UTRECHT UNIVERSITY
Graduate School of Natural Sciences

Game and Media Technology master thesis

FlowerPower: investigating the effects of perceiving the actions of others through handheld augmented reality and physically seeing litter on creating a sense of self-efficacy for picking up litter

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Abstract

This thesis proposes a method for improving one's sense of self-efficacy to pick up litter. Litter has been a growing issue, with many previous methods focusing on behaviour change as a prominent solution. An important factor for achieving behaviour change is self-efficacy, which relies on perceiving the actions of others. Furthermore, previous solutions fail to account for the effect of physically seeing litter. Hence, this research aims to investigate the effects of perceiving the actions of others and physically seeing litter on the creation of a sense of self-efficacy for picking up litter. To investigate the effects of perceiving the actions of others, two prototypes for a mobile application named *FlowerPower* were developed: AR mode and list mode. AR mode utilizes handheld AR to visualize litter pick-ups as digital flowers, whereas list mode shows these litter pick-ups as comments in a list. To test the effect of physically seeing litter, these prototypes were tested inside and during a walk, resulting in three different conditions: AR-out, LIST-out and LIST-in. Self-efficacy changes were measured using a pre- and post-questionnaire, the responses of which were analyzed by applying a two-way ANOVA to each individual question. The results show no significant differences in self-efficacy ratings between the conditions. We reasoned that that perceiving the actions of others is not enough by itself to generate more self-efficacy for picking up litter; furthermore, the evidence regarding the effects of physically seeing litter is inconclusive. However, analysis of the pre- and post-questionnaire showed that the use of FlowerPower slightly increased participants' sense of self-efficacy in all conditions.

Contents

1. Introduction

1.1 Background

Littering has been a growing issue across the globe. Its impact reaches many different scales, from local to global [1]. Various studies have demonstrated its impact in biological [2, 3], economical [4, 5, 6] and human health [2, 7] contexts. The issues described in these studies show that littering is a serious problem that needs to be addressed.

As such, several litter reduction methods have already been applied with varying degrees of success. One such method is the dedicated cleanup, which is a large event that targets a specific area. The idea is that volunteers collect trash in the designated area, which can be effective for keeping specific places clean [8]. Another litter reduction method is prevention, which can be achieved through encouragement of anti-littering behaviour [9]. Spreading awareness is another common method for litter reduction, as awareness can create motivation to perform pro-environmental behaviour [10].

All of these methods have flaws. Dedicated cleanups are expensive [5, 6] and only operate on a small scale; prevention does not work effectively on repeat-offenders [9] and a large portion of litter does not come from citizens; awareness alone is often not enough for individuals to effectively incorporate sustainable practices in their daily lives [11].

Considering the fact that there will always be litter, it is reasonable to conclude that picking up litter on a large scale would be the ideal solution. However, encouraging individuals to join pick-up activities can be tricky as this often requires a change in behaviour. This is a complex process, influenced by multiple psychological factors. One such factor is self-efficacy, which is generally described as an individual's belief to perform the required actions to produce a specific outcome. Self-efficacy has been described as one of the most important factors for behaviour change in general [12]. Furthermore, a lack of self-efficacy is one of the main reasons for not picking up litter [13]; within this context, self-efficacy can best be described as an individual's belief that picking up litter contributes to solving the litter problem. Because of its importance within the behaviour change process and to keep the scope of this research reasonable given the time constraints, the focus will be on self-efficacy.

Similarly to behaviour change, the process of creating a sense of self-efficacy is influenced by many factors. However, several of these factors rely on perceiving the actions of others: for instance, seeing previous accomplishments or individuals actively performing pick-up behaviour can create a sense of self-efficacy [12]. As such, we need a method for showing individuals the actions of others.

This can be done through visualizing actions through a website or application. Web-based interventions have been employed in the past, but to varying degrees of success. In particular, studies have not employed life-style changing web-based interventions effectively [14], requiring frequent updates and notifications to change behaviour. A website can only convey information through lists and data, which may cause individuals to feel detached from the problem. Additionally, cognition is inherently limited [15]: when presented with numbers and statistics, users may not interpret them in a meaningful way. As such, it would be better to put users in a situation where they can see the litter *and* perceive others' efforts to combat it.

This approach requires combining real-world data with digital data, which can be done with Augmented Reality (AR). AR visualizes digital information through head-mounted displays or phone screens (referred to as handheld AR), while keeping the user engaged with the real world. In general, AR has been used for a variety of different purposes. For instance, AR is commonly used for making repetitive exercises less tedious, such as training [16].

Another good example is entertainment, which has been a major use case for handheld AR: this includes games like Pokémon GO and Ingress. Within the context of environmental sustainability, AR shows potential to be a useful tool. Previous studies have employed AR techniques for learning and retention purposes [17]; however, AR has not been used for creating a sense of self-efficacy for performing pro-environmental behaviour [13]. Furthermore, research regarding the use of AR within the context of litter reduction is non-existent. Hence, the goal of this research is to find out whether AR can be used to create a sense of self-efficacy in individuals to pick up litter.

To achieve this goal, we will develop two prototypes of a smartphone application named *FlowerPower*. The first prototype will allow users to visualize their own litter pick-up actions in AR, whereas the second prototype will show litter pick-ups as comments in a list and will be used as a comparison. These prototypes will be named *AR mode* and *list mode* respectively. Furthermore, an experiment will be conducted to compare both modes in different environments, which will test the effectiveness of physically seeing litter. The required data will be gathered using a pre- and post-questionnaire and analyzed using an appropriate statistical test.

1.2 Research question

We will be answering the following question:

To which extent does perceiving visualized actions of others in combination with physically seeing litter create a sense of self-efficacy for picking up litter in an urban environment?

1.3 Contributions

This research will have the following contributions:

1. A prototype of a smartphone application named FlowerPower. The prototype will allow users to visualize their own pick-up actions, which can be seen by others using handheld AR.
2. An answer to the proposed research question, which will give an indication as to whether or not action visualization can be used to create a sense of self-efficacy for picking up litter. This could lead to more effective designs for litter-reduction applications focused on behaviour change.

1.4 Thesis overview

The rest of this thesis is divided into chapters. Chapter 2 discusses literature regarding the impact of littering, behaviour change, the role and effects of self-efficacy, sustainable human-computer interaction and AR. Then, chapter 3 describes the methodology: this includes the design and implementation of the prototype, as well as a detailed explanation of the experimental setup. After this, chapter 4 lists the results. Chapter 5 discusses the results, as well as emphasizing limitations and describing some potential directions for future work. Finally, chapter 6 summarizes the main conclusions.

2. Literature overview

This chapter summarizes relevant literature. It is divided into several sections: firstly, litter and its impact are discussed. Then, several behaviour change theories are described within a general context and the context of litter reduction. After this, the concept of self-efficacy is discussed and its role for achieving pro-environmental behaviour is highlighted. Lastly, developments within sustainable human-computer interaction (SHCI) are discussed, finishing with a short overview of AR and its uses for environmental sustainability.

2.1 Litter impacts

As stated in section 1.1, several studies have shown the impact of littering in different contexts. To show the severity of the littering issue and why it needs to be addressed, this section describes each context in more detail.

In a biological context, several harmful consequences of litter have been recorded. A well-known problem is that plastic debris can choke and entangle wildlife, as stated by Werner et al. [18]. A study by Barnes et al. addresses the concern of plastic fragmentation, which may occur due to exposure to UV light [2]. The study states that smaller animals can ingest fragmented pieces of plastic, leading to clogged digestive systems and other health hazards; this is supported by Werner et al. [18]. Other types of litter can poison sea life: for instance, cigarette butts contain heavy metals and toxic chemicals [19]. A study by Kadir et al. states that cigarette butts can have lethal or sub-lethal effects on sea creatures, through absorption or ingestion [20]. On the contrary, some species flourish and spread through litter. A study by Gracia et al. identifies three different groups of species that will latch onto persistent debris and be transported to other habitats [3], which is supported by Barnes et al. [2]. The study by Gracia et al. also states that litter can increase dispersal rates for these creatures, which allows them to reproduce quickly in foreign habitats. Because of this, these groups can threaten the wildlife of native habitats through directly harming other species in the environment or out-competing them.

The impacts of litter in an economical context are less destructive but still important to note. A study by Krelling et al. found that litter can reduce the attractiveness of recreational places, such as beaches [4]. Although small amounts of litter were not enough to deter tourists, 15 litter items per m^2 deterred 85% of the participants. Additionally, a study by Newman et al. states that cleanup campaigns are often time-consuming and expensive [5], which is supported by Mouat et al. [6].

Human health is another important context to take into consideration. The study by Barnes et al. states that micro-plastics can absorb toxic chemicals, which we ingest through consumption of sea animals [2]. A study by Gallo et al. notes that the long-term consequences of this phenomenon are unknown [21], due to a lack of empirical data. However, it also states that micro-plastics can certainly damage the human body on a microscopic level by affecting cells, changing genes, etc. Furthermore, a study by Campbell et al. reveals that interacting with particular types of litter can directly injure us [7]. The study focuses on beaches and identifies wounds as the most prevalent type of injury, often caused by sharp objects.

2.1.1 Spatial litter distributions

Generally, litter distributions can be split into two categories: type and spatial. Type distributions are not relevant for this research: there is no research on the effect of specific litter types on the mindset of individuals. Furthermore, individuals will not be required to interact with litter during the experiment: doing so would raise ethical concerns, as participants could get hurt or damaged by picking up litter. On the contrary, spatial distributions are important to take into account when performing the experiment. This is because the experiment will take place in a specific area: the state of this area can influence the mindset of individuals regarding litter reduction [9]. To be precise, a clean area encourages visitors to keep the area clean, whereas a littered area suggests that litter is accepted. As such, the effectivity of litter reduction techniques may be dependent on spatial distributions: hence, this section gives a short overview of spatial litter distributions in urban areas.

A study by Farzadkia et al. investigated the spatial distributions of several area types in Qazvin: residential, commercial, administrative, recreational and diverse [22]. To clarify, a diverse space is a mix of two or more types of spaces: for example, a residential area with some shops in it, a commercial area with a large playground etc. The study found that residential, administrative and recreational spaces generated the least amount of waste, whereas commercial and diverse space generated the most amount of waste. This difference can mostly be attributed to the size of the population and the amount of visitors in these areas: commercial and diverse spaces tend to receive many visitors during the day, which ultimately leads to more littering. The study also mentions other contributing factors, such as the quality of clean-up services and physical characteristics of passages.

A study by Seco Pon and Becherucci describes a similar spatial distribution assessment for Mar del Plata [23]. The study found that the harbor contained the most amount of litter. Mar del Plata is a large coastal city: as such, the harbor attracts many visitors, which leads to more littering. Furthermore, the sea transports additional litter into the harbor, increasing the level of pollution. The study links littering to three variables: amount of pedestrians, parked cars and bins. It was found that areas with a greater number of pedestrians contain more litter, which is supported by the study by Farzadkia et al. These areas serve a variety of purposes and are heavily used by locals and visitors. Additionally, the study found that parked cars in such areas contribute to more cigarette butts: before entering their car, people throw their cigarette butts onto the street. Interestingly, the amount of bins did not directly correlate with the amount of litter. This is because full trash bins often become litter magnets, where individuals throw their trash next to the bin. Nevertheless, the study states that a lack of trash bins can be used as an excuse to litter.

A study by Xiong et al. uses machine learning to analyze the spatial distribution of litter in Bejing, as well as identifying four different factors that influence litter generation [24]. These factors are as follows:

1. Presence of a permanent population.
2. Level of road cleaning.
3. Presence of branch roads.
4. Presence of commercial areas.

Previously discussed studies support the notion that a dense population and high-traffic areas like commercial districts increase the amount of littering. When it comes to road infrastructure and cleaning level, the study notes that the local government plays an important role to keep the roads clean and should take sufficient action to do so.

Lastly, a report by Rijkswaterstaat indicates that the spatial distribution of litter in the Netherlands is somewhat similar to previously discussed urban locations [25]. In particular, the report states that fine waste is common in commercial and public transport areas, which is supported by the studies above. Additionally, care locations (i.e. hospitals, nursing homes, etc.) have the most amount of fine and coarse waste, while also having the most amount of bins. This can be explained through the litter magnet concept described by Seco Pon and Becherucci, where full trash bins lead to people throwing their trash next to the bin [23].

To conclude, there are two common factors that contribute to litter generation in urban environments: population and type of area. In particular, multi-purpose areas that attract many visitors tend to generate a great amount of waste, such as commercial areas. It is likely that such areas have an effect on the mindset of individuals, which should be taken into account when performing the experiment.

2.2 Behaviour change

As stated in section 1.1, the goal of this research is to create a sense of self-efficacy in individuals for picking up litter. In the long term, this could lead to a behaviour change in those individuals: however, there are many other factors that influence the behaviour change process. There are multiple different theories that attempt to describe the exact requirements of behaviour change, each with their own explanations and subtleties. This section describes behaviour change in more detail and provides a detailed explanation for three prominent behaviour change theories. Furthermore, a small part of this section is dedicated to the effects of seeing the actions of others, explained through the social learning theory.

Firstly, it is important to identify potential barriers for behaviour change. These can be split into two categories: structural and psychological. Structural barriers are usually beyond an individual's control, such as government decisions, living situation, etc. Hence, it is more interesting to focus on psychological barriers. A study by Gifford categorizes such barriers into several different categories, each with their own subcategories [15]:

- Individuals may have limited cognition about the problem, which prevents them from taking action. For instance, people may be ignorant, uncertain or too optimistic. Furthermore, deep-rooted instincts can be a problem, such as the inability to make decisions with long-term benefits. Gifford also states that a lack of self-efficacy falls under this category.
- Individuals may have worldviews that conflict with pro-environmental behaviour. Some individuals believe that technology will solve the problem or that a deity or god will come down to save humanity. A less extreme example is the fear of change: several people flourish in the status quo and do not want to lose their current position.
- Individuals may compare themselves to other people through societal norms and perceived inequity. Norms are a double-edged sword: Gifford states that norms can be used to enforce positive change, but can also cause negative changes if used carelessly.
- Individuals may sink time or money into decisions, which makes it harder to reverse such decisions. Habits are a good example: Gifford states that they are extremely persistent and hard to break, especially when the individual has already put a lot of time or money into it. As such, a large push is needed to permanently change a habit.
- Individuals may not have trust in experts or authorities. This can come in many forms: people may have had bad experiences with the authorities, deny the problem, feel like pro-environmental decisions threaten their freedom etc.
- Individuals may not want to deal with the risks that come with behaviour change. Gifford describes several types of risks and all of them affect individuals on a personal level.
- Individuals may not achieve adequate behaviour change. These people have the right intention but only take easy and usually ineffective actions, or fall back into bad habits after some time.

Most of these barriers are difficult to address. In particular, some barriers are dependent on outside influences, such as society and authorities. Other barriers are persistent, such as habits and ideologies. These barriers are beyond the scope of this research and will not be discussed further: however, it is good to acknowledge that they exist, as they could influence the results.

