Applying Motivational Techniques for User Adherence to adopt a Healthy Lifestyle in a Gamified Application

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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 the key driving factor 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. Most of the existing physical activity gamification application focuses on elements such as reward, leaderboard and competition, while very few of them investigate various motivational elements using motivational techniques. Therefore, as a part of the project we found useful to develop a system with which to measure different ways to implement motivational elements and to identify which motivational technique works on certain age groups. 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 results show that certain age group participants adopt certain characteristics. Therefore, the Purpose component of SDT motivates participants of all age groups to be physically active compared to other SDT components. In addition, 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.

Keywords

Gamification; User Adherence; Behavior Change Techniques; Game Application; Healthy Lifestyle.

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 wellbeing 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. Also, desk jobs adversely affect individuals' health, leading to less physical activity, which causes a sedentary lifestyle. Secondly, many people spend time on digital leisure activities such as TV, smartphones, etc., which require constant sitting, and continuous seating for a long time, causing spine disorders. Finally, shopping has become easy. More people are using online services for shopping or buying groceries. Sitting in one place and with one click, the items are at doorsteps, which leads to increasing sedentary behavior.

Consequently, people are adopting unhealthy lifestyles, which cause health problems. One of the important causes for sedentary behavior is a lack of motivation, 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 [2]. Gamification is defined as "the use of game design elements within non-game contexts" [3]. The advantage of gamification is to enhance user engagement and user experience. Gamification is used in various industries, such as the health sector [4], social media [3], education [5] and many more. Game-based technology, also known as gamification, is used to promote intrinsic motivation. It increases the level of involvement and motivation. There are two types of motivation, namely, intrinsic motivation rises from doing things 'for their own sake' while extrinsic motivation rises from external factors [2]. Extrinsic motivation includes feedback such as money or verbal praise while intrinsic motivation includes group quests [6].

According to Kasurinena and Knutas [7], 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.

However, user adherence is a key factor in the domain of gamification. More insight is required into the driving factors responsible for user adherence [8]. The goal of this study is to focus on user adherence and encourage them to live a physically active life.

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 main challenge is encouraging people to focus on their well-being by being physically active and avoiding a sedentary lifestyle. Advanced technology, such as gamification, can help people to change their habits [7]. However, existing gamification application developed focuses on elements such as points, badges, and leaderboard, but only a few of them investigate various motivational components using motivational techniques such as BCT and SDT. After a comprehensive review of these studies, the outcome suggests a gap in the research, and more research is required for the factors responsible for motivation. Therefore, to provide a better solution and fill this research gap, this research proposes a methodology using a user-centered development methodology linked 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. We supplemented the app with the definition of Performance Functions which can be used to measure which motivating factors encourage users of certain age groups to stay active for a longer term.

1.2. Key Research Contributions

At the initial stage, an in-depth survey and workshop with colleagues were conducted to examine different existing gamification technologies and motivational techniques used to motivate people to be physically active. The study's outcome indicates that a better development of the system 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:

- Proposing 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 pilots. We systematically gathered feedback from 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.

The next section provides a state-of-the-art summary of relevant work on user adherence. We explain which adherence features we have considered and how we implemented them in the current system. We further explain the various mechanisms we used for continuous assessment of the product and the embedded adherence strategies. In section 3, we proposed a methodology linked with a motivational technique guided by User-centered Development Process. Also, a detailed discussion of a workshop conducted with colleagues and stakeholders is explained in this section. The development of the application is discussed in section 4, linking it with motivational techniques. The validation and results are discussed in section 5, which gives information on which motivational technique works best for our system. The conclusion and future work are provided in section 6.

2. Related Work

This section focuses on the research closely related to user adherence and gamified applications used in healthcare. The research conducted by Rose et al. [9], designed a gamified mobile health application known as '*MYSUGR*' to examine the behavior of a group of diabetic patients over 12 weeks. The outcome of this research was positive. 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 to 70%. Hence, further investigation is required on factors contributing to user adherence.

Findings reported in Stinson et al., [8] suggest that the '*mhealth*' pain assessment tool has positive outcomes for cancer patients. The quality of life and user participation was improved in teenagers aged between 9-18 over a 2-week observation period. The tool helped teenagers in 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's engagement, for instance, rewarding systems.

Cechetti et al. [10] research developed two types of m-Health application 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 in comparison to the group without gamification. However, further study is required for user adherence.

Torrado et al. [11] 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 story and reward system to keep users engaged. Three research strategies were used in this study such as 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 feedback from experts. 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 is too complex and more customization features are required. This means it will affect user adherence. People with intellectual disabilities may find it challenging to use the complex system and they may tend to stop using the system.

Alsaleh et al. [12] 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) control group with 10 children and b) treatment group with ten children. The treatment group children watched the educational video with information about the right 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 provided to both the groups being the same, the treatment group performed well as compared to the control group. The authors suggest that gamification has a positive effect on children's behavior and it encourages them to eat healthy foods.

Cafazzo et al. [13] developed and designed an application known as *bant* for adolescents with type 1 diabetes. The adapter was used to automatically transfer blood glucose readings to the *bant* app running on the devices which allows the users to get the feedback in real-time. The twelve-week pilot was conducted with twenty youth aged twelve to sixteen. During this pilot each participant was provided with a LifeScan glucometer, iPhone or iPod Touch. 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 50% improvement in the daily average frequency of blood glucose.

Ilhan et al. [14] proposed the *Sleepy Bird* application with the aim to improve sleep-wake up behavior. *Sleepy Bird* was designed with the aim to address sleep-related problems as well as to encourage individuals to change daily habits and improve their health. The gamification elements used in this app were notification, leaderboard, scores, lives and visual elements. Two versions of the application were gamified and non-gamified. 26 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 was successful in motivating the users to change their sleeping pattern as compared to the non-gamified version. The users who used the non-gamified version showed lack of motivation. Thus, it can be inferred that the application can be improved by adding more motivating elements and gamified features.

Navarro-Alamán et al. [15] 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 10 items. Also, Usefulness, Satisfaction and Ease of Use were used with four elements a) Satisfaction b) Usefulness c) Ease of learning d) Ease of use. These elements were used to measure ease of use. The outcome of this approach was positive and it increased the motivation in the participants.

Some of the Motivational Factors / Gamification Elements discussed by other researchers are as follows:

Competition- Competition caused by leaderboards can create social pressure to increase the player's level of engagement and sense of not being alone [3].

Setting Goals- According to Munson et al. [16] research, setting primary and secondary goals has a positive impact on the application users. If one goal becomes unachievable, the other may still be a realistic goal. If app users are having a good week, they may push themselves to achieve the goal.

On the other hand, Strecher et al. [17] research suggests that a difficult goal has a positive linear relationship with the level of performance. Setting specific challenging goals leads to increase performance.

Online trophies- Munson et al. [16] research, concluded that Online trophies and ribbons failed to engage most participants, which raises questions about how such rewards can be designed to encourage users to stay active for a long term.

Liking- According to Ozanne et al. [18], liking behavior can be used for various reasons. The gratified usage motivation includes bonding, entertainment, information/discovery and self-identification. The research focuses on bonding which is used for congratulating or showing support to others by liking.

2.1. Problem Definition, Aims, and Objectives

As we explained above, several options were considered to increase motivation. However, this is not necessarily used in the main stream application currently available in the market. For example, many applications such as MyFitnessPal, FitBit and Runkeeper [19] have been developed to improve health and well-being, but user adherence is a major challenge and needs more research. Also, according to Rasche et al. [20], the main reason to quit Pokémon Go was due to boredom and reaching a high goal was too challenging. 57% of users left the app due to boredom and 29% due to not being able to reach a high goal.

Therefore, this research addresses the issue of user adherence for the longer term by using techniques such as BCTs and SDT. It is based on the experience and knowledge of colleagues from the Sport and Psychology Department to get insight into this area of research.

The aims of this research are as follows:

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

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

The main objectives of this research are as follows:

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

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

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.

This section discussed the related work by other researchers, the problem definition, aims and objectives of this project. The next section presents the methodology used in this research, which has four stages: Stakeholder Involvement, Design, Development, and System Validation. The development methodology was linked with motivational techniques. This part of the section explains the user-centered methodology, and the workshops conducted with colleagues and stakeholders focusing on system design.

