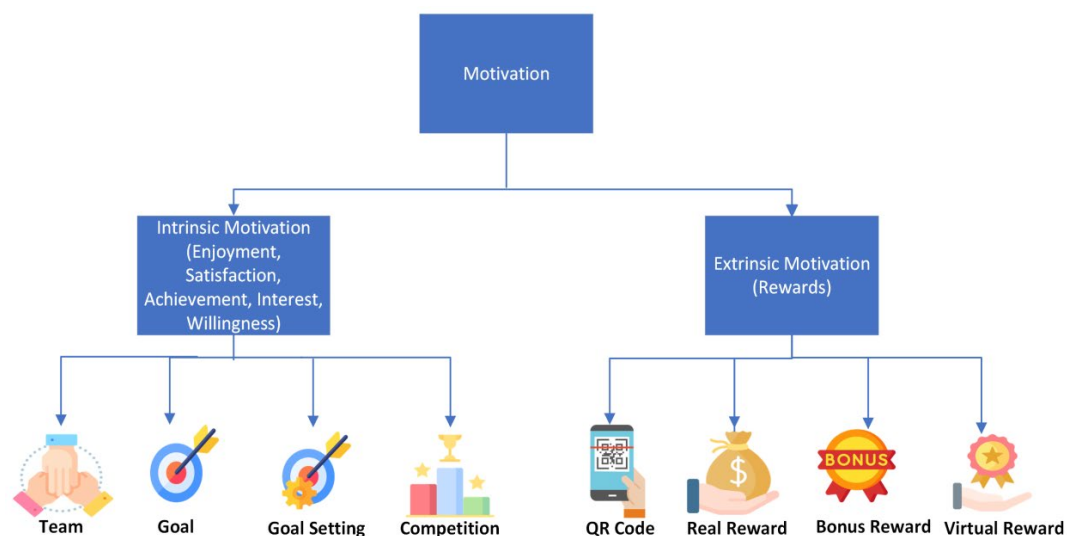


Figure 3. 3: Types of Motivations used in the app.

The features using intrinsic motivation in this research are Teams, Goals, Goal Setting and Competition. Features such as Teams and Competition are used to raise intrinsic motivation by working in a team with other members willingly. Working in a group and competing gives a feeling of enjoyment, achievement and interest. Goals and Goal Settings are for doing things for their own sake and willingly. The user sets daily and weekly goals. If the goal is completed, it gives a sense of achievement.

The features used for extrinsic motivation are QR codes, Real Rewards, Bonus Rewards and Virtual Rewards. These features reward users for the activities they have completed. For instance, scanning QR codes can also be used to reward users for their positive behavior and help them claim Real Reward, Bonus Reward or Virtual Reward. Here, Real Reward allows users to get drinks, sandwiches, or gym passes after achieving the desired outcome whereas Bonus Reward means the users get the reward for their efforts. As for Virtual Reward, it allows users to obtain a virtual coin with which they can use to acquire different avatars.

In this section we discussed the methodology used in this research. Using this methodology, we designed a system architecture and linked it with BCTs and SDT components. In the next section we describe development of an application using these.

3.4. BCTs and SDT components used in OnTheMove!

Fig.2.2. shows BCT category representatives (in the center) and how they are linked with the features (on the outer edge) used in the app. The seven BCT categories are used in this research.

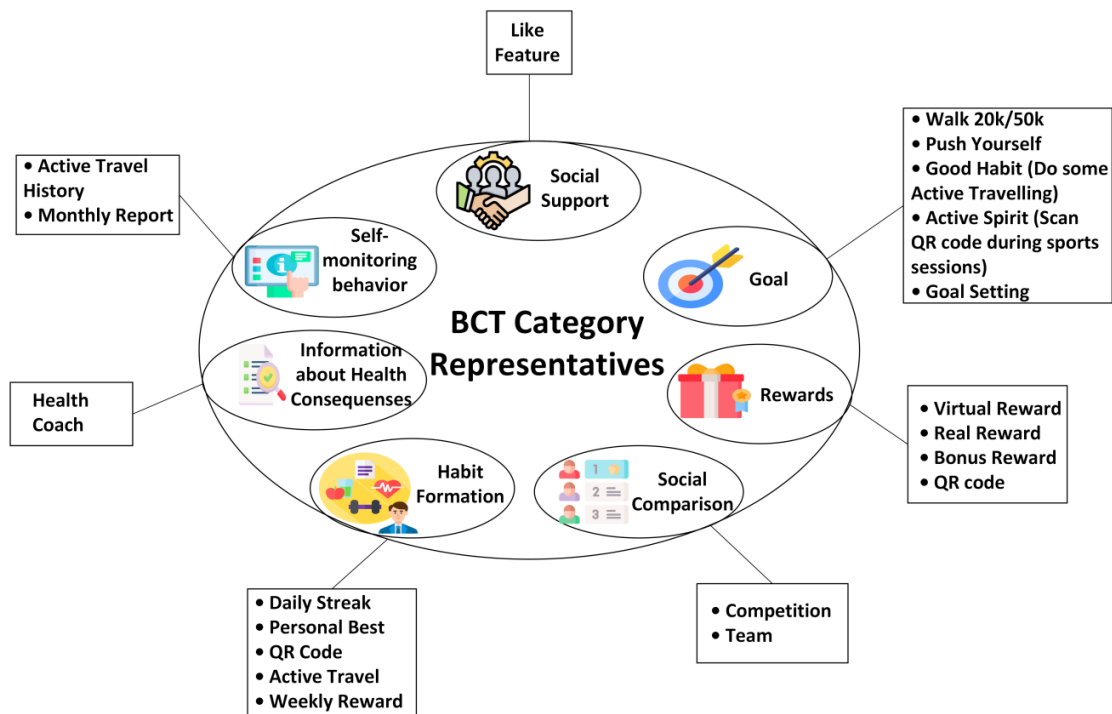


Figure 3. 4: BCT category representatives used in the app.

The BCT category representatives used in this application are as follows:

- *Goal* – The goals used in this application are Walk 20k/50k, Push Yourself, Good Habit and Active Spirit. Here, the user has to walk 20k/50k, Push Yourself include goal setting where the user has to set their daily steps for daily goals and weekly steps for weekly goal; Good Habit is to do active travelling, and Active Spirit is to scan QR code during any sports sessions.
- *Rewards* – The rewards can be achieved in four ways in this app: Virtual, Real, Bonus, and QR code. Virtual and Bonus rewards are digital rewards; for instance, users can purchase Avatars using Virtual Rewards, and for Bonus Rewards, users get coins. However, with Real Reward and QR code, users can buy coffee, sandwich, gym passes etc. These rewards are explained in section 4 in more detail.
- *Social Comparison* – This BCT is used in Teams, and Competition where the user compares their steps with other teams or team members. It encourages users to achieve the task.
- *Habit Formation* – To form a habit of the users, the feature used are Daily Streak, Personal Best, QR code, Active Travel and Weekly Reward (each feature is explained in detail in section 4). It helps the user change their behavior and adopt vigorous habits.

- *Information about the Health Consequences* – This BCT is used as Health Coach in this application to provide information to the users about the health effects (explained in detail in section 5.1.2).
- *Self-monitoring behavior* - helps users modify their behavior by controlling their behavioral patterns and adopting a healthy lifestyle. It raises self-awareness. The users can monitor their behavior using features such as Active Travel History (explained in section 5.1.1) and Goals Monthly Report (described in section 5.1.2).
- *Social Support* – The user likes the steps of other team members to encourage or support each other (explained in section 4).

Fig. 2.3 illustrates the four SDT components and how they are linked with the features of the application.

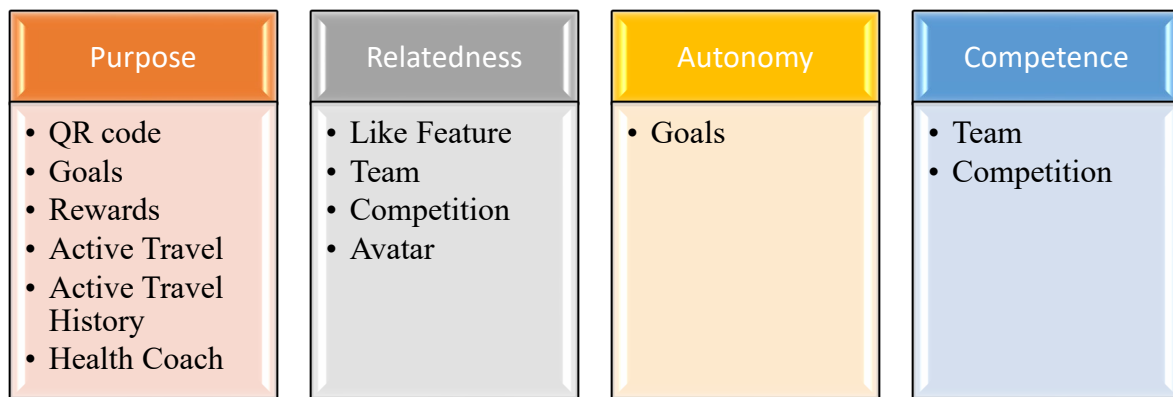


Figure 3. 5: SDT Components used in the app.

SDT components and their links with the feature of the application are as follows:

- *Purpose* – is intrinsic motivation which is to do activities willingly. This is closely related to the features such as QR code, Goals, Rewards, Active Travel, Active Travel History and Health Coach. It gives a sense of motive to the users.
- *Relatedness* – feeling connected to others. Like Feature, Team, Competition and Avatar give a sense of connection with other team members by liking their steps and competing with other team members.
- *Autonomy* - is the freedom to make decisions of your own without any pressure. This is closely related to goals. This gives the freedom to users to take their own decision and decide the steps they would like to walk.
- *Competence* – is a feeling of success and achievement. Team and Competition give a feel of self-efficiency to the users.

Chapter 4

Development of OnTheMove! App

The OnTheMove! application has been developed using BCTs and SDT in the Main Development stage of UCIEDP. The application mainly focuses on user adherence and encourages users to stay active using small physical activities. Fig. 7 shows the proposed application architecture.

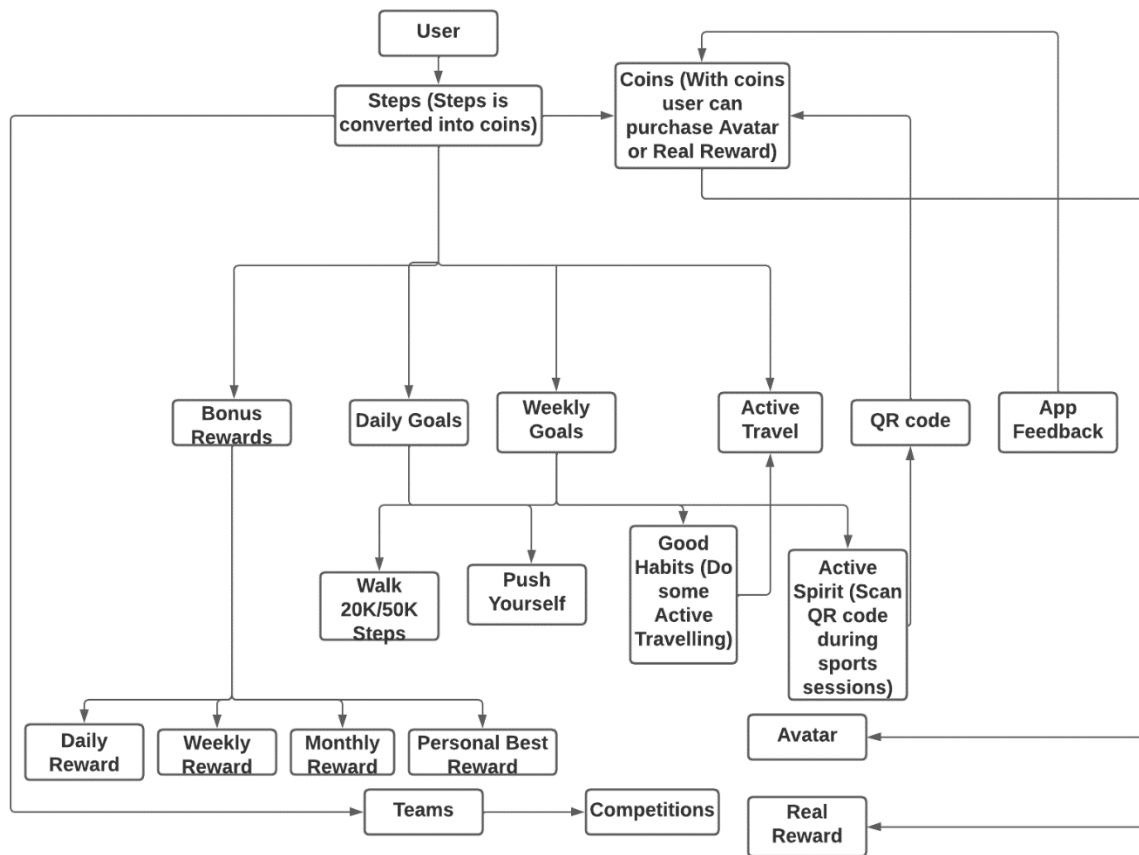


Figure 4. 1: Application Architecture

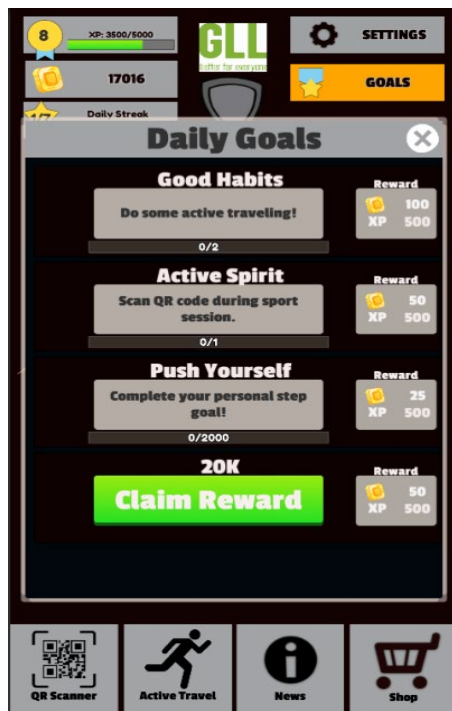
When the user opens the OnTheMove! application, the user gets steps from the Health app in iOS and the android sensor in android, and using the algorithm, the steps are converted into virtual coins (top of Fig.4.1). The coins can be used to buy Avatars or Real Rewards (top right-hand side of the figure). Users can buy different avatars depending on their age, such as teen

avatars, mature/ adult avatars and older adult avatars. These steps can also be used for Bonus Rewards (center left of the figure), such as Daily, Weekly, Monthly and Personal Best Reward, Goals such as daily and weekly, and Active Travel. These Daily and Weekly Goals include goals, such as Walk 20k/50k, Push Yourself, Good Habit and Active Spirit. There are different types of incentives; some are increased rewards for more activities, but we also have the age factor to consider, where older users get benefits for their efforts. One of the main tools used in the app is the QR code (center right of the figure) which is complementary to step counting and used to associate rewards with user behaviors. Apart from step counting, users can also be rewarded for activities associated with QR codes, such as swimming or perhaps lifting weights. Also, the user gets coins by providing feedback using the application (center right of the figure).