Removing intrinsic psychological barriers is necessary to achieve behaviour change. However, that does not guarantee that behaviour change actually occurs: several theories stress the importance of other factors. One such theory is the Theory of Planned Behaviour (TPB), created by Ajzen [26]. The theory makes a distinction between predicting behaviour and predicting the intent of performing said behaviour. Ajzen states that intention alone cannot be used to accurately predict behaviour: external factors may prevent an individual to fully adopt the desired behaviour. Alternatively, a prediction may be completely wrong if the intention changes after assessment. Lastly, some behaviours require more effort than others, regardless of intention.

However, Ajzen states that in absence of external factors, intent can still be used as an indication for achieving the actual behaviour. The theory of planned behaviour describes the relation between intent and actual behaviour, identifying two primary factors that influence an individual's attempt at performing a behaviour: attitude and perceived social norms. Attitude describes an individual's view towards the problem, determined by assessments of success and failure. Ajzen states that an individual is more likely to attempt a behaviour if the advantages of success outweigh the disadvantages of failure. Perceived social norms describe how an individual views what is "normal" in society. In particular, an individual is more likely to adopt behaviour if important people in the environment of said individual approve of the behaviour. This concept is also known as normative social influence and has been proven to be effective for behaviour change. A study by Deutsch et al. notes that its effects are based on three different factors [27]: group pressure, others with matching opinions and uncertainty about opinions of the self. If one or more factors are present, normative social influence has great effects on behaviour change. A study by Nolan et al. supports the notion that normative social influence is one of the most powerful methods of achieving behaviour change [28].

Going back to the TPB, the theory explicitly defines behavioural expectancy as the expectation of being able to perform the desired behaviour. Behavioural expectancy is affected by two factors: the intent to attempt a behaviour and perceived behaviour control, i.e. the belief that one has enough control over their actions to perform the desired behaviour. In an additional study by Ajzen, it is clarified that perceived behavioural control is also an important factor for influencing intent and consequently behaviour, alongside attitude and social norms [29]. Furthermore, the study mentions that perceived behavioural control can be split into self-efficacy and control. Self-efficacy will be explained in much more detail in section 2.3, but generally it describes how an individual sees the effects of their own actions. Control describes the perceived level of agency, i.e. the level of control an individual feels like they have on their own actions.

Figure 2.1 provides an overview of the theory. Note that the figure does not reflect that behavioural control (b_c) also influences intent, as stated by Ajzen's followup study. The symbols are explained below:

1. p_s and p_f denote the probabilities that a behaviour succeeds or fails respectively. p_r denotes the probability that important people in the environment of an individual approve of the behaviour.
2. $\Sigma b_{s_i} e_i$ describes previous successful actions, whereas $\Sigma b_{f_i} e_i$ describes previous failed actions.
3. A_s and A_f describe attitude towards success and failure respectively. Combined with p_s and p_f respectively, this results in the attitude A_t for trying a behaviour.
4. $\Sigma b_i m_i$ describes previous actions by important people in the environment.
5. SN describes the subjective norm of a behaviour. It is multiplied with p_r, resulting in the subjective norm SN_t of attempting a behaviour.
6. I_t describes the intention of trying a behaviour, influenced by A_t and SN_t.
7. B describes the actual behaviour, influenced by an attempt B_t to perform the behaviour and the degree of control C a person has over their actions.
8. BE denotes the behavioural expectation, influenced by the intention I_t and the perceived behavioural control b_c.

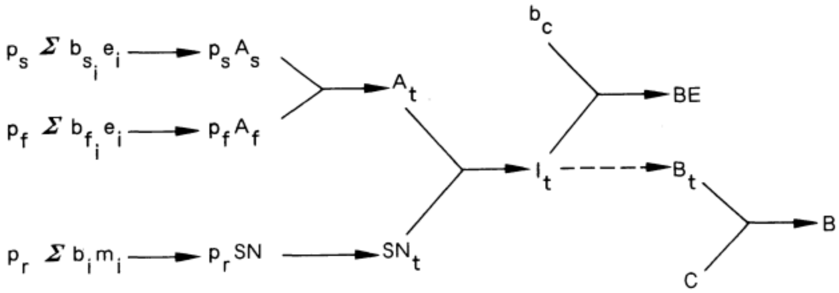

Figure 2.1: An overview of the theory of planned behaviour [26]. The graph shows the effects of individual factors on attitudes and subjective norms and consequently their effects on intent, behavioural expectancy and the actual behaviour.

Another prominent behaviour change theory is the value-belief-norm theory, which was designed with pro-environmental movements in mind [30]. The theory describes three factors that encourage an individual to join a movement: personal values, beliefs and personal norms. Unlike the TPB, this theory presents the factors as a causal chain, where one factor influences the next.

Firstly, the study mentions personal values. These can influence decision-making through self-interest or altruism, though the study mostly focuses on altruistic values. In the case of self-interest, joining the movement may be beneficial in the long run for the individual. Similarly, the benefit of others may encourage an individual to join. The second important factor is the existence of beliefs, which refer to general worldviews that may encourage the individual to join. The study refers to the New Ecological Paradigm (NEP), which states that human actions have severe effects on the fragile biosphere. Attaining this worldview and thus being aware of such effects can lead to increased motivation to tackle the problem. Lastly, the study emphasizes personal norms. These are influenced by awareness of consequences and how much the individual thinks they are responsible for solving a problem, which in turn are influenced directly by the individual's values and worldview. If all three factors align, a moral obligation is created, which heavily encourages individuals take action.

The previous two theories focused on influencing factors of behaviour change, rather than the process itself. The transtheoretical model addresses this by dividing the behaviour change process into six stages [31]: precontemplation, contemplation, preparation, action, maintenance,and termination. Furthermore, the corresponding study identifies ten processes of change that are used to stay within or progress to another stage. Some notable ones include support from relatives and awareness, though the study lists many others. The model emphasizes the role of other factors such as temptations, self-efficacy and more. In particular, it describes that individuals should have a sense of total self-efficacy at the termination stage.

As stated in the introduction of this section, it is important to look at the effects of seeing the actions of others. The social learning theory addresses this by emphasizing the importance of observational learning for adopting a new behaviour. In particular, the theory states that behaviour is learned through observing a model: this model can be an individual, a set of instructions or some form of media. There are four mediators that determine whether or not behaviour from the model is replicated:

1. Attention: the model must capture the interest of the observer and the behaviour must be worth imitating.
2. Retention: the behaviour must be easy to recall.
3. Motor reproduction: the individual must have the ability to perform the behaviour.
4. Motivation: the individual must have the will to perform a behaviour.

Furthermore, the theory states several other factors that may facilitate the imitation process. The nature of the models plays a significant role: models with a high status or with similarity to the individual may have a greater effect on the process. Moreover, reinforcement and punishment are mentioned as additional mediators.

To summarize, achieving behaviour change is an extremely complex process. Structural barriers may prevent individuals from changing behaviour at all and internal barriers are influenced by many different factors. This section discussed three different theories, each describing behaviour change in a different manner. The theory of planned behaviour describes behaviour change as a construct of intent and expectations, which is influenced by attitude, social norms and perceived behavioural control. The value-belief-norm theory lists behaviour change as a chain of causal variables, namely personal values, beliefs and personal norms. Lastly, the transtheoretical model defines behaviour change on a temporal scale, identifying several stages in the process and methods to stay or progress to new stages. These theories have some aspects in common: for instance, all three theories mention the effect of others in some form. Furthermore, the TPB and the transtheoretical model note the importance of self-efficacy. In particular, the TPB describes the effects of others and self-efficacy in the context of behaviour change. Lastly, we have seen that seeing the actions of others is an important part of adapting behaviour through observational learning.

2.2.1 Litter reduction

Several studies have used behaviour change techniques to reduce litter. This section provides an overview of these techniques, describing their advantages and disadvantages.

A commonly employed litter reduction technique is the dedicated cleanup. As stated in section 1.1, a dedicated cleanup is a large event that targets one specific area. Organizers of dedicated cleanups employ different strategies for attracting volunteers and creating engagement: for instance, a study by Storrier et al. emphasizes the importance of local partnerships, which engages communities, raises awareness and facilitates debate [8]. The study describes a large cleanup event for beaches in Scotland, demonstrating its effectiveness on a local scale.

Social marketing is another method of attracting participants to dedicated cleanups. This method was proposed by a study by Lafreniere et al. and is based on the aforementioned theory of planned behaviour [32]: if individuals have a positive attitude toward environmental protection, believe others do as well, and believe that picking up litter is an effective way of protecting the environment, motivation to participate is increased. To attract participants to annual cleanups of a local nature reserve, the study focused their marketing on four specific groups that would be likely to have these three qualities. Individuals within these groups already have an underlying motivation to join the dedicated cleanup and may encourage each other to join. The study mentions the following group types:

1. Business groups, wanting to involve themselves with the local community.
2. New residents and unconnected individuals, wanting to interact with others or to create relationships and social links through the event.
3. Active family and friend groups, who already spend much time outside.
4. Middle schools students, encouraged by their teachers for educational purposes.

The strategy turned out to be successful, attracting sponsors and volunteers each year through targeted promotion and communication.

Another common recruitment strategy is to provide an incentive for joining a dedicated cleanup. Several studies have experimented with different types of rewards: for instance, a study by Powers et al. uses small monetary rewards to incentivize visitors of recreational areas to pick up trash [33]. Visitors were given one of two types of rewards: one half received 25 dollars at the end of the experiment, whereas the other half received a lottery ticket for each bag of trash that they collected for a chance at winning 20 dollars. Both types turned out to be effective but the lottery ticket reward was preferred over the other type. However, it can be difficult to sustain a system based on monetary rewards due to a lack of funding. A study by Muth et al. addresses this by introducing educational rewards through the so-called "incentive system" [34], which targets recreational and wilderness environments. The system makes use of rangers, who may ask families and children to help pick up litter. In exchange, participants are taught about the environment. Much like the monetary system, this system was also proven to be effective. Other types of educational rewards can be used as well: a study by Sawdey et al. describes a cleanup campaign for cigarette butts on a university campus, providing participating students with extra credit [35].

It is important to note that dedicated cleanups have numerous problems that make it difficult for them to work on a larger scale. For instance, repeated dedicated cleanups require constant funding to keep areas clean. The project by Storrier et al. only received funding for 3 years and the study questions whether or not it could be continued [8]. Studies by Newman et al. and Mouat et al. state that organized cleanups are expensive and time-consuming [5, 6], thus making them less likely to receive funding. Another issue with dedicated cleanups is the stigma surrounding them, discouraging individuals to join. The study by Lafreniere et al. describes it as follows [32]: individuals may not want to pick up litter in public places if they are the only ones doing it. The study proposes the use of road signs to indicate that there are volunteers picking up litter, but this may not always be feasible. The study also mentions other roadblocks, such as weather conditions, precarious terrain and a lack of responsibility for picking up litter thrown on the ground by others.

However, the greatest downside of dedicated cleanups is that they operate on a small scale. The studies above mention that dedicated cleanups are effective for specific areas, such as beaches or nature reserves. Furthermore, they also state that dedicated cleanups only temporarily solve the issue. For instance, the study by Storrier et al. states that litter would continue to wash up on shores for years to come, even if humanity stopped dumping litter in the ocean [8]. When taking previous downsides into account, it becomes clear that dedicated cleanups are not a feasible long-term solution for the litter problem.

A second reduction technique is prevention. By reducing the number of littering individuals, the total amount of litter is reduced as well. A study by Kolodko et al. describes littering as a response to a commons dilemma [9]. Individuals tend to take actions that they think will benefit themselves; however, adding up the costs of individual actions results in everyone being worse off. The study proposes several solutions that attempt to reduce the perceived individual benefits of littering. These include fines, availability of bins and more. In the context of this research, it is important to highlight two particular solutions: participation in pick-up activities and social pressure. Regarding the former, the study notes that involving community residents in pick-up activities is an important part of creating internal motivation for residents to stop littering, which is supported by a study by Roales et al. [36]. Regarding the latter, the study describes that individuals tend to follow their peers through direct or indirect social pressure. A good example of indirect social pressure is the existence of a clean space, which implies that there is a social norm for not throwing litter on the ground. This notion is supported by Moqbel et al. [37], which comes to a similar conclusion.

Applying the aforementioned prevention solutions may not always have the same effect, as the perceived benefits differ from person to person. This notion is supported by a study by Moqbel et al., which states that littering behaviour is dependent on several internal and external factors [37]. Hence, the study by Kolodko et al. mentions that interventions should be tailored towards specific individuals or groups. In particular, repeat offenders would require severe pressure through incentives or penalties to change their behaviour. The study mentions that it would be better to focus on those individuals that occasionally litter and potentially feel bad about doing it, which are more likely to have their behaviour changed. Furthermore, individuals with uncertainty about their own actions or motivations are more likely to change their behaviour through normative social influence, as stated by Deutsch et al. [27], thus reinforcing the idea of targeting those with more potential to change their behaviour. However, it should be noted that there is a portion of litter that does not originate from citizens. This litter comes from factories, farmers, natural sources and more; prevention of such litter cannot be solved through behaviour change alone, thus making prevention an imperfect solution.

A third reduction technique is raising awareness. By communicating the consequences of littering to individuals, they may be motivated to join pick-up activities. Raising awareness is considered to be an important component of pick-up campaigns, as described by a study by Rees et al. [10]: the study mentions that awareness is needed for initiating a change in attitude. As such, raising awareness has been incorporated into previous campaigns, such as the one described by Storrier et al. [8]. However, awareness by itself may not result in the desired behaviour. A study by Demirci et al. measured students' understanding of sustainability and found that students did not know how to effectively integrate sustainability into their own life, despite knowing about the concept [11].

Other reduction techniques include garbage classification and recycling programs: these are rather small-scale but still mentioned here for completeness. Regarding classification, a study by Kuang et al. found that garbage classification behaviour is dependent on contextual factors, such as public attitude and knowledge [38]. Regarding recycling, a study by Moqbel et al. states that the presence of recycling programs can motivate individuals to stop littering [37]. Additionally, a study by Chen mentions embracement of recycling as one method of reducing marine litter [39].

To summarize this section, we have seen several litter reduction techniques in the context of behaviour change. Dedicated cleanups are effective for specific areas and employ different strategies for recruiting participants. These strategies include establishing partnerships with local companies, social marketing, providing different kinds of incentives and more. However, dedicated cleanups have several downsides and are not feasible in the long term. Another discussed technique is prevention, which can be achieved by increasing the perceived cost of littering. Some notable methods include participation in pick-up activities and social pressure, which can play a big role in achieving long term behaviour change. The third discussed technique is raising awareness, which has been an important component in sustainability campaigns. However, raising awareness by itself does not guarantee a behaviour change. Lastly, we briefly discussed two smaller litter reduction techniques: garbage classification and recycling programs. Behaviour regarding garbage classification follows a similar pattern to prevention: whether or not it is performed depends on contextual factors. The existence of recycling programs can motivate individuals to stop littering, but it is mentioned as one of multiple possible factors. To conclude, each previously discussed method has its own advantages and disadvantages. Amongst these methods, dedicated cleanups seem to show great promise, employing multiple effective strategies to motivate people to pick up litter. As such, this research expands upon the concept by focusing on picking up litter on a larger scale.

