Encouraging Stair Use: How to Motivate People to Choose Stairs Over the Elevator?

Filip Tatarek

Bachelor’s Thesis

Creative Technology

UNIVERSITY OF TWENTE

Supervisor: Sebastian Schneider

Critical observer: Adrea Papenmeier

January 2025

Abstract

Physical inactivity is a growing concern, especially at universities, where students and employees tend to spend the majority of their day sitting. It can have negative effects on health, from increasing the risk of chronic diseases to deterioration of mental well-being. A simple and accessible way of tackling this issue is to encourage stair use, as taking the stairs is a significantly healthier option than using the elevator. Unlike standing still in an elevator, stair-climbing requires physical activity, which is beneficial for health.

This research aimed to design an interactive installation that motivates people to take the stairs. It examined the different types of motivation that make people act, techniques of influencing behaviour with design, and existing interventions. Ultimately, it focused on fostering intrinsic motivation, which was found to be the most promising way of encouraging stair use.

The chosen concept, Digital Garden, was an installation which visually responded to people taking the stairs. It reacted to the user's location, spawning sprouts in a virtual garden when the users began climbing the stairs and transforming the sprouts into full plants when the users reached the top. The garden visualization was displayed on two screens placed next to the staircase. This concept aimed to foster intrinsic motivation by making the stair-climbing experience more interesting and enjoyable.

The installation was evaluated through usability testing and a controlled experiment, which involved twenty participants who climbed the stairs under two conditions, once with and once without the installation. A questionnaire, behavioural measure, and interviews were used to collect data and asses the product's impact on the stair-climbing experience and intrinsic motivation. The findings showed a significant increase in interest and enjoyment of climbing the stairs with the installation, as well as a higher likelihood of participants choosing to take the stairs again. The results also indicated the installation's success in targeting intrinsic motivation.

Despite these promising findings, further research is needed to assess the installation's true impact on users in a real-world environment. Longitudinal studies should also be conducted to evaluate its long-term effects. Nevertheless, the results indicated that the Digital Garden has great potential to encourage stair use, making it a promising approach for universities wanting to increase the well-being of their students and employees.

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Chapter 1: Introduction

Every day, many university students and staff face the options of taking the stairs or the elevator. Whether a conscious decision or an unconscious routine, it can have significant health implications. This is because taking the stairs is a form of vigorous physical activity (Eves et al., 2006) that, if done regularly, can be beneficial in preventing premature death and several chronic diseases, such as diabetes, cardiovascular disease, cancer, obesity, hypertension and depression (Warburton et al., 2006). In contrast, using the elevator requires a lot less physical movement. The energy cost of standing still in the elevator is more than 5.3 lower than that of stair-climbing (Mansoubi et al., 2015; Bassett et al., 1997) and only slightly larger than that of sitting (Bassett et al., 1997). This minimal movement contributes to physical inactivity, which can have negative effects on human health (Warburton et al., 2006; Lee et al., 2012). It contributes to an increased risk of heart disease, diabetes, or cancers, and lowers life expectancy (Lee et al., 2012). According to the World Health Organization (WHO, 2024), the recommended levels of physical activity are not met by 80% of adolescents and almost one-third (31%) of adults. Additionally, in a university environment, it is common to be physically inactive not only through taking the elevator but also through sedentary behaviour. According to self-reported data extracted from 125 studies, students spend around 7.29 hours a day sitting (Castro et al., 2020), while office workers were found to be sedentary for around 70% of the working day (Ryan et al., 2011; Thorp et al., 2012).

When taking the stairs or the elevator, one option requires physical exercise, whereas the alternative means remaining physically inactive. Despite the clear health benefits of stair-climbing, a vast number of people still use the elevator. Research suggests that the proportion of people taking the stairs compared to people taking the elevators or escalators is around 8.1% without any interventions (Bauman et al., 2017). A study conducted at a university found that convenience and quickness are among the main reasons for choosing the elevator (Elliott et al., 2020).

Since stair-climbing can offer many health benefits, a simple and accessible way of addressing the issue of physical inactivity, especially concerning at universities, is to encourage stair use. Therefore, the aim of this project was to encourage university students and employees to use the stairs in an interactive way. The main research question guiding the project was: "How can the stair-climbing experience be modified to increase the number of people taking the stairs instead of the elevator at the university using interactive technology?".