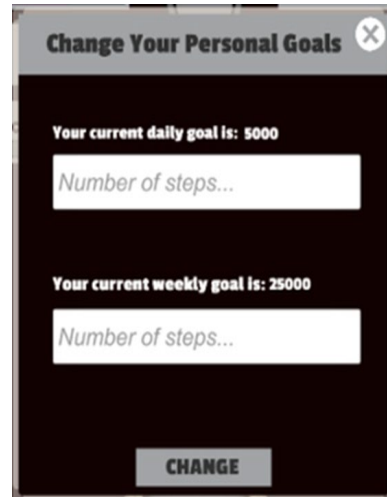
Now we are going to explain the different features of the application. We have selected some of the main features of the application to discuss in this section:

Age Band- This feature was implemented after a discussion with supervisors about how to accommodate adults who couldn't participate in the competition due to their age. During the meeting, it was decided that if the user is above 40, the steps would be adjusted accordingly. Users are required to input their age in the settings. Once done, the steps are incremented based on the user's age. For example, if the user's age is 51 and they have walked 112 steps, it becomes $112 * 5.1 = 571.2$ steps, which is the original steps multiplied by 10% of the user's age. This adjustment is made to enhance user adherence and to make it achievable for older users by rewarding them for their efforts.

Goals- Used to self-regulate and monitor the behavior. It also satisfies the user's need for autonomy and purpose. Users can set and change their daily and weekly goals (Fig.4.2 b). These goals are Good Habit, Active Spirit, Push Yourself and 20k/50k (Fig.4.2 a). The experiment conducted by Munson et al. [50] states that the outcome of having primary and secondary goals was positive: if a user fails to achieve one goal, they can still work on the second goal. Users get rewarded for meeting the goals.



a)



b)

Figure 4. 2: Users can view their Daily Goals and change their daily and weekly personal goal steps.

Rewards- It raises extrinsic motivation. It gives a sense of achievement and appreciation. There are 3 types of rewards in the app a) Virtual Reward includes Avatars and coins b) Bonus Reward includes Daily Streak, Personal Best, Push Yourself, Walk 20k/50k and Weekly Reward c) Real Reward is provided by the stakeholders and includes hot meals, Sandwiches, Gym and swimming sessions (Fig.4.3). The user can also see the location from where they can claim their Real Rewards.

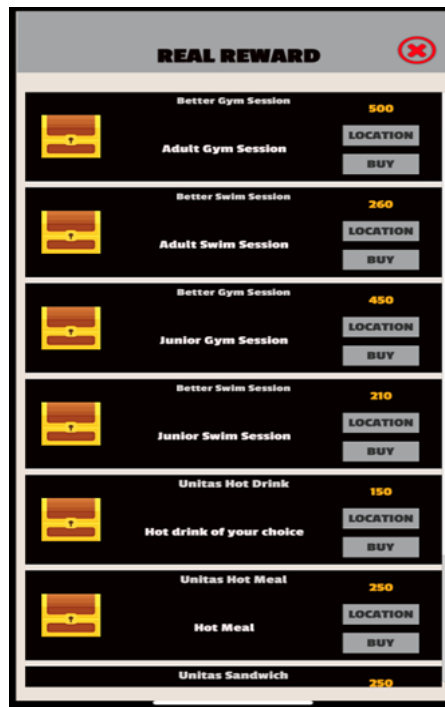


Figure 4. 3: Real Reward for different age groups

The app includes an age-based rewards for citizens. Table 4.1 shows the age code applied to different age groups.

Citizens	Age Ranges	Age Codes
Children	5-12 years	C
Teenagers and youngest adults	13 – 18 years	T
Mature adults	18- 65 years	M
Elder citizens	65+	E
All	5 to 65+ years	ALL

Table 4. 1: The age codes used for different age groups.

Table 4.2 shows the rewards linked to different age groups and the code applied to each reward.

Types of Rewards	Rewards	Applies to
Real Rewards	Better Adult Gym Session	M, E
	Better Adult Swim Session	M, E
	Junior Gym Session	T
	Junior Swim Session	T
	Unitas Hot Drinks	ALL
	Unitas Hot Meal	ALL
	Unitas Sandwich	ALL
	Unitas Soft Drink i.e. Juice, Water or Milkshake	ALL
Virtual Rewards	Coins	All
	Age Band Coefficient	E
	Children Avatars	C
	Teen Avatars (Boy/Girl)	T
	Mature Avatars (Male/Female)	M, E
	Animal Avatars	ALL
Bonus Rewards	Daily Streak	ALL
	Weekly Reward	ALL
	Walk 20k	ALL
	Push Yourself	ALL
	Personal Best	ALL

Table 4. 2: The rewards applied to the age group.

Daily Streak- Used in the app to help form new habits. Habit Formation, and thus long-term change, involves consistent repetition of behavior until the behavior becomes automatic [30]. Daily Streak is when the user is active and opens the app seven days regularly. They get some rewards. If the user misses one day of completing a daily goal or challenge, the streak will be broken, and the user will have to start over again. The 7-day streak keeps the user motivated to complete any goal or challenge daily in order to collect bigger rewards. The Progress bar is implemented for the Daily Streak where users can see their progress and improve their walking habits (top left hand-side of Fig. 4.4).

Weekly Reward- This is implemented to help users to develop a new habit of staying active. This is for user adherence, where after a certain period of time users get stuck to the routine due to behavior change. When the user is active throughout the week and has more than 10,000 steps in a week, the Weekly Reward window appears on Monday, and the user can claim his/her reward. The Weekly Reward was to keep the user motivated throughout the week. Also, this reward is given to the users on the basis of their fidelity and effort.

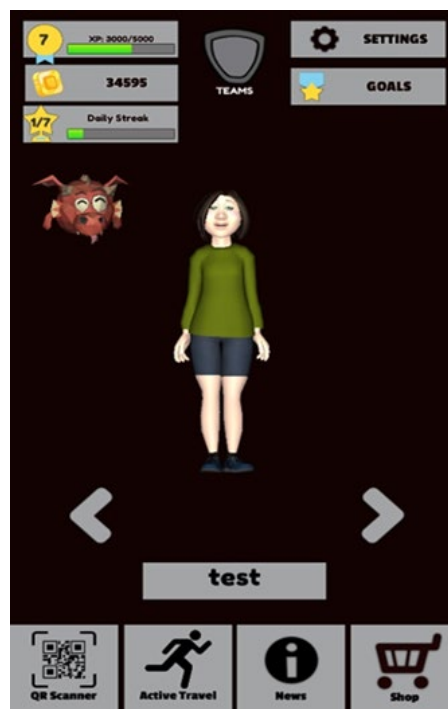


Figure 4. 4: Main Screen of the Application.

QR Code- The QR code feature is implemented to reward user's efforts. It can be used in a school's physical education (PE) program, where PE teachers may use it to reward students for their positive behaviors during PE classes. For instance, PE teachers reward students with positive attitudes even if they have not been the fastest in a race or reward people with more efforts to change and stick to a healthy lifestyle (Fig 4.5, Fig 4.6 and Fig 4.7). Also, they could use QR codes to reward children for finding specific landmarks or completing certain physical tasks during the hunt, promoting both physical activity and problem-solving skills. The PE teacher can provide students with a QR code, which the student has to scan using the app to claim the reward. This is to acknowledge and encourage good performance, teamwork, or improved physical abilities. Teachers may use this feature to motivate and track student's progress. The lower left-hand side of Fig. 4.4 shows the application's main screen, where we have a QR code button to claim the reward. This feature rewards people who have demonstrated positive behaviors such as trying the hardest, being more cooperative with the rest of the team,

or the one that has improved the most. The QR code helps Habit Formation and rewards older people for their efforts and positive behaviors. This feature not only helps develop new habits but also rewards competence, which helps in user adherence.

Compared with step counting, the QR code feature offers several advantages and is applicable in various scenarios and situations, both to individual and group activities and suitable for diverse age groups, including adults and children.

In individual activities, a person can use the QR code feature to claim the reward for achieving personal fitness goals. For instance, individuals engaging in outdoor activities, such as jogging in a park or swimming in a pool, can make use of the QR code feature to claim rewards for their physical efforts. When jogging in a park and swimming in a pool, users can scan a QR code placed at designated locations in the park, near the pool or at specific locations provided by the application. This allows them to mark their progress and achievements while acknowledging their time spent swimming, which might not be accurately measured by traditional step-counting methods. This approach not only makes the tracking of these activities more precise but also adds an element of motivation by recognizing and rewarding their commitment to a healthy lifestyle. It also has the advantage of increasing the diversity of activities tracked. In group activities, the QR code becomes a tool for recognizing teamwork and collective achievements. For example, a group of friends participating in a fitness challenge can scan a QR code to celebrate their achievements.

Once users are notified that they have accomplished the goal or reached the milestones, they can claim the QR code from specific locations such as shops, gyms or parks. These locations will be physical distribution points for the QR codes, allowing users to claim their rewards. The process of distribution of QR codes through these locations not only encourages users to achieve their fitness goals but also enhances user engagement with local businesses. It promotes social interaction and incentivizing users to explore various locations while working towards their fitness goals, adding an interactive element to their fitness journey. This increases the level of motivation and fun in the step-counting experience.

The QR code feature is flexible and is suitable for both adults and children. In a school, the feature can reward children during active playtime or sports activities. For adults, it can be a motivational tool during a gym session, while for children, it can make physical activity more entertaining and rewarding. It can be applied in numerous situations, promoting healthy behaviors and encouraging users of all ages to stay active and motivated. The various aspect

of the QR code shows its adaptability, which makes it a valuable tool for both individual users and educators, such as PE teachers, in a school setting.

Scenario- The QR code is helpful for rewarding activities that cannot be counted and for forming a habit. As explained in the above text, it is not necessarily a teaching tool and is not limited to the school environment but can be used by anyone. This scenario shows how the QR code can be used and how the reward can be claimed in OnTheMove! App in a school setting. A competition was conducted in the school. Fred participated in the competition and tried to improve his lifestyle by actively walking after using the ‘OnTheMove!’ application (Fig 4.5). Although he was not the winner in the competition, the PE teacher appreciated him by rewarding him for his efforts and positive attitude.

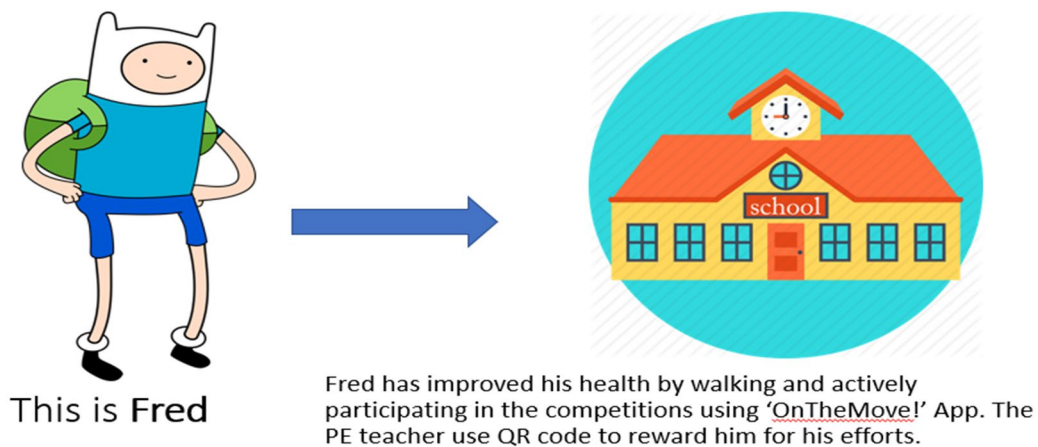


Figure 4. 5: Scenario for claiming reward using QR code.

The PE teacher gave Fred a QR code to claim the reward. Fred clicked the QR code icon and scanned the QR code provided by his PE Teacher (Fig 4.6).

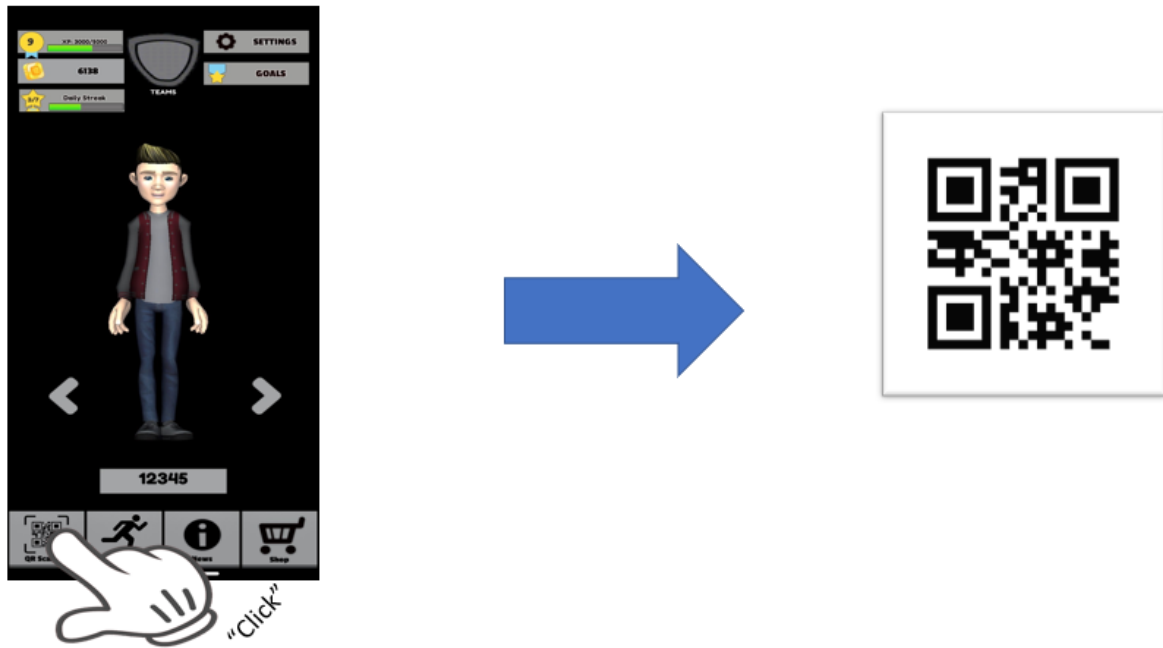


Figure 4. 6: Screenshot for claiming reward using QR code.