2.3 Self-efficacy

As described in section 1.1, self-efficacy is one's belief to perform the required actions to produce a specific outcome. This section explains the concept in more detail by describing one of the most prominent self-efficacy theories and comparing it to previously discussed behaviour change theories.

The aptly-named self-efficacy theory was created by Bandura [12]. The theory describes four factors that affect one's sense of self-efficacy:

1. Performance accomplishments describe an individual's past attempts at performing a certain behaviour. It is heavily based on personal mastery expectations: successes raise these expectations, whereas repeated failures can lower them. Bandura states that repeated successes are important for developing a strong sense of self-efficacy; furthermore, a series of successes reduces the impact of occasional failures.

2. Vicarious experiences describe the actions of others. The act of seeing others perform certain behaviour without adverse consequences can create a sense of self-efficacy in observers: "if others can do it, why would I not be able to do it?".

3. Verbal persuasion describes the act of influencing others with words, rather than actions. Individuals are led to believe that they can overcome the barriers that prevented them from performing a certain behaviour.
4. Physiological state relates to the mental and physical state of the individual. Different states can influence the perception of one's abilities, which can increase or decrease the level of self-efficacy based on the circumstances. For instance, being in a state of negative arousal can reduce an individuals' sense of self-efficacy. Bandura gives the example of stress and fear, which would create such a state.

Bandura notes that performance accomplishments are the most influential. This is because this factor is based on personal experience and mastery, whereas vicarious experiences and verbal persuasion are mostly dependent on the actions of others. Furthermore, physiological states can be dependent on outside factors. The theory describes that concrete experiences in one of the four categories are the most effective for increasing self-efficacy.

Furthermore, the theory separates the behaviour from the outcome. Self-efficacy expectations directly influence behaviour: however, whether this behaviour leads to a certain outcome or not is mediated by the belief that certain actions will lead to certain outcomes, known as outcome expectancies. Figure 2.2 illustrates this difference.

Figure 2.2: Diagram illustrating the difference between self-efficacy and outcome expectations.

The study notes that treatment for creating a sense of self-efficacy will not have the same effect on all participants. This is because some individuals may have had more efficacy-altering experiences than others, causing fluctuations in perceived self-efficacy. This concept is similar to the one described by Kolodko et al. [9]. The study focuses on perceived benefits rather than perceived self-efficacy: however, both studies come to the conclusion that it is better to focus on individuals that already have motivation to change their behaviour.

A followup study by Bandura elaborates more on the consequences of having a sense of self-efficacy [40]. In particular, the study states that many types of behaviours can be attributed to self-efficacy, such as coping, stress, stubbornness and more. This is because self-efficacy affects thought patterns, actions and emotions: in general, higher levels of self-efficacy lead to more performance accomplishments and less emotional arousal. A good example of emotional arousal is fear, though other emotions can be triggered as well.

Other theories support the notion that self-efficacy is important for behaviour change, but also stress the importance of other factors. The previously discussed theory of planned behaviour describes perceived social norms and attitude separately from self-efficacy [26]; Gifford mentions a lack of self-efficacy as one of many barriers preventing behaviour change [15]; the transtheoretical model explains self-efficacy as one of several factors influencing individual stages [31].

To conclude, self-efficacy can be described using the aptly-named self-efficacy theory. This theory states that there are four factors that influence the creation of a sense of self-efficacy, two of which dependent on the actions of others. Generally speaking, influencing these factors is most effectively done through concrete experiences: however, effects may differ between individuals because of previous efficacy-altering experiences. Regarding the effects of self-efficacy, the theory states that a sense of self-efficacy directly influences behaviour by affecting different parts of the brain. Whereas self-efficacy influences behaviour, outcome expectancies mediate the transition between behaviour and the desired outcome. When looking at other behaviour change theories, self-efficacy is usually described as a factor that can influence behaviour. However, most previously discussed theories do incorporate the concept in some form or another and there is evidence that it plays a major role in the behaviour change process, marking its importance.

2.3.1 Pro-environmentalism

Within the context of pro-environmentalism, self-efficacy can best be described as one's belief to perform pro-environmental actions that will lead to a sustainable environment. There have been several studies connecting self-efficacy to pro-environmental behaviour, some of which highlighted in this section. Furthermore, part of this section is dedicated to self-efficacy studies regarding littering.

Several studies note that a sense of self-efficacy positively correlates with pro-environmental behaviour. For instance, a study by Schutte et al. states that self-efficacy has a great positive influence on sustainability motivation, which consequently leads to more pro-environmental behaviour [41]. The study notes that interventions for increasing self-efficacy were effective and resulted in more pro-environmental behaviour. Another example is a study by Surjanti et al., which assesses the effects of self-efficacy and self-concept on sustainable behaviour through participatory ecological learning [42]. The study found that self-efficacy had a significant effect on behaviour, whereas self-concept did not.

Other studies describe the role of self-efficacy in more detail. In particular, it is often described as a mediator of sorts: for instance, a study by Meinhold et al. describes self-efficacy as a mediator between attitude and behaviour [43]. In other words, self-efficacy determines whether the desire to perform a certain behaviour is turned into actual behaviour: this notion is very similar to Bandura's explanation [12]. Furthermore, the study notes that there is a positive correlation between a pro-environmental attitude and pro-environmental behaviour under adolescents.

A study by Plechat et al. also describes self-efficacy as a mediator, but takes a slightly different approach by focusing on awareness instead of attitude [44]. The study uses a virtual reality simulation to stimulate pro-environmental food choices. Middle school students were assigned to one of two conditions: awareness and awareness combined with self-efficacy. The simulation incorporates awareness by visualizing the impact of their food choices; for the self-efficacy condition, the simulation encouraged users to re-select more sustainable foods and showed users the gradual restoration of nature. The study found that both conditions were effective for achieving pro-environmental behaviour, but the condition with self-efficacy was significantly more effective. Hence, the study considers self-efficacy to be a mediator between awareness and performing the desired behaviour. The importance of awareness is further stressed by a study by Kornilaki et al. [45], which states that awareness is a key factor for feeling effacious. However, the study by Plechat et al. makes it clear that awareness alone is not the most effective method of achieving behaviour change, which is supported by a study by Demirci et al. [11]. To reiterate, this study notes that grasping the concept of sustainability and its consequences is not enough to make effective sustainable decisions.

Several studies mention the effect of pro-environmental behaviour on others. The study by Kornilaki et al. investigated why some companies perform sustainable behaviour, whereas others do not [45]. The study states that comparisons with other companies encourage employees to do research and gain necessary skills for sustainable behaviour. Furthermore, a study by Mughal et al. describes the effect of employees performing pro-environmental behaviour [46]: the study notes that individual behaviours, stimulated by self-efficacy, resulted in leadership more geared towards pro-environmentalism. This concept also works the other way around: a study by Guo et al. found that managers play a big role for encouraging pro-environmental behaviour [47]. In particular, managers with a sense of self-efficacy stimulate better waste management and other sustainable practices.

Lastly, some studies researched the effects of self-efficacy on anti-littering behaviour specifically. A study by Ojedokun and Oluyinka found that a high level of environmental self-efficacy correlates to motivation to take littering prevention actions [48]. A study by Singh et al. supports this and states that self-efficacy has a significant effect on individuals' intention of adopting anti-littering behaviour [49]. The study uses the theory of planned behaviour as a basis and states that attitude and subjective norms also have significant effects.

To conclude, all previously discussed studies emphasize the positive influence of self-efficacy on pro-environmental behaviour. It is often seen as a mediator between a psychological state and behaviour; examples of such states include awareness and attitude. Furthermore, the effects of self-efficacy can spread through pro-environmental management and comparisons with green entities, such as companies. Lastly, studies specifically tailored towards anti-littering behaviour come to similar conclusions as studies focusing on general pro-environmental behaviour. Hence, it is clear that self-efficacy is an important part of achieving anti-littering behaviour.

2.4 Sustainable human-computer interaction

Human-computer interaction (HCI) is a research field that focuses on the design and evaluation of interactive systems and technologies. When a system or technology is designed to promote sustainable behaviour, it falls under sustainable human-computer interaction (SHCI). This section describes several SHCI studies in the context of waste and litter reduction.

Firstly, a study by Hansson et al. gives an overview of progress in the field, assigning several SHCI papers to UN sustainability goals [50]. In particular, the study identifies twelve papers that relate to the reduction of waste generation and places them under three different categories: longevity, re-use and other. The last category contains studies about persuasive technologies, aimed to change the behaviour of individuals. These technologies use a variety of techniques to change behaviour, such as gamification and normative social influence.

A study by Comber and Thieme describes a method for preventing and recycling food waste, combining the aforementioned gamification and normative social influence into a single application [51, 52]. The study describes BinCam, a system consisting of two parts: a smart camera attached to a bin and a separate application embedded in Facebook. The camera identifies waste and posts a stream of pictures on Facebook, allowing users to see the waste generation of other users. Furthermore, the application contains achievements that reward sustainable behaviour. This approach was proven to be effective for raising awareness and gaining a sense of perceived behavioural control; however, the study notes that normative social influence was not as effective as expected. As discussed before, normative social influence is more effective if it comes from important people [27]. Connections on Facebook are often weaker than real-life relations, thus resulting in less social pressure.

Other studies address this by applying similar techniques to groups. For instance, a study by Bertran et al. introduces the Grumpy Bin [53], which operates very similarly to BinCam. It tracks waste generation with a smart camera; however, pictures are only sent to members of the household. Furthermore, bad behaviour is punished by the system. Whereas this system is merely a concept, a study by Farr-Wharton et al. introduces a functional camera system [54]. The study takes a slightly different approach by monitoring the fridge instead of the bin, sending photos of the fridge to household members. It was found that this approach was effective for waste reduction and gaining awareness: housemates encouraged each other to follow the scheme. However, the study also highlights some of the ethical and privacy issues for a method like this, as the camera may capture unwanted footage.

Hence, other persuasion systems use different methods to achieve behaviour change. One such method is gamification, which was briefly described as part of the BinCam application. A study by Aydin et al. puts more focus on the concept, introducing a mobile application for reducing food waste [55]. The application uses a point system, rewarding good behaviour and punishing bad behaviour by adding and subtracting points respectively. Furthermore, the application contains achievements for additional positive reinforcement. The study found that the application was effective in the short-term; however, long-term viability was not tested.

Interactive bins are another method for encouraging anti-littering behaviour. According to a study by Thaler et al., small changes in the environment can significantly affect behaviour [56]. Applying this concept to bins results in interactive bins with sounds or additional functionality, encouraging users to use the bin. The idea has been explored by several studies: for instance, a study by Tan [57] found that robotic bins with anthropomorphic qualities increased intentions to use the bins. The behaviour was mediated by feelings of empathy towards the bins. Furthermore, a study by Brasileiro et al. investigated the effectiveness of interactive bins and concluded that it is essential to use alternative technological measures to contribute to sustainability [58].

To conclude, several studies have already employed several different systems to reduce waste and litter. In the context of behaviour change, persuasive technologies are often used to achieve the desired behaviour. These technologies employ gamification, normative social influence, engagement through interactivity and more to encourage individuals to perform sustainable behaviour. These techniques often use the power of seeing the actions of others, showing its importance for behaviour change. However, it should be noted that none of the systems mentioned above take self-efficacy into account.

2.5 Augmented Reality

As described in section 1.1, augmented reality (AR) can enhance the real world by visualizing digital information through head-mounted displays or phone screens. This section describes the technology and gives a short overview of the state-of-the-art, outlining some relevant use cases.

Different studies have given different definitions to AR. A study by Rauschnabel et al. describes it as a technology that can combine digital information with the real world, in real-time [59]. Other studies give a bit more nuance to this definition: for instance, an article by Craig describes AR as a medium [60]. As such, it can be used to keep users engaged with the real world, while presenting additional digital information.

AR is a relatively new technology. However, quick progress has been made on its development in the past decade. A survey by Dargan et al. summarizes numerous studies applying AR in various different fields [61]. The study concludes that AR has a bright future with the potential to enrich the lives of many. However, the study acknowledges that the technology is still relatively new: as such, many theoretical, technical and ethical issues remain to be solved. This includes high cost, high complexity, a lack of comfort and more.

The technology can be split into two categories: head-mounted displays and handheld. Head-mounted displays require the user to wear a headset of sorts, usually showing the world through a set of glasses. These glasses can visualize digital information for the user in real-time. On the other hand, handheld AR only requires a smartphone device to visualize information. Handheld AR is more accessible than a head-mounted display, but has inherent limitations due to less powerful hardware.

Both types have unique advantages and disadvantages. As such, one type is often favoured over the other in certain fields. For instance, a survey by Butaslac et al. summarizes the use of AR in the field of training [62]. The study states that head-mounted displays are used more often, as it allows users to perform actions with their hands. Handheld AR is often used for entertainment: a study by Cao et al. describes various different applications of handheld AR within the field of entertainment [63]. For example, AR can be used to create unique mobile games, such as Pokémon GO. Furthermore, the study mentions social media, which allow users to apply filters to themselves or the environment.

Within the context of this research, an important use-case of AR is stimulation and motivation. Both types of AR are often employed to make monotonous tasks less tedious, such as exercises or other physical activities. For instance, a study by Nekar et al. uses AR to increase motivation to perform exercises [16]; furthermore, a study by Althoff et al. proves that Pokémon GO is effective at stimulating physical activity [64].

Lastly, there is little research on the benefits of AR within the field of environmental sustainability. A study by Breves et al. mentions that empirical research on AR's benefits beyond education is minimal [17]: most studies focus on the effectiveness of AR for knowledge acquisition. Furthermore, the study by Breves et al. notes that these studies are often focused on a particular niche and lack a sound methodology. As such, their results cannot be used to make statements about general effectiveness of AR for creating environmental attitudes and behaviours.

Lastly, the study describes three central gaps that should be investigated:

1. The role of psychological and sociodemographic factors.
2. The content of immersive productions.
3. The way in which individuals process information.

A survey by Cosio et al. presents similar findings [13]. In particular, it notes that there is a severe lack of empirical evidence for the benefits of using AR for environmental sustainability. Furthermore, the study supports the notion that the majority of research within this field is focused on education. As we have seen in section 2.2, awareness is not the only factor that stimulates behaviour change: as such, it is unclear how to effectively use AR for stimulating pro-environmental behaviour. Lastly, the study describes the impact of several psychological factors on behaviour change. One of these is self-efficacy: the study identifies a lack of self-efficacy as an obstacle for behaviour change and suggests expanding AR research into this area.

To conclude, AR is a relatively new technology that can enhance the real world by visualizing digital information through head-mounted displays or phone screens, often referred to as handheld AR. Both of these types have advantages and disadvantages in certain fields: head-mounted displays are powerful and allow the user to have their hands free, whereas handheld AR is much more accessible. AR has been employed in various areas, such as training, entertainment, education and more. Within these areas, AR can be used to create motivation for monotonous tasks. Lastly, we have seen that research regarding AR in the context of environmental sustainability is lacking: previous studies have focused primarily on education and awareness rather than behaviour change. Recent studies suggest looking into the role and effects of psychological factors within the context of AR for environmental sustainability. In particular, a lack of self-efficacy is noted as an obstacle for behaviour change: the goal of this research is to address this issue for litter pickup behaviour using handheld AR.