To develop a viable solution, literature was reviewed on the workings of motivation, ways of influencing behaviour with design, and existing interventions aimed at encouraging stair use. Then, after conducting a survey with the target group to gather contextual information, potential solutions were explored, out of which one was refined and implemented. The final product was evaluated to see whether it successfully motivates people to take the stairs. Chapter 2 provides an overview of the background research as well as a deeper insight into the health implications of taking the stairs and the elevator. Chapter 3 describes the research methodology used to develop and evaluate the solution, while Chapters 4, 5, and 6 present the design process and realisation of the interactive installation. Chapter 7 provides the results of the evaluation, and Chapter 8 discusses the findings, limitations, and recommendations for future research. Finally, Chapter 9 provides the conclusion, summarising the key points of the project.

Chapter 2: Background Research

2.1. Encouraging Stair Use

To design an effective solution encouraging stair use, the first step is to understand how motivation works and how design can influence behaviour. This section explores these aspects through a literature review, addressing two important questions: "How can people be motivated to take the stairs?" and "How to influence behaviour with design to encourage stair use?".

Motivating people to act

People are motivated to act by different kinds of factors. According to Ryan and Deci (2000b), the main distinction can be made between acting out of one's own self-interest and acting because of external reasons. Therefore, it can be said that there are two main types of motivation: intrinsic and extrinsic. Intrinsic motivation works when someone does something because they find it interesting, satisfying or enjoyable (Ryan & Deci, 2000b; Di Domenico & Ryan, 2017; Ryan & Deci, 2000a). In other words, there is no separable reward for acting, but the action is a reward in itself (Ryan & Deci, 2000a). In contrast, extrinsically motivated people act to achieve a certain separable outcome (Ryan & Deci, 2000b; Di Domenico & Ryan, 2017; Ryan & Deci, 2000a), meaning that a person behaves to, for example, obtain a reward or to avoid punishment. These two types of motivation show that people can be encouraged to take the stairs either with external influence or by appealing to their internal motives.

The difference between intrinsic and extrinsic motivation

The difference between intrinsic and extrinsic motivation is not only in the definition but also in their effect on behaviour. As Ryan and Deci (2000b) claim, intrinsically motivated people are more interested in an activity and show more confidence and excitement, which results in better performance. Moreover, their persistence, well-being and self-esteem are higher (Ryan & Deci, 2000b). This suggests that targeting people's intrinsic motivation is a better way to influence their behaviour and facilitate behavioural change than motivating them extrinsically. This statement is supported by Boldina et al. (2022), who reference the work of Hein et al. Their findings show that intrinsically motivated people are more likely to be involved in a task at a personal level, resulting in a higher chance of a sustained behavioural change. In addition, Peeters et al. (2013), who designed Social Stairs, an interactive installation allowing the users to play songs together by walking on different steps, also argue that intrinsic motivation makes a person more likely to engage in a certain behaviour and helps with sustaining that behaviour, as described by Deci. Therefore, fostering intrinsic motivation seems to be the most promising way to effectively influence behaviour.

Intrinsic motivation and encouraging stair use

Since intrinsic motivation is more likely to make a person engage in a certain behaviour than extrinsic motivation, targeting it with design seems to be a more effective way of encouraging stair use. However, for stair-climbing to be intrinsically motivated, it needs to be interesting and enjoyable or satisfying (Ryan & Deci, 2000b; Di Domenico & Ryan, 2017; Ryan & Deci, 2000a). Therefore, the stair-climbing experience must be modified while accounting for the factors which enhance or disrupt intrinsic motivation.

Conditions affecting intrinsic motivation

Several conditions can either facilitate or diminish intrinsic motivation. Those conditions are presented by Ryan and Deci (2000b) in the cognitive evaluation theory (CET), developed by them in one of their previous works. CET states that intrinsic motivation can be enhanced by satisfying several basic psychological needs, the first of which is competence. A higher perceived feeling of competence during an action will result in a higher intrinsic motivation. Therefore, positive feedback or optimal challenges, which have a positive effect on the feeling of competence, can increase intrinsic motivation. On the opposite side, negative feedback or shaming can diminish one's intrinsic motivation because of a lower perceived competence (Ryan & Deci, 2000b). The need for competence is the first of the conditions that must be considered when designing an intervention focused on intrinsic motivation.

The feeling of competence cannot enhance intrinsic motivation by itself. As CET states, another psychological need, autonomy, must also be satisfied. This means that the individual must perceive their behaviour as self-regulated. Therefore, factors which increase the sense of autonomy, such as choice or opportunities for self-direction, can boost intrinsic motivation (Ryan & Deci, 2000b). Moreover, similarly to the feeling of competence, lower autonomy undermines intrinsic motivation. This can happen because of extrinsic rewards, pressure, deadlines, etc. (Ryan & Deci, 2000b), when the person shifts from perceiving the cause of their behaviour as internally regulated to controlled by external factors (Ryan & Deci, 2000a). Therefore, autonomy must also be taken into account to effectively influence behaviour using intrinsic motivation.