After clicking the icon, a camera opens, and Fred scans the QR code (the right-hand side of Fig 4.6). After scanning the QR code, the message appears as 'Code successfully scanned' (Fig 4.7). Fred Clicked 'OK' and got the points for his efforts. The rewards can be real rewards or Avatars.

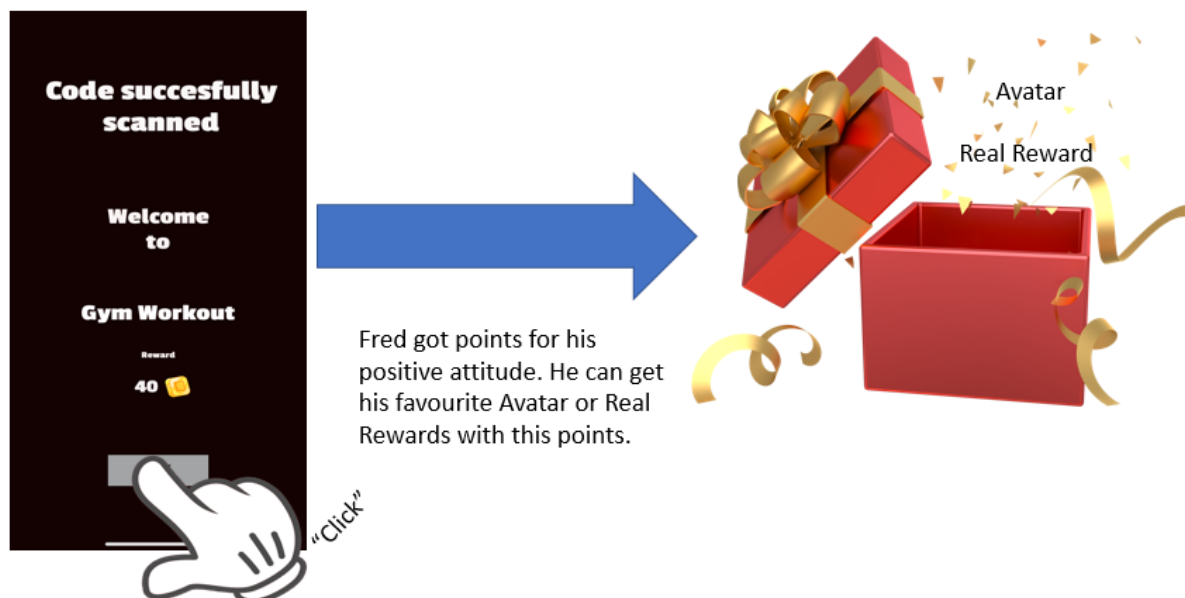


Figure 4. 7: Screenshot of getting a reward for a positive attitude.

The images of Fig 4.5, 4.6 and 4.7 were created by Bene [11] for a previous prototype of the system. However, these images were later updated according to a current prototype.

Transfer Steps- The user can transfer their steps to team competition and goals such as Push Yourself or Walk 20k (Fig.4.8). This gives a feeling of autonomy and purpose. Also, BCT reward has been used where users get rewards such as virtual coins, which help to retain users.

FAQ- This section is available in the application displaying the frequently asked questions by users with links to explanatory documents (Fig. 4.9).

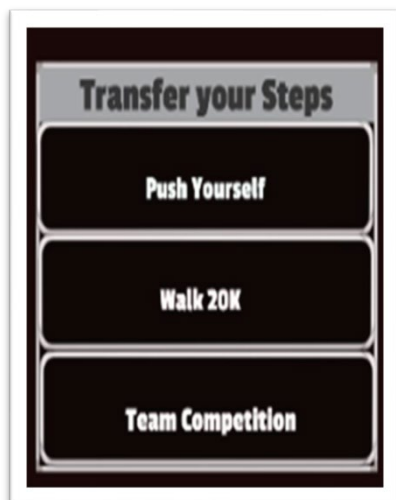


Figure 4. 8: Transfer Steps to goals or competitions.

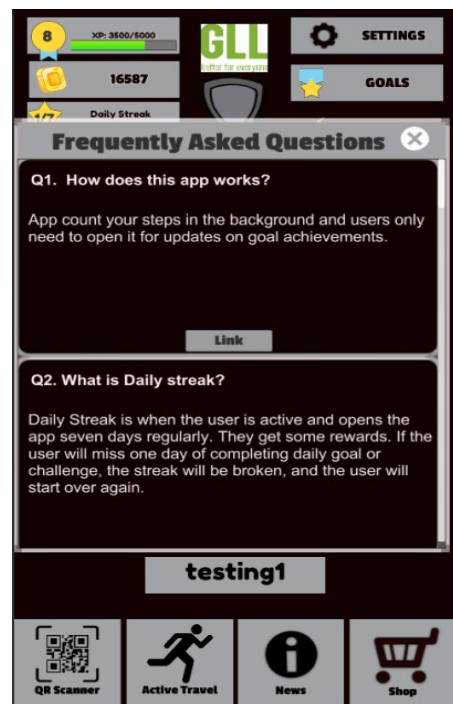


Figure 4. 9: Frequently asked questions

Flexibility for Teams and Competition Creators- This feature is for personalization, where the creator of the team/competition gets the flexibility to add, delete, send or accept requests. Fig. 4.10 illustrates the flexibility for Teams creators where the creator of the team can remove the participants from the team, send a request to participate in various competitions, select and delete the competitions created by the team creator, and delete the team. Fig. 4.11 presents the flexibility for the competition creator where the creator of the competition can add the teams to the competition, accept the team request to join the competition, update the details of the competition (such as start and end dates of the competition, reward for the winner, description of the competition etc.), select and delete teams, and delete the competition if no longer required.

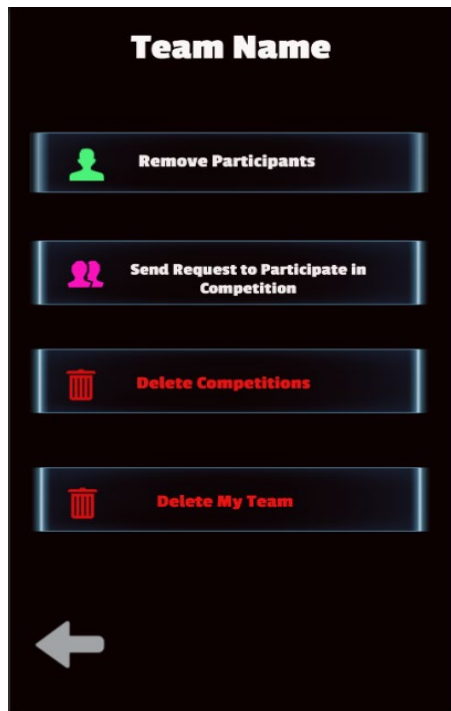


Figure 4. 10: Flexibility feature for team creators.

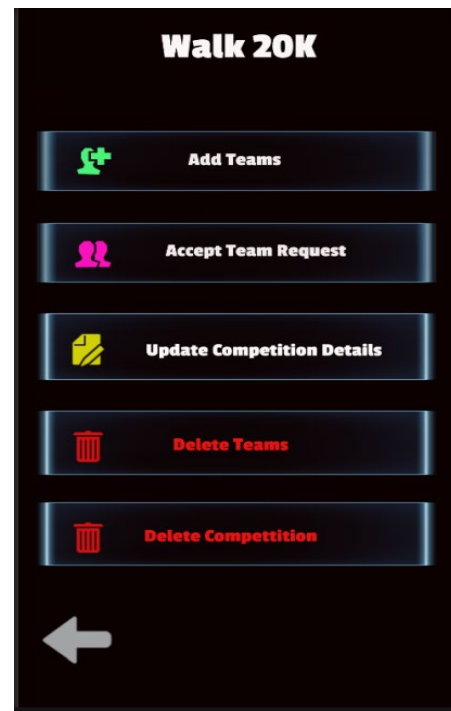


Figure 4. 11: Flexibility feature for competition creators.

Add/Delete Teams– This feature uses SDT autonomy where creators of the competitions have the flexibility to delete/add teams. Figures 4.12 and 4.13 presents in more detail the ‘add teams’ and ‘delete teams’ options mentioned in Figure 4.11.



Figure 4. 12: Flexibility for competition creators to add teams in competition.

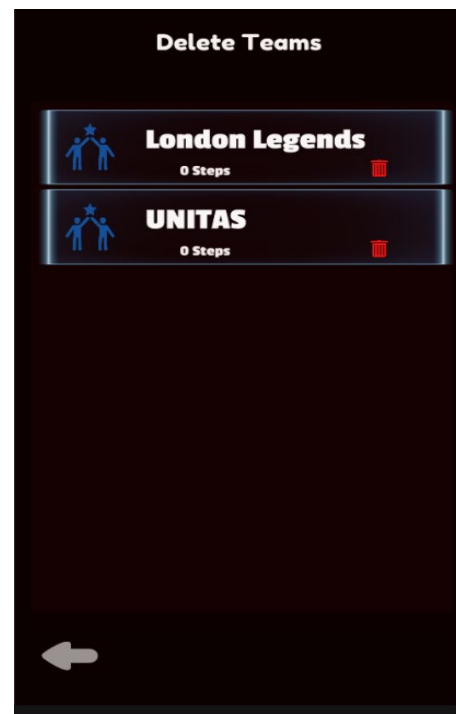


Figure 4. 13: Flexibility for competition creators to remove teams from competition.

Sending Request to Competition- Teams can send requests to participate in the competition (Fig 4.10). To send a request, the team creator has to upload documents for verification. As shown in Fig. 4.14, the team creator clicks on the button ‘Send Request’ to request to participate in the competition. They have to upload documents such as Passport, Driving License or BRP, as presented in Fig. 4.15, for verification. This ID document is only visible to the competition creator. Also, the team creator can remove the teams from the competition if they no longer want to participate.

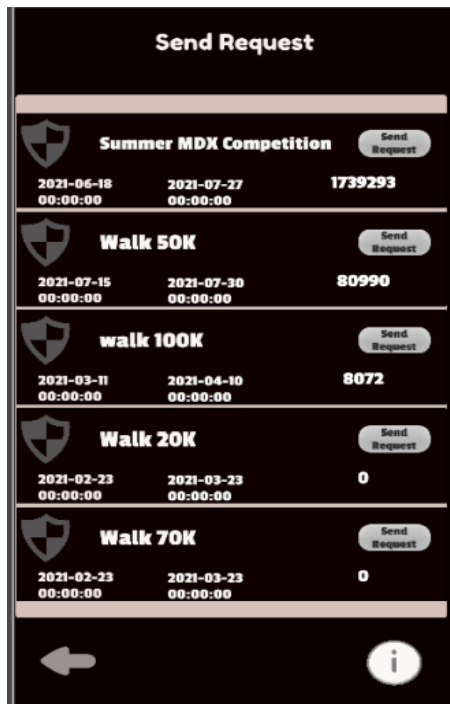


Figure 4. 14: Team send request to competition.

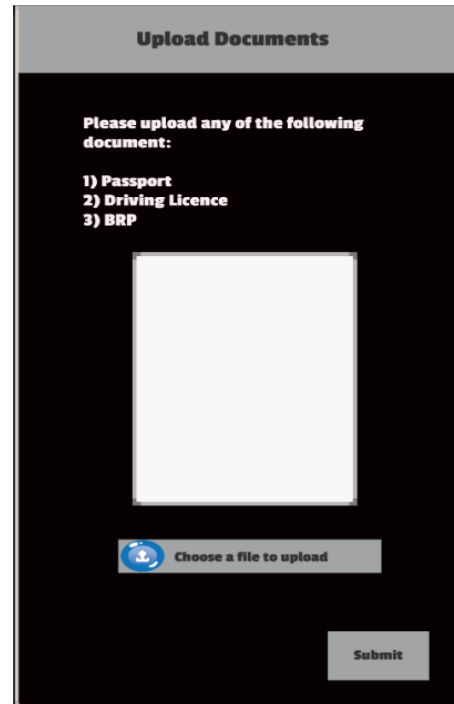


Figure 4. 15: Teams upload documents to send request to competition.

Accept/Decline the Team Request – In Fig. 4.11, clicking the button ‘Accept Team Request’ takes the creator to the screen shown in Fig. 4.16, where the competition creator was able to accept or decline the team request by viewing the documents such as BRP, Passport or Driving License. In Fig. 4.16, clicking the ‘document icon’ enables the competition creator to view the documents submitted by the teams.

Team Competition- Users can create, join and view teams. Also, they can create and join competitions. The competitions can be between two or more organizations (Fig.4.17). The Team Competition is used to give users the feeling of competence and relatedness with other users.

Liking- To keep users motivated, a Like Feature has been implemented. The users can like the steps of other users to congratulate or show their support (Fig.4.17). This feature has been implemented to give users a sense of Social Support and relatedness.

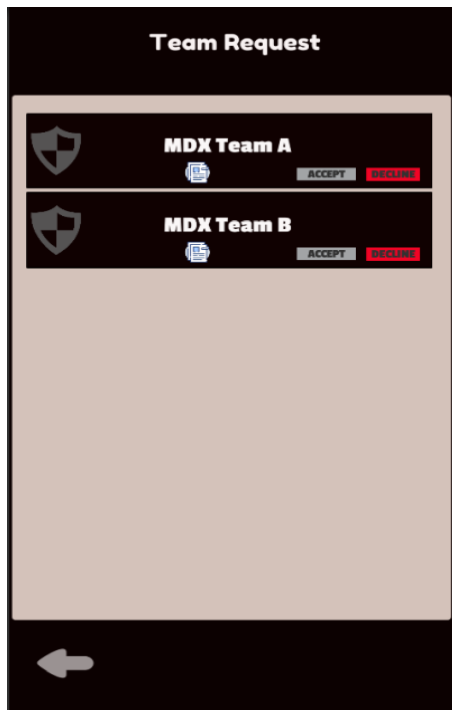


Figure 4. 17: Accept/ Decline Team Request.