3. Methodology

This chapter describes the methodology in detail. The first section establishes the experiment conditions; the second and third sections cover the design and implementation of FlowerPower respectively; Lastly, the fourth section describes the experimental setup. This section also covers some potential research directions that were not chosen due to time constraints.

3.1 Conditions

This section establishes the experiment conditions. These are based on the two variables from the research question: *perceiving the visualized actions of others* and *physically seeing litter*.

Regarding the first variable, section 1.1 describes two methods for action visualization: web-applications and AR. Both methods will be represented by separate modes, named *list mode* and *AR mode* respectively. Both modes are intentionally similar to allow for an equal comparison; the overall concept is based on Bandura's self-efficacy theory [12]. As described in section 2.3, the theory states that self-efficacy is influenced by four factors: performance accomplishments, vicarious experiences, verbal persuasion and physiological states. AR mode and list mode incorporate performance accomplishments and vicarious experiences: as such, it is hypothesized that both modes will increase participants' self-efficacy. However, it is also hypothesized that AR mode results in a greater sense of self-efficacy than list mode. This is because AR mode shows vicarious experiences more effectively than list mode: it allows users to see all relevant actions in an intuitive manner. By looking around, users can immediately see performed pickups in their vicinity. In contrast, list mode presents actions as comments in a list: users must determine their location on the map to see which comments are relevant for them, which is less intuitive. The map can be hard to interpret due to the limited cognition of the human mind [15]. The design will be further described in section 3.2.
The second variable can be tested by making the distinction between using FlowerPower during a walk and using FlowerPower inside. When using FlowerPower during a walk, the psychological distance between the user and the litter problem is shortened: this is because the user can physically see litter. A study by Chu et al. notes that creating a sense of self-efficacy is more effective at closer psychological distances [65]: hence, we hypothesize that using FlowerPower during a walk results in a greater sense of self-efficacy than using it inside.

Combining the conditions for the two independent variables results in the final conditions, which are as follows:

- AR-out: participants using AR mode during a walk.
- LIST-out: participants using list mode during a walk.
- LIST-in: participants using list mode and being inside.

Note that using AR mode inside is rather pointless and is thus not included. This is because AR mode only shows visualized litter pick-ups in the close vicinity of the user: as such, it is unlikely that AR mode would show anything if the user was inside. To conclude this section, the following is a summary of the three aforementioned hypotheses:

1. AR mode and list mode will increase participants' sense of self-efficacy: hence, participants from all conditions should experience a greater sense of self-efficacy.
2. AR mode will generate more self-efficacy than list mode.
3. Using FlowerPower during a walk results in a greater sense of self-efficacy than using FlowerPower inside.

3.2 Design

As stated in section 1.3, one of the contributions of this research is a prototype of a smartphone application. To test the research question, this prototype will be split into the two aforementioned modes: AR mode and list mode. This section describes the design of both modes, as well as other important design decisions.

The core concept of AR mode is as follows: users can place flowers in the digital world, which can be seen through AR by other players and themselves. This concept focuses on vicarious experiences by letting the user see flowers placed by other users, representing previous litter pick-ups. Furthermore, it loosely incorporates performance accomplishments by allowing the user to see their own previously placed flowers. The user must be near the location of the initial placement to see their own flower.

List mode is very similar. It shows the user a list of performed pick-ups in the form of numbered comments. Exact pick-up locations are shown on a map, where each location corresponds with a comment. List mode acts as an alternative version of AR mode: as stated before, both modes share a similar design to allow for an equal comparison. Users can see comments placed by others, representing vicarious experiences. Similar to AR mode, performance accomplishments are loosely incorporated: users can see their own comments if they happen to come across them in the list.

Originally, a buddy system was planned to incorporate verbal persuasion in AR mode. The system would distinguish AR mode from list mode and would allow users to work together to place a special flower. Consequently, this would encourage users to persuade friends to use FlowerPower. Unfortunately, the buddy system is not implemented due to time constraints. Instead, AR mode adapts a similar system to list mode: users can add a comment to a flower. It can be argued that both modes loosely integrate verbal persuasion through comments: when a user places a flower or registers a litter pick-up in the list, they may choose to encourage other users to pick up litter. However, this is not a requirement. Regarding physiological states, this factor was deemed too dependent on the individual and outside influences. Hence, it is not included in the design of both modes.

The remainder of this section highlights other design decisions. For instance, this project focuses on mobile AR, which has several advantages: firstly, smartphone applications can be distributed to a broad public. As such, this makes it easier to recruit participants for the experiment. Secondly, handheld AR is more practical than head-mounted displays for a variety of reasons. An HMD isolates the user from the environment and makes it difficult to share the experience without sharing the HMD itself [66]. Furthermore, only a fraction of the population owns a display. Within the last four years, only 28.49 million headsets were shipped worldwide [67]. In contrast, 1.73 billion people have access to mobile AR [68]: as such, focusing on mobile AR increases the size of the pool of participants significantly.

As stated before, AR mode uses flowers as digital objects to signify litter pick-ups. This choice is based on thematic reasoning, as flowers represent nature and pro-environmentalism. It should be noted that other objects could be more effective for creating a sense of self-efficacy: yet, research on this topic is non-existent and the effects would most likely not have a large impact on the results.

The core design of FlowerPower introduces a problem: cheating. Users can place a flower without picking up litter, which is practically impossible to detect. Requiring a photo or a recording to place a flower was considered as a possible solution, but was ultimately decided against as it would raise ethical concerns and introduce an extra step to the process. Instead, the decision was made to leave out external incentives like rewards or challenges. This discourages cheaters from placing flowers without picking up litter, as it does not provide additional rewards.

3.3 Implementation

This section describes the implementation of FlowerPower, which consists of two parts: AR mode and list mode. The following sections discuss the implementation of both modes in more detail.

3.3.1 AR mode

AR mode is implemented in Unity 2022.3.19f1. Unity features a wide array of AR integration options. This project uses the AR foundation packages, which implements basic AR features such as tracking and interactions. Furthermore, ARCore is used to build the AR mode to Android platforms.

Building

Unity allows the user to build to Android systems, provided that developer mode and USB debugging are enabled on the phone. However, building to iOS can only be done using a MacBook, which was not available for this research. Furthermore, Android is more common than iOS [69]. Hence, it was chosen to ignore iOS and focus on Android. This decision meant that participants with an iPhone would not be able to install AR mode; to remedy this issue, a separate testing phone was bought. This phone runs on Android and will be used for testing and experimenting.

Flower

As mentioned before, a litter pickup is signified by a digital flower. The model for this flower was created in Blender 4.0. Figures 3.1 and 3.2 show two colorless prototypes and figure 3.3 shows the first colored design. This design has one flaw: the stem looks strange if the flower is placed in the air. Some clouds were added to mitigate this issue, resulting in the final design in figure 3.4.

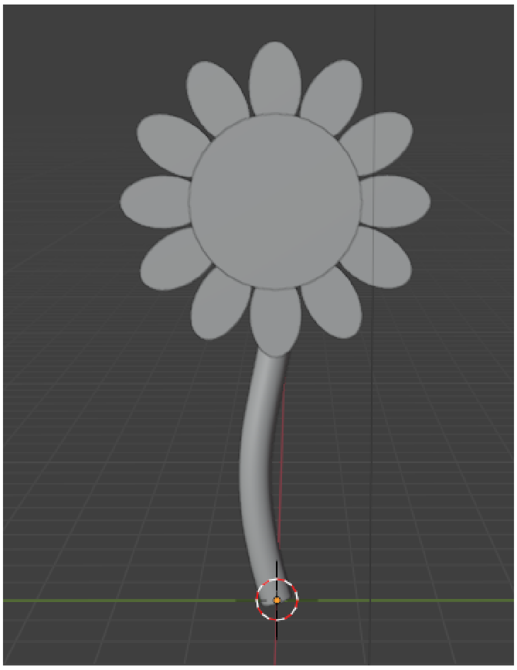

Figure 3.1: The first prototype of the flower design for AR mode.

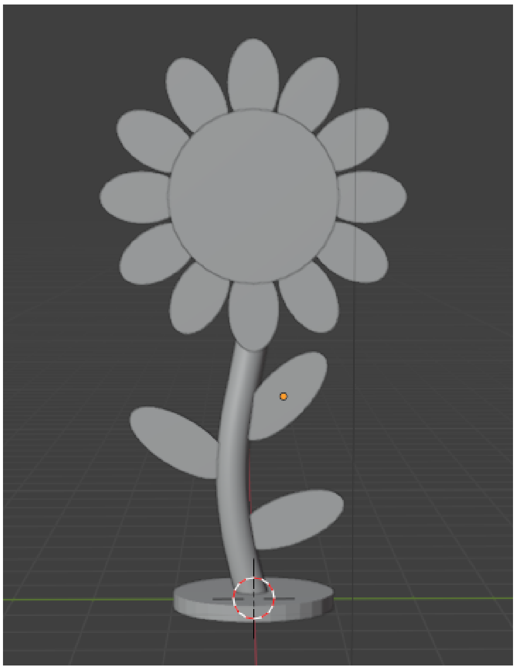

Figure 3.2: The second prototype of the flower design for AR mode. This prototype shows the full structure of the flower.

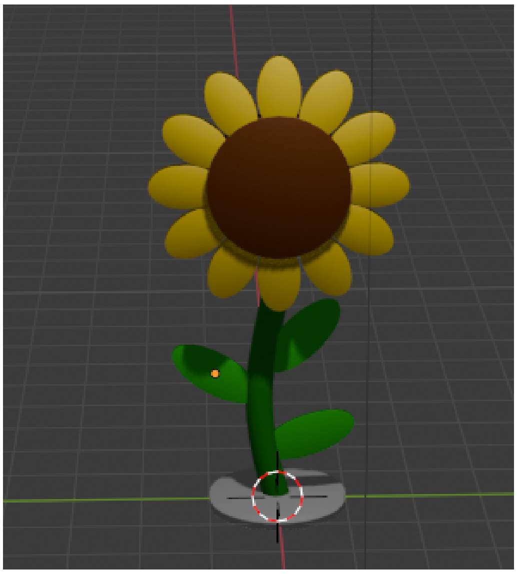

Figure 3.3: The third prototype of the flower design for AR mode. This prototype is identical to the second, but features colors.

Figure 3.4: The final flower design for AR mode. The colors were adjusted and clouds were added to make the flowers look better in the air.

The model needs some form of movement to make it look more dynamic. Initially, the flower model would be given an animation. This animation would need to be imported to Unity, which can be done by exporting it as an FBX file in Blender and subsequently importing the FBX file in Unity. This posed an issue: the stem was animated by moving the control points of a curve. Those control points are lost when exporting the animation as an FBX file. This results in the stem not being animated in Unity. Alternatively, the animation can be imported as an Alembic file, which bakes the animation of the stem into the model. However, this solution does not work for Android, which does not support Alembic. As such, it was decided to add a rotation to the flower instead, which creates sufficient movement.

Two additional features were added in Unity: fog and text bubbles. The fog was implemented to counter a depth issue: to be precise, the perceived distance between the user and the flower is smaller than the actual distance, which creates the illusion that the flowers move with the user. This effect makes it difficult to decipher the exact location of a flower. It would be difficult to remove the effect without using an external API; as such, each flower was given some fog based on the distance between the flower and the camera to simulate depth. For instance, flowers within 20 meters of the camera do not have any fog, whereas flowers farther away from the camera and close to the far viewing plane (100 meters) are completely covered in fog. The fog was implemented using Unity's particle editor: by increasing or decreasing the amount of particles that spawn, the fog gets thicker or fades away.
Text bubbles were implemented to personalize flowers. Each flower contains a text bubble that appears when the user taps on the flower: a bubble contains a name and a description, set by the user who placed the flower.

GPS

As stated in the design, flowers are placed at real-world locations. As such, we need to acquire GPS coordinates of the current location of the phone, which can be used as a reference point for placing the flowers. The basic framework was adapted from a tutorial video [70] and uses the Input module to handle location. When AR mode is booted up for the first time, it requests access to the fine location of the phone. If AR mode has access, it gathers three values: latitude, longitude and compass. Latitude and longitude are continuously updated, whereas the compass is used only once during flower placement.

Requesting GPS coordinates can take varying amounts of time. The process is dependent on the age of the phone: older phones often need to wait several minutes to locate themselves, which is inconvenient for the experiment. Turning on Location Accuracy using Google Services somewhat mitigates this issue but requires an internet connection. It cannot be guaranteed that all participants have a phone that meets these requirements, which was another important reason for buying a separate phone for the experiment.

Placement

Each flower is linked to a set of GPS coordinates. These coordinates need to be translated to Unity's 3D coordinate system, such that flowers will appear at their real-world location in AR. To achieve this, several different APIs were considered, such as Mapbox and the Google Cloud API. However, Mapbox was considered too complex for a project like this; furthermore, the Google Cloud API requires a Google Cloud account, which can take a long time to set up. As such, it was decided to create the translation algorithm from scratch.

Ultimately, the goal is to show flowers that are close to the user. To be more precise, flowers within 100 meters of the phone will be shown to the user. We can use the current location of the phone as a point of reference, which is represented by the camera in Unity. The camera is placed at the origin; as such, we need to calculate the relative positions of nearby flowers. This can be done as follows:

1. Convert the GPS coordinates of the phone to a vector. This vector will be referred to as the *camera vector*: it starts at the center of the Earth and points to a position on the surface of the Earth that corresponds with the GPS coordinates.
2. The length of the camera vector is equal to the radius of the Earth at its surface position. The Earth is not entirely round: as such, we can use the latitude to determine the rough radius at a certain surface position.
3. At the tip of the camera vector, create a plane orthogonal to the camera vector. This will be referred to as the *camera plane* and can be seen in figure 3.5.
4. Each flower has its own set of coordinates. Perform step 1 for all flowers, resulting in a set of vectors. These will be referred to as *flower vectors*.
5. All flower vectors are expanded until they intersect with the camera plane. At each intersection, a flower is placed: this is illustrated by figure 3.6.
6. The camera and flowers are transformed such that the camera is at the origin of Unity's coordinate system and the plane is aligned with the x- and z-axis.
7. Lastly, the flowers are rotated such that the direction of Unity's camera aligns with the direction of the phone camera. This is done using the phone's internal compass.