Besides competence and autonomy, there is a third psychological need that can affect intrinsic motivation. According to Deci and Ryan (2000b), it is relatedness. Relatedness refers to feeling a meaningful connection to others (Di Domenico & Ryan, 2017). Deci and Ryan (2000b) give an example of infants who exhibit more exploratory behaviour when in the presence of their parent or students who have less intrinsic motivation to study when their teacher is unwelcoming. However, as Deci and Ryan (2000b) argue, a satisfied need for relatedness might not be necessary to support intrinsic motivation since a lot of intrinsically motivated actions are performed alone. Relatedness still seems to play a role in affecting this type of motivation; however, it is not as important as competence and autonomy. Therefore, relatedness could be included in the intervention, but the main focus should be on the other two needs.

Influencing behaviour with design

There are several types of influence a product design can have on its users. According to Tromp et al. (2011), those types can be classified along the two dimensions of force and salience, meaning that the influence can be anywhere between strong or weak and hidden or apparent. Therefore, four types of influence, seductive, decisive, coercive and persuasive, can be determined. Seductive influence is weak and hidden, persuasive is weak and apparent, decisive is strong and hidden, and coercive is strong and apparent. Tromp et al. (2011) argue that since coercive design is strong and explicit in its influence, people experience it as externally motivating. This is also the case for persuasive design; however, here, only a weak influence is felt. As for the decisive design, it "decides" for people, taking away their choice. An example of this design given by Tromp et al. (2011) is a building without elevators, where people must take the stairs. Since the previous part of this research determined that it is best to target intrinsic motivation to encourage stair use, coercive and decisive designs do not seem to be appropriate for this task, as they rely on external influence. Additionally, it is not desired to take away people's choice, as for intrinsic motivation to work, the feeling of autonomy needs to be satisfied. Therefore, seductive design appears to be the solution, as Tromp et al. (2013) state that people under its influence usually perceive their behaviour as self-regulated. However, persuasive design, even though described by Tromp et al. (2011) as externally motivating, can also potentially be applied to encourage stair use. This is because persuasive technology is defined as the use of technology aimed at affecting behaviour (Hamari et al. 2014), which aligns with the goal of this project. A discussion about persuasive technology is presented in Section 2.3.

Seductive and persuasive design

In relation to previous findings, the best design for an installation encouraging stair use should be between seductive and persuasive. The two strategies identified by Tromp et al. (2011) as connecting these designs seem to align with the findings about intrinsic motivation the most. The first strategy, "Trigger different motivations for the same behavior" (Tromp et al., 2011, p. 15), suggests that people could be motivated to climb the stairs for other reasons than obtaining health benefits, e.g. by making the experience more enjoyable, which aligns with the findings about intrinsic motivation. The second strategy, "Elicit emotions to trigger action tendencies" (Tromp et al., 2011, p. 15), implies that the staircase could encourage people to take the stairs by eliciting certain emotions. Positive emotions such as curiosity, fun, entertainment or excitement could be targeted to make the experience interesting, and competence and relatedness to account for the conditions enhancing intrinsic motivation. The two design strategies connecting seductive and persuasive proposed by Tromp et al. (2011) seem to support fostering intrinsic motivation and can be used in designing the product encouraging stair use.

2.2. Health Implications of Taking the Stairs and the Elevator

To highlight the importance of this project, it is crucial to understand the health benefits of stair use and the health risks of taking the elevator. This section examines the contribution of stair-climbing to well-being as well as why encouraging stair use can be an accessible way to address the issue of physical inactivity.

Health benefits of taking the stairs

Regular physical activity has many benefits. They include the prevention of multiple chronic diseases, such as diabetes, cancer, cardiovascular disease, obesity, and premature death (Warburton et al., 2006). Physical movement is also beneficial for mental health, as it can help in preventing the symptoms of depression and anxiety (World Health Organization, 2020). Therefore, since climbing the stairs is a form of physical activity, doing it regularly can result in enhanced health and well-being. Additionally, studies about stair-climbing found that this form of exercise can offer significant aerobic improvements and decrease body fat (Fardy & Ilmarinen, 1975).