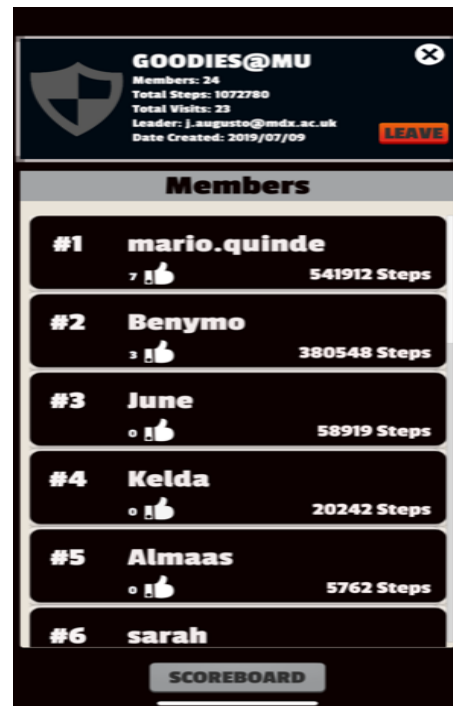
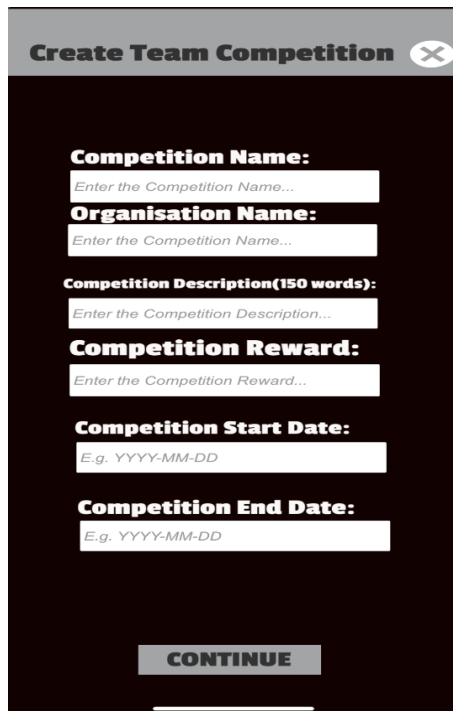


Figure 4. 16: Step competition with team members and Like Feature.

Create Competitions – The creator of the competition will be able to create competitions, a view of which competitions the user has accepted, which teams form part of that competition, and the start and end date of the competition (Fig. 4.18). Also, the competition creator will be able to update the competition details (Fig 4.19).



Create Team Competition ✕

Competition Name:
Enter the Competition Name...

Organisation Name:
Enter the Competition Name...

Competition Description(150 words):
Enter the Competition Description...

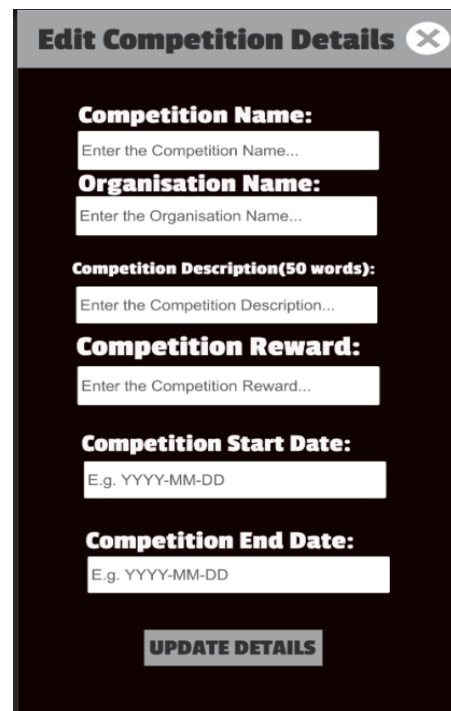
Competition Reward:
Enter the Competition Reward...

Competition Start Date:
E.g. YYYY-MM-DD

Competition End Date:
E.g. YYYY-MM-DD

CONTINUE

Figure 4. 18: The creator of the competition can create multiple competitions.



Edit Competition Details ✕

Competition Name:
Enter the Competition Name...

Organisation Name:
Enter the Organisation Name...

Competition Description(50 words):
Enter the Competition Description...

Competition Reward:
Enter the Competition Reward...

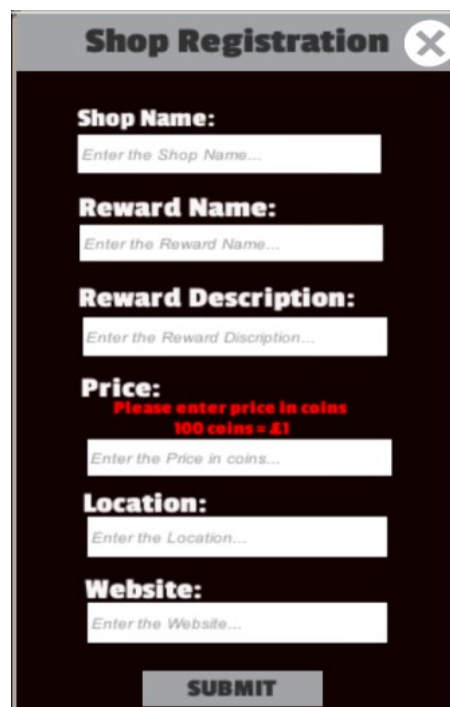
Competition Start Date:
E.g. YYYY-MM-DD

Competition End Date:
E.g. YYYY-MM-DD

UPDATE DETAILS

Figure 4. 19: The creator of the competition can update the competition.

Shop Registration- Shop owners will be able to register and add offers in the app (Fig. 4.20).



Shop Registration ✕

Shop Name:
Enter the Shop Name...

Reward Name:
Enter the Reward Name...

Reward Description:
Enter the Reward Discription...

Price:
Please enter price in coins
100 coins = £1
Enter the Price in coins...

Location:
Enter the Location...

Website:
Enter the Website...

SUBMIT

Figure 4. 20: The shop owner can register to provide real rewards to the users.

Shop Details - Users can see the shop name and location in the real reward Scene (Fig. 4.21), and the User can view their real reward transaction (Fig. 4.22).

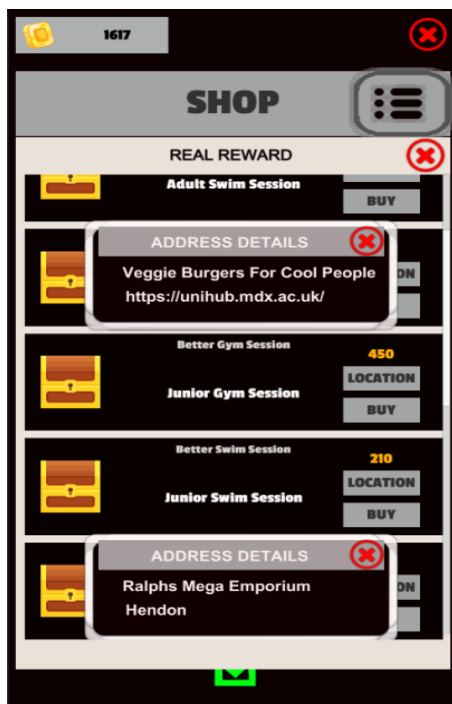


Figure 4. 21: Real Rewards shop name and location.

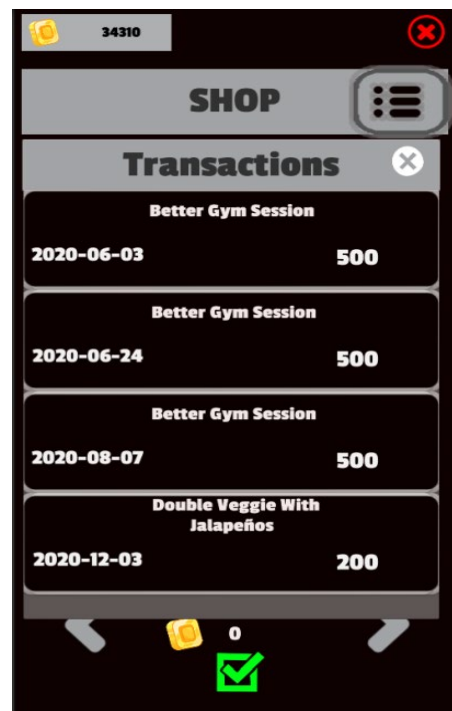


Figure 4. 22: User's real rewards transactions.

User Review - Users can provide their reviews, which helps to improve the application (Fig. 4.23).

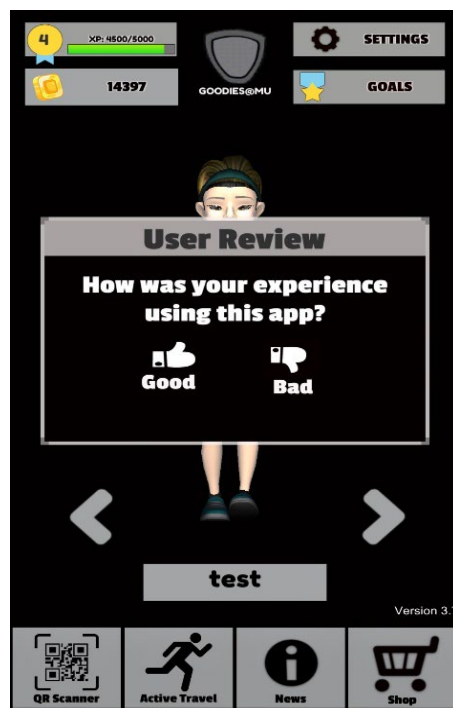


Figure 4. 23: Screenshot of user's review about the application.

Feedback – The users can provide feedback using ‘Send Us Your Feedback’ button (Fig. 4.24).

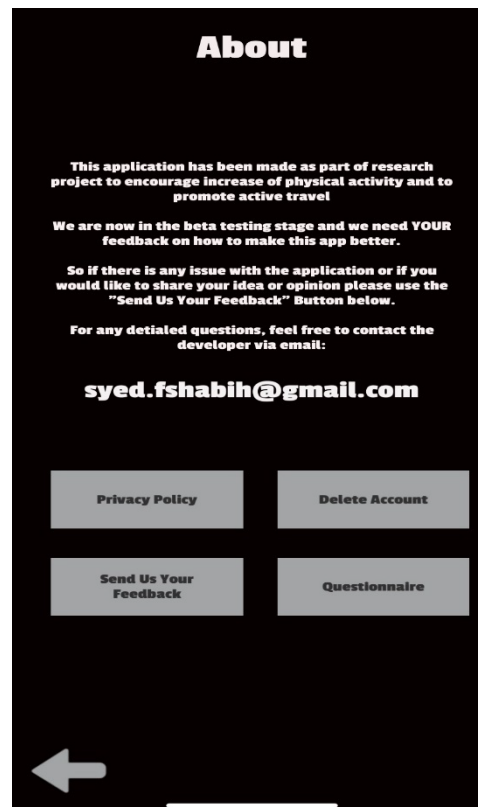


Figure 4. 24: Sending Feedback from OnTheMove! App.

Link to the questionnaire- The questionnaires for each pilot were made accessible via links in the OnTheMove! App's news section, as illustrated in (Fig 4.25). These links were introduced during the COVID-19 lockdown, serving the purpose of keeping users informed and facilitating their access to the questionnaires. At the end of each pilot, users can complete the questionnaire by clicking the provided button.

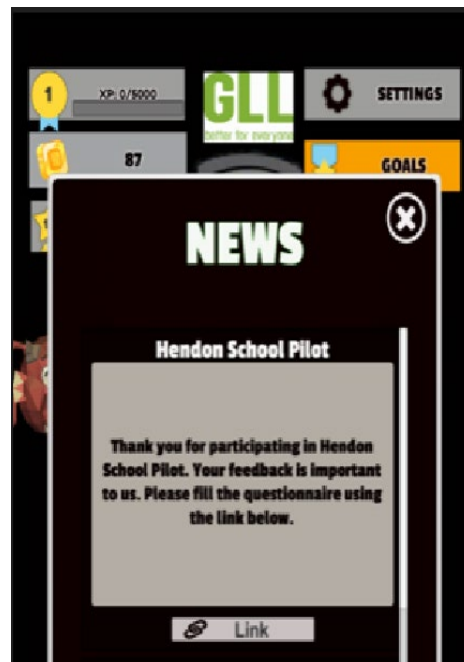


Figure 4. 25: Link to the questionnaire in OnTheMove! App.

In this chapter, we explained the development of OnTheMove! app and explained the main features. This chapter also linked each adherence feature with BCTs and SDT components. In the next chapter, we will discuss the validation and results. We will focus on the last stage of the UCIEDP methodology, 'IE Installation'. Section 5.1 will explain in detail the entry and exit questionnaires used in each pilot. The results of these pilots are used to improve the application and get information about how the app will benefit the users. We will also explain in section 5.2 how new quantitative metrics give us information on each BCT representatives and SDT components.

Chapter 5

Validation and Results

The OnTheMove! application was designed to implement the motivational technique for user adherence. It collects the steps and converts them into coins, and the steps can also be transferred to goals and competitions. The application was then examined using pilots with different organizations to enhance our system using user feedback and to get in-depth knowledge about each component of BCTs and SDTs by measuring it using quantitative metrics (PFs) in our system. These pilots are discussed in this section.

The validation section is connected to the UCIEDP methodology. It consisted of several iterations which encouraged interaction and feedback from stakeholders. Six pilots were conducted with various age groups. The respondents were genuine participants who were focused on health. Genuine participants are sincerely interested in participating in the pilots and competitions to improve their health. These individuals are not just going through the motions; they are genuinely motivated to take part in these activities with the goal of enhancing their health. In each of the pilots, we contacted the potential participants through external organizations (for example, schools, gyms and a city council). All the participants were from London. It is amongst the most diverse city in the world, with participants from different social, economic and cultural backgrounds. There was an ethical approval process for each pilot. Participants had to sign consent to take part, and answer to the questionnaire were anonymous. In addition, the participant has the right to withdraw at any time. The first three pilots were conducted using questionnaires, and in the last three pilots, we used a mix of questionnaires and Performance Functions. The entry and exit questionnaires were used to improve the app functionality, while the Performance Functions were used to determine which adherence feature and technique worked best.

5.1. Entry and Exit Questionnaires

The entry questionnaire was provided at the initial stage to the users to gather some information such as

- How often the user visits the places such as gym, park, leisure center etc.
- How many steps does the user take approximately per day?

After downloading and using the app, users were rewarded for participating in the pilot and giving feedback. After the pilot ends, the exit questionnaire was provided to get feedback which included some of the following questions:

- Has the user been visiting leisure centers, parks, open spaces etc. more often after installing this application?
- Any other comments or suggestions for improvement?
- Is there any feature that the user generally dislikes and thinks should be removed?
- Has the user noticed an increase in physical activity?

These questionnaires were used in all the pilots. The improvements were made using the feedback from the users.

5.1.1. Unitas Pilot (2020)

The first pilot was conducted in Unitas, London with 25 users participating in two weeks ‘Step Challenge’. The user with more steps wins the competition. The first, second and third winners got a prize. The purpose of this challenge was to gather feedback from users and to enhance the functionality of the application.

After the step challenge, a survey was conducted to get feedback from the users. An example from the questionnaire was ‘What type of rewards do you prefer?’. The options given were: a) Real Rewards b) Virtual Rewards c) both the same. The result was 71.43% preferred ‘Real Rewards’ while ‘Virtual Rewards’ and ‘both the same’ were 14.29% respectively (Fig. 5.1).

