Do I need to validate the responses I have mentioned below such as users ranking features 8 out of 10 and reporting increased motivation?

# **Evaluation**

This chapter provides an evaluation of the application, analysing the impact the application had on motivating pro-environmental behaviour change by motivation levels and realisation of a reduction in individual carbon footprints, through the gamification principles applied. To evaluate the application, questionnaires about participants motivation levels were carried out before and after using the application, as well as analysing any change in participants’ carbon footprint scores over time.

## **Method**

To evaluate the application built for this project, the author decided to utilise a combination of questionnaires and analysing realised user data, as well as observing which of the requirements outlined in chapter 4 on implementation were met. The author decided to utilise questionnaires and specifically questions following the LIKERT format, answering questions on a scale of 1-10 because this method facilitates collecting information on participants’ motivation levels before and after using the app. The author decided to use questionnaires as they are an inexpensive, efficient and quick means of collecting high volumes of information from participants, being particularly effective for measuring qualitative data such as participants motivation levels, attitudes and willingness to reduce individual carbon footprints. The author decided on the method of analysing realised carbon footprint scores from user data after having used the application because this method provides quantitative insights into the effect of this application, adding a different perspective or means to evaluate the application. ***<ADD REFERENCE ABOUT WHY QUESTIONNAIRES ARE GOOD AND QUALITATIVE VS QUANTITATIVE RESEARCH>***

In order to conduct and analyse data from questionnaires and users having used the app, the author applied and received ethical approval from the Trinity College Dublin Ethics Committee. A copy of the application is included in the appendix section at the end of this report, namely appendix 1, as well as a copy of the questionnaires sent to participants, namely appendix 2.

## **Questionnaire Responses**

Before trialling the application, participants were asked to answer questions relating to their motivation to reduce their individual carbon footprint and provide reasons for their level of motivation. A copy of the questionnaire is attached in the appendix at the end of this report, namely appendix 1. The results of the responses from the 10 participants revealed that of the 10 participants, only 2 responded with a motivation level of 3 or more prior to using the application. Popular reasons for such little motivation were a feeling of negligible individual impact, difficulty in seeing the benefit or consequences of your environmental actions and a feeling of no personal reward in return for sacrifices or changing your environmental actions.

After 11 days of using the gamified, social mobile app in this project, participants were again asked to answer questions about their motivation levels. The results indicate that of the 10 participants involved in this study, after using the gamified social mobile app, 6 participants reported increased motivation levels, between the ranges of 5-8 out of 10 for their level of motivation. This is an increase in motivation levels above 3 out of 10 from 2 to 6 participants, a 200% increase. This increase is illustrated in figure xxx below.

***<INSERT GRAPH showing before and after scores so that the reader can visualise the data>***

When asked to respond as to why their level of motivation had or had not increased, participants responded by saying the feeling of mutual accountability in the cooperation aspect of the game, the team leaderboard, was a source of motivation. In this case, participants attributed this motivation to the feeling of a social etiquette, and responsibility to not let your teammate down, and that helping the environment was not the reason for wanting to reduce individual carbon footprints. Participants further divulged that by viewing their individual scores over time they could visually see their performance, motivating them to improve their scores, or not to decline in scores.

With the ability to view the breakdown of their daily emission logs, participants reported these breakdowns to facilitate learning, aiding them in reducing their carbon footprints where one user reported changing his commute to training from driving solo, to carpooling with a teammate. Another user reported after realising the carbon footprint produced by consuming beef in comparison to chicken, decided to substitute beef for chicken for his dinner on two occasions.

When asked about their overall experience using the app, all 10 participants reported running into no errors in the application, felt the most frequent tasks could be completed quickly and that no task was overly complex.

When asked about their overall experience, all participants reported enjoyment using the app, referencing the clear layout and navigation of the app to be very user friendly and easy to use.

## **Changes in Carbon Footprint Scores**

While the questionnaires provided insights into whether users felt an increase in motivation to reduce their individual carbon footprints, and why, the realised carbon footprint scores of the participants, that is, the tangible reduction, increase or consistency in their carbon footprints, provides insights into whether meaningful action was taken, or did participants only feel motivation but did not actually take meaningful action by reducing their carbon footprints.