Health risks of not taking the stairs

As opposed to stair-climbing, taking the elevator does not require much physical movement, making it a less healthy option. By using the elevator, people trade physical movement, which is beneficial for health, for inactivity. This physical inactivity increases the likelihood of many diseases, such as breast and colon cancers, diabetes, heart disease, and cardiovascular disease (Warburton et al., 2006; Lee et al., 2012). It also contributes to the risk of depression (Warburton et al., 2006). Essentially, almost the same diseases which can be prevented with physical activity can also be caused by physical inactivity. Furthermore, physical inactivity lowers life expectancy (Warburton et al., 2006; Lee et al., 2012). According to Lin et al. (2012), if the inactivity worldwide was decreased by 10%, more than half a million deaths could be prevented each year.

The reason for stair-climbing

Even though physical movement can significantly improve health, a large part of the population does not exercise enough. According to the World Health Organization (2024), their recommendations for physical activity are not met by around 80 % of adolescents and 31% of adults. WHO suggests that adults should do at least 150 to

300 minutes of moderate-intensity physical activity or 75 to 150 minutes of vigorous-intensity physical activity per week (World Health Organization, 2020). Stair climbing seems to be a good way to contribute to meeting these recommendations since it is free, easily available, publicly accessible, and does not require any special equipment (Teh & Aziz, 2002). Additionally, one's time does not need to be specifically allocated to climbing the stairs since it can be done while doing something else, for example, going to an office at work or a classroom at the university. Stair-climbing, therefore, does not have to be a goal in itself, but it can be done while doing other everyday activities.

Since physical activity contributes to good health, while physical inactivity undermines it, taking the stairs instead of the elevator is a more beneficial option for individual health and well-being. However, despite the benefits of stair use, data from 50 studies suggest that the proportion of people taking the stairs compared to people taking the elevators or escalators is only around 8.1% without any interventions (Bauman et al., 2017). Taking the stairs might be even more important for university staff and students who tend to sit for prolonged periods of time. According to self-reported data, students spend approximately 7.29 hours a day sitting (Castro et al., 2020), and office workers sit for around 70% of their working hours (Ryan et al., 2017; Thorp et al., 2012).

2.3. Existing Work

This section examines the existing work that has been done to encourage physical activity and stair use. This review identifies potential effective strategies which can be built upon, as well as opportunities for a novel solution.

Persuasive technology (PT) is a type of technology used to motivate people to engage in certain behaviours. Hamari et al. (2014, p. 118 - 119) define it as “the use of technology that is aimed at affecting people’s/users’ psychological attributes, such as attitudes or motivations, which are further presumed to affect behaviour”. The solution this project seeks for, therefore, seems to be a form of PT. In the field of health and well-being, many persuasive technology interventions have been designed to promote physical activity and discourage sedentary behaviour. A literature review of 170 such studies found that PTs are usually effective in doing so. The studies were also classified using the Persuasive System Design (PSD) model, which provides a framework for designing persuasive technologies by providing multiple persuasive design principles and suggesting how they can be transformed into system requirements (Oinas-Kukkonen & Harjumaa, 2009).

Even though PT interventions have been successful in encouraging physical activity, most studies focused on mobile, desktop or online applications and wearable devices as technology platforms (Aldenaini et al., 2020), leaving room for different types of solutions to be explored. Furthermore, most of them seem to be focused on trying to increase the users’ overall physical activity and decrease the amount of sedentary behaviour (Aldenaini et al., 2020). Not many PTs were identified that tried to motivate people to engage in a specific form of physical activity, such as stair-climbing. Furthermore, most of the interventions do not appear to be targeting intrinsic motivation, so trying to encourage healthy behaviour by making it enjoyable or satisfying. In fact, the PSD model does not seem to provide any principles which would allow to design a persuasive system encouraging a specific behaviour by fostering intrinsic motivation. Therefore, there are not many PT interventions targeted at promoting physical activity, which motivate to engage in a certain form of it by invoking intrinsic motivation. Only two such systems designed to encourage the specific activity of stair-climbing were identified.

One of the two identified projects meant to encourage stair use with interactive technology is the Piano Staircase. This installation was built to motivate people to use the stairs instead of the escalator by turning the staircase into a piano keyboard, where each step produced a sound. Peeters et al. (2013) mention the data gathered by Volkswagen, the developer of the Piano Staircase, which shows that 66% more people took the stairs instead of the escalator on the first day of the installation. However, the Piano Staircase was not tested for any long-term effects, and Peeters et al. (2013) argue that people could quickly lose interest in it.