Q5 - What type of rewards do you prefer?

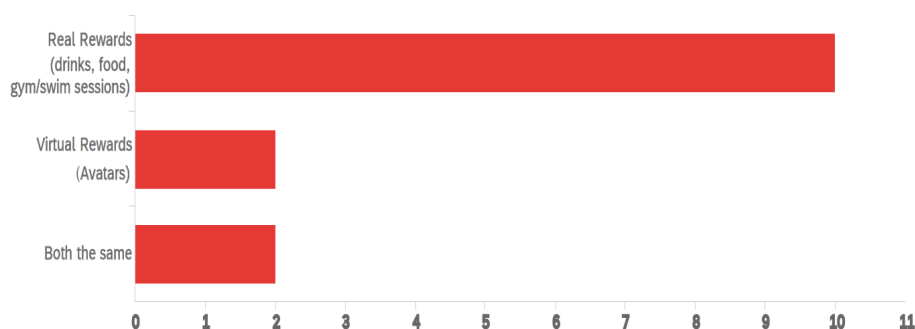


Figure 5. 1: The result of the questionnaire for reward.

The other question asked was ‘Do you think that your physical activity improved while using the app?’. The options given were: a) Definitely yes b) Probably yes c) Might or might not d) Probably not e) Definitely not. 46.15% of participants chose ‘Definitely yes’ and 23.08% chose ‘Probably yes’ as compared to ‘Probably not’ and ‘Definitely not’ which were 0% (Fig. 5.2).

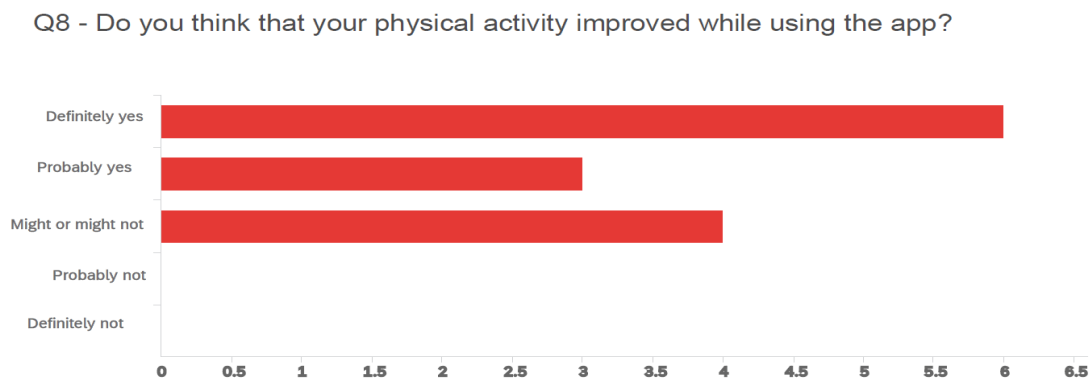


Figure 5. 2: The result of the questionnaire for the app.

Finally, some of the feedback received from the questionnaires was:

- The most liked features of the app are: Real Reward, Virtual Reward and Step count.
- Users enjoyed the app due to the following reasons: It improves health, is easy to use, encourages people to move around and offers attractive incentives to walk more which also helps to improve mental health.

Improvements- We got feedback to customize the avatar, add more choices of avatar and to be able to see past walking history. Therefore, we implemented an Avatar Customization feature (Fig.5.3) and step count history also known as ‘Active Travel History’ (Fig.5.4).

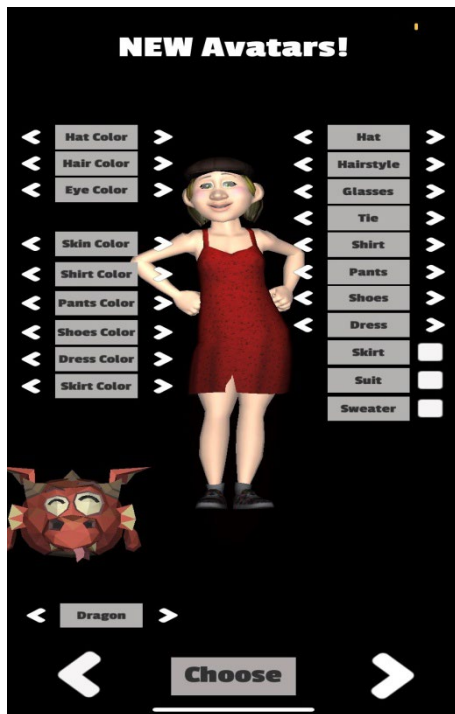


Figure 5. 3: Avatar Customization



Figure 5. 4: Active Travel History

a) *Avatar Customization*- The user can customize the avatar skin color, dress, glasses, hair and other features (Fig.5.3). This feature gives a sense of personalization, autonomy and relatedness. If the user has not walked certain steps, the avatar makes a sad facial expression. However, to make it happy, the user has to walk 10% of the average daily steps.

b) *Active Travel History*– The user was able to see their past walking history (Fig.5.4). This feature has been implemented using BCT self-monitoring behavior along with SDT components such as competency and purpose.

5.1.2. MDX Spring 2021 Pilot

A pilot was conducted in Spring with 29 participants from Barnet. Some of the feedback received from users:

- Personal goal feature helped to be physically active.
- Increase in physical activity after using the app.
- Real reward is more effective in encouraging physical activity.
- Have been visiting leisure centers, parks, open spaces etc. more often after installing OnTheMove! Application.

Improvement- One of the participants could not increase his physical activities due to his tight schedule. Therefore, Reward Effort also known as Personal Best and Health Coach was implemented. Personal Best is for making small changes in day to day activity and getting reward for small efforts. In addition, a Health Coach was implemented to provide hints and tips related to health.

a) Reward Effort- The main aim of this feature is to reward the small efforts of the users. This is to reward fidelity or loyalty of the users. This feature encourages them by rewarding the users for the effort and courage to change their lifestyle from sedentary to active. However, the aim is to make people physically active not necessarily by running, swimming or jogging. The user also gets rewarded for changing their lifestyle. This is done by using the concept “Personal Best”. The term Personal Best is used in athletics. Here the algorithms are used to know the best time users have ever done the specific task such as running, jogging etc. For example, for a beginner it could be 35’ for 5k, but after running for a couple of years it could be 20’ (depending on age). If one day the person does S steps and next time s/he increases her/his latest PB by I%, with a fixed I%. This I coefficient will have to start big and diminish with time. For example, if a person’s first walk is 5k it should not be that difficult to walk another 5k (which is a 100% increase!) however after a year or so if that person manages to walk 10k a 100% increase will be 20k which is too big of a jump. To start with some minimum distance D (easy but meaningful, can be 1k) and first reward 100% improvement of that initial PB, then reduce the expectation in a factor of a constant C, i.e., $(100-C)\%$, then $(100-2C)\%$, then $(100-3C)\%$, etc. For example, if $C=10$ we go 100%, 90%, 81%, 73%, 64%, and so on. This feature is used in this app to praise and encourage users which satisfy the need of purpose and competence.

b) Health Coach - This section is available in the application displaying useful information on how to be healthier (Fig. 5.5). This is BCT information about health consequences. It gives a sense of purpose for the users.

c) Goals Monthly Report - Users were notified monthly about the performance displaying the report of goal accomplishment on 28th of every month. This is BCT self-monitoring behavior (Fig. 5.6).



Figure 5. 5: Health related information **Figure 5. 6:** Information about achieved goals.

5.1.3. MDX Summer 2021 Pilot

A pilot was conducted in Summer 2021 with different age groups. Some of the feedback received from users:

- Group score and Real Rewards are more effective in encouraging physical activities.
- One of the participants said “*The rewards were nice*”.

The features such as Personal Best, Health Coach and Goals Monthly Report were developed and tested in this pilot. However, it was difficult to measure the success or failure of these features. Therefore, we realized we needed more precise ways to measure the effectiveness of each feature using motivational techniques and capturing feedback. This motivated us to introduce the Performance Functions, which were in addition to the entry and exit questionnaires. These questionnaires were used in all six pilots, but Performance Functions were used in the last three pilots.

This was an intermediate step. For the final year, we found a more precise way to measure SDT Components and BCTs using Performance Functions.

5.2. Measuring Effectiveness of BCTs and SDT Using Performance Functions

Using a questionnaire gives only general information, while using Performance Functions gives more specific information. We used performance data collected during the pilot to measure user adherence to the app. This data was used to calculate BCT usage individually to evaluate adherence. Also, user adherence was calculated using data from the following questions such as:

- How many days did the participant use the app?
- How many days did the participant use each feature of the app individually?
- What is the frequency of each feature used on a daily basis?

The aim was to correlate the highest overall user adherence to the app by a user with the use of specific BCTs and to identify which BCT is more effective in user adherence. Hence, Performance Functions were created and this information was used to measure the effectiveness of BCTs and SDT. These Performance Functions (PF) were used for the last three pilots such as Middlesex University Winter 2021 Pilot, Unitas Pilot 2022 and Hendon School Pilot 2022 (<https://figshare.com/s/0a0a01a98e37aae0ab1c>). Due to the Covid-19 and lockdown, we did the last three pilots together.

As we explained in section 3.1.1 about SDT, SDT components, BCT and BCT representatives and in Fig. 3.4 about the BCT representatives that we used for our research. We noticed that each of the SDT components is closely linked to some BCTs, and measuring the magnitude of the impact of these BCTs together gives us a measure of SDT called $SDT_{Purpose}$. We translated BCTs into our system as Information about health consequences, Habit Formation, Self-monitoring of behavior, Goals and Rewards. They are all related to SDT called Purpose. Therefore, we add up all the BCTs related to measure the $SDT_{Purpose}$. Relatedness was another SDT in our system. We found it closely related to Social Comparison and Social Support. Therefore, we used these two BCT representatives to measure relatedness. SDT component called Autonomy is related to BCT representative called goals in our system. Finally, Competence which is one of the SDT components is related to Social Comparison.

PF 1(A): To calculate SDT components,

$SDT_{Purpose} (u) = BCT_{Habit\ Formation} + BCT_{Information\ about\ health\ consequences} + BCT_{Self-monitoring\ of\ behaviour} + BCT_{Goals} + BCT_{Reward}$

$SDT_{Relatedness} (u) = BCT_{Social\ Support} + BCT_{Social\ Comparison}$

$$\text{SDT}_{\text{Autonomy}}(\mathbf{u}) = \text{BCT}_{\text{Goals}}$$

$$\text{SDT}_{\text{Competence}}(\mathbf{u}) = \text{BCT}_{\text{Social Comparison}}$$

Where, ‘u’ is the user.

- $\text{BCT}_{\text{Habit Formation}}$ includes features such as Daily Streak, Personal Best, QR Code, Active Travel and Weekly Reward.
- $\text{BCT}_{\text{Information about health consequences}}$ includes Health Coach.
- $\text{BCT}_{\text{Self-monitoring of behavior}}$ includes Active Travel History and Goals Monthly Report.
- $\text{BCT}_{\text{Goals}}$ includes Walk 20k/50k, Push Yourself, Good Habits (Do some Active Traveling), Active Spirit (Scan QR code during sports sessions) and Goal Setting.
- $\text{BCT}_{\text{Reward}}$ includes Virtual Reward, Bonus Rewards, Real Rewards and QR code.
- $\text{BCT}_{\text{Social Support}}$ includes Like Feature.
- $\text{BCT}_{\text{Social Comparison}}$ includes joining Team Competitions.

PF 1(B): The $\text{SDT}_{\text{Purpose}}$ has more BCTs as compared to other SDT components. Therefore, to balance it we calculate the relative number of SDT components.

$$\text{SDT} = \frac{\text{Relative number of SDT used by each user}}{\text{Number of BCTs used in each SDT component}}$$

$$\text{SDT}_{\text{Purpose}} = \frac{\text{SDT}_{\text{Purpose}}(\mathbf{u}_1) + \text{SDT}_{\text{Purpose}}(\mathbf{u}_2) + \dots + \text{SDT}_{\text{Purpose}}(\mathbf{u}_i)}{5}$$

$$\text{SDT}_{\text{Relatedness}} = \frac{\text{SDT}_{\text{Relatedness}}(\mathbf{u}_1) + \text{SDT}_{\text{Relatedness}}(\mathbf{u}_2) + \dots + \text{SDT}_{\text{Relatedness}}(\mathbf{u}_i)}{2}$$

$$\text{SDT}_{\text{Autonomy}} = \text{SDT}_{\text{Autonomy}}(\mathbf{u}_1) + \text{SDT}_{\text{Autonomy}}(\mathbf{u}_2) + \dots + \text{SDT}_{\text{Autonomy}}(\mathbf{u}_i)$$

$$\text{SDT}_{\text{Competence}} = \text{SDT}_{\text{Competence}}(\mathbf{u}_1) + \text{SDT}_{\text{Competence}}(\mathbf{u}_2) + \dots + \text{SDT}_{\text{Competence}}(\mathbf{u}_i)$$

PF 2: To calculate user adherence (A) using BCTs, we counted the number of BCTs used by a user ‘u’ in relation to the total number of BCTs available in the app:

$$\mathbf{A}(\mathbf{u}) = \frac{\text{Number of BCTs used by user u}}{\text{Total number of BCTs available in the app}}$$

For example, if a user Sam used 4 BCTs such as Habit Formation, Reward, Goals and Social Support i.e. $\text{BCT}_{\text{Habit Formation}} + \text{BCT}_{\text{Reward}} + \text{BCT}_{\text{Goals}} + \text{BCT}_{\text{Social Support}}$, then, he used four BCTs out of 7 available in the system, that is:

$$\mathbf{A}(\text{Sam}) = \frac{4}{7} = 0.57$$

PF 3: To measure individual user's adherence with the app, we can identify who actively uses the app in one or more features. Let us suppose, there is a finite set of 'adherence features' $F = \{f_1, f_2, \dots, f_i\}$, then,

$$N_u = u_{f1} + u_{f2} + u_{f3} + \dots + u_{fi}$$

represents a total number of features a user 'u' has used, where u_f is the number of times user 'u' used the feature 'f'.

PF 4: To calculate the proportion P of users who used adherence feature f with a certain level of intensity, then,

$$P(f, x) = \frac{\text{Total number of users who used adherence feature f with intensity x}}{\text{Total number of users who used adherence feature f}} = \frac{T1(f, x)}{T1(f)}$$

where 'x' is the level of intensity with which the total number of user's 'T' used the feature 'f'.

For example, the intensity threshold could be having used feature f most days = 51% i.e. $x = 0.51$.