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) [21]. The UCIEDP is used in this research for iterative improvement and to incorporate novel design ideas. It guides the development of the system. Methodology emphasizes the direct involvement of stakeholders at all stages of the project. Fig.1 shows how the project evolved from the low maturity level of the app to a high level through iterations. Four stages of this methodology are Stakeholder Involvement, Design, Development and System Validation of UCIEDP.

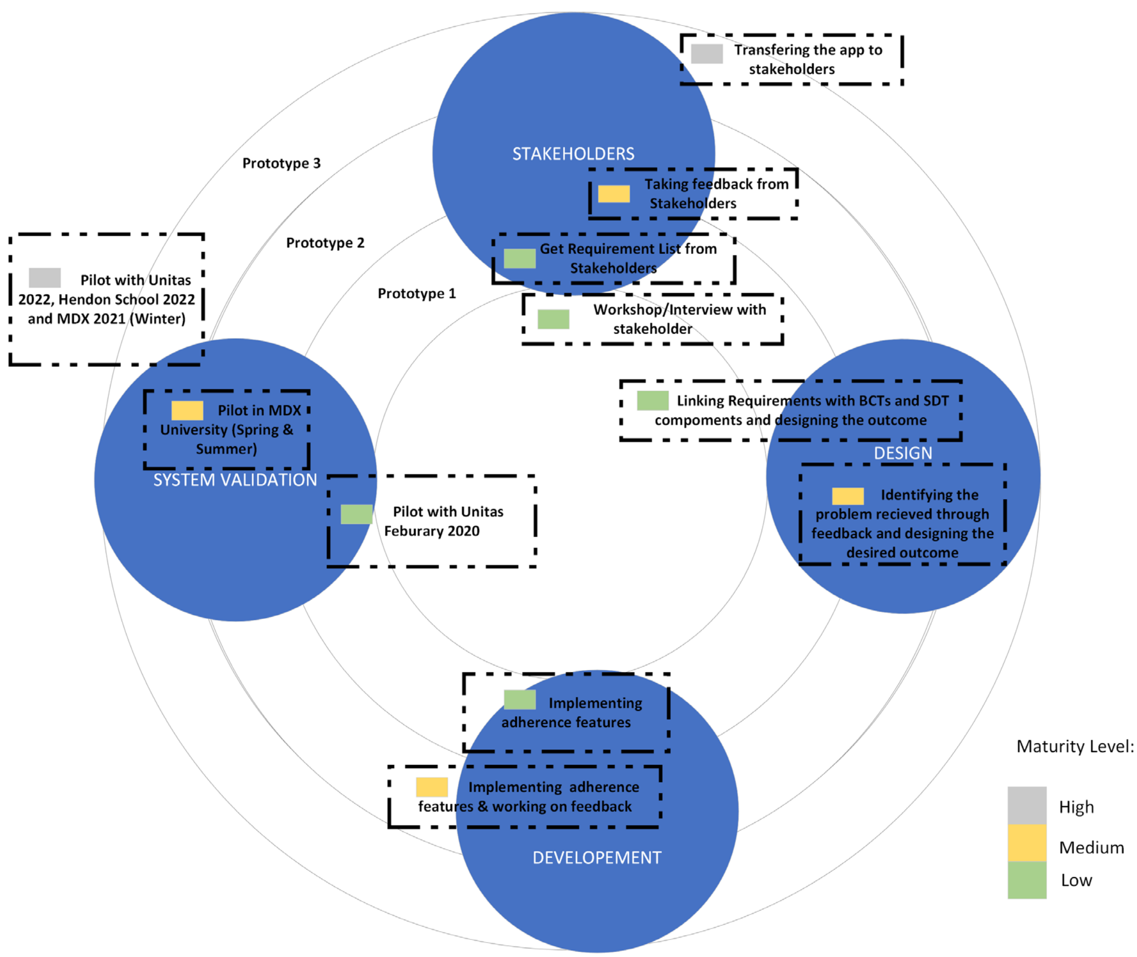


Fig. 1. Project evolution using UCIEDP

3.1. Stakeholder Involvement

The Stakeholder Involvement is the initial stage of UCIEDP in which the workshop was conducted with colleagues and stakeholders to get the list of requirements and insight on the research area.

3.1.1. Workshop with Colleagues

At the start of this project, a workshop was conducted at Middlesex University London in Nov 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 were 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 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. [22] 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 [23]. Others include Repetition and Substitution, Comparison of Behavior and Natural Consequences. A combination of BCTs is important. BCTs are useful and can be used for a long time [24]. According to research conducted by Mercer et al. [25], 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 with 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. [3] and Shi et al. [26], SDT is when 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. [24] 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 to do activities willingly and retain them for a longer term. These SDT factors are necessary 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 stakeholders in November 2019. This workshop took place in London with 8 participants, including GLL (Greenwich Leisure Limited) Managers and Barnet Council Managers. This workshop was focused group, and a qualitative approach was used in this workshop. The workshop started with the presentation of the app by Bene [28], 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. 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. every month. Finally, 87 requirements were identified (https://figshare.com/s/6e8d720807cd3984cb77). Table.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 1. 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 Design stage of UCIEDP. Fig. 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.

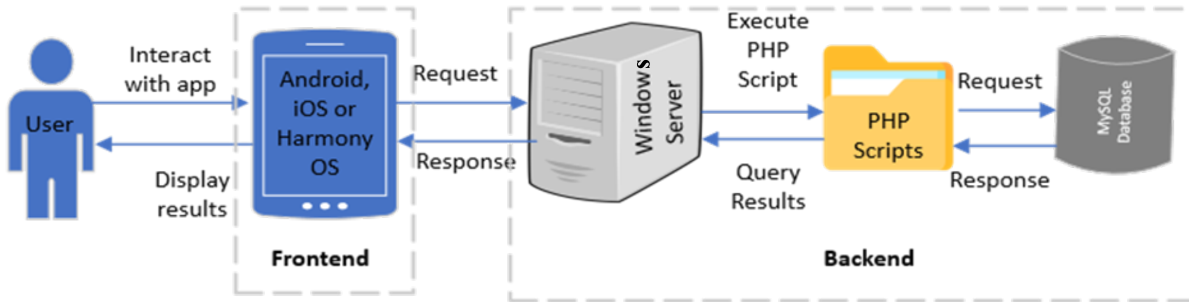


Figure 2. System Architecture

3.3. Intrinsic and Extrinsic Motivation used in OnTheMove! App

Intrinsic motivation arises from psychological needs such as Enjoyment, Satisfaction, Achievement, Interest, Willingness [2], and extrinsic motivation arises from extrinsic reward [6]. Fig.3 shows two types of motivations: intrinsic and extrinsic motivations. Also, the features used in the app use these motivations.

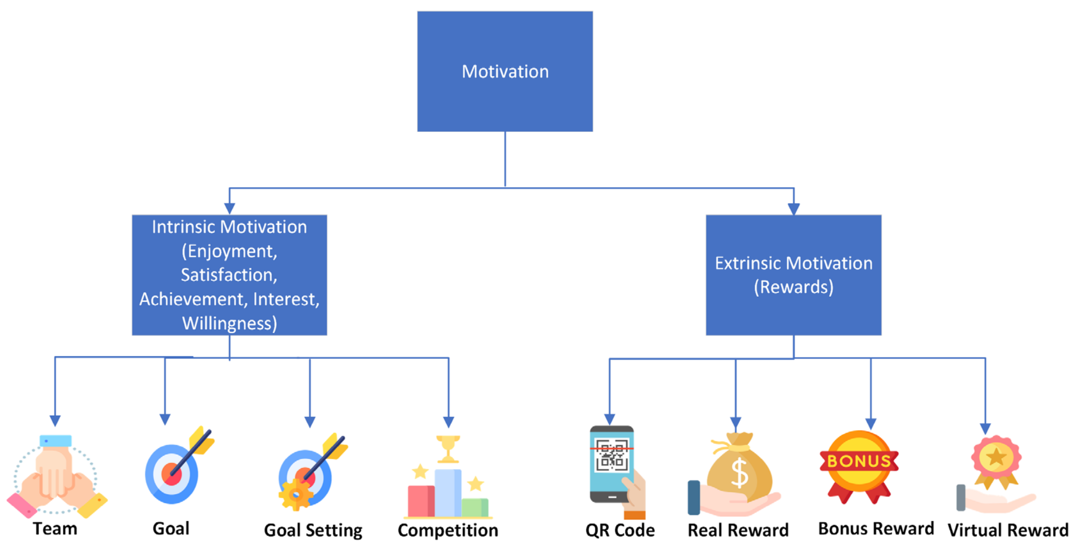


Figure 3. Types of Motivations used in the app.