Based upon the Piano Staircase idea, Peeters et al. (2013) designed Social Stairs, an interactive installation allowing the users to play songs together by walking on different steps. The users could use the stairs alone, but collaborating resulted in a richer and louder sound. Since Peeters et al. (2013) argued that simple persuasion, such as the Piano Staircase, only works temporarily, they decided to design for long-term behavioural change. They claim that it is most probable to achieve it when the motivation is intrinsic, which can be seen by looking at the effect of the Social Stairs on behaviour; some people started visiting the installation repetitively to see whether the stairs are still working and if something is happening there. At first, they were taking the stairs out of curiosity, but afterwards, it became their new habit (Peeters et al. 2013). This example shows how making a design appeal to someone's intrinsic motivation can result in a more sustainable behavioural change.

Both the Piano Staircase and the Social Stairs are examples of interactive technology aimed at encouraging stair use. Moreover, they both seem to be doing so by fostering intrinsic motivation. However, they both focus on playing sounds with each step while climbing the stairs, leaving room for different approaches to be explored.

From the field of promoting stair use, the most common strategy seems to be the use of point-of-decision prompts or signs. This approach involves placing signs encouraging people to take the stairs instead of the elevator (Bauman et al., 2017). Despite this strategy being popular and effective (Bauman et al., 2017), Allais et al. (2017) argue that people get used to the signs and the change in behaviour is only short-term. Moreover, these interventions rely on extrinsic motivation by using external cues to influence behaviour. Since the previous findings of this research suggest that the focus should be on intrinsic motivation, an alternative approach must be explored.

Chapter 3: Methods and Techniques

After conducting background research, methods and techniques were established to guide the design, development, and evaluation of the solution. This chapter introduces the way of gathering contextual information, the design method which was followed by this project, as well as the usability testing and evaluation methods of the product.

3.1. Context Analysis

To gain a better understanding of the factors influencing stair and elevator use at the university, a survey was conducted with university students and staff. The results of the survey were expected to help in designing the product by guiding the ideation phase. The research questions to be answered with the survey were the following:

- Why do people take the stairs?
- Why do people take the elevator?
- How aware are people of the benefits of taking the stairs?
- What could be changed about or added to the staircase to motivate people to take the stairs more?

The survey was conducted online using Microsoft Forms, and the questions were mostly open questions to avoid biasing the users' answers. Participants, who consisted of University of Twente students and staff, were recruited by invitation through student group chats and flyers with QR codes spread in several university buildings, allowing to easily collect data from a large audience. The survey questions are presented in Appendix A.

After conducting the survey, the collected data was cleaned. It was checked whether the responses were complete and whether they did not repeat. The responses to the open-ended questions regarding the reasons for stair and elevator use were coded using predefined as well as emergent themes, where the frequency of same-category answers was calculated. Similarly, the frequency was noted for the awareness level of the stair-climbing benefits, measured using a 5-point Likert scale. Suggestions about changes to the staircase were not coded but used in the ideation process of developing potential solutions.

The results were analysed and used to help in guiding the ideation phase of the design process described in the following section. The results and analysis of the survey are discussed in section 4.2. Context Analysis Results.

3.2. The Design Process

The design method followed by this project was the Design Process for Creative Technology (Mader & Eggink, 2014), illustrated in Figure 1. This process consists of four stages: Ideation, Specification, Realisation and Evaluation.