PF 5: To calculate the proportion P of users who used adherence feature f, then,

$$P(f) = \frac{\text{Total number of users who used adherence feature f}}{\text{Total number of users who participated in the pilot}} = \frac{T2(f)}{T2}$$

where total number of user's 'T' used the feature 'f'.

PF 6: To calculate the proportion P of users who used multiple M adherence feature f, then,

$$\begin{aligned} & P^M(f, x) \\ &= \frac{\text{Total number of users who used multiple adherence feature f}_j \text{ with intensity x}}{\text{Total number of users who used multiple adherence feature f}_j} \\ &= \frac{T3(f1, x) + T3(f2, x) + \dots + T3(fi, x)}{T3(f1) + T3(f2) + \dots + T3(fi)} \end{aligned}$$

where 'x' is the level of intensity with which the total number of user's 'T' used the multiple feature 'f_j'.

For example, the intensity threshold could be having used feature f most days = 51% i.e. $x = 0.51$.

$T3(\text{Reward Effort}, 0.33)$ represents the total number of user's 'T' who used Reward Effort at least a third of the days (approximately an average of three days a week).

$$P^M(\text{QR code}, 0.33) = \frac{T3(\text{Reward Effort}, 0.33) + T3(\text{Active Spirit}, 0.33)}{T3(\text{Reward Effort}) + T3(\text{Active Spirit})}$$

Notice that in this formula we do not include $T3(\text{Winner})$ because a user can be a winner and use the QR code but this does not necessarily mean they like the QR code feature. However, if they like the QR code feature they may use the QR code using Active Spirit or Reward Effort for most days.

PF 7: To calculate how many users used adherence features in relation to the natural frequency, we can classify features into daily (D) weekly (W) and monthly (M):

$$P^d(f, x) = \frac{D(f, x)}{T}$$

with $D(f, x)$ being the proportion of users who used f most days with the level of intensity 'x' if $f \in D$.

$$P^w(f, x) = \frac{W(f, x)}{T}$$

with $W(f, x)$ being the proportion of users who used f most weeks with the level of intensity 'x' if $f \in W$.

$$P^m(f, x) = \frac{M(f, x)}{T}$$

with $M(f, x)$ being the proportion of users who used f most months with the level of intensity 'x' if $f \in M$.

For example, the intensity threshold could be having used feature f most days = 51% i.e. $x = 0.51$.

For example, if the pilot was done in 10 days, if 50 users participated in the pilot and 25 used Daily Streaks with 5 of them using it 6 or more days (i.e., level of intensity), then,

$$P^d(\text{Daily Streaks}, 0.51) = \frac{D(\text{Daily Streak}, 0.51)}{T} = \frac{5}{50} = 0.1 \text{ (or 10\%)}$$

Example from Hendon School Pilot,

$$P^d(\text{Daily Streaks}, 0.51) = \frac{D(\text{Daily Streak}, 0.51)}{T} = \frac{10}{17} = 0.58 \text{ (or 58\%)}$$

$$P^w(\text{Active Travel}, 0.51) = \frac{W(\text{Active Travel}, 0.51)}{T} = \frac{9}{17} = 0.52 \text{ (or 52\%)}$$

$$P^w(\text{Personal Best, 0.51}) = \frac{W(\text{Personal Best, 0.51})}{T} = \frac{4}{17} = 0.23 \text{ (or 23\%)}$$

$$P^m(\text{Goals Monthly Report, 0.51}) = \frac{M(\text{Goals Monthly Report, 0.51})}{T} = \frac{1}{17} = 0.05 \text{ (or 5\%)}$$

We use the features Daily Streak, Active Travel, Personal Best, and Goals Monthly Report for this Performance Function because these features are used specifically daily, weekly or monthly. However, some of the features such as Like, Active Travel History and Health Coach can be used anytime.

PF 8: $u(f) = c$

Where, 'u' represents the user who has used a specific adherence feature (f) and 'c' is the number of times a user clicked on the icon.

For example, if a user has clicked on the 'Health Coach' icon 'c' number of times, then,

$$u(\text{Health Coach}) = c$$

PF 9: To calculate user adherence (A^d) using days, we can identify how many days a user 'u' used the app from the beginning to the end of the pilot and the total number of the days pilot took place,

$$A^d(u, x) = \frac{\text{Number of days u who used one or more features of the app with intensity 'x'}}{\text{Total number of days within period of system used}}$$

For example, if the pilot took place for 10 days and the user used one or more features of the app for 5 days, then,

$$A^d(\text{Sam}, 0.51) = \frac{5}{10} = 0.5 \text{ (50\%)}$$

5.2.1. Middlesex University Winter Pilot (2021)

The MDX Pilot was conducted between 21st December 2021 and 27th January 2022. Six adult users participated in the Pilot. The feedback we received from users:

- Liked features of the app are: Reward for walking, Active Travel, Shop and the integration with the native OS steps counter. It makes the application easy to use as the user can focus on the competition and rewards.
- 67% of participants noticed increased physical activity after using this app.

- 67% of participants say that they have been visiting the leisure centers more often after using the app.
- Team ranking was effective in encouraging physical activity.

Next, we highlight some of the interesting findings of the pilot. In the MDX Pilot, 66% of Daily Streak was used across all participants, and 17% of both Personal Best and Active Travel features (Fig. 5.7) were used. To calculate the user's use of adherence features, daily, weekly and monthly Performance Function PF7 is used. Fig. 5.8 depicts that User1 and User2 used more BCTs in comparison with others (Performance Function PF2).

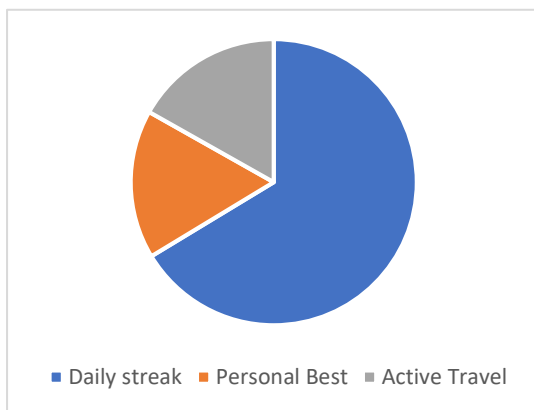


Figure 5. 7: Calculating users use of adherence features daily (D), weekly (W) and monthly (M) in MDX Pilot.

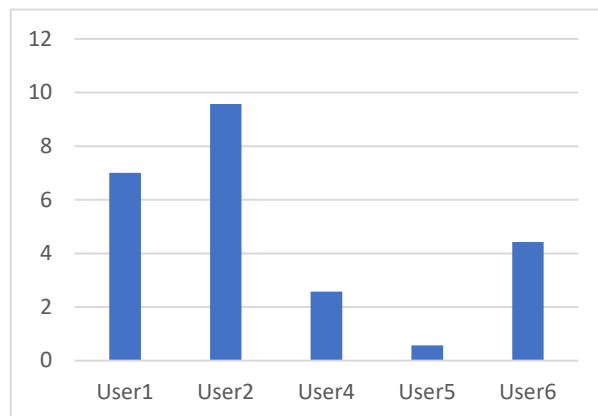


Figure 5. 8: Measure for adherence to BCTs by each user in MDX Pilot.

User1 used 78% and User2 used 84% of adherence features (PF9) during 38 days (Fig.5.9). Autonomy and Purpose are the most used SDT components by the participants as compared to Competence and Relatedness (Fig.5.10). All of these parameters were compared with Performance Function PF1(B).

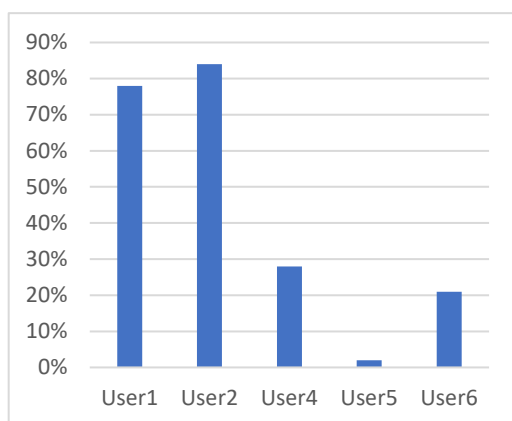


Figure 5. 10: Percentage of one or more adherence features used by users during MDX Pilot.

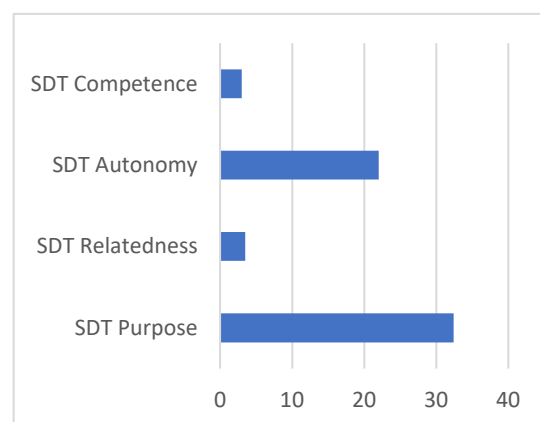


Figure 5. 9: Units to measure SDT components used during MDX Pilot.

The adherence feature (PF4) with the highest level of intensity was Daily Streak (39%). However, Personal Best (12%) was the least used feature. The reason for the significant difference is that Daily Streak is used daily compared to Personal Best which is used weekly (Fig. 5.11).



Figure 5. 11: Level of intensity with which adherence feature is used (BCT_{Habit Formation}) in MDX Pilot.

5.2.2. Unitas Pilot (2022)

The Unitas Pilot was conducted in London between 13th January 2022 and 28th February 2022. Twelve teenagers participated in this pilot. The feedback we received are as follows:

- Most liked features of the application are: a) 3 participants liked the avatars in the application, b) Being able to enter a school competition and having a league table, c) Fast and efficient, d) The step count and the daily goals, e) 3 participants liked step counts, f) Daily goals and, g) Rewards.
- 75% of users noticed increased physical activity.
- 75% of participants say that they have been visiting the leisure centers more often after using the app.
- Some of the Real Rewards that encourage physical activity are Vouchers such as healthy foods, Free food/drinks and swimming.

The rest of the section will highlight the main findings of this pilot. In the Unitas Pilot, 69% of Daily Streak was used across all participants. Both Personal Best and Active Travel were used with 16% intensity (Fig. 5.12). Performance Function PF7 is used to calculate the user's use of adherence features daily, weekly and monthly. Fig. 5.13 depicts that User2 used more BCTs in comparison with others (PF2).

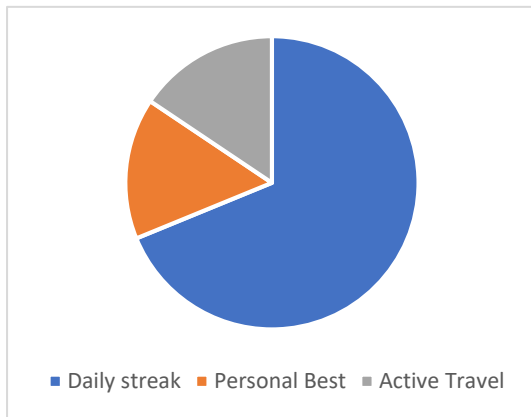


Figure 5. 12: Calculating users use of adherence features daily (D), weekly (W) and monthly (M) in Unitas Pilot.

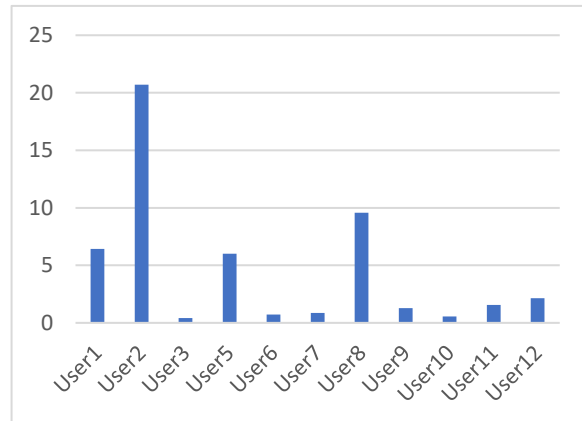


Figure 5. 13: Measure for adherence to BCTs by each user in Unitas Pilot.

Six participants used 100% of adherence features for 47 days (Fig.5.14). Performance Function PF9 is used for the percentage of one or more adherence features used by each user. Purpose is the most used SDT component by the participants as compared to other SDT components (Fig.5.15). All of these SDT components were compared with Performance Function PF1(B).

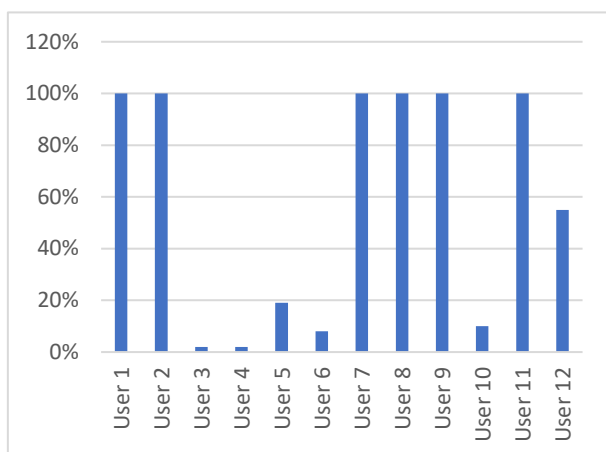


Figure 5. 14: Percentage of one or more adherence features used by each user during Unitas Pilot.

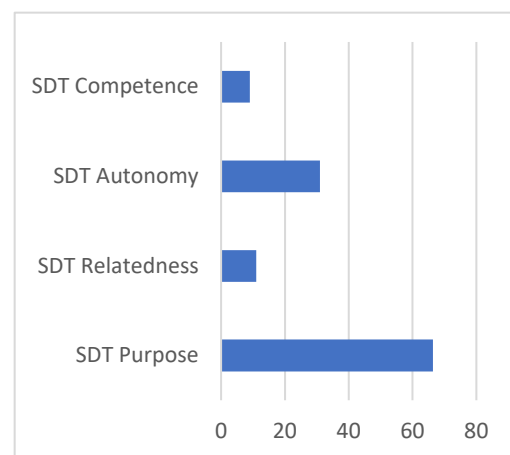


Figure 5. 15: Units to measure SDT components used during Unitas Pilot.

The pie chart shows that the adherence feature (PF4) with the highest level of intensity was Active Travel (32%) compared to other features. However, 27% of Daily Streak was used by the participants (Fig. 5.16).