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, in Real Reward, users can get drinks, sandwiches, or gym pass after achieving the desired outcome.

3.4. BCTs and SDT components used in OnTheMove! App

Fig.4. 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.

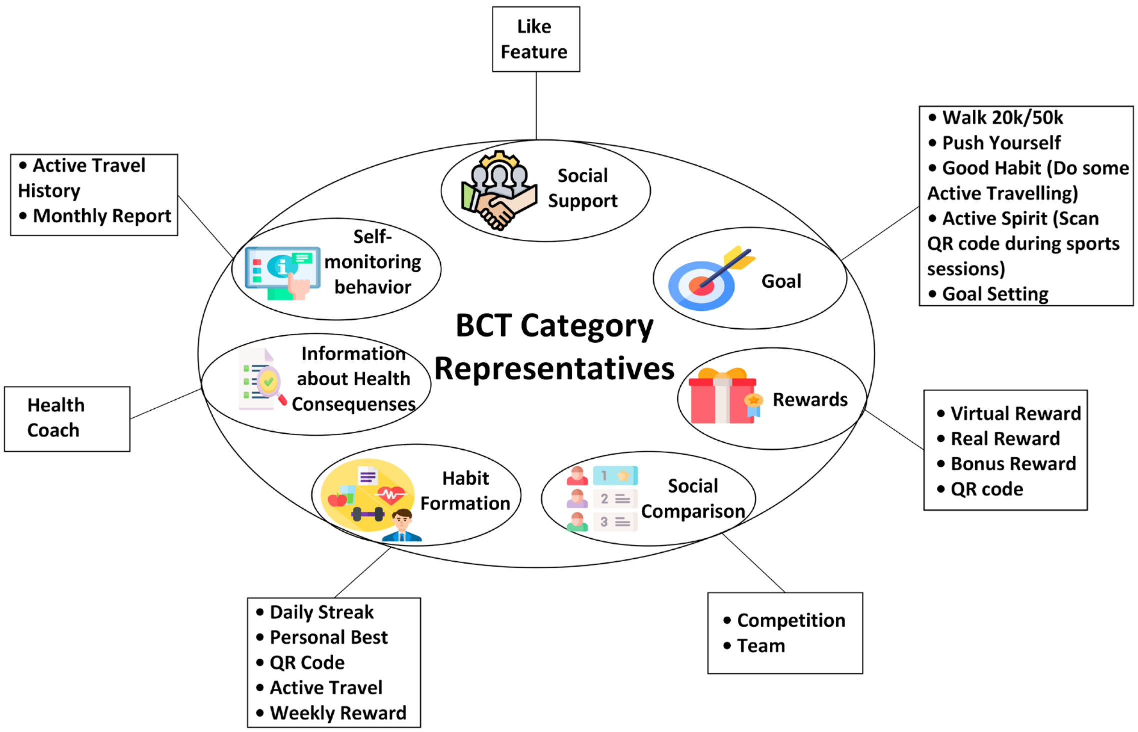


Figure 4. BCT category representatives used in the app.

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

- *Goal* – The goals used in this application are Walk 20k/50k, were the user has to walk 20k/50k, Push Yourself include goal setting were the user have 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 were 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. 5 illustrates the four SDT components and how they are linked with the features of the application.

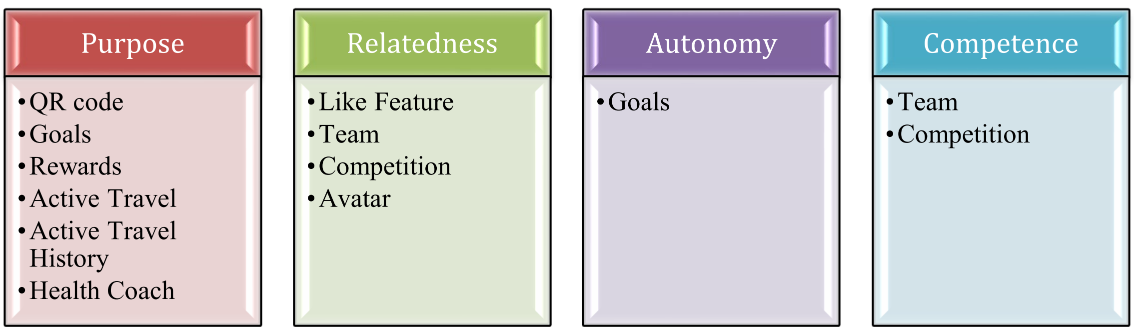


Figure 5. SDT Components used in the app

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.

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.

4. Development of OnTheMove! app

The OnTheMove! application has been developed using BCTs and SDT in the Development stage of UCIEDP. The application mainly focuses on user adherence and encourages users to stay active using small physical activities. Fig. 6 shows the proposed application architecture.