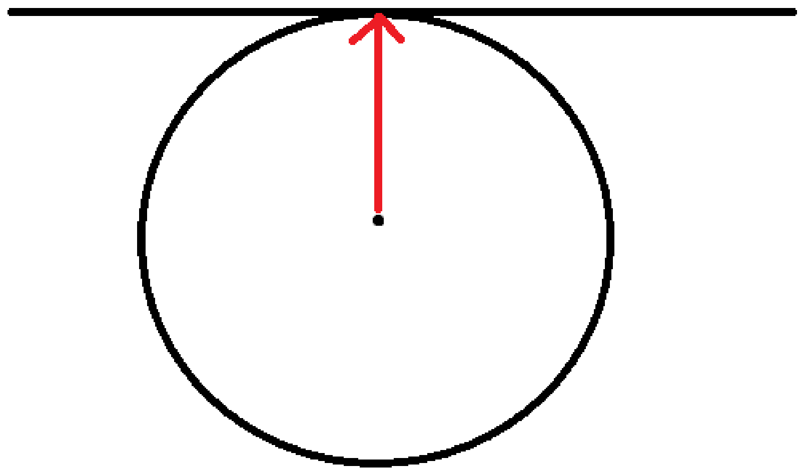

Figure 3.5: The red arrow represents the *camera vector*, which is a vector from the center of the Earth to the position of the phone. The *camera plane* is orthogonal to the camera vector and will be used to place flowers around the phone.

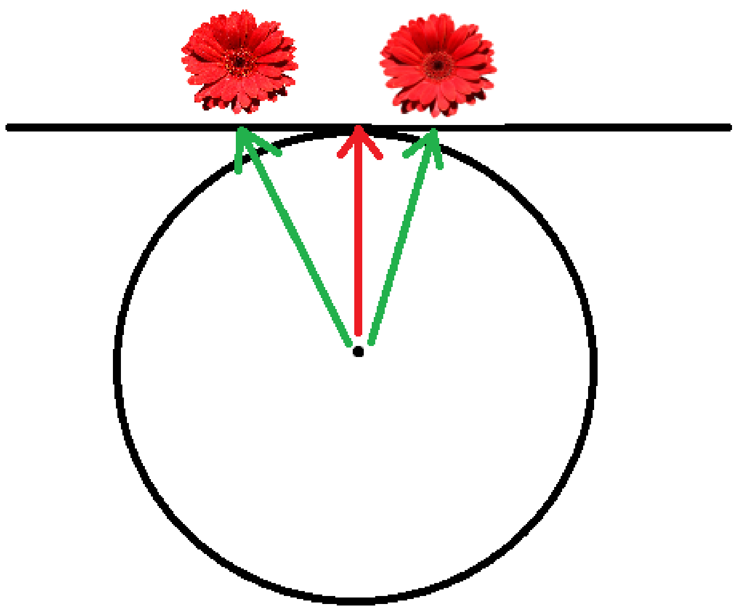

Figure 3.6: The green arrows represent *flower vectors*: a flower vector points from the center of the Earth to its position on the surface Earth. Flower vectors are expanded until they hit the camera plane, resulting in intersections at which flowers are placed.

There are some design choices that need to be addressed. For instance, projecting all flowers onto a plane only works on a small scale. As the user moves further away from the origin, the flower positions become less accurate. This should not pose a problem for the experiment because the walking route is short. Additionally, the error may be negligible for larger routes, but confirming this would require additional testing. A theoretical fix is to occasionally recalculate the flower positions using the current position of the phone as a new point of reference. However, this fix was not implemented for the prototype due to time constraints.

Furthermore, altitude information is ignored. Altitude could be used to place flowers at a certain height; however, its values are too inconsistent. This decision comes with a downside: all flowers are placed at the initial height of the camera. If the user moves vertically, the flowers will remain at the initial height of the camera. This becomes a problem if the user moves a significant vertical distance; the text would become unreadable or flowers would be too far to be rendered. Occasionally moving the flowers to the current height of the camera would be a potential solution, but this was not implemented for the prototype due to time constraints. However, this bears no consequences on the experiment as it will be performed on flat terrain.

Lastly, the placement code is not suited for large amounts of flowers. It will place all flowers, regardless of distance from the camera. This will not be an issue for the experiment, which uses 10 pre-determined flowers. In further development, the issue can be solved by limiting the amount of flowers that the system can place. This can be achieved by sorting flowers based on distance, which allows AR mode to place the top X flowers closest to the camera. However, this solution may not be ideal for improving performance, as it requires the distances to be updated frequently. If the number of flowers is very large, updating distances may harm the performance in the long run. Fine-tuning and testing this solution would take a long time, hence it was not implemented for the prototype.

User-placed flowers

AR mode contains basic functionality for letting the user place a flower. After picking up litter, a user can tap the "Register trash" button in the main menu. This brings up two prompts:

- A *name* prompt, which allows the user to fill in a name.
- A *description* prompt, which allows the user to fill in a description. The user is asked to write about the type of litter that they picked up.

Figure 3.7 shows the two prompts. After filling in these prompts and tapping "Place", a flower is placed at the location of the phone. This flower can be seen in AR and can be interacted with; however, this prototype does not save user-placed flowers. After closing the AR mode, any flowers placed via this method are removed.

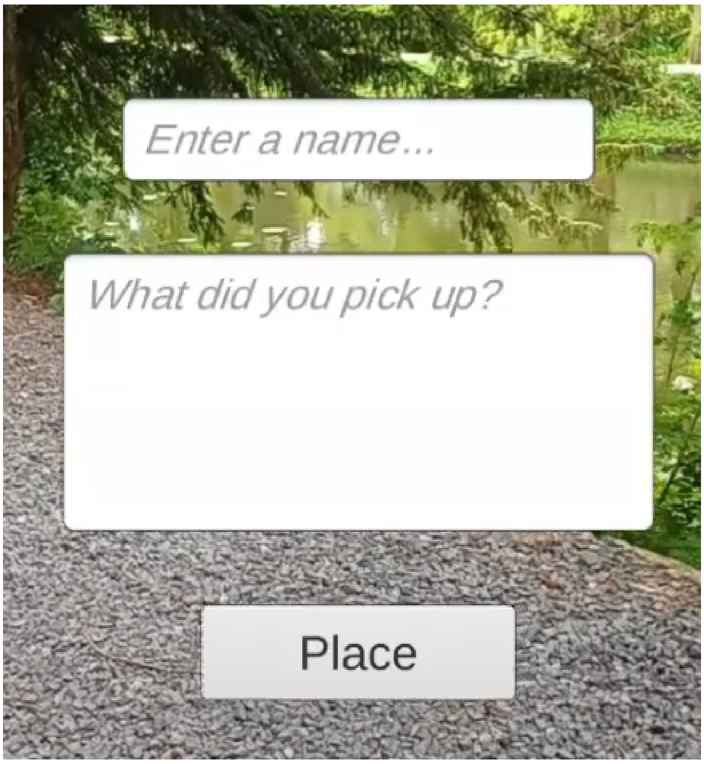

Figure 3.7: The two prompts the user can fill in before placing a flower in AR mode.

Miscellaneous features and decisions

This subsection highlights some miscellaneous features and decisions.

One major problem during development was the issue of refocusing. If AR mode loses track of the environment for an extended period of time, it may reset the AR session. This causes the coordinate system to reset, which shifts flowers to incorrect positions. It is possible to detect when AR mode loses focus; when this happens, AR mode waits until focus is regained and replaces the flowers afterwards.

As mentioned before, the compass is used to align the Unity camera with the phone camera. This poses a problem, as the compass values can be rather inconsistent. To mitigate this issue, AR mode stalls for 3 seconds to give the compass time to initialize. Afterwards it takes an average of values over 2 seconds, resulting in one value that can be used for alignment.

Lastly, the prototype contains a basic UI. This UI informs the user about the state of AR mode, such as when the prototype is initializing or refocusing: this can be seen in figure 3.8. Furthermore, the UI can be used to navigate between AR and registering trash, which can be seen in figure 3.9.

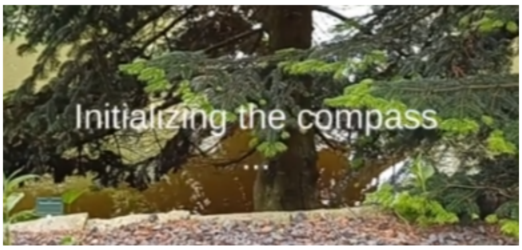

Figure 3.8: The initializing screen when AR mode is booted up.

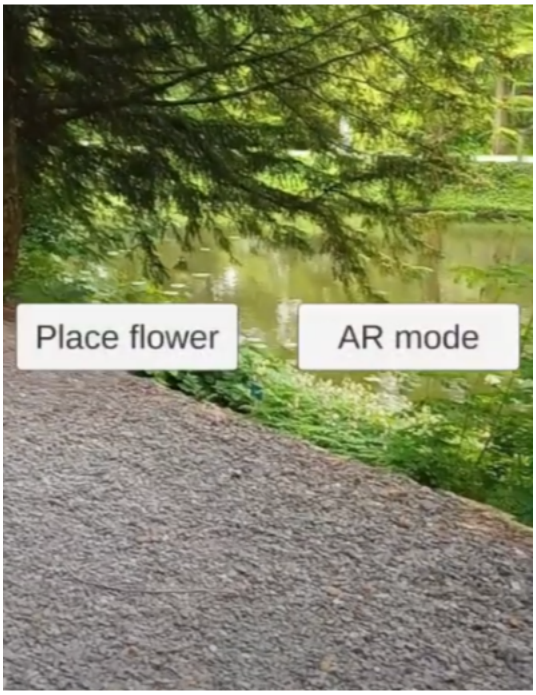

Figure 3.9: The main menu of AR mode. Users can place a flower or select "AR mode" to see other flowers.

3.3.2 List mode

As stated before, list mode is a basic alternative for AR mode. It represents popular map-like approaches like the NL Schoon map [71] and is implemented as a web page. Figure 3.10 shows the concept: at the top of the page, a map with several numbered locations is displayed. Each number corresponds with a comment: these comments contain a name, a description and a photo of the location *after* the litter was picked up. The photo was added to make the comparison with AR mode more equal. We argue that AR mode should still create a greater sense of self-efficacy: AR mode allows users to see the litter in real-time, whereas the photo is only a snapshot in time. Hence, AR mode should still provide a more complete picture of vicarious experiences than list mode.

Trash locations

A map of the botanical gardens. The numbers match the ID's in the table below.

ID	Name	Description	Photo
1	Nick	Saw a plastic cup and threw it away.	
2	Alice	Picked up a plastic bottle!	

Figure 3.10: A snippet of list mode, showing a map of the Botanical Gardens and two entries in the list. Each marker on the map corresponds to the ID of a comment. Furthermore, comments contain a name, a description and a photo of the location after litter was picked up.

The page itself is made using Bootstrap 4.5.2 [72]. It is hosted on an external server to facilitate access from mobile devices. Originally, list mode was planned to contain an interactive map. This map would contain markers to indicate pick-up locations: tapping on a marker would show the corresponding comment. Furthermore, list mode would match AR mode by allowing the user to add a comment. These concepts were unfortunately not implemented due to time constraints.

3.4 Experimental setup

This section describes the experimental setup. It includes details about the location, procedure, target audience and more.

3.4.1 Location

Location is an important variable to take into account: as stated in section 2.1.1, spatial litter distributions could potentially influence the mindset of individuals. To keep the scope of this research reasonable, it was chosen to keep the location for all conditions consistent. In particular, Utrecht Science Park was chosen for accessibility reasons, as it is easily reachable by tram or bus. The AR-out and LIST-out conditions will be tested in the Botanical Gardens, which is located in the middle of Utrecht Science Park. Performing the experiment in a regular urban environment may raise ethical concerns regarding safety, as participants may not be paying attention to the traffic when using FlowerPower. Furthermore, walking through the gardens simulates the feeling of walking through an actual park. The LIST-in condition will be tested in a classroom at Utrecht Science Park, which will be reserved beforehand.

3.4.2 Procedure

The experiment procedure is split into four phases: preparation, pre-experiment, experiment and post-experiment. The preparation phase is identical for all conditions: all participants are given a general explanation of the experiment and are randomly assigned to a condition.

In the pre-experiment phase, participants are given more detailed instructions on what they need to do during the experiment. This includes a small explanation about FlowerPower and how it should be used. In particular, AR-out and LIST-out participants are informed that the FlowerPower is supposed to be used during walks; furthermore, the Botanical Gardens are presented as a "park". LIST-in participants are informed that the FlowerPower should be used inside and not during walks; furthermore, it is made clear that list mode represents a map-like application. If everything is clear, the participants receive a special testing phone. The rest of the experiment is performed on this phone, which eliminates the aforementioned issues that may arise from using FlowerPower on other phones (see section 3.3). After receiving the phone, participants are given a pre-questionnaire, which consists of three parts: a consent form, some demographic questions and questions to measure self-efficacy.

In the experiment phase, participants from the AR-out and LIST-out groups must take a walk around the Botanical Gardens, using their assigned mode during the walk. Participants must walk a specific route, shown in Figure 3.11:

- The black arrow shows the starting point and the direction of the walk.
- The blue line shows the route.
- The red dots show the location of simulated litter pickups, corresponding to specific flowers/comments. Each flower/comment was given a name, description and location close to the route.

Figure 3.11: A map of the Botanical Gardens. The blue line shows the route participants must walk during the experiment; the black arrow indicates the starting point and the direction of the route; the red dots show the location of simulated litter pick-ups, i.e. flowers or comments.

Participants from the LIST-in group are instructed to look at the list in a room at Utrecht Science Park. It should be noted that all are supervised by the researcher, regardless of condition.

In the post-experiment phase, participants must fill in the post-questionnaire, which contains the same self-efficacy questions as the pre-questionnaire and an open field for comments. Lastly, participants receive a small gift for their participation.

3.4.3 Target audience

Another important variable is target audience, as there are several litter reduction strategies aimed towards specific groups. Initially, this research did not have a focus on a particular group. However, after finalizing the location, it became clear that the great majority of participants will be students from Utrecht University. The main reason for this is that the botanical gardens are free for students. As such, it was decided to focus on students, which should be taken into account when analyzing and discussing the results.

3.4.4 Questionnaire

As stated before, this research employs two questionnaires. The first questionnaire contains the consent form, which can be found in appendix A. Furthermore, it contains the following demographic questions:

1. What is your age? (open field)
2. What is your main occupation? I.e. study, job etc. (open field)
3. How would you describe your gender?
    - Male
    - Female
    - Other
    - I'd prefer not to say
4. How often have you visited the botanical gardens?
    - Often
    - Sometimes
    - Never

These questions are meant to capture general statistics and could be used to help explain the results. However, it is important to note that these questions were not specifically chosen to be related to self-efficacy: it was deemed necessary to record demographic data, but it remains to be seen whether this data can be used to explain the results.

Lastly, the pre-questionnaire contains several questions to measure the participants' sense of self-efficacy for picking up litter. The first three were adapted from a study by Xu et al. [73]:

1. I believe I have the ability to use green and low pollution products.
2. I am confident that I can overcome the barriers that prevent me from using green and low-polluting products.
3. I am confident that I can stick with environmentally friendly products that will have long-term benefits.

The study by Xu et al. adapted these questions from a paper by Armitage and Connor [74]. Unfortunately, neither paper provides weights for the individual questions. The implications of this will be described in section 3.4.6.