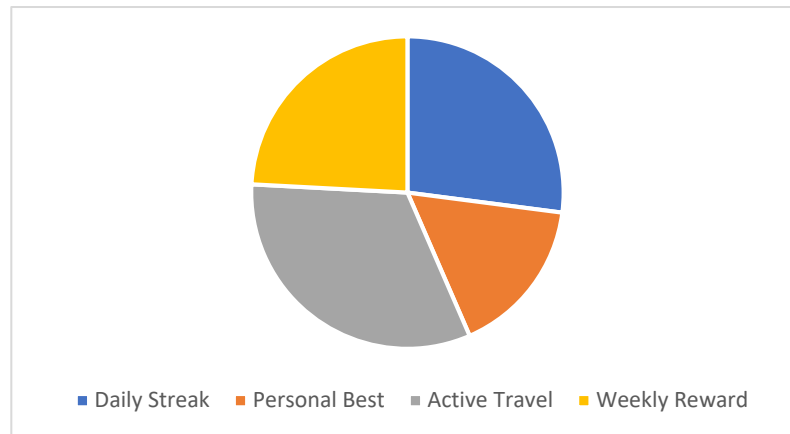


Figure 5. 16: Level of intensity with which adherence feature is used (BCT_{Habit Formation}) in Unitas Pilot.

Improvements- One participant wanted to get fitness updates. Therefore, a Notification feature was implemented so that if the user has lower steps than last week, they get a notification to stay active (Fig.5.17).

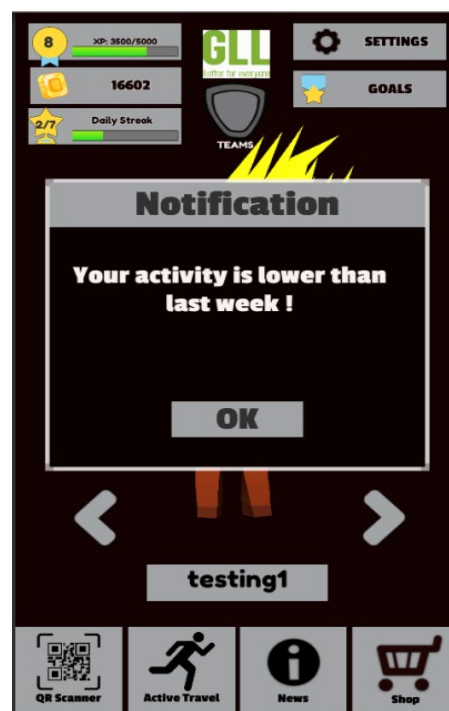


Figure 5. 17: Users get a notification if they have lower steps than the previous week.

5.2.3. Hendon School Pilot (2022)

In this pilot 17 users participated which was conducted at Hendon School between 21st January 2022 and 4th April 2022. Most of the users were children. The feedback summarizes as follows:

- Participants liked features such as Team, Team board, having a leaderboard against friends/ classmates, Checking moves and the daily goals.
- The children liked Animal avatars.
- They liked some of the rewards encouraging Physical Activity are the goals with higher rewards, Competition, Real Rewards such as money off or passes to somewhere and higher energy.

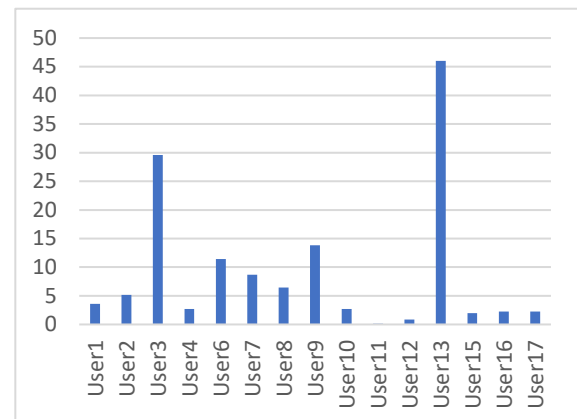
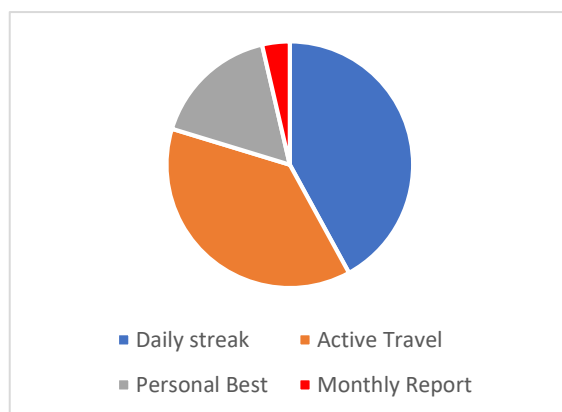


Figure 5. 19: Calculating users use of adherence features daily (D), weekly (W) and monthly (M) in Hendon School Pilot. **Figure 5. 18:** Measure for adherence to BCTs by each user in Hendon School Pilot.

Now, we will highlight the results of this pilot. In the Hendon School Pilot, Daily streak (42%) and Active Travel (38%) are used across all participants. On the other hand, Personal Best (17%) and Goals Monthly Report (4%) are the least used features in this pilot (Fig. 5.18). Goals Monthly Report is used significantly less because this report is available to users once a month has passed. These percentages are calculated using Performance Function PF7. Fig. 5.19 depicts that User3 and User13 used more BCTs in comparison with others, as measured using PF2. Fig. 5.20 depicts that two participants used 100% of adherence features for 47 days (PF9).

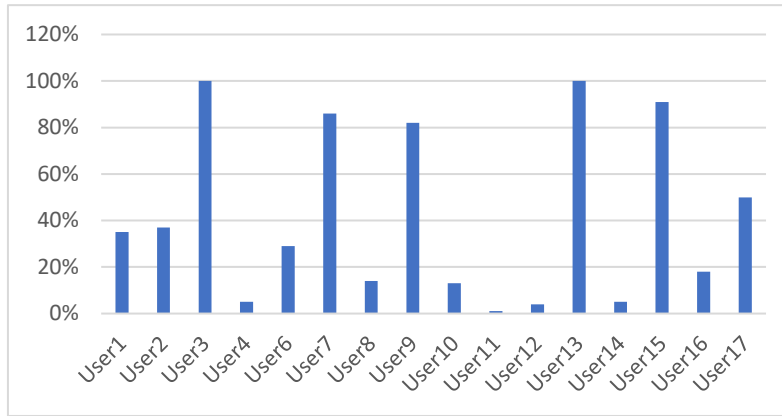


Figure 5. 20: Percentage of one or more adherence features used by each user during Hendon School Pilot.

Purpose is the most used SDT component by the participants as compared to other SDT components (Fig.5.21). Performance Function PF1(B) is used to measure the units of SDT components. The pie chart in Fig. 5.22 shows user level of adherence in BCT_{Habit Formation}. The adherence feature (Performance Function PF4) with the highest level of intensity was Active Travel (35%) compared to other features.

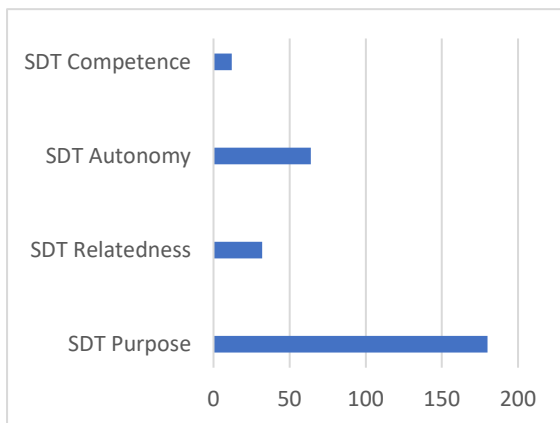


Figure 5. 22: Units to measure SDT components used during Hendon School Pilot.



Figure 5. 21: Level of intensity with which adherence features are used (BCT_{Habit Formation}) in Hendon School Pilot.

Improvements- Some participants in the Hendon School Pilot said that they did not set personal goals because they did not know how to do it. Also, one participant commented, “Was not sure how the app was working”. Therefore, the ‘Do you Know?’ feature was added to notify the user how to use the app and set up personal goals (Fig. 5.23). In addition, a link in the FAQ feature was added to direct the participant to access documents or videos with more details (Fig.4.9).

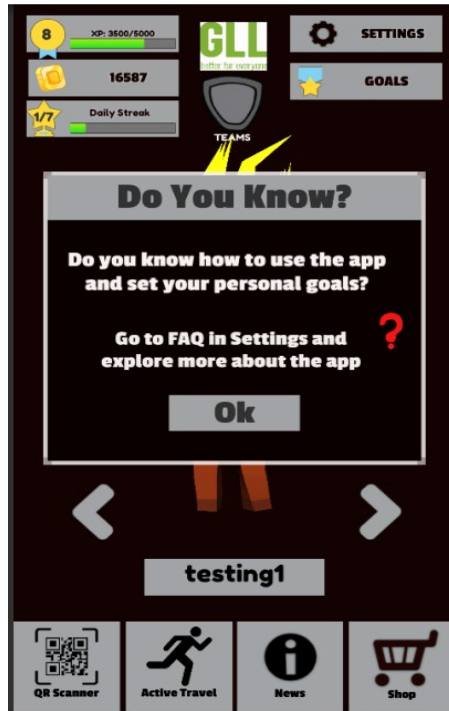


Figure 5. 23: Screenshot of ‘Do You Know?’ where users get this notification to explore more about the app in detail.

In this chapter, we discussed in detail the questionnaires and Performance Functions used in the pilots. The entry and exit questionnaires were used in all the pilots to get general information and feedback from the users, and this feedback helped to make improvements in the application. Quantitative metrics (called Performance Functions) were also introduced in this section which are complementary to the questionnaires and were used to measure the effectiveness of motivational techniques such as BCTs and SDTs. The next chapter presents the discussions and conclusions.

Chapter 6

Discussion and Conclusions

The research started with identifying the key problems related to a lack of motivation to adopt a healthy lifestyle for the longer term. It was identified that gamification is used to motivate people to improve their well-being. It led to investigating the gamification elements and driving factors behind user adherence, advantages and challenges of gamification. Therefore, initial aim **A1** was introduced. The research further investigated the existing literature review on motivational techniques and how to implement them in gamification applications. This helps to propose aim **A2**. The aim **A3** was introduced to examine the effectiveness of these motivational techniques.

This chapter provide details of the aims and objectives of this research. Also, discusses the overall achievement and outcome of this research based on the aims and objectives. The aims (A) and objectives (O) are as follows:

A1 – To identify the advantages and challenges of using gamification for well-being.

A1- O1: To identify the challenges in the existing gamification applications for well-being.

A1- O2: To identify the factors encouraging the uptake of gamification for well-being.

A2 – To propose a method to develop a gamification application using motivational techniques.

A2 – O1: To identify how motivational techniques work on different age groups.

A2 – O2: To combine traditional development methodologies with motivational techniques.

A3 – To develop a gamification system and to examine user adherence by conducting pilot studies with different organizations.

A3 – O1: To implement motivational techniques in the proposed system.

A3 – O2: To design questionnaires to gather feedback from the users for general information on how to develop a suitable gamification application.

A literature review was conducted to identify the advantages and challenges of using gamification to encourage people to be physically active. As a result of the literature survey,

we gained a better understanding of the topic. The literature review in chapter 2 revealed that some of the substantial problems in gamification applications are motivations and user adherence (**A1 – O1**). This review allowed us to better understand the different techniques used in state of the art. We saw a preponderance of rewards, challenges, leaderboards, and community badges (**A1-O2**) within this field.

To obtain more information on user engagement, a workshop was conducted early on in this project with colleagues from Psychology, Management Leadership, and Sports. This workshops purpose was to gain in-depth knowledge about recommended physical activity for different age groups and to gather information about how motivational techniques work in various age groups (**A2 – O1**). An important outcome of this workshop was the relevance of Habit Formation, user adherence, Behavior Change Techniques, and Self-Determination Theory. It was identified that the traditional development methodologies to create a gamification application could be improved by using the concept of motivational technique, which raises intrinsic and extrinsic motivation. We realized that BCTs and SDT can be used to drive the requirements elicitation process. Therefore, another workshop was conducted with stakeholders to obtain the requirements putting emphasizes on BCTs and SDT. We adopted UCIEDP because of the need for iterative refinement to gradually incorporate these new design ideas, as explained in chapter 3 in more detail (**A2 – O2**).

As outlined in chapter 3, we then developed an application influenced by BCTs and SDT (**A3 – O1**). We implemented features such as Challenges, Leaderboards, Teams, Competitions, Daily Streak, Personal Best, Weekly Rewards, Virtual and Real Rewards, Age Band related rewards, and Bonus Rewards impacted by BCTs and SDT. Chapter 4 reports this development in detail. The development process consists of iterations followed by pilots in which features were added and tested to improve the quality of the application. Using these pilots, data was collected from the different age group users for validation. All this process is discussed in chapter 5. Each pilot had entry and exit questionnaires designed to gather feedback from the users (**A3 – O2**). This feedback allows us to make improvements to the application. However, to get more specific information about the techniques, we introduced Performance Functions (PFs), which are discussed in detail in section 5.2. PFs provided a source of feedback complementary to the questionnaires on the assessment of BCTs and SDTs. Utilizing the PFs, the outcome of this experiment suggests that $SDT_{purpose}$ is the most used SDT component among others. Additionally, the most used features of $BCT_{Habit\ Formation}$ with intensity are Daily Streak and Active Travel. A detailed report was provided in chapter 5 on the outcome of the

different pilots conducted and which techniques work the best for our pilots (**A3 – O3**). Due to the development of the application using motivational techniques as explained in chapter 4 and investigating user adherence in chapter 5, aim **A3** was achieved completely in that all the features were developed, implemented, and thoroughly evaluated.

After addressing the achieved aims and objectives, the focus will shift to a comparative examination, offering insights into the distinctive contributions made to the field. This analysis will lead to an exploration of how this research extended or complemented existing work. Examples include physical activity apps like HikePal [45], and Active2Gether [38], which focus on measurable activities like steps, floors climbed, and distance traveled. These activities give users tangible metrics for tracking their progress and achieving fitness goals. However, it has limitations in capturing certain activities, particularly those challenging to measure accurately, such as weightlifting, yoga or swimming, where the emphasis is on strength, flexibility, and form rather than easily quantifiable metrics. To address this limitation, we implemented the use of QR codes (More detail is provided in subsection ‘QR Code’, chapter 4). These QR codes are more than just a conventional metric. They function as a rewarding mechanism and habit formation. This feature not only acknowledges user’s efforts in activities that are difficult to quantify but also incentivizes and rewards such engagements. For instance, a user's swimming session, which might not be fully captured by step counts alone, becomes a valuable and rewarding experience through the QR code feature. By adding this complementary reward system, OnTheMove! App aims to enhance the user experience, helps in habit formation and encourages physical activities.