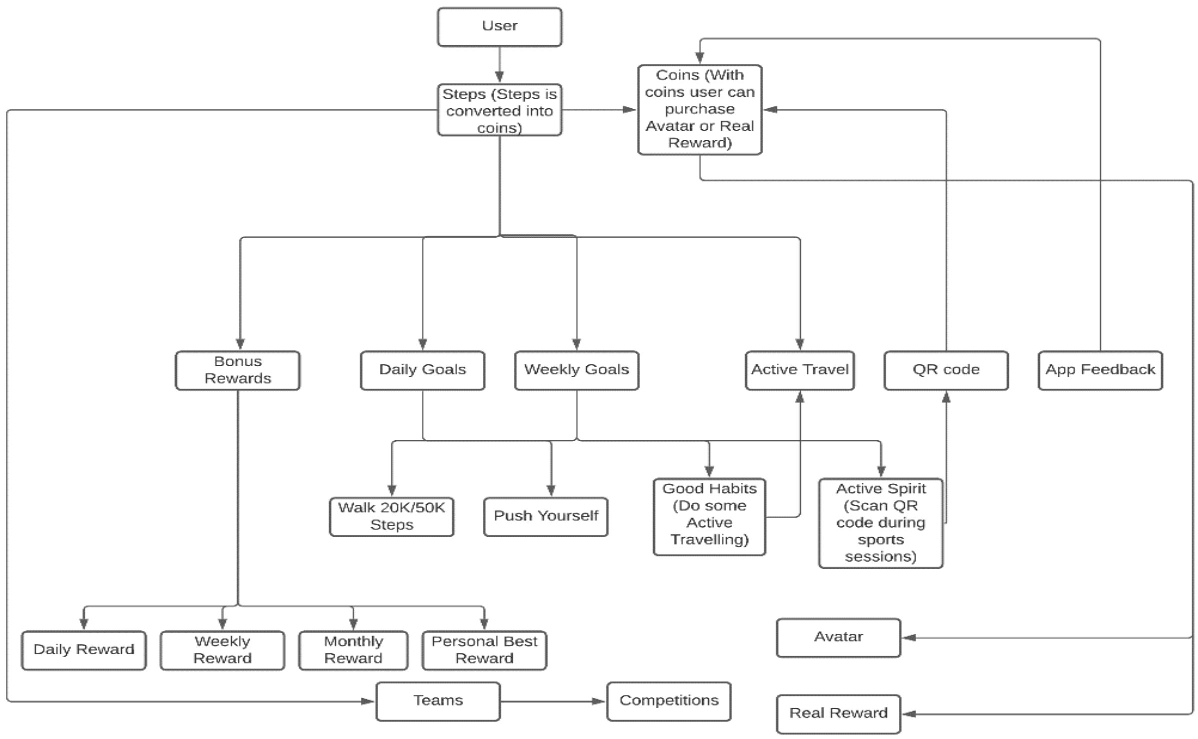


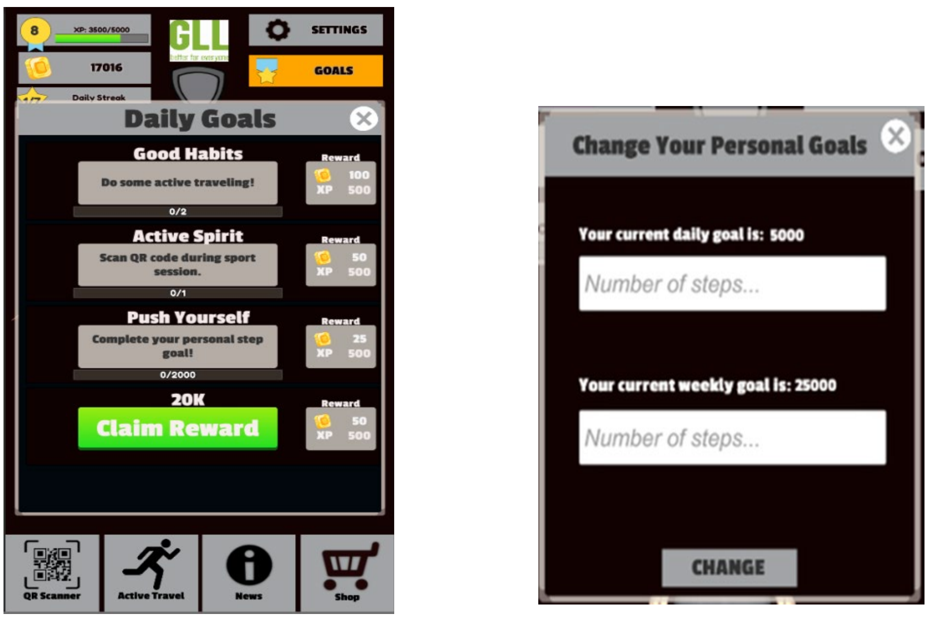
Figure 6. Application Architecture

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.6). 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 allows the users to add their age. Once it's done, steps are incremented according to the user's age, e.g. if the age is 51 and the steps walked is 112, then it becomes 112*5.1=571.2 steps. If the user is above 40, the steps are adjusted accordingly. This is for 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.7 b). These goals are Good Habit, Active Spirit, Push Yourself and 20k/50k (Fig. 7 a). The experiment conducted by Munson et al. [16] 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 7. Daily Goal and Change Personal Goal

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.8). The user can also see the location from where they can claim their Real Rewards.

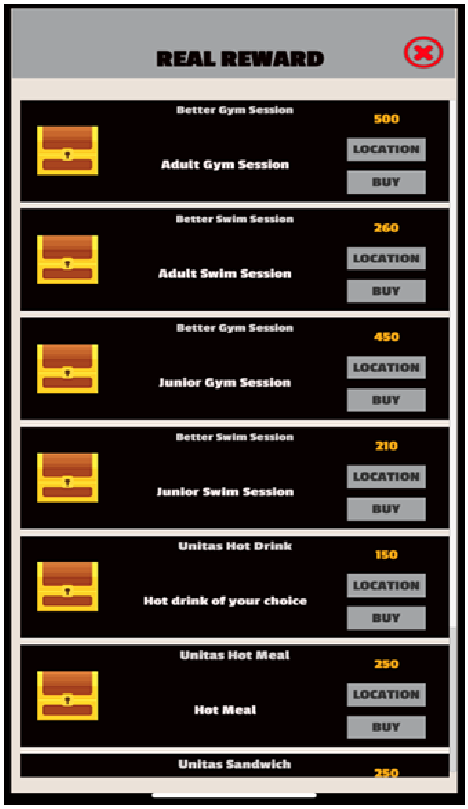


Figure 8. Real Reward for different age groups

The app includes an age-based rewards for citizens. Table 2 shows the code applied to different age groups.

Citizens	Codes
Children	C
Teenagers and youngest adults	T
Mature adults	M
Elder citizens	E
All	ALL

Table 2. The codes used for different age groups.

Table 3 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 3. The rewards and codes 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 [29]. 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. 9).

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.

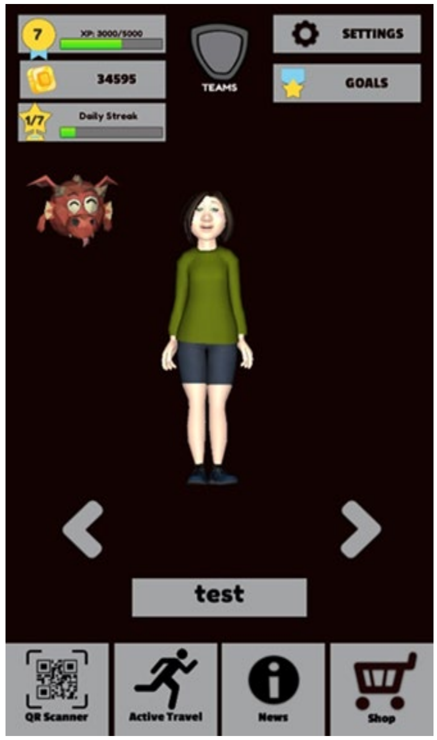


Figure 9. Main Screen of the Application

QR Code- The QR code feature is implemented to reward users' efforts; for instance, PE teachers can 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. The lower left-hand side of Fig. 9 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.

Transfer Steps- The user can transfer their steps to team competition and goals such as Push Yourself or Walk 20k (Fig.10). 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. 11).

Figure 10. Transfer Steps to goals or competitions

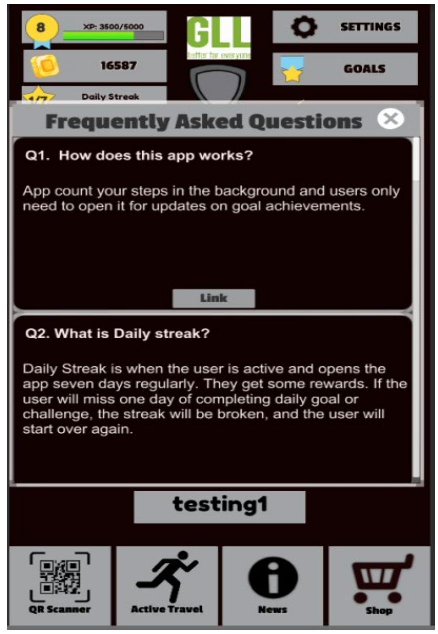


Figure 11. Frequently asked questions

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. 12 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. 13 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.

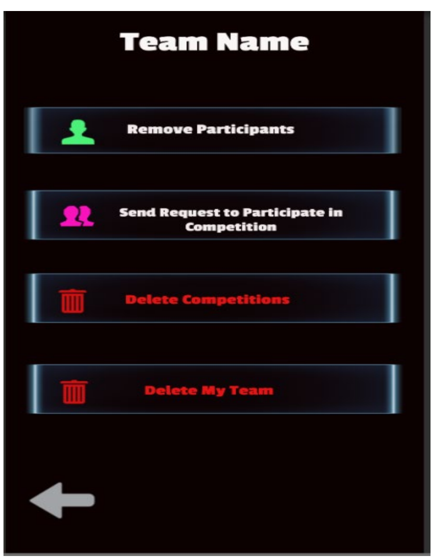


Figure 12. Flexibility feature for team creators

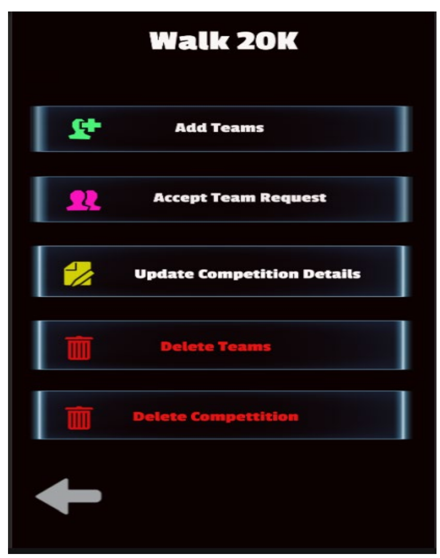


Figure 13. Flexibility feature for competition

Add/Delete Teams– This feature uses SDT autonomy where creators of the competitions have the flexibility to delete/add teams. Figures 14 and 15 presents in more detail the ‘add teams’ and ‘delete teams’ options mentioned in Figure 13.