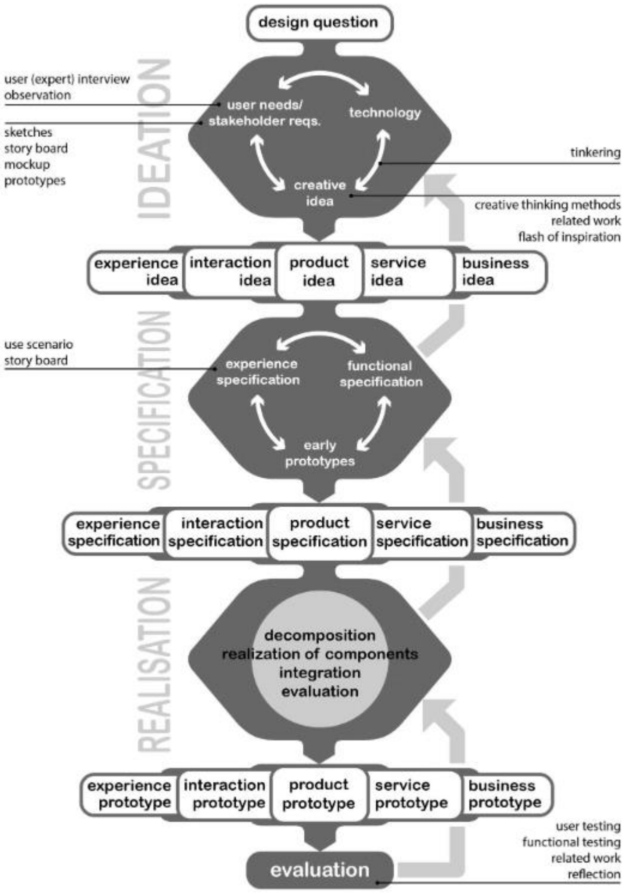


FIGURE 1. DESIGN PROCESS FOR CREATIVE TECHNOLOGY

1. Ideation Phase

The starting point of this design process was the design question "How to design a stair-climbing experience which will encourage people to take the stairs instead of the elevator by fostering intrinsic motivation?". The ideas were generated based on the user requirements derived from the background research, the survey insights, and the research into related work. This background knowledge allowed to understand the user domain and the problem more in-depth, which helped to describe the requirements. The ideation consisted of a divergence stage, where a brainstorm about many potential solutions was conducted, and a convergence stage, where the ideas were narrowed down to those which fit the requirements the best, ultimately leading to a preferred concept. The ideation process and its outcome are described in Chapter 4: Ideation.

2. Specification Phase

In the specification phase, several variations of the idea chosen in the ideation phase were evaluated with the project supervisors and potential users. The prototypes consisted of storyboards and scenarios, as well as digital design alternatives for the product. These prototypes were easy to make and easy to discard, allowing to explore multiple design options without any personal attachment or investing a lot of time in a specific idea. The goal of this phase was to explore the design space and to get feedback on the design ideas. The ideas were discarded or kept, leading to a product specification. The results of the specification phase are presented in Chapter 5: Specification.

3. Realisation Phase

The first step of the realisation stage was decomposition. The product specification was broken down into separate parts, which had to be worked on individually, as well as the components necessary to build the product. Next, out of all possible solutions, those which were the most feasible and suited the requirements the best were selected. Afterwards, the necessary components were bought, and the individual parts were combined to form a final product. At the end of this phase, a usability testing session was conducted, and it was checked whether the product aligned with the specifications. The realisation phase is described in Chapter 6: Realisation.

4. Evaluation Phase

In the evaluation phase, an experiment was conducted to assess the effectiveness of the product. It was tested with participants, and the necessary data was collected and analysed. An in-depth description of this research study is presented in Chapter 7: Evaluation.

3.3. Usability Testing and Research Study

To evaluate the final product, it had to be tested on two aspects: technical usability and effectiveness.

3.3.1. Usability Testing

First, a usability test was conducted to identify potential design flaws, areas for improvement, and to obtain general feedback about the installation. The evaluation was done with fellow students, who were asked to climb the staircase with the installation and complete a questionnaire. The participants were also observed to see whether the installation functions properly. A discussion about the usability testing session and its results is detailed in section 6.4. Usability Testing.

3.3.2. Research Study

To evaluate whether the installation effectively encourages stair use, an experiment was conducted in the Gallery building on the University of Twente campus, where the impact of the installation was tested with participants. The goal of the experiment was to assess whether the installation made stair-climbing more interesting and enjoyable, and whether it increased intrinsic motivation to take the stairs. The study's design and results are presented in Chapter 7: Evaluation.

Chapter 4: Ideation

The goal of this project was to design an interactive installation that motivates people to take the stairs by fostering their intrinsic motivation. Therefore, the main focus of the ideation phase was on generating ideas that align with the principles of intrinsic motivation. However, other aspects, such as the potential ethical concerns or practical constraints, were also considered in designing the product.

This chapter introduces the user requirements developed based on the background research, ethical concerns, and the location of the installation. Furthermore, it examines the potential constraints of the project and presents the results of the context analysis survey. Then, it describes the ideation process along with the final concept.

4.1. User Requirements and Constraints

To make sure that the product fosters intrinsic motivation, several user requirements were developed based on the background research.

Requirements based on the background research

1. The product must foster intrinsic motivation:
    a. The experience must be interesting, enjoyable, and satisfying.
    b. The product must satisfy the users' need for competence.
    c. The product must satisfy the users' need for autonomy.
    d. The product could satisfy the users' need for relatedness.