Some studies have explored gamification elements such as competition [5], goals [50] and points [46] to sustain user motivation and engagement. In this study, we not only added these gaming elements but also introduced Performance Functions to evaluate the effectiveness of motivational techniques using gamification elements. Performance Functions are algorithms designed to quantify user performance, adherence or engagement within the gamified system. This involves a more quantitative and analytical approach to understanding user adherence. These functions help assess how well users respond to competition, achieve goals, or earn points within the gamified app. More details about the introduction and application of Performance Functions are provided in Section 5.2 of the research.

Existing research [75, 76, 77] highlights a lack of standardization (explained in Section 2.6). Particularly, the study [77] emphasizes the need for careful consideration of stakeholder requirements as a key factor for achieving improved outcomes. In response to these insights,

the current research adopts a user-centred methodology, incorporating testing and validation processes along with the regular updating of the requirement list after each iteration. Through this iterative approach, the aim is to address the identified challenges and contribute to a more effective research methodology that aligns with the needs and expectations of stakeholders. This strategic focus is on engaging stakeholders and conducting a comprehensive investigation of their needs, ensuring a flexible approach to navigate the complexities of this research.

Although gamification applications are increasingly popular many of them have been used in connection with health. There have been some noticeable shortcomings, such as how to keep users engaged for the long term and which elements motivate the users most. In this project, we explore how extra motivational factors can be incorporated and assess the level of success of these extra motivational factors. Similar studies conducted considered a population with diabetes [44, 46, 47] and separately, in other cases, cancer [10,49], focused on investigating how gamification elements improve well-being. However, these studies did not include motivational theories such as BCT and SDT. The paper presented here instead focuses on measuring the effectiveness of BCT and SDT in detail. We measure each BCT and SDT component used in our pilots. Our pilots indicated that users tend to favor SDT_{purpose}, especially BCT_{Habit Formation}, such as Daily Streak and Active Travel features. Also, it was noticed that due to differences in the age of populations, the adults preferred Daily Streak while teenagers and children preferred Active Travel for BCT_{Habit Formation}. In other words, the difference between the MDX Pilot and the other two pilots, i.e., Hendon School Pilot and Unitas Pilot, is that Daily Streak is the most used BCT_{Habit Formation} among adults. However, Active Travel was most used by children and teenagers in Hendon School Pilot and Unitas Pilot. There has been increased interest in BCTs in the past, such as a study conducted by Mercer et al. [100], which shows that self-monitoring and self-regulation are the most preferred BCTs in teenagers and adults.

6.1. Conclusions

In conclusion, although gamification helps to improve engagement and enhancing user experience, previous research suggests that user adherence is still a challenge and requires more research. This study conducts a comprehensive analysis of the fundamental elements that contribute to encouraging and retaining citizens to become more physically active and focus on their health. The strategy is to keep people engaged by using a gamified app and inspiring them to stay fit. One of the main factors in gamification is adherence of participants with the system. Hence, in this research, we developed an application to focus on adherence. The

adherence features implemented in ‘OnTheMove!’ are Bonus Rewards, Real Rewards, Like feature, Personal Best, Competitions between different teams, Goals and Age Band. This app is for all age groups. An age band coefficient is used for people above the age of 40. This feature is implemented to ensure that the activities are achievable for them. Moreover, a QR code is implemented in this application, which is a powerful tool and complementary to the step counter. The two uses of QR codes in the app are:

- a) It is to ensure that the participants are rewarded for positive behavior change.
- b) It is used to reward for activities that cannot be counted, such as weight lifting, swimming and many more.

The motivational techniques used in this research are BCTs and SDTs. Based on BCT and SDT, the key extrinsic and intrinsic motivational elements have been implemented to boost motivation in users to adapt to an active lifestyle for the long term. As mentioned in chapter 3, we have prioritized the BCT and used the ones balancing benefit with complexity. BCTs and SDT have been implemented to boost motivation in users to adapt to an active lifestyle.

Six pilots were conducted in organizations such as Middlesex University, Unitas and Hendon School to gather feedback and data. The feedback was gathered using entry and exit questionnaires which were used to improve the functionality of the app. Additionally, a set of Performance Functions were created to investigate which motivational features make a difference in user adherence and were used in the final year of the project along with questionnaires. The outcome of the pilot suggests that SDT_{purpose} is the most used SDT component, among others. Additionally, the most used features of BCT_{Habit Formation} with intensity are Daily Streak and Active Travel. All in all, the conclusion of this research is encouraging and has a positive impact on participants to stay active.

6.2. Limitations and Future Work

This research, and its results, have to be considered in context. One aspect to consider is the population sample size. In total, our project benefitted at different stages with the feedback from stakeholders and users. Secondly, some features cannot be measured using Performance Functions such as Age Band and Avatar Customization. Thirdly, we focused on the BCT category and not the individual BCTs due to time constraints. One of the examples is adding BCT Prompts/cues, which could be a positive addition to the virtual Health Coach concept. Finally, the last three pilots were delayed and conducted together due to the COVID-19

lockdown. During the lockdown, people were less active. Getting more participants was challenging because some potential participants were outside the UK, either suffering from COVID-19 or in quarantine. Additionally, students located outside the UK were unable to install the OnTheMove! app, as it was designed exclusively for UK participants.

One possible direction to further research is to explore more complex, Artificial Intelligence-based models of encouragement such as [104] and persuasion, for example: [105, 106, 107, 108]. Exploring advanced AI models for encouragement and persuasion, particularly when incorporating gamification, shows great potential for expanding research. One potential area of investigation involves enhancing personalization and adaptability in persuasive systems [109] through machine learning algorithms. These algorithms dynamically adjust strategies based on individual user behaviors and preferences, creating a more engaging, game-like experience [110]. Additionally, AI models, complemented by gamification principles, can predict user behaviors and offer proactive, context-aware interventions, enhancing the effectiveness and timeliness of persuasive messages in a gamified framework. Moreover, integrating emotion recognition technologies within AI models opens up possibilities for tailoring persuasive strategies based on user's emotional states, promoting interventions that have a more significant impact, and enriching the overall user experience [106]. Overall, further exploration in these directions, with a focus on gamification, may hold the potential to contribute to the evolution of persuasive technologies.

To conclude, this project provides some additional evidence of the positive effects of digital technologies to motivate citizens into more active and healthier lifestyles. Also, given its specific importance to society, we expect these concepts to be further explored with additional studies involving more citizens with a bigger and more diverse population. To achieve widespread adoption of the system, the following should be considered:

- Collaboration with various stakeholders is crucial. This includes partnerships with fitness facilities, local councils, schools and companies. Gyms could use it to enhance member engagement, councils might find it beneficial for community health initiatives, schools could incorporate it to promote physical activity among students, and companies could use the OnTheMove! App for employee wellness programs.
- The real rewards, including tangible incentives such as discounts or recognition for fitness achievements, serve as powerful motivators. It enhances user motivation, encouraging continued participation and promoting adherence to a healthier lifestyle. These real rewards not only boost motivation but also contribute to the long-term

commitment of users to the app. By recognizing and rewarding fitness achievements, the app creates a sense of accomplishment and satisfaction, reinforcing positive behavior. This encourages users to consistently participate in physical activities, contributing to the adoption of healthier habits.

- The commitment to regular app updates plays an important role. Continuous improvement through updates not only enhances the system's functionality but also demonstrates a dedication to meeting the evolving needs of users. Regular updates keep the application fresh, relevant, and aligned with the latest technological advancements, contributing to sustained user interest and participation.
- To make it accessible and appealing to users of all age groups, the design should accommodate various technological skills and preferences of individuals, ranging from children to older adults. Moreover, system updates and personalization improvements are crucial to enhance the overall user experience and keep the application aligned with evolving user needs and expectations.
- A user-friendly design is crucial to serving a diverse audience, ensuring ease of use and encouraging individuals with varying levels of technological proficiency to engage with the platform actively.
- The system needs to be accessible across different platforms, including iOS, Android, and HarmonyOS, to reach a broader audience.

By addressing these considerations, the system can aim to achieve widespread use and make a meaningful impact on promoting active and healthier lifestyles across various segments of the population.

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Publications

The following two peer-reviewed papers have been published in a workshop and journal article as a part of this project.

Fatima, S., Augusto, J.C., Moseley, R., Urbonas, P. (2022). Gamification for Healthier Lifestyle – User Retention. In: et al. Service-Oriented Computing – ICSOC 2021 Workshops. ICSOC 2021. Lecture Notes in Computer Science, vol 13236. Springer, Cham. https://doi.org/10.1007/978-3-031-14135-5_17

Fatima, S., Augusto, J.C., Moseley, R., Urbonas, P., Elliott, A., Payne, N. (2023). Applying Motivational Techniques for User Adherence to adopt a Healthy Lifestyle in a Gamified Application. In: Entertainment Computing, Elsevier. Volume 46, May 2023. <https://doi.org/10.1016/j.entcom.2023.100571>

Appendix A: Project Background

Project Details

This project was funded by Barnet Council and Greenwich Leisure Limited. This research was conducted in collaboration with colleagues from the Psychology Department, Management Leadership and Organizations Department and London Sports Institute from Middlesex University.

Avatars

The avatars were implemented as part of this research for different age groups, such as teenagers, mature adults and elderly citizens. The avatar packages, such as *Toon Teens* and *Toon People*, were created by the JBGarraza developer. Specifically, the *Toon Teens* avatars were chosen for teenage users, and *Toon People* avatars were used for adult and mature users. Additionally, Suriyun developed the *Cute Pets* animal avatars used in this project.

Logo of OnTheMove! App

Xiaojuan Zhang, a PhD student, designed the logo and worked on the app's graphic design.

Technological platforms the app was available

Below are the Technological platforms on which the ‘OnTheMove!’ app was tested and worked:

Android	iOS	Harmony OS
Samsung S7	iPhone 6s plus	Huawei (P40 Lite)
Samsung S10	iPhone 11 pro	
Samsung Galaxy A5 (2017)	iPhone 10X	
	iPhone 7	

The app worked on these phones before it was transferred to the stakeholders. Though the app was tested on a few phones, it might work on other phones. The Android version was available on Google Play Store, the iOS on App Store, and the Harmony OS version on Huawei App Gallery.

Pilots and Ethical Approval Process

The term ‘Pilot’ is defined in research [111] as “A version of the main study run in miniature to determine whether the components of the main study can all work together”. It is unlike “Feasibility studies which are used to estimate important parameters needed to design the main study” [112]. In other words, a pilot is to determine if all the elements work together, whereas a feasibility study is to decide whether or not it is possible to conduct a full-scale study. In this research, I have used the ‘pilot’.

The pilots were conducted with organizations such as Unitas, Hendon School and Middlesex University. In each of the pilots, we contacted the potential participants through external organizations (for example, schools, gyms and a city council). All the participants were residents of London. It is amongst the most diverse cities in the world, with participants from different social, economic and cultural backgrounds.

There was an ethical approval process for each pilot. Participants had to sign consent to take part, and answer to the questionnaires were kept anonymous. In addition, the participant had the right to withdraw at any time.

Appendix B: Entry Questionnaire

Questionnaire before using the application.

1. What type of phone are you using (e.g., iPhone10, Samsung S10)?
2. Have you ever used any App/smartphone game that encourages physical activity? If yes, please write the name and short description of what you liked/disliked about the App/Game.
3. Do you know how many steps do you take approximately per day? If yes, please write how many.
4. How often (per week) do you visit any kind of leisure centre, park, green space or similar exercise related or recreational spaces?
5. What facilities, parks or open spaces do you usually visit?
6. Would you visit those places more often if you got rewarded for it or it were part of an individual or collective game?
7. Do you own the Fit and Active Barnet (FAB) membership card? If yes, how often have you been using it?

Appendix C: Exit Questionnaire

Questionnaire after using the application.

1. What are the features that you like about this application?
2. What features do you think need improvement? Why?
3. Is there any feature that you generally dislike and think it should be removed?
4. Did you set up personal goals during this period? Did it help you? Why?
5. Have you noticed an increase in physical activity?
6. Which type of rewards were perceived as more effective in encouraging physical activity?
7. Have you been visiting leisure centres, parks, open spaces etc. more often after installing this application?
8. Which avatars did you like? Why did you like those ones?
9. How would you like avatars to be improved?
10. Any other comments or suggestions for improvement?

Appendix D: OnTheMove! Guide

1. How to install the app?

- Android

<https://drive.google.com/file/d/1repVpL1ibZwnmx3LoclDlf58nH-bCh1s/view?usp=sharing>

- iPhone

<https://drive.google.com/file/d/1iouRrLeslLfPtTP2XvrARUravewjoRr/view?usp=sharing>

- Huawei

https://drive.google.com/file/d/1EfgSYdnFCsmjmT8qpFfJi_Skt2Ungzmn/view?usp=sharing

2. Installation Guide

- Video for registering as a new user, selecting or customising avatar.

<https://drive.google.com/file/d/1lD1onFdvGNgBneLWxYQmlWldGwkKqHdU/view?usp=sharing>

- Video for Android Permission.

<https://drive.google.com/file/d/19gi8VHMSE-5NHzx7SeXT93n9vR9qgc5K/view?usp=sharing>

3. Avatar

- Change Avatar

<https://docs.google.com/document/d/1XkZSg394G32sAtumiQm7CJWA-apReaXw/edit?usp=sharing&ouid=108676778579919062385&rtpof=true&sd=true>

- Customized Avatar

https://drive.google.com/file/d/1h83Tk8TL5KW_Ad2kFAxn-11vIkRPBZud/view?usp=sharing

- Change the background color and add avatar

https://drive.google.com/file/d/1OuAZ0Ecj985Vy7_kAAXvh8APjbRKG98U/view?usp=sharing

4. Reward and QR code

- Bonus Rewards

https://docs.google.com/presentation/d/1BVj6_grv4cEVtTRaEwnycetbvFYqnMT3/edit?usp=sharing&ouid=108676778579919062385&rtpof=true&sd=true

- Real Rewards

<https://drive.google.com/file/d/16RjOV06pyqVbHHgEanuBQK-IPklOD7fL/view?usp=sharing>

- Reward Redemption System

<https://docs.google.com/presentation/d/1-Fvl-c690DuvLLOE8aW60In-gByq2fKz/edit?usp=sharing&ouid=108676778579919062385&rtpof=true&sd=true>

5. Teams and Competitions

- Document for team and competition

<https://drive.google.com/file/d/1hhsouyzDKancrLjtSHPHu1RFdICDLRi/view?usp=sharing>

6. Shop Registration

- Video on Shop Registration

<https://drive.google.com/file/d/1Dp18mjzOsgFMkMRG0tZDAsJghuxJhvJP/view?usp=sharing>

7. More Videos and Documents

- [Add your age](#)
- [Check active travel history](#)
- [Create a team](#)
- [Frequently asked questions](#)
- [Hints and tips scenario](#)
- [Set personal goal](#)
- [Shop and equip](#)
- [Step counter](#)
- [User review](#)