The first two questions were transformed to fit the context of this research. Furthermore, the third question in the study by Xu et al. combines two factors: habits and long-term outcomes. The study investigates several psychological factors; as such, each questionnaire section was kept rather short. For this research, it would be better to measure both factors independently. Hence, the third question was split into two separate questions about habits and outcomes respectively. This results in the following four questions:

1. I believe I have the ability to pick up litter during walks.
2. I believe that I can overcome the barriers that prevent me from picking up litter during walks.
3. I believe that I can regularly pick up litter during walks.
4. I believe that picking up litter by myself during walks contributes to solving the litter problem.

The original questionnaire uses a 7-point Likert scale. However, a 5-point Likert scale was found to be more practical for this research. This is because 5 points can be translated to the following intuitive responses: strongly agreed, agreed, neutral, disagreed, strongly disagreed.

The post-questionnaire contains the same four self-efficacy questions, meant to be answered with the added context of FlowerPower. This makes it possible to measure potential increases in self-efficacy. Furthermore, there is an open field for comments, encouraging feedback regarding the functionality of the prototype.

3.4.5 Participants

To determine the number of participants needed, participant counts of other studies in the field were examined [75, 76, 77, 78]. The optimal count seems to be around 100 participants. However, this number is not feasible for a research of this scope, given the limited time for the experiment. As such, the goal is to recruit roughly 50 participants.

In the end, 46 participants were recruited. The following demographic data was gathered:

1. The average age is 22.76, with a standard deviation of 2.152. All participants were between the age of 18 and 27.
2. All participants are students at Utrecht University, except for 3. However, these three participants had graduated very recently and will thus be included in the results.
3. The participant group consists of 30 males, 13 females, 2 other, and 1 unspecified.
4. Before the experiment, 15 participants never visited the gardens; 24 participants only visits sometimes; 7 participants visit often.

Two statistical tests were used to check for potential demographic differences between conditions. Firstly, a one-way ANOVA test was applied to the age data. The results of this test are shown in figures 3.12 and 3.13. There are no statistical differences between the conditions regarding age: $F_{age}(0.265) < F_{crit}(3.21), p = 0.768$.

ANOVA

age

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.541	2	1.270	.265	.768
Within Groups	205.829	43	4.787		
Total	208.370	45			

Figure 3.12: Results of the one-way ANOVA test on the age data. There are no significant differences between conditions.

Multiple Comparisons

Dependent Variable: age
Tukey HSD

					95% Confidence Interval	
(I) condition	(J) condition	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
AR-out	LIST-out	.371	.813	.892	-1.60	2.35
	LIST-in	-.200	.775	.964	-2.08	1.68
LIST-out	AR-out	-.371	.813	.892	-2.35	1.60
	LIST-in	-.571	.790	.751	-2.49	1.35
LIST-in	AR-out	.200	.775	.964	-1.68	2.08
	LIST-out	.571	.790	.751	-1.35	2.49

Figure 3.13: Individual comparisons of the conditions regarding the age data. P-values were corrected using the Tukey HSD test; there are no significant differences between conditions.

Secondly, two chi-squared tests were applied to the gender and visits data. The results of these tests are shown in figures 3.14 and 3.15 respectively. There are no statistical differences between conditions regarding gender and visits: $P_{gender} = 0.437, P_{visits} = 0.950$.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.876[a]	6	.437
Likelihood Ratio	6.704	6	.349
Linear-by-Linear Association	1.569	1	.210
N of Valid Cases	46		

a. 9 cells (75.0%) have expected count less than 5. The minimum expected count is .30.

Figure 3.14: Results of the chi-squared test on the gender data. There are no significant differences between conditions.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.708[a]	4	.950
Likelihood Ratio	.697	4	.952
Linear-by-Linear Association	.029	1	.865
N of Valid Cases	46		

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.13.

Figure 3.15: Results of the chi-squared test on the visits data. There are no significant differences between conditions.

3.4.6 Data analysis

Data analysis will be performed using a statistical test. Choosing a fitting test depends on two aspects: variables and type of data.

Regarding the former, the experiment has one dependent variable: self-efficacy. Furthermore, there are two independent variables: the aforementioned conditions and the pre/post-questionnaires. A commonly used test that fits this criterion is the two-way Analysis of Variance (ANOVA). However, ANOVA has one downside: its results are less meaningful if performed on ordinal data. An alternative test exists for ordinal data: ordinal logistic regression. This test fits the aforementioned criterion and provides meaningful results for ordinal data. However, the results are much more difficult to interpret: hence, two-way ANOVA was chosen over ordinal logistic regression.

Applying ANOVA to ordinal data requires us to make the values numerical, which will be done using the following mapping:

- Strongly disagreed → 0
- Disagreed → 1
- Neutral → 2
- Agreed → 3
- Strongly agreed → 4

Furthermore, the two-way ANOVA test will be applied to each individual question. As stated before, the papers by Xu et al. and Armitage et al. do not provide any weights for the individual questions, which prevents us from calculating a weighted average over all questions [73, 74]. However, Xu et al. does provide factor loadings for its questions: 0.754, 0.742 and 0.772 for Q1, Q2 and Q3 respectively. It would be difficult to integrate these factor loadings into our questionnaire; however, it should be noted that the differences between the factor loadings are small. This suggests that each question is roughly as important for measuring self-efficacy. Furthermore, our additional question is merely a separation of Xu's third question. Hence, we will assume that each question is of similar importance for measuring self-efficacy, which allows us to draw general conclusions.

4. Results

This chapter provides an overview of the results. Sections 4.1 and 4.2 show the quantitative and qualitative results respectively.

4.1 Results

The distribution of participants is as follows: AR-out had 15 participants, LIST-out had 14 participants and LIST-in had 17 participants. The following subsections show the results of applying the two-way ANOVA to the self-efficacy questions. To reiterate, these were as follows:

1. I believe I have the ability to pick up litter during walks.
2. I believe that I can overcome the barriers that prevent me from picking up litter during walks.
3. I believe that I can regularly pick up litter during walks.
4. I believe that picking up litter by myself during walks contributes to solving the litter problem.

Each subsection contains several tables for pairwise comparisons. Note that pairwise comparisons need to be corrected, as multiple comparisons can lead to false positives: hence, the pairwise comparison for condition was corrected using the Bonferroni correction. The pre-post variable cannot be corrected, as it can only have two possible values.

4.1.1 Question 1

Tests of Between-Subjects Effects

Dependent Variable: Q1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.589[a]	5	.318	.823	.537
Intercept	1086.515	1	1086.515	2811.359	<.001
condition	1.117	2	.558	1.445	.241
prepost	.403	1	.403	1.044	.310
condition * prepost	.081	2	.041	.105	.901
Error	33.237	86	.386		
Total	1134.000	92			
Corrected Total	34.826	91			

a. R Squared = .046 (Adjusted R Squared = -.010)

Figure 4.1: Tests of between-subjects effects for question 1, summarizing the F- and P-values for the independent variables.

Condition

Multiple Comparisons

Dependent Variable: Q1
Bonferroni

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
AR-out	LIST-out	.1119	.16336	1.000	-.2870	.5108
	LIST-in	-.1549	.15572	.968	-.5351	.2253
LIST-out	AR-out	-.1119	.16336	1.000	-.5108	.2870
	LIST-in	-.2668	.15865	.289	-.6542	.1206
LIST-in	AR-out	.1549	.15572	.968	-.2253	.5351
	LIST-out	.2668	.15865	.289	-.1206	.6542

Based on observed means.
The error term is Mean Square(Error) = .386.

Figure 4.2: Pairwise comparisons of the condition variable for question 1. The P-values were corrected for multiple comparisons using Bonferroni correction.

Pairwise Comparisons

Dependent Variable: Q1

(I) Pre-post	(J) Pre-post	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
Pre	Post	-.133	.130	.310	-.391	.126
Post	Pre	.133	.130	.310	-.126	.391

Based on estimated marginal means
a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 4.3: Pairwise comparisons of the pre-post variable for question 1.

3. Condition * Pre-post

Dependent Variable: Q1

Condition	Pre-post	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
AR-out	Pre	3.400	.161	3.081	3.719
	Post	3.467	.161	3.148	3.786
LIST-out	Pre	3.214	.166	2.884	3.545
	Post	3.429	.166	3.098	3.759
LIST-in	Pre	3.529	.151	3.230	3.829
	Post	3.647	.151	3.347	3.947

Figure 4.4: Pairwise comparisons of the interaction between the conditions and pre-post variables for question 1.

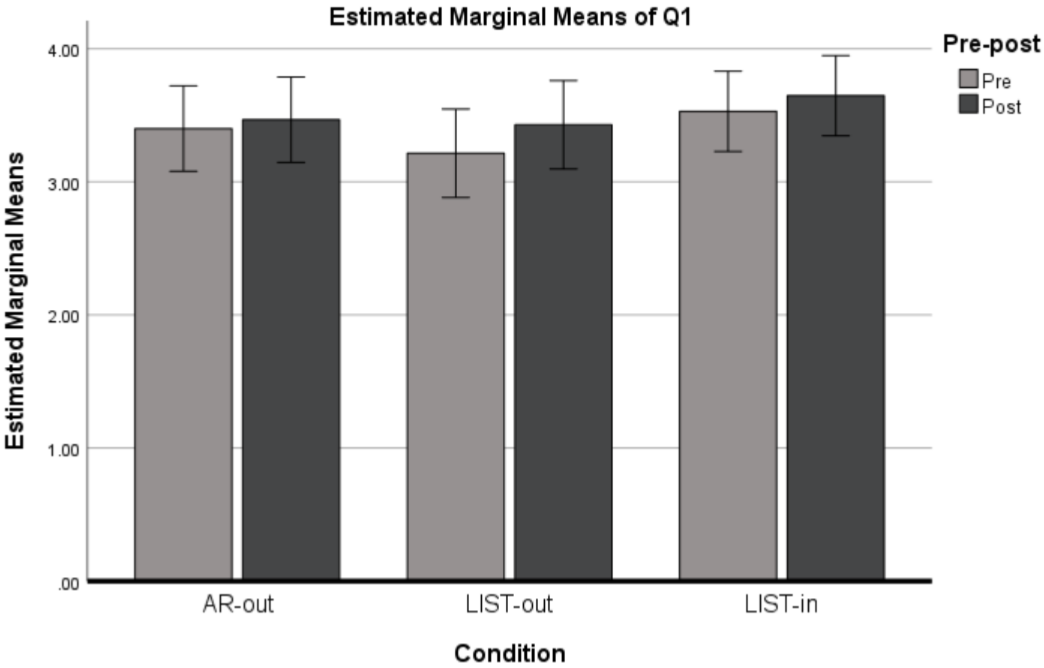

Figure 4.5: A graph showing the estimated marginal means for question 1. The error bars represent 2 x standard error.

4.1.2 Question 2

Tests of Between-Subjects Effects

Dependent Variable: Q2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5.165[a]	5	1.033	1.330	.259
Intercept	806.546	1	806.546	1038.494	<.001
condition	1.928	2	.964	1.241	.294
prepost	2.592	1	2.592	3.337	.071
condition * prepost	.455	2	.227	.293	.747
Error	66.792	86	.777		
Total	888.000	92			
Corrected Total	71.957	91			

a. R Squared = .072 (Adjusted R Squared = .018)

Figure 4.6: Tests of between-subjects effects for question 2, summarizing the F- and P-values for the independent variables.

Condition

Multiple Comparisons

Dependent Variable: Q2
Bonferroni

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
AR-out	LIST-out	-.1643	.23157	1.000	-.7297	.4011
	LIST-in	-.3471	.22075	.359	-.8861	.1920
LIST-out	AR-out	.1643	.23157	1.000	-.4011	.7297
	LIST-in	-.1828	.22490	1.000	-.7319	.3664
LIST-in	AR-out	.3471	.22075	.359	-.1920	.8861
	LIST-out	.1828	.22490	1.000	-.3664	.7319

Based on observed means.
The error term is Mean Square(Error) = .777.

Figure 4.7: Pairwise comparisons of the condition variable for question 2. The P-values were corrected for multiple comparisons using Bonferroni correction.

Pairwise Comparisons

Dependent Variable: Q2

(I) Pre-post	(J) Pre-post	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
Pre	Post	-.337	.184	.071	-.703	.030
Post	Pre	.337	.184	.071	-.030	.703

Based on estimated marginal means
a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 4.8: Pairwise comparisons of the pre-post variable for question 2.

3. Condition * Pre-post

Dependent Variable: Q2

Condition	Pre-post	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
AR-out	Pre	2.667	.228	2.214	3.119
	Post	2.933	.228	2.481	3.386
LIST-out	Pre	2.857	.236	2.389	3.325
	Post	3.071	.236	2.603	3.540
LIST-in	Pre	2.882	.214	2.457	3.307
	Post	3.412	.214	2.987	3.837

Figure 4.9: Pairwise comparisons of the interaction between the conditions and pre-post variables for question 2.

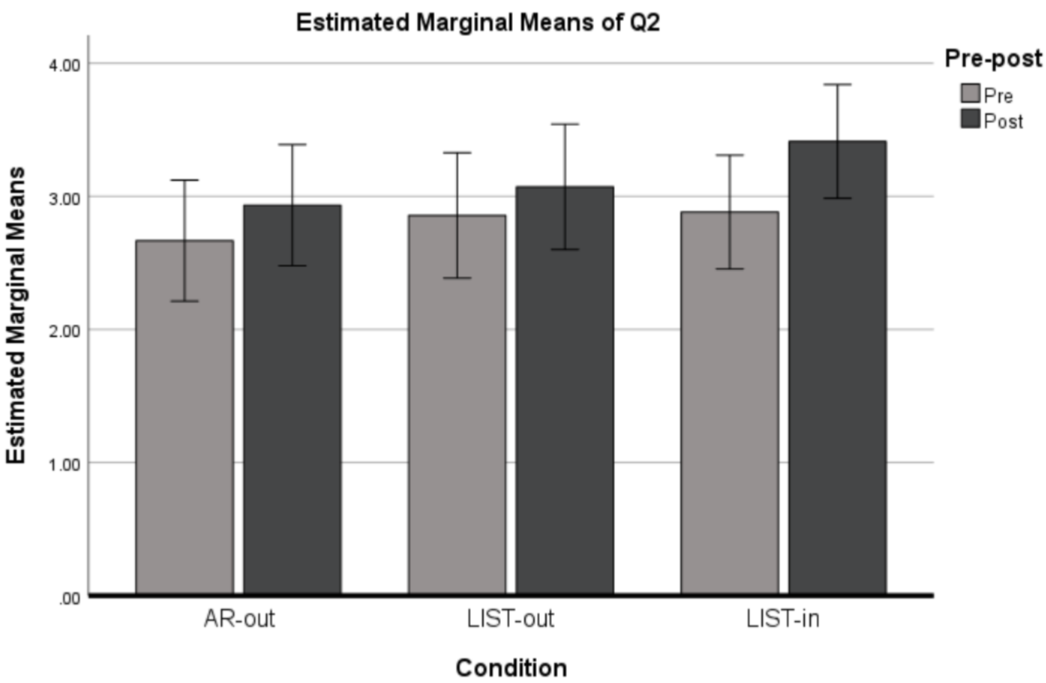

Figure 4.10: A graph showing the estimated marginal means for question 2. The error bars represent 2 x standard error.