Those requirements were based on the three conditions that can enhance intrinsic motivation and were developed to make sure that those conditions are fulfilled. The need for relatedness "could" be satisfied since it was found that this need is not necessary for intrinsic motivation to work.

Besides fostering intrinsic motivation, the product should also be safe and unobtrusive. This is because the stairs are frequently used, and not everyone might want to interact with the installation. Additionally, the installation cannot increase the danger of taking the stairs. Therefore, a few requirements have been developed based on the suggestions from the university's Ethical Committee.

Requirements from the university's Ethical Committee

2. The product must allow users who do not wish to interact with the installation to use the stairs as a regular staircase:
    a. The product must not slow down the users or interrupt their routine.
3. The product must not increase the danger of stumbling or falling down the stairs:
    a. By adding physical obstacles to the staircase.

b. By scaring the users with sudden loud noises or bright flashing lights.

Additional requirement was also made based on the nature of the installation. This requirement was developed to make sure that the installation will function properly at a staircase at the university.

Requirement based on the location

4. The product must work with multiple individuals taking the stairs at once:
    a. Every person climbing the stairs must be able to interact with the system.

Constraints

In addition to the user requirements that had to be accounted for, there were also several physical and environmental constraints caused by the nature of the stairs on which the installation was going to be located.

The major physical constraint of this project was the build of the stairs, as staircases have a predefined shape, width, height and number of steps. These aspects could not be changed; therefore, the installation had to work with them. This required a strategic placement of the installation's elements, such as the sensors, LEDs, displays, projectors, cables, etc., to avoid obstructing the users' path or view. Furthermore, since staircases at the university are frequently used, the installation had to be robust and durable. Moreover, it had to function with multiple users taking the stairs at the same time. Additionally, the setup process of the installation had to be quick and unobtrusive so as not to stop the users from being able to use the stairs. Another potential constraint of the project was the number of materials needed, e.g. sensors, as it was supposed to cover an entire flight of stairs.

4.2. Context Analysis Results

The survey described in Section 3.1 was expected to provide additional insights to add more user requirements for the ideation process. The results showed that the main reason for taking the elevator is a large number of floors to go, which was a response provided by 65% of the respondents. The main reason for taking the stairs was quickness (provided by 45% of the respondents), followed by physical exercise (35%). The results, therefore, do not directly help in designing a system encouraging stair use since, to account for the main reason for elevator use, many floors to go, the solution should cover multiple floors. However, since building such a big installation is not feasible for this project, the results of this project can be used for designing future interventions with a bigger scope.

Interestingly, the survey found that most participants were already aware of the health benefits of stair-climbing. 32% of the respondents indicated that they think taking the stairs is fairly beneficial, 36% that it is very beneficial, and 20% that it is extremely beneficial. Only 12% thought that it is only slightly beneficial. This shows that people are aware of the health benefits of taking the stairs, therefore, the intervention should not focus on spreading awareness.

The respondents also provided several suggestions about what could be done to the staircase to make them more eager to take the stairs. The most popular answers included adding interactive aspects or making the staircase more visually appealing. They also suggested adding sounds, lights, colours, or gamifying the experience. Therefore, while the survey did not provide specific user requirements for the product, it showed the importance of making an engaging, visually appealing, and interactive installation.

4.3. Ideation Process

Based on the identified user requirements and constraints, various concepts were explored, including different types of technology that can be used to interact with the user, such as LEDs, sounds, displays, projections and Augmented Reality (AR). Some concepts also combined multiple technologies. More unconventional methods, such as smell diffusers or physical feedback, like vibration, were rejected due to ethical concerns since the installation had to be safe and unobtrusive.

Below is a list of the chosen ideas, along with their descriptions, categorised by similarity. The full list of the ideas and paper prototypes is presented in Appendix B.

Category: Reacting to each step of the user with lights.

1. Steps light up with colours when stepped on:
    a. User chooses a colour palette with a button.
    b. Stepping on a step lights it up.
    c. The nearby steps also light up but less and gradually fade.
    d. Consecutive steps create a colour transition effect.
    e. The user can choose the colour of each step by stepping on it multiple times, allowing to “paint” the stairs.
2. When the user steps on the stairs, a spot on the next stair lights up, leading the user all the way up on a random path.

Category: The users customise their experience of stair-climbing.