Upon analysing the data, 3 out of 10 users exhibited a realised decrease in their individual carbon footprints between the first and last days’ carbon footprints. ***Although the other participants did not deliver a reduced carbon footprint, the results indicate that the gamified social mobile app in this project lead to a reduction in 30% of participants’ carbon footprints. In terms of actual carbon footprint reduction levels, the realised difference between their worst and best carbon footprint score was 2.57kg, 3.8kg, and 2.9kg of carbon dioxide equivalent, representing an overall decrease of 14%, 23% and 19% in their carbon footprints respectively. Upon analysing the breakdown of these scores, to reduce these scores, users began to carpool or substitute beef for a different source of meat such as chicken or turkey. (NEED TO REPHRASE, make it sound more believable, less of a reach)***

## **Requirements – Convert into table saying they were met as opposed to long text paragraphs**

The requirements outlined in the design section in chapter 2 of this report were split into 2 categories: functional and non-functional requirements. The below 2 sections discuss whether these requirements were met.

### **Functional Requirements**

The functional requirements outlined in chapter 2, the design chapter, were:

* **To sign in**
  + Users have the ability to sign in to the app using their login credentials. If invalid credentials are entered, the user will not progress to the home screen because no matching authenticated user will be found in the database. Upon entering invalid credentials, the user will receive an alert explaining which part of the credentials are incorrect, the email, password, or both. This functional requirement **has been met**.
* **To log food emissions**
  + From the homepage, users can click the log emission button, and from there select the food option. On the log food screen, users can select their source of food, the portion size and the unit of measurement, such as grams, pounds, ounces or millilitres, catering for a variety of different users’ preferences. As such, this functional requirement **has been met**.
* **To log transport emissions**
  + Similarly to logging food emissions, users click the log emission button from the homepage, except this time select transport. On the transport screen, users select their mode of transport, the distance travelled and the unit of distance, either kilometres or miles. If a car is selected, the user is prompted to provide the size and fuel type of the car. Therefore, this functional requirement **has been met**.
* **To view history of logs for the current day and their co2e contribution**
  + To view the breakdown of their carbon footprint for the current day, users can view the history of their logs on the homepage. This breakdown is further illustrated through a pie chart on the homepage. From this, this functional requirement **has been met**.
* **To compete in individual leaderboard**
  + At the end of each day, a score is generated for each user based on their emission logs for that day. Users can view their scores in the individual leaderboard by selecting the second tab in the navigation bar. To speed up locating your position in the leaderboard, the logged in user’s position is highlighted in green. Thus, this functional requirement **has been met**.
* **To compete in team leaderboard, cooperating with teammate**
  + Exactly like the individual leaderboard, using this score, combined with the score of their paired teammate, the user can view their position in the team leaderboard by selecting the third tab of the navigation bar, with their position being highlighted in green. This functional requirement **has been met.**
* **To view individual progress chart illustrating individual’s carbon footprint scores over time**
  + At the end of each day when a score is generated for each user, this score is added to the users’ individual history or my scores tab on the navigation bar. This is the last tab, the fourth tab on the navigation bar. By selecting the fourth tab, users can view their performance or history of scores over time, and see if they have been improving, facilitating self-competition. This functional requirement **has been met**.

### **Non-functional Requirements**

The non-functional requirements outlined in chapter 2, the design chapter were:

* **Cross-functional application**
  + Having implemented the application in React-Native the application is cross-functional and thus this non-functional requirement **has been met**. Android and iOS users are able to use the app, catering for either phone provider.
* **Easy to use application**
  + Results from participants’ answers in the questionnaire revealed all participants enjoyed using the app, referencing the clear layout and navigation of the app to be very user friendly and easy to use. Thus, this non-functional requirement **has been met**. This result has been achieved through a clear navigation bar, tidy, minimal screens and explanatory text on screen such as alerts.
* **Frequent tasks are performed quickly** 
  + All users were asked in the questionnaire to rank the speed at which frequent tasks could be complete on a scale from 1-10. The results from this were an average score of 8 out of 10, 10 being the tasks were completed as fast as they could imagine, 1 being terribly slow. A score of 8 out of 10 is well above average, thus this non-functional requirement **has been met**. This score has been achieved through the implementation of the navigation bar and the emission log button being pinned to the bottom of the home screen being accessible from any position on this screen.
* **Complex tasks are broken down to reduce complexity**
  + When asked to rank the complexity of the app on a scale of 1 – 10, participants provided an average ranking of 2 out of 10, with 10 being extremely complex and 1 being very simple. Having received the second best ranking for complexity, this non-functional requirement **has been met**. To reduce complexity and thus achieve this satisfying score for application complexity, users can select from different units of measurement such as grams, pounds, ounces and millilitres when logging food emissions and from kilometres or miles when logging transport emissions. Additionally, a history of emission logs for the current day are displayed on the homepage and alert messages are provided for incorrect login attempts.
* **Reduced likelihood of user errors**
  + Insights from participant feedback on their experience with making mistakes and running into errors using the application reported in a score of 3 out of 10, with 10 signifying always making mistakes and running into errors. Having achieved a well above average score, this non-functional requirement **has been met.** The features reducing the likelihood of errors for the application are displaying the history of logs on the homepage, and the confirmation button which appears when a user attempts to log an emission.

## **Conclusion**

By analysing the questionnaire responses before and after using the app, and by analysing the change in realised carbon footprint scores over time while using the application, this chapter has evaluated the application and proven to be an effectful application. 30% of participants reported increased motivation to reduce their individual carbon footprint after using the application, and 30% of participants were found to have a realised, tangible reduction in their carbon footprint over time. The functional and non-functional requirements for the application have been met, justified by responses from the data collected from users through the questionnaires. By implementing the use of console logs, the author was able to test the application, leading to the resulting positive evaluation.

# **Discussion**

This section discusses the overall effect building this application had on tackling the knowledge action gap problem identified as the motivation and goal for this project in the introduction chapter, in chapter 1.

## **Solving the Environmental Knowledge Action Gap Problem**

The environmental knowledge action gap identified in chapter 1, and carried forward as the motivation for this project, is not completely solved because this gap has developed over hundreds of years, and as such, cannot be solved in such a short time span. However, the results indicate a step in the right direction, and by a shifting of approach to motivating a reduction in individual carbon footprints and thus an increase in pro-environmental action through effective message frames which satisfy the psychological user needs of autonomy, competence and relatedness, this increase in motivation and thus pro-environmental action will compound over time, with the hopes of drastically reducing this detrimental gap. The environmental knowledge action gap has been reduced through building this application, but still has room for further reduction.

## **What Worked and What did not Work**

The research discussed in the literature review highlighted the need to satisfy the psychological user needs of autonomy, competence and relatedness as illustrated by the self-determination theory, and the need to reframe message frames from altruistic to self-enhancing, targeting personal gain for those to be motivated, as illustrated by the inclusion model for environmental concern. Additionally, achievement and social gamification features were emphasised as an effective way to satisfy these psychological user needs of autonomy, competence and relatedness.

**What Worked**

* Reframing message frames to focus on self-enhancing values increased motivation and thus increased pro-environmental action for the majority of users
* Targeting psychological user needs of autonomy, competence and relatedness outlined by self-determination theory proved important
* The social and achievement gamification features implemented proved to satisfy all 3 psychological user needs of autonomy, competence and relatedness for the majority of users
* Users began to behave pro-environmentally without even realising they were doing so

Although the majority of users were motivated to reduce their individual carbon footprints and thus increase their pro-environmental action, not all users were motivated to do so.

**What did not Work**

* The minority of users saw little to no change in motivation due to not valuing competition or winning as important to them
* The social and achievement gamification features implemented did not satisfy all 3 psychological user needs of autonomy, competence and relatedness for the minority of users

The fact that not all users were motivated to reduce their individual carbon footprint reiterates the point made in the literature review when analysing existing solutions of Ant Forest and Green Life, that effective design is crucial to achieve increased motivation, and the dangers of assuming gamification will motivate pro-environmental behaviour. The need to address psychological user needs of autonomy, competence and relatedness and to reframe message frames as providing personal gain remain accurate, however, the danger here lies in assuming all users’ psychological needs of autonomy, competence and relatedness will be satisfied by the same gamification features. Clearly, the particular personal gain emphasised in the self-enhancing message frame of the app will not appeal equally to all users. A variety of users thus requires a variety of self-enhancing message frames.

# **Appendix**

Attach copy of questionnaire here