4.1.3 Question 3

Tests of Between-Subjects Effects

Dependent Variable: Q3

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5.243[a]	5	1.049	1.251	.292
Intercept	776.883	1	776.883	927.150	<.001
condition	1.698	2	.849	1.013	.367
prepost	3.545	1	3.545	4.230	.043
condition * prepost	.023	2	.011	.014	.986
Error	72.062	86	.838		
Total	858.000	92			
Corrected Total	77.304	91			

a. R Squared = .068 (Adjusted R Squared = .014)

Figure 4.11: Tests of between-subjects effects for question 3, summarizing the F- and P-values for the independent variables.

Condition

Multiple Comparisons

Dependent Variable: Q3
Bonferroni

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
AR-out	LIST-out	-.3381	.24053	.490	-.9254	.2492
	LIST-in	-.2078	.22929	1.000	-.7677	.3520
LIST-out	AR-out	.3381	.24053	.490	-.2492	.9254
	LIST-in	.1303	.23360	1.000	-.4401	.7006
LIST-in	AR-out	.2078	.22929	1.000	-.3520	.7677
	LIST-out	-.1303	.23360	1.000	-.7006	.4401

Based on observed means.
The error term is Mean Square(Error) = .838.

Figure 4.12: Pairwise comparisons of the condition variable for question 3. The P-values were corrected for multiple comparisons using Bonferroni correction.

Pairwise Comparisons

Dependent Variable: Q3

(I) Pre-post	(J) Pre-post	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	95% Confidence Interval for Difference[b] Upper Bound
Pre	Post	-.394[*]	.191	.043	-.775	-.013
Post	Pre	.394[*]	.191	.043	.013	.775

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 4.13: Pairwise comparisons of the pre-post variable for question 3.

3. Condition * Pre-post

Dependent Variable: Q3

Condition	Pre-post	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
AR-out	Pre	2.533	.236	2.063	3.003
	Post	2.933	.236	2.463	3.403
LIST-out	Pre	2.857	.245	2.371	3.343
	Post	3.286	.245	2.799	3.772
LIST-in	Pre	2.765	.222	2.323	3.206
	Post	3.118	.222	2.676	3.559

Figure 4.14: Pairwise comparisons of the interaction between the conditions and pre-post variables for question 3.

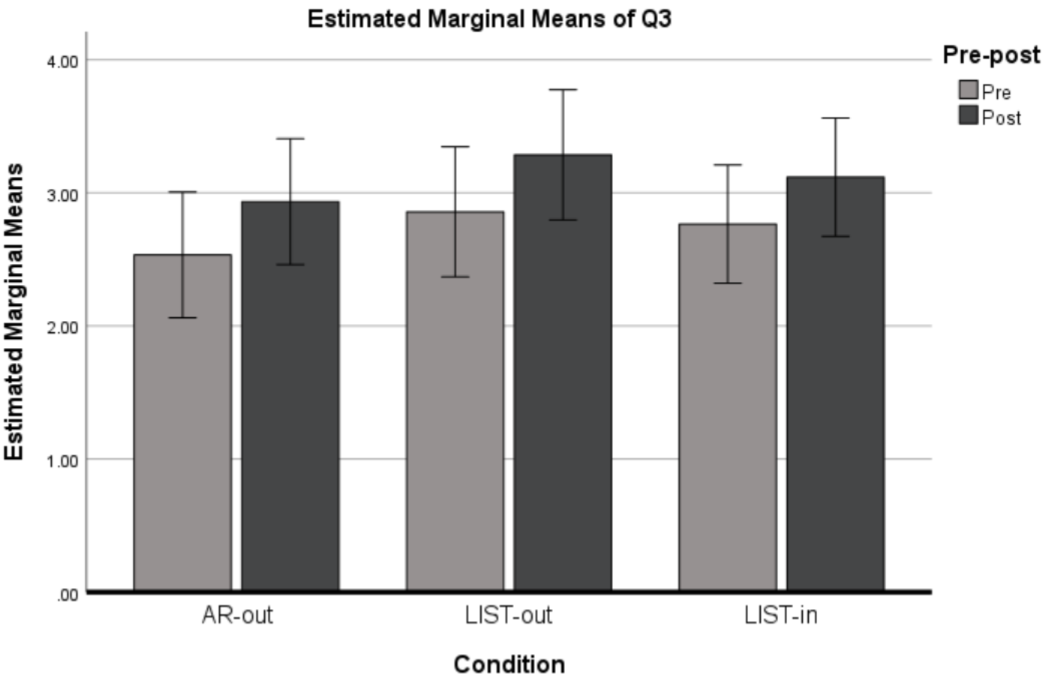

Figure 4.15: A graph showing the estimated marginal means for question 3. The error bars represent 2 x standard error.

4.1.4 Question 4

Tests of Between-Subjects Effects

Dependent Variable: Q4

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.872[a]	5	.974	.912	.477
Intercept	688.883	1	688.883	644.885	<.001
condition	3.475	2	1.737	1.626	.203
prepost	1.103	1	1.103	1.033	.312
condition * prepost	.310	2	.155	.145	.865
Error	91.868	86	1.068		
Total	798.000	92			
Corrected Total	96.739	91			

a. R Squared = .050 (Adjusted R Squared = -.005)

Figure 4.16: Tests of between-subjects effects for question 4, summarizing the F- and P-values for the independent variables.

Condition

Multiple Comparisons

Dependent Variable: Q4
Bonferroni

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
AR-out	LIST-out	.1643	.27159	1.000	-.4988	.8274
	LIST-in	-.3000	.25889	.749	-.9321	.3321
LIST-out	AR-out	-.1643	.27159	1.000	-.8274	.4988
	LIST-in	-.4643	.26376	.246	-1.1083	.1797
LIST-in	AR-out	.3000	.25889	.749	-.3321	.9321
	LIST-out	.4643	.26376	.246	-.1797	1.1083

Based on observed means.
The error term is Mean Square(Error) = 1.068.

Figure 4.17: Pairwise comparisons of the condition variable for question 4. The P-values were corrected for multiple comparisons using Bonferroni correction.

Pairwise Comparisons

Dependent Variable: Q4

(I) Pre-post	(J) Pre-post	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
Pre	Post	-.220	.216	.312	-.650	.210
Post	Pre	.220	.216	.312	-.210	.650

Based on estimated marginal means
a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 4.18: Pairwise comparisons of the pre-post variable for question 4.

3. Condition * Pre-post

Dependent Variable: Q4

Condition	Pre-post	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
AR-out	Pre	2.667	.267	2.136	3.197
	Post	2.733	.267	2.203	3.264
LIST-out	Pre	2.357	.276	1.808	2.906
	Post	2.714	.276	2.165	3.263
LIST-in	Pre	2.882	.251	2.384	3.381
	Post	3.118	.251	2.619	3.616

Figure 4.19: Pairwise comparisons of the interaction between the conditions and pre-post variables for question 4.

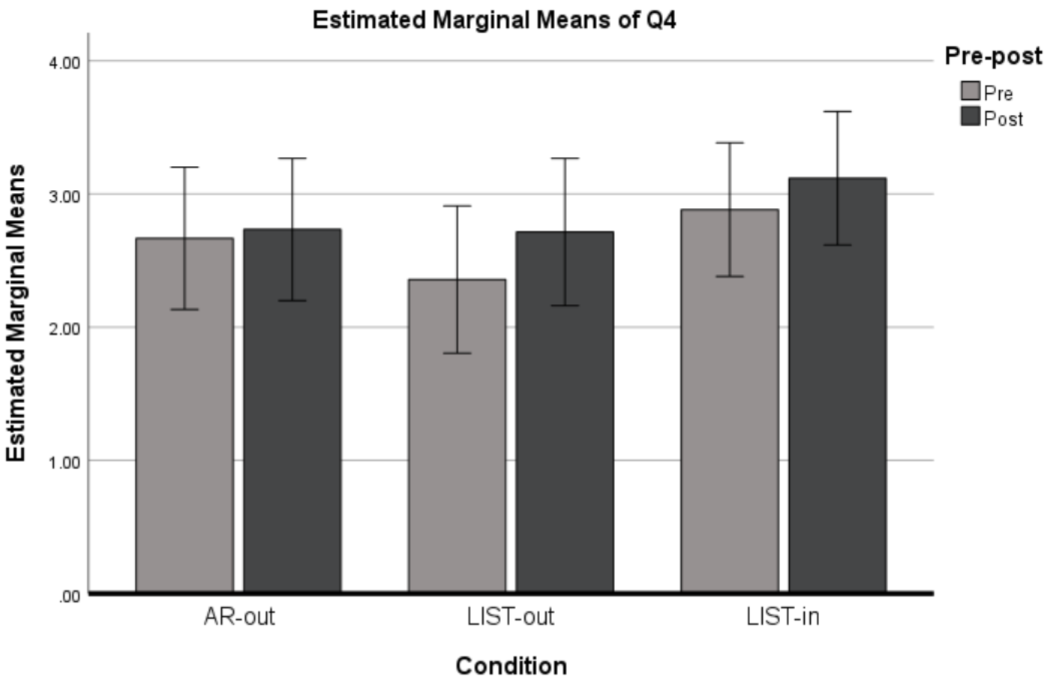

Figure 4.20: A graph showing the estimated marginal means for question 4. The error bars represent 2 x standard error.

4.1.5 Summary

Figure 4.21 summarizes the P- and F-values in a single table. Furthermore, figure 4.22 shows the critical F-values for both independent variables and the interaction between the variables.

Questions	P_{cond}	$P_{prepost}$	$P_{condxprepost}$	F_{cond}	$F_{prepost}$	$F_{condxprepost}$
Q1	0.241	0.310	0.901	1.445	1.044	0.105
Q2	0.294	0.071	0.747	1.241	3.337	0.293
Q3	0.367	0.043	0.986	1.013	4.230	0.014
Q4	0.203	0.312	0.865	1.626	1.033	0.145

Figure 4.21: P- and F-values for each question.

	Condition	Pre-post	Condition x pre-post
F_{crit}	3.10	3.95	3.10

Figure 4.22: Critical F-values for both independent variables and the interaction between the variables.

4.2 Comments

This section summarizes the comments: each comment was counted and categorized. It is important to note that the prompt asked for comments regarding the functionality of the prototype. Furthermore, self-efficacy was not mentioned in the pre-experiment phase. Hence, the majority of comments pointed out practical flaws and did not focus on self-efficacy.

Several comments criticized the general concept of FlowerPower:

- Six participants pointed out the lack of an incentive, such as gamification through challenges and rewards or community interaction.
- Three participants mentioned that FlowerPower introduces an extra barrier for picking up litter.
- Two participants stated that they found it odd to walk around with their phone out for long periods of time.
- Two participants were not convinced that picking up litter would solve the actual problem.
- Two participants noted that a lack of timestamps brings question to a flower/comment's effectiveness.
- One participant pointed out that there is no difference between a clean area, an area without any app-users or an area without any litter pickups (from the perspective of the application).
- One participant expressed that it would be nice to highlight areas where litter needs to be picked up, but this would be difficult due to the problem described above.

Other comments talk about the impact of the type of trash:

- One participant pointed out that certain types of litter will be easier to pick up than others.
- One participant mentioned the impact of fear of contamination.

Many participants pointed out technical flaws of AR-mode. Participants frequently found it difficult to determine the exact location of flowers. Multiple reasons were listed:

- Three participants stated that flowers looked like they were moving with the user.
- One participant noted that flowers were not obscured by real-world objects.
- One participant mentioned that the meaning of the fog was unclear. This was not explicitly told beforehand, as it seemed intuitive to understand.

Furthermore, several participants criticized the text display above the flowers:

- Two participants found the text hard to read in certain situations.
- One participant mentioned that tapping flowers to see the text was inconvenient.

A few participants wrote down some miscellaneous comments about AR mode:

- One participant wanted more variety regarding flower types.
- One participant found it hard to pay attention to the environment while using FlowerPower.

The list application received some comments as well:

- One participant noted that photos can be hard to recognize and should be more prominent within the application.

- One participant suggested the addition of a photo before picking up litter, showing the change a little more clearly.
- One participant found the description of a comment distracting, emphasizing the need to guide the user while writing a comment.

Lastly, there were several general comments about FlowerPower:

- One participant mentioned the possibility of fraud.
- One participant suggested that flowers or comments should be clustered if too many are in close proximity.
- One participant recognized the social incentive of the application.
- Two participants noted that the Botanical Gardens are not quite representative of a real-world park, as they are cleaned often.

5. Discussion

This chapter discusses the results. The first section analyzes the results and the second section discusses limitations and potential future research directions.

5.1 Analysis

This section provides some insight into the results. Important observations are highlighted and relevant results are discussed.

First and foremost, it should be noted all quantitative results are insignificant. The only exception is the difference between the pre- and post-questionnaire for question 3, which is significant with $P_{prepost} = 0.043$ and $F_{prepost}(4.203) > F_{crit}(3.95)$.

The lack of differences between conditions can be explained for all questions by splitting the research question and analyzing the two variables independently. Regarding the notion of *perceiving the actions of others*, it was hypothesized in section 3.1 that AR mode would create a more complete picture of vicarious experiences than list mode, consequently resulting in a greater sense of self-efficacy. However, we have seen that this is not the case. We argue that the effect of vicarious experiences is not enough on its own to create a significant difference in self-efficacy generation between AR mode and list mode. Bandura states that performance accomplishments play a bigger role for generating self-efficacy than vicarious experiences [12]. This is because personal experience and mastery have a greater effect on one's sense of self-efficacy than the actions of others. Furthermore, we argue that the absence of verbal persuasion contributed to the lack of differences. Bandura notes that the effect of verbal persuasion on self-efficacy is smaller than the effect of performance accomplishments; however, it is still an important part of self-efficacy.
Alternatively, it can be argued that vicarious experiences could have been integrated more effectively. Several participants failed to recognize the social incentive, noting that FlowerPower needed some other form of incentive. This could be attributed to the fact that all comments in the experiment were placed by strangers; we have seen that individuals are more likely to be persuaded by friends or relatives, as demonstrated by Lafreniere's strategy to recruit volunteers [32]. Thus, the effects of vicarious experiences could have been weakened by the lack of a strong social incentive through friends or relatives.