Figure 14. Flexibility for competition creators to add teams in competition

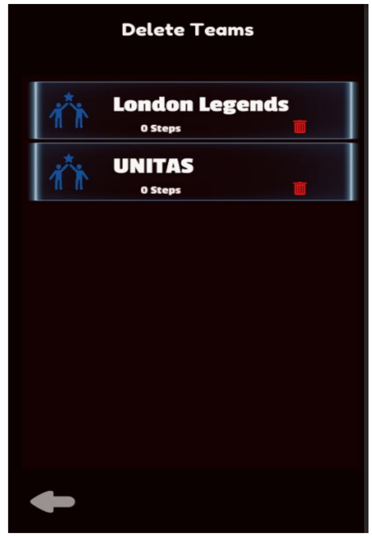


Figure 15. Flexibility for competition creators to remove teams from competition

Sending Request to Competition- Teams can send requests to participate in the competition (Fig 12). To send a request, the team creator has to upload documents for verification. As shown in Fig. 16, 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. 17, for verification.

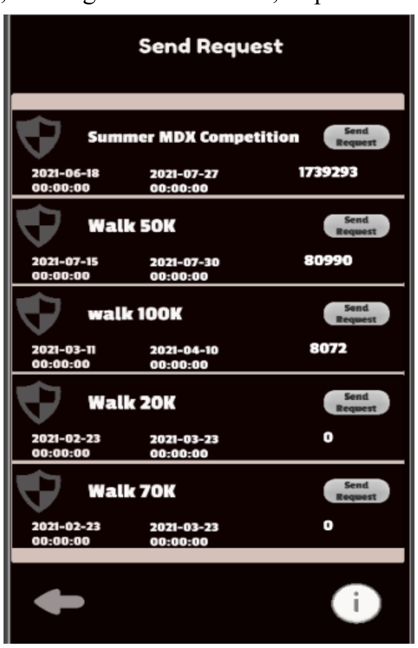


Figure 16. Team send request to competition

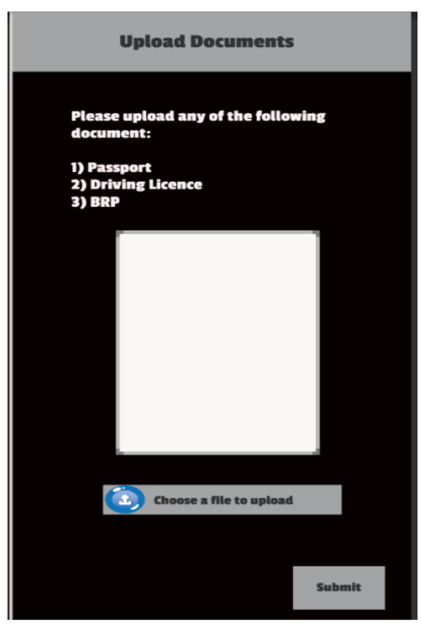


Figure 17. Teams upload documents to send request to competition

Accept/Decline the Team Request – In Fig. 13, clicking the button 'Accept Team Request' takes the creator to the screen shown in Fig. 18, 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. 18, 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.19). 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.19). This feature has been implemented to give users a sense of Social Support and relatedness.

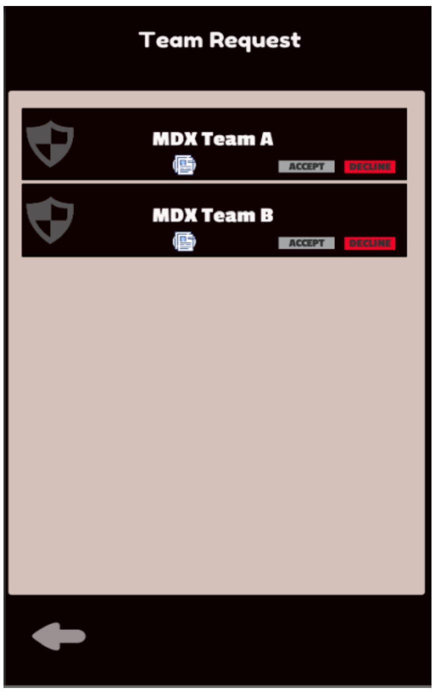


Figure 18. Accept/ Decline Team Request

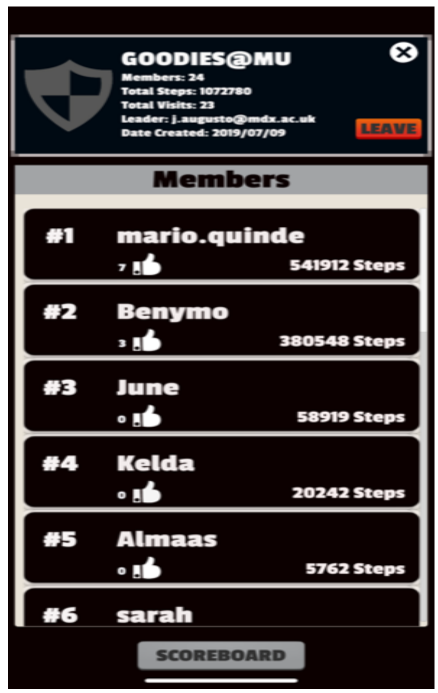


Figure 19. Step competition with team members and Like Feature.

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

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. 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. 20).

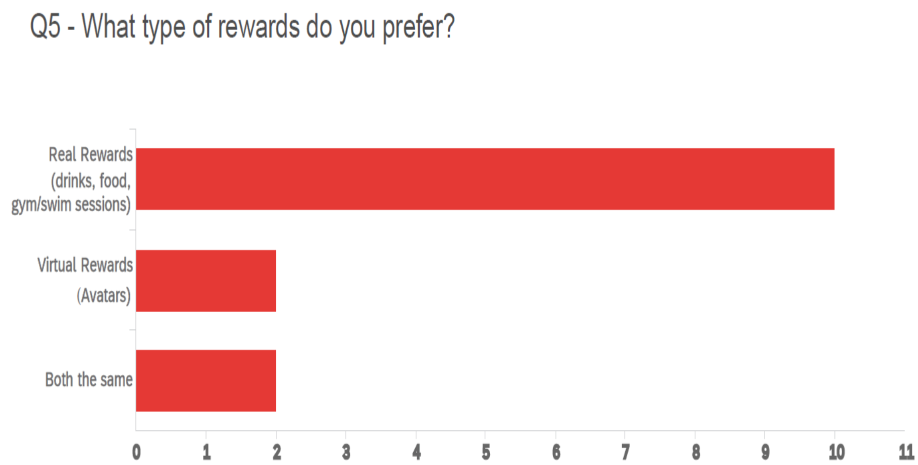


Figure 20. The result of the questionnaire for reward

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. 21).