3. The user chooses colours, brightness and ambience before going on the stairs:
    a. Using a touchscreen or buttons.
    b. The user can select a colour palette and adjust the brightness.

    c. The user can also select the style of lighting, such as fading in and out, blinking, etc.
4. The user chooses a theme before going on the stairs, then the lights and sounds (and possibly visuals) adapt accordingly:
    a. E.g. Ocean, space, forest, winter theme.
    b. Lights and sounds form an atmosphere of the selected theme.
    c. E.g. choosing the ocean theme would result in blue colours, whale sounds, bubble sounds, etc.
    d. Colors could become lighter the higher the step.

Category: Something is revealed as the user climbs.

5. Pixel art, where the users "reveal" the artwork by stepping on the pixels, which then change from empty to coloured:
    a. After the artwork is fully revealed, a new artwork loads.
6. A displayed artwork which starts empty and gets revealed as the user goes up.
    a. For example, a blank canvas is displayed, which starts to get coloured from the bottom as the user progresses.

Category: Reacting to the user's steps with sounds.

7. The user selects a theme, and then a sound effect from that theme plays with every step.
8. At each step, the user can choose from a set of melody loops:
    i. Each step would be a different instrument.
    ii. E.g. the first step would be a kick pattern, the second step would trigger a snare loop, and the next steps would allow to play sounds such as the bassline, chords, or melody.
    iii. Therefore, the user would be able to make a custom melody from the loops while climbing.
    iv. The users could play together by triggering different instruments, mimicking a band.
    v. The loops would be synchronised and in the same key so that the melody does not fall out of rhythm or key.
    vi. Upon triggering a new loop, the old loop would play out until it ends, and then the new loop would play.

Category: Something happens when the user reaches the top of the stairs.

9. A garden, shown on a display or projected:
    a. Every time the user takes the stairs, the garden flourishes: A new plant is added, a plant grows bigger, wildlife appears, etc.
10. A bar is charged as the user goes up:

    a. After the user reaches the top of the stairs and the bar is fully charged, the user can choose one of the creatures that is displayed and feed it.

Category: Something happens as the user climbs, following the user's progress.

11. Evolution show:
    a. A certain object is displayed next to the user as the user climbs.
    b. For example, an egg.
    c. As the user goes up, the egg hatches, the chicken grows, etc.
    d. This could also show the evolution of a certain car model, or a human, or how Earth changed over time, or the sprouting and growth of a plant, etc. There are many different possibilities.
12. A story that is spoken or displayed with text, getting revealed as the user goes up:
    a. To hear the next part of the story, the user must keep on moving up.

Category: A user is accompanied by something while climbing.

13. AR creature:
    a. The user can select a creature that will accompany the user when climbing.
    b. The user can customise the look of the creature after reaching the top or feed the creature.
    c. Each user can have their own creature which they can interact with every time they take the stairs.

4.4. Final Concept

The ideas were evaluated based on the user requirements, feasibility, and novelty. Additionally, they were presented to the project supervisors, who helped to choose the direction they would like to see the project go in. Based on these aspects, the Digital Garden concept was chosen as the most promising solution.

The Digital Garden aimed to encourage stair use by displaying a garden on the screen next to the staircase, which would flourish as the users climbed the stairs. For example, with each user who reached the top of the stairs, a new plant would be added to the garden, or an already existing plant would grow, as shown in Figure 2. The display located at the top of the staircase would allow the user to instantly see the garden grow.

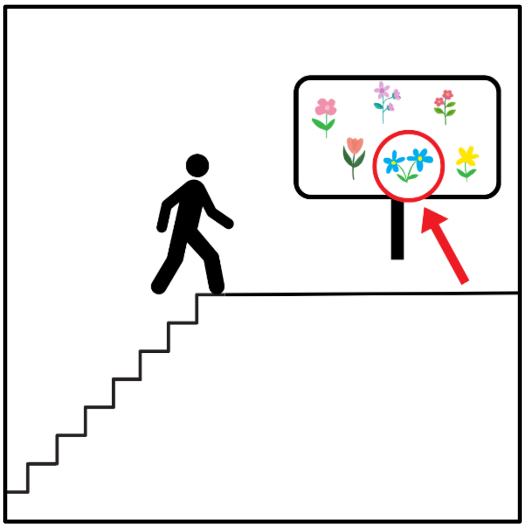


FIGURE 2. NEW PLANT APPEARS AS THE USERS REACHES THE TOP OF THE STAIRS

The ability of the installation to react as the users reach the top was one of the reasons this idea was chosen, as it was expected to motivate them to climb to the top of the stairs rather than simply play with the installation, which could happen with many of the other concepts. This also differentiated it from the Piano Staircase and the Social Stairs, which did not focus on motivating the users to reach the top of the stairs but instead focused on playful interactions.