Regarding the notion of *physically seeing litter*, it was hypothesized that using FlowerPower during a walk results in a greater sense of self-efficacy than using it inside. We argued that this difference can be attributed to the psychological distance between the individual and the litter problem: a user would physically see litter when using FlowerPower outside, shortening the psychological distance and consequently increasing self-efficacy levels. We argue that the aforementioned lack of differences between conditions does not reject the hypothesis: this is because there is almost no litter in the Botanical Gardens. The gardens can be categorized as a recreational space: as stated in section 2.1.1, this type of space is considered relatively clean [22]. Furthermore, the gardens are regularly cleaned by volunteers. Hence, we can conclude that the psychological distance between users and the litter problem was equal for all participants, thus resulting in no differences between levels of self-efficacy. However, we cannot accept the hypothesis either, as there is insufficient evidence for the notion that a smaller psychological distance leads to a greater sense of self-efficacy for picking up litter.
Additionally, it can be argued that the effect of physiological states mitigates potential increases in self-efficacy even further. Physiological states refer to the state of the individual: Bandura notes that fear and stress can reduce levels of self-efficacy. In section 3.4.5, we saw that the majority of participants do not frequently visit the gardens. Hence, most participants in the AR-out and LIST-out conditions were unfamiliar with the Botanical Gardens, which can lead to stress

or fear, consequently leading to less self-efficacy. On the contrary, all participants were (former) students of the Utrecht University and knew about the location for the LIST-in condition, leading to a greater level of self-efficacy. This is supported by the results: the LIST-in condition results in a greater level of self-efficacy than the other two conditions for questions 1, 2 and 4. However, it should be noted that these self-efficacy differences are not significant, but they are present nonetheless.

The following paragraphs will analyze each question individually. Within these paragraphs, we will attempt to explain the relation between the pre- and post-questionnaire for each question. Furthermore, we will provide additional reasoning regarding the lack of differences between conditions if needed.

Question 1's general lack of differences can attributed to two different reasons. Firstly, the phrase "ability to pick up litter" incorporates the physical ability to pick up litter. As such, it makes sense that there is no difference between conditions: physical abilities are entirely independent from self-efficacy. Furthermore, physical abilities are unlikely to change within the duration of the experiment. This would explain why participants would not change their response after the experiment, as they would not be "more capable" of picking up litter than before.
Mental abilities are unlikely to change as well: picking up litter is a trivial task that does not require much thought. Hence, it is likely that most participants already knew how to pick up litter before the experiment, and would still possess the ability after the experiment.

Regarding question 2, the lack of differences between conditions can also be attributed to specific types of barriers. To be precise, there are various types of barriers that are independent of self-efficacy, such as structural barriers and deep-rooted instincts [15]. These barriers are unlikely to be affected by using FlowerPower. For instance, a few participants mentioned fear of contamination: this fear is deep-rooted, complex and persistent [79]. Another external barrier that came up is the type of litter: certain types of litter are easier to pick up than others. Section 2.1.1 states that there is no research on the effect of litter types on the mindset of individuals, but this does not mean that no such effect exists.
Looking at the lack of differences between the pre- and post-questionnaires, we argue that FlowerPower does not generate enough self-efficacy to overcome internal barriers. As stated in section 3.2, FlowerPower's design is primarily based on vicarious experiences and performance accomplishments. However, participants did not place any flowers beforehand: hence, the overall self-efficacy generation primarily relied on vicarious experiences. As we established earlier in this section, vicarious experiences is generally considered to be a weaker factor for generating self-efficacy. This is because it relies on the actions of others, rather than one's own experience [12]. As such, it seems likely that vicarious experiences alone are not enough to create a significant increase in self-efficacy.

Question 3 is the only question with a significant difference between the pre- and post-questionnaire. When answering this question, it is likely that participants were thinking of habits: the term "regularly suggests habitual behaviour. This would explain why participants were confident they would be able to pick up litter regularly using FlowerPower, as habits are extremely persistent [15]. Once the habit to pick up litter has been created, it is unlikely to go away. As such, FlowerPower would be able to help with creating such a habit, resulting in regular pickups. Another reason could be that participants felt like FlowerPower would fit well into their daily routine. However, this is unsupported by the comments.

Regarding the lack of differences between the pre- and post-questionnaires for question 4, it is likely that FlowerPower was perceived to not have any effect on the litter problem. This could be attributed to the notion presented for question 2's lack of differences: within the experiment, FlowerPower relied solely on vicarious experiences to create a sense of self-efficacy. Alternatively, it can be argued that the connection between FlowerPower and picking up litter was unclear. In all conditions, participants did not see any litter: this may have caused participants to question the purpose and consequently the long-term effectiveness of FlowerPower.

To summarize the analysis regarding the pre- and post-questionnaires, there was a lack of differences in levels of self-efficacy for 3 out of 4 questions. It seems likely that this is a consequence of our focus on vicarious experiences: we argued that this factor cannot cause a significant increase in self-efficacy on its own. However, an important observation to make is that participants were still slightly more positive in the post-questionnaire. Furthermore, the results for question 3 do show a significant increase in self-efficacy: this supports our hypothesis that FlowerPower improved participants' sense of self-efficacy in all conditions, albeit only slightly. This suggests that both prototypes have potential, which can be unlocked by integrating the aforementioned self-efficacy factors more effectively; more on this in section 5.2.

Another observation to make is that most participants were positive, regardless of condition or pre- and post-questionnaire. This can be attributed to the fact that all participants were between the age of 18 and 27: research states that younger people tend to be more pro-environmental [80, 81], which positively correlates with self-efficacy [41]. Furthermore, research states that young individuals generally have more self-efficacy than old individuals [82]. Other demographic factors may also influence environmental attitudes, consequently leading to greater levels of self-efficacy: for instance, a study by Lang et al. notes that students from different studies tend to have different environmental attitudes [83]. However, it is difficult to use this information to draw direct conclusions, as most participants did not specify their exact study. Moreover, the study states that their conclusion is based on several factors, such as financial security and political ideologies. Regarding gender differences, research states that males generally have a greater sense of self-efficacy than females [82]. Specifically, young males tend to have high levels of self-efficacy, which helps explain the general positivity in the responses.

Lastly, it should be noted that the comparison is unequal. In the initial design, list mode was supposed to match AR mode by allowing the user to add comments and to interact with comments on a map. As stated in section 3.2, these features were not implemented due to time constraints. To make up for this, participants in the list conditions were given an explanation as to how the mode would function if it were fully implemented. This left part of the functionality of list mode to the imagination of the participant. Because of this, practical limitations came up less often for list mode as it would be difficult to think of limitations of non-existent features.
Furthermore, the experiment explanation contained a flaw. As stated earlier, all participants were given a condition-specific use-case for a realistic scenario; as demonstrated by research, explanations have a significant influence on decision making [84]. Hence, we argue that the provided use-case influenced participants' responses to the questionnaire. To be precise, participants interpreted the use-case as a strict instruction: this is supported by several comments, which state that FlowerPower would introduce an extra step for picking up litter. This suggests that participants saw FlowerPower as a requirement, not a tool. This misinterpretation caused participants to be more critical of the effects of FlowerPower, which explains part of the lack of differences regarding the pre- and post-questionnaires.

5.2 Limitations & future work

This section addresses some of the limitations of this research. Furthermore, some potential future work directions are discussed.

An important limitation of this research is the focus on vicarious experiences. As stated in section 5.1, self-efficacy generation during the experiment was primarily based on vicarious experiences, which led to a lack of differences between conditions and the pre- and post-questionnaires. This raises a question: would the other factors have a greater effect on self-efficacy generation than vicarious experiences? Hence, future research should investigate the effects of individual factors on self-efficacy generation, as well as looking into the effect of all factors combined. To accomplish this, the remaining factors should be integrated into the design of FlowerPower, which can be done as follows:

1. Performance accomplishments can be integrated by showing the user a list of their own flowers or comments.

2. Verbal persuasion can be integrated through the buddy system. As described in section 3.2, such a system would encourage users to verbally persuade their friends to join them.
3. Physiological states cannot be implemented directly, but their influence on one's sense of self-efficacy can be measured in a questionnaire.

Furthermore, we established that the effect of vicarious experiences could have been greater. Future research should seek to improve the effect of vicarious experiences by adding timestamped comments. The idea is that recently placed flowers show a more accurate representation of vicarious experiences in the area; as a bonus, this concept can also be applied to performance accomplishments, as more recent accomplishments could have a greater effect on one's sense of self-efficacy. Furthermore, participants highlighted various technical flaws with AR mode; fixing these flaws could help to increase the effect of vicarious experiences.

Another limitation is the aforementioned unequal comparison. Due to time constraints, LIST mode was unable to be fully realized as a map-like application. To make up for this, participants were told how list mode would function if it were fully implemented. While the core functionality remains similar to AR-mode, participants had to imagine the missing features based on the given explanation. We argued that practical limitations would come up less often for list mode because of this. Hence, future research should focus on creating a proper map-like application, such that future comparisons are equal.

The experiment itself was limited by several factors. Firstly, the participant pool was limited to students and recently graduated individuals. This choice was necessary to recruit enough participants but comes with a downside: the participant pool is not representative of the general population. To be precise, the majority of participants were young, male students: research states that these qualities all correlate with a greater sense of self-efficacy [82]. Secondly, the size of the participant pool was rather limited: this was another deliberate choice to be able to recruit enough participants. However, this choice has implications for the accuracy of the results, as ANOVA usually requires a large sample size. Therefore, future research should seek to expand the participant pool by increasing the size of the pool and including participants from different sociodemographic groups.

Location also played a large role during the experiment. As stated in section 3.4.1, the Botanical Gardens were chosen for safety and accessibility reasons. However, the gardens are not a good representation of the general urban environment, as pointed out by a few participants. This is because the gardens can be classified as a recreational space, which contains less litter than other types of urban environments like commercial and diverse spaces [22]. Furthermore, the gardens are frequently cleaned: as such, there is significantly less litter compared to regular parks. This has a consequence: participants from all groups did not see any litter. As such, the psychological distance between each participant and the litter problem remained stagnant, consequently leading to no differences in self-efficacy. Hence, future research should further investigate the effect of physically seeing litter on participants' sense of self-efficacy. This can be done by manually placing pieces of litter on the ground before performing the experiment, which would not have been possible for this project due to ethical considerations.

Lastly, the analysis itself is limited by two factors. Firstly, ANOVA's results are less meaningful when performed on ordinal data. The decision to use ANOVA over other method was deliberate, as it allowed us to interpret the results. However, future research should use ordinal logistic regression instead, as it gives more meaningful results when performed on ordinal data. Secondly, we assumed that each question is roughly as important for measuring self-efficacy, based on the factor loadings of the paper by Xu et al. [73]. This assumption was necessary to draw conclusions; however, the exact weights of each question are unknown. Hence, future research should focus on determining the importance of each question.

6. Conclusion

In this thesis, we sought to answer the following research question:

To which extent does perceiving visualized actions of others in combination with physically seeing litter create a sense of self-efficacy for picking up litter in an urban environment?

To answer this question, we investigated the effects of *perceiving visualized actions of others* and *physically seeing litter* on creating a sense of self-efficacy for picking up litter.

To test the effect of perceiving visualized actions of others, we developed two prototypes of a smartphone application named FlowerPower: AR mode and list mode. The design of these prototypes is based on Bandura's self-efficacy theory, integrating vicarious experiences and performance accomplishments. AR mode allows the user to perceive visualized actions using AR, presenting litter pickups as digital flowers. List mode is presented as a basic alternative, showing litter pickups in the form of comments in a list. We hypothesized that both modes would increase participants' sense of self-efficacy; furthermore, we also hypothesized that AR mode would create a greater sense of self-efficacy than list mode by giving a more complete picture of vicarious experiences.

To test the effect of physically seeing litter, we sought to investigate the difference between using FlowerPower inside and using FlowerPower during a walk. We hypothesized that using FlowerPower during a walk would result in a greater level of self-efficacy: the user would physically see litter, shortening the psychological distance between them and the litter problem. Consequently, this would lead to a greater sense of self-efficacy.

All hypotheses were tested in an experiment. This experiment combined the variables in the research question into three different conditions: AR-out, LIST-out and LIST-in. Quantitative results were gathered using a pre- and post-questionnaire, containing questions to measure potential changes in self-efficacy for picking up litter. Furthermore, qualitative results were gathered using an open comment question.

Regarding the pre- and post questionnaires, the results showed that there were no significant changes in self-efficacy ratings for three out of four questions: we argued that this is a consequence of focusing on vicarious experiences. However, we also observed that participants were still slightly more positive in the post-questionnaire; furthermore, the analysis of question 3 did show a significant difference in self-efficacy ratings. Thus, we accept the first hypothesis and we can conclude that both variants of FlowerPower improved participants' sense of self-efficacy, albeit only slightly.

Regarding the conditions, the results showed that there were no significant difference in self-efficacy ratings between the three aforementioned conditions. We argued that there were two reasons for this:

1. Regarding the two modes, we reasoned that this lack of differences can be attributed our focus on vicarious experiences: the effect of this factor is not enough on its own to create a significant difference in self-efficacy levels between AR mode and list mode. Additionally, we argued that vicarious experiences could have been implemented more effectively. Hence, we reject the second hypothesis and we can conclude that AR mode does not create a greater sense of self-efficacy than list mode.
2. Regarding in/out, we reasoned that the psychological distance between the user and the litter problem was equal for all participants, consequently leading to no differences in self-efficacy. This is because the Botanical Gardens did not have any visible litter: as such, participants in the AR-out and LIST-out conditions were not exposed to litter.

> The findings suggest that we cannot reject the third hypothesis; however, there is insufficient evidence to support the claim that a smaller psychological distance would lead to a greater sense of self-efficacy.

When interpreting these results, we established several limitations. The qualitative analysis revealed various technical issues in AR mode, as well as the inequality of the comparison between AR mode and list mode. Furthermore, our conclusions can only be applied to the demographic of young, primarily male students. Lastly, we established that the analysis could have been more meaningful by using ordinal logistic regression instead of ANOVA.

To conclude, the experiment suggests that perceiving visualized actions of others does not create a greater sense of self-efficacy for picking up litter than seeing such actions in a list. Furthermore, there is inconclusive evidence to confirm whether physically seeing litter has an effect on self-efficacy for picking up litter. However, the use of AR mode and list mode slightly increased participants' sense of self-efficacy in all conditions, given the limitations of the research. As such, we argue that both prototypes have potential: to unlock this potential, it is recommended to integrate verbal persuasion and psychological states, as well as improving the integration of vicarious experiences and performance accomplishments. Furthermore, future research should investigate the effects of these individual factors, as well as researching the notion that physically seeing litter affects one's sense of self-efficacy for picking up litter.

Appendices

A. Consent form

This consent form was adapted from `https://www.uu.nl/en/media/90795`. All points that were not applicable for this research have been removed.

Before proceeding, please read the information below.

- I confirm that I am 18 years of age or over.
- I confirm that the research project "FlowerPower" has been explained to me. I have had the opportunity to ask questions about the project and have had these answered satisfactorily.
- I had enough time to consider whether to participate.
- I consent to the material I contribute being used to generate insights for the research project "FlowerPower".
- I understand that my participation in this research is voluntary and that I may withdraw from the study at any time without providing a reason.
- I consent to allow the fully anonymized data to be used in future publications and other scholarly means of disseminating the findings from the research project. I understand that the data acquired will be securely stored by researchers, but that appropriately anonymized data may in future be made available to others for research purposes.
- I understand that the University may publish appropriately anonymized data in appropriate data repositories for verification purposes and to make it accessible to researchers and other research users.

I have read the information above and I consent to participating in this research.

- Yes
- No

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