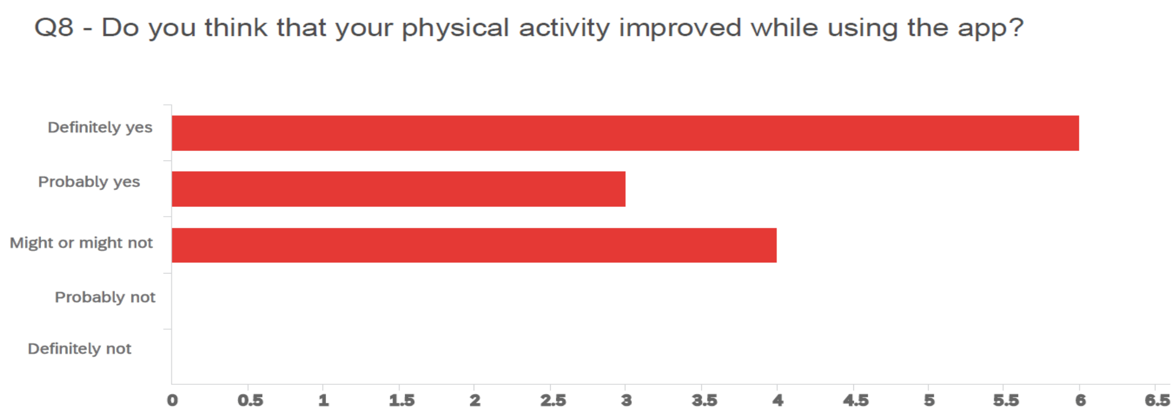


Figure 21. The result of the questionnaire for the app

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.22) and step count history also known as 'Active Travel History' (Fig.23).

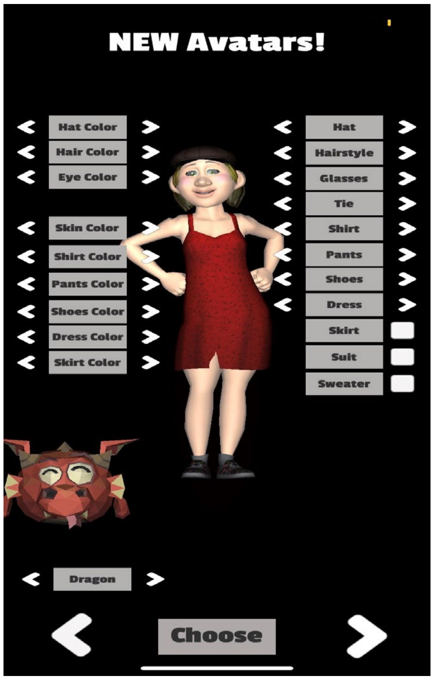


Figure 22. Avatar Customization

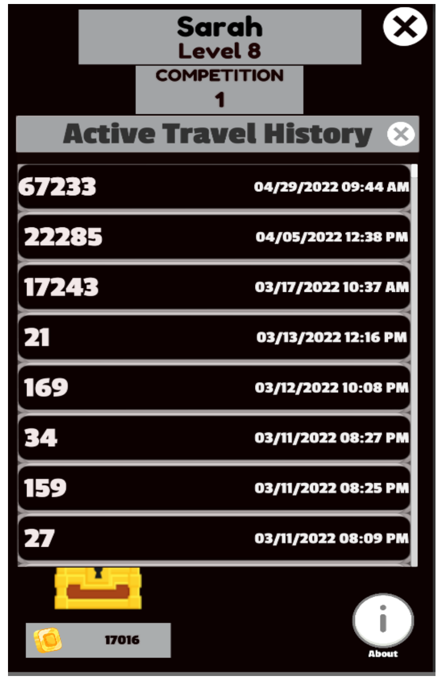


Figure 23. Active Travel History

a) Avatar Customization- The user can customize the avatar skin color, dress, glasses, hair and other features (Fig.22). 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.23). 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 get 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. 24). 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. 25).

Figure 24. Health related information

Figure 25. 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*".

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

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. 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.

<u>**PF 1(A):**</u> To calculate SDT components,

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

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

$$\mathbf{SDT_{Autonomy}\,(u) = BCT_{Goals}}$$

$$\mathbf{SDT_{Competence}\,(u) = BCT_{Social\ Comparison}}$$

Where, 'u' is the user.

$BCT_{Habit\ Formation}$ includes features such as Daily Streak, Personal Best, QR Code, Active Travel and Weekly Reward.

$BCT_{Information\ about\ health\ consequences}$ includes Health Coach.

$BCT_{Self\text{-}monitoring\ of\ behavior}$ includes Active Travel History and Goals Monthly Report.

BCT_{Goals} includes Walk 20k/50k, Push Yourself, Good Habits (Do some Active Traveling), Active Spirit (Scan QR code during sports sessions) and Goal Setting.

BCT_{Reward} includes Virtual Reward, Bonus Rewards, Real Rewards and QR code.

$BCT_{Social\ Support}$ includes Like Feature.

$BCT_{Social\ Comparison}$ includes joining Team Competitions.

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

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

$$SDT_{Purpose} = \frac{SDT_{Purpose}(u_1) + SDT_{Purpose}(u_2) + \ldots + SDT_{Purpose}(u_i)}{5}$$

$$SDT_{Relatedness} = \frac{SDT_{\mathbf{Relatedness}}(u_1) + SDT_{\mathbf{Relatedness}}(u_2) + \ldots + SDT_{\mathbf{Relatedness}}(u_i)}{2}$$

$$SDT_{\mathbf{Autonomy}} = SDT_{\mathbf{Autonomy}}(u_1) + SDT_{\mathbf{Autonomy}}(u_2) + \ldots + SDT_{\mathbf{Autonomy}}(u_i)$$

$$SDT_{\mathbf{Competence}} = SDT_{\mathbf{Competence}}(u_1) + SDT_{\mathbf{Competence}}(u_2) + \ldots + SDT_{\mathbf{Competence}}(u_i)$$

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:

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

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

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

PF 3: To measure individual users' 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' $\mathbb{F} = \{ f_1, f_2, \ldots, f_i \}$, then,

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

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

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

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

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

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

$$\mathbf{P^{M}(f,x)} = \frac{\textbf{Total number of users who used multiple adherence feature fj with intensity x}}{\textbf{Total number of users who used multiple adherence feature fj}}$$

$$= \frac{\mathbf{T3(f1,x) + T3(f2,x) + .. + T3(fi,x)}}{\mathbf{T3(f1) + T3(f2) + .. + T3(fi)}}$$

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

$\mathrm{T3(Reward\ Effort,\ 0.33)}$ 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).

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

Notice that in this formula we do not include $\mathrm{T3(Winner)}$ 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):

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

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

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

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

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

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

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

Example from Hendon School Pilot,

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

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

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

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

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: $\mathbf{u(f) = c}$

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,

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

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,

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

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

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

5.2.1. Middlesex University Winter Pilot (2021)

The MDX Pilot was conducted between 21st Dec 2021 and 27th Jan 2022. Six adult users participated in the Pilot. The feedback summarize as follows:

- 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. 26) were used. To calculate the user's use of adherence features, daily, weekly and monthly Performance Function PF7 is used. Fig. 27 depicts that User1 and User2 used more BCTs in comparison with others (Performance Function PF2).

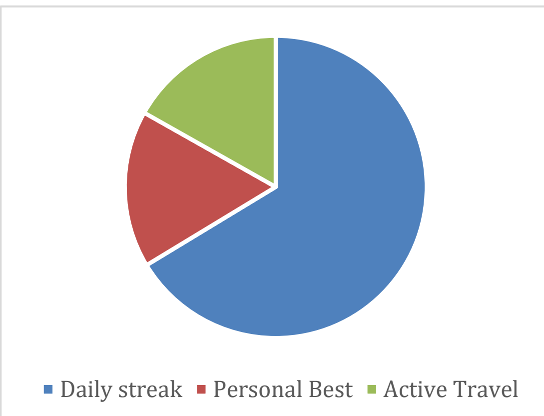


Figure 26. Calculating users use of adherence features daily (D), weekly (W) and monthly (M) in MDX Pilot

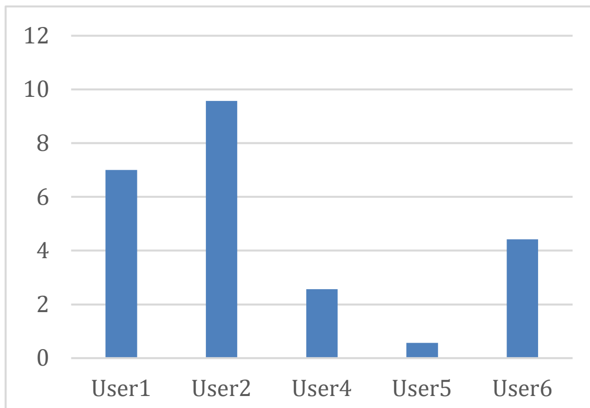


Figure 27. Measure for adherence to BCTs by each user in MDX Pilot.

User1 used 78% and User2 used 84% of adherence features (PF9) during 38 days (Fig.28). Autonomy and Purpose are the most used SDT components by the participants as compared to Competence and Relatedness (Fig.29). All of these parameters were compared with Performance Function PF1(B).

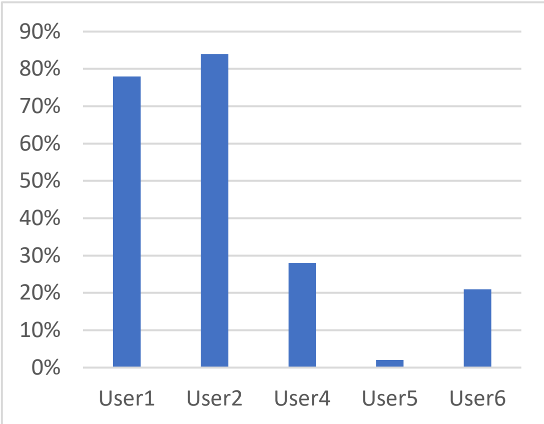


Figure 28. Percentage of one or more adherence features used by users during MDX Pilot

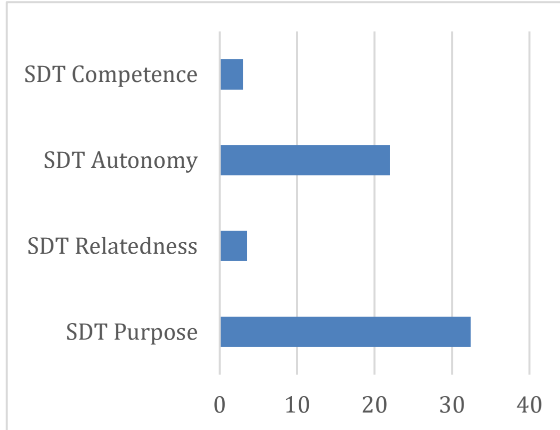


Figure 29. Units to measure SDT components used during MDX Pilot.

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. 30).

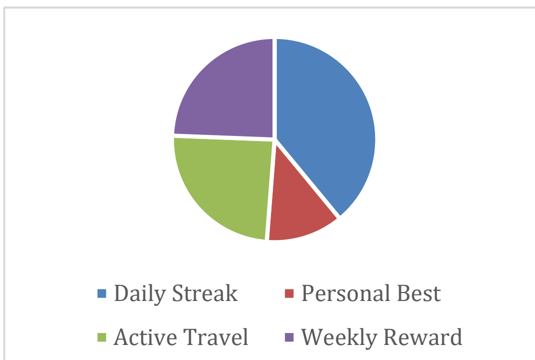


Figure 30. Level of intensity with which adherence feature is used ($BCT_{Habit\ Formation}$) in MDX Pilot.

5.2.2. Unitas Pilot (2022)

The Unitas Pilot was conducted in London between 13th January and 28th February. 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. 31). Performance Function PF7 is used to calculate the user's use of adherence features daily, weekly and monthly. Fig. 32 depicts that User2 used more BCTs in comparison with others (PF2).

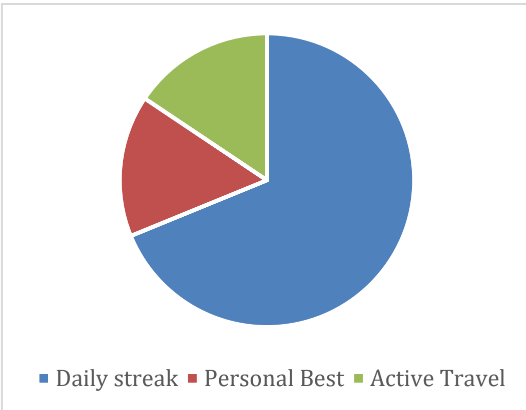


Figure 31. Calculating users use of adherence features daily (D), weekly (W) and monthly (M) in Unitas Pilot.

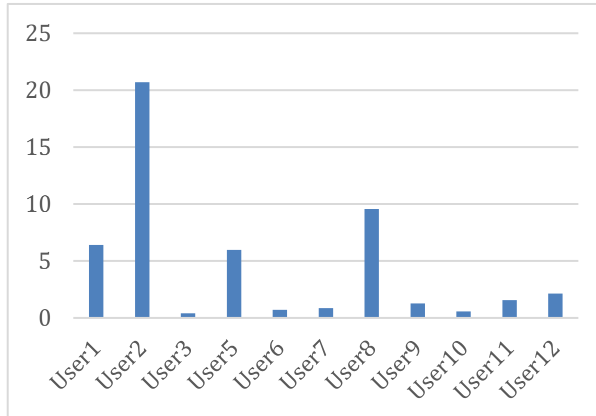


Figure 32. Measure for adherence to BCTs by each user in Unitas Pilot.

Six participants used 100% of adherence features for 47 days (Fig.33). 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.34). All of these SDT components were compared with Performance Function PF1(B).

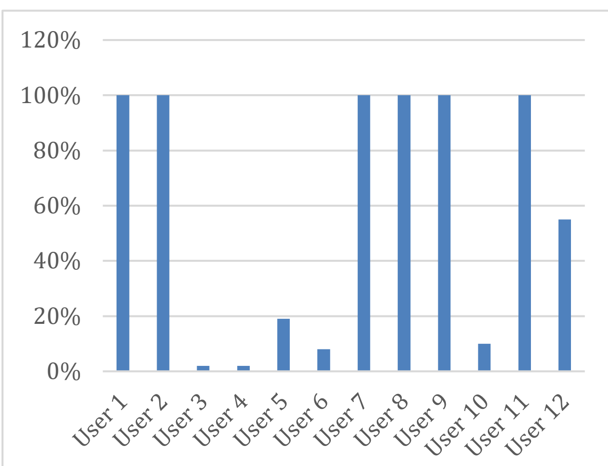


Figure 33. Percentage of one or more adherence features used by each user during Unitas Pilot.

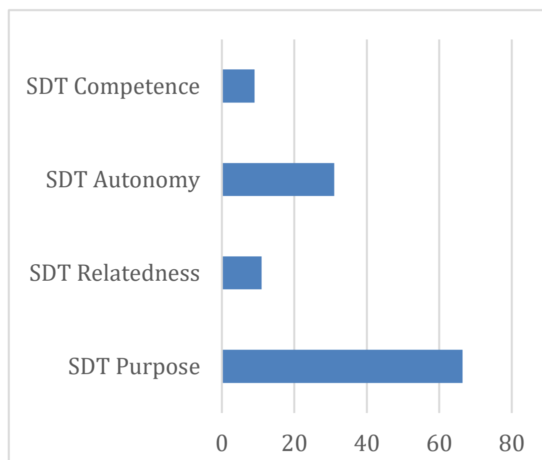


Figure 34. Units to measure SDT components used during Unitas Pilot.

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. 35).

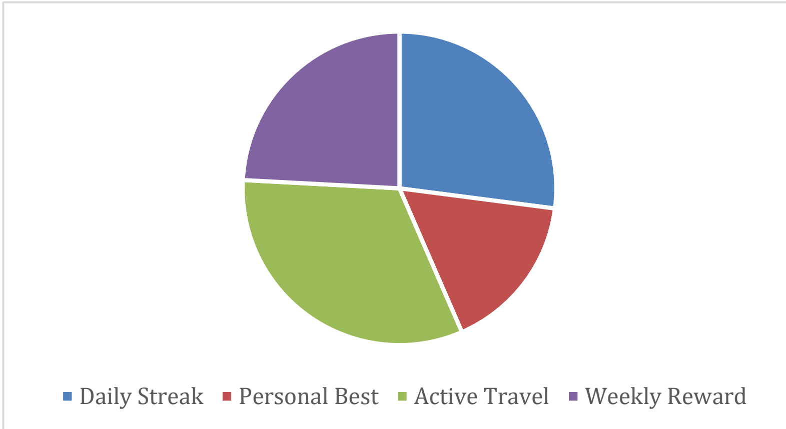


Figure 35. Level of intensity with which adherence feature is used ($BCT_{Habit\ Formation}$) in Unitas Pilot.

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.36).

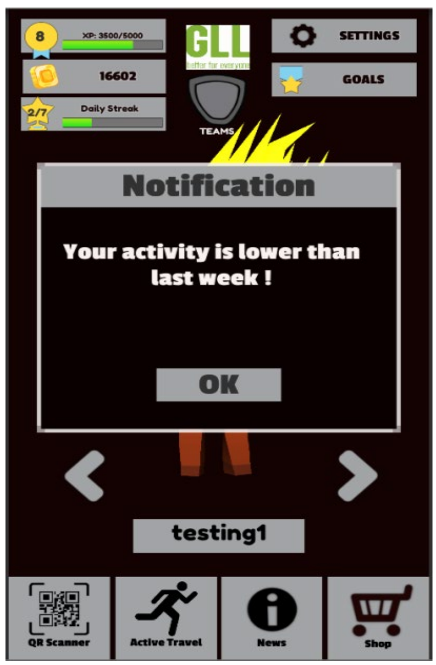


Figure 36. Users get a notification if they have lower steps than the previous week.

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.

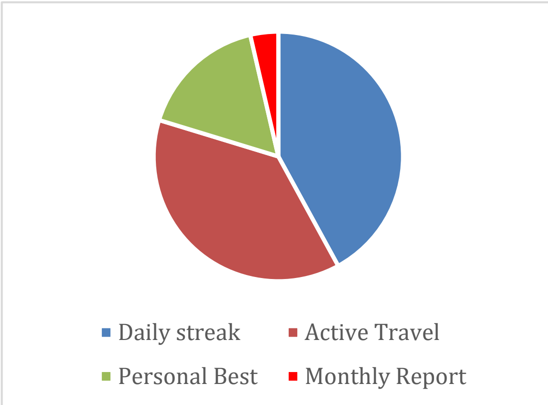


Figure 37. Calculating users use of adherence features daily (D), weekly (W) and monthly (M) in Hendon School Pilot.

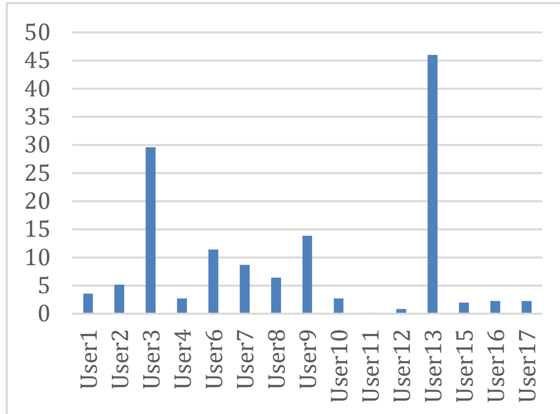


Figure 38. Measure for adherence to BCTs by each user in Hendon School Pilot.

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. 37). 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. 38 depicts that User3 and User13 used more BCTs in comparison with others, as measured using PF2. Fig. 39 depicts that two participants used 100% of adherence features for 47 days (PF9).

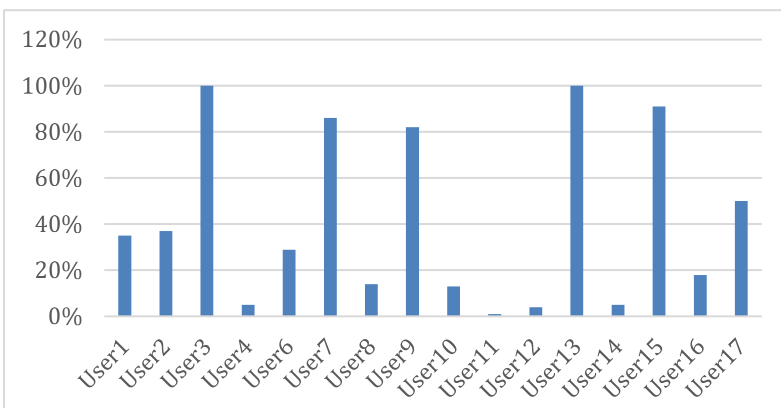


Figure 39. Percentage of one or more adherence features used by each user during Hendon School Pilot.

Purpose is the most used SDT component by the participants as compared to other SDT components (Fig.40). Performance Function PF1(B) is used to measure the units of SDT components. The pie chart in Fig. 41 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.

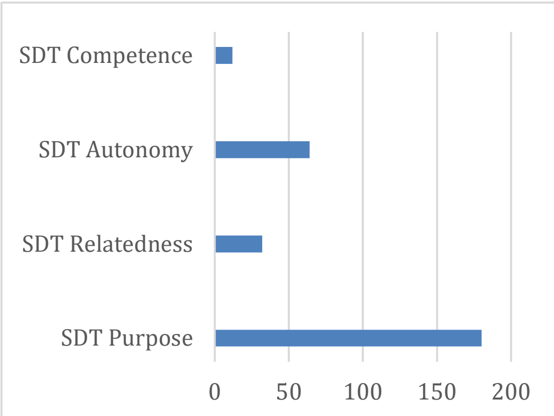


Figure 40. Units to measure SDT components used during Hendon School Pilot.

Figure 41. Level of intensity with which adherence features are used ($BCT_{Habit\ Formation}$) in Hendon School

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. 42). In addition, a link in the FAQ feature was added to direct the participant to access documents or videos with more details (Fig.11).

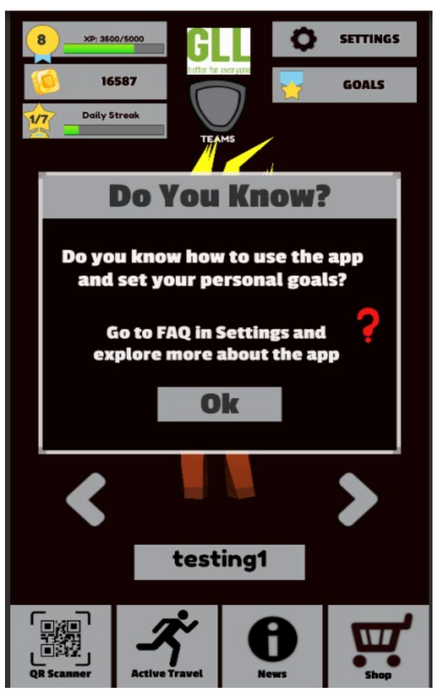


Figure 42. Screenshot of 'Do You Know?' where users get this notification to explore more about the app in detail.

In this section, we discussed the questionnaire and performance function used in the pilots in detail. 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 was used to measure the effectiveness of motivational techniques such as BCTs and SDTs. The next section presents the conclusion of this research and future work.

6. Discussion

This section discusses the overall achievement and outcome of this research based on the aims and objectives stated in sections 1.1 and section 2.1.

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 section 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 section 3 in more detail **(A2 – O2)**.

As outlined in section 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. Section 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 section 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 section 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 section 4 and investigating user adherence in section 5, aim **A3** was achieved completely in that all the features were developed, implemented, and thoroughly evaluated.

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 motive 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 [9,12, &13] and separately, in other cases, cancer [8], 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. [25], which shows that self-monitoring and self-regulation are the most preferred BCTs in teenagers and adults.

7. Conclusion and Future Work

In conclusion, although gamification is used for user 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 users 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. The main factor in gamification is user adherence. Hence, in this research, we developed an application to focus on user adherence. As mentioned in section 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.

6.1. Limitations and Future Work

This research and 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.

One possible direction to further research is to explore more complex, Artificial Intelligence-based models of encouragement, for example: [30], and persuasion, for example: [31,32, 33, and 34].

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.

Acknowledgements. This project has benefited from the input of colleagues: Ondrej Benes, M.Sc. and Dr Simon Best (Management Leadership and Organizations Department). We would like to thank Greenwich Leisure Ltd (GLL) and Barnet Council team for their contribution. Also, we appreciate the work of author JBGarraza for creating avatars such as Toon teens and Toon people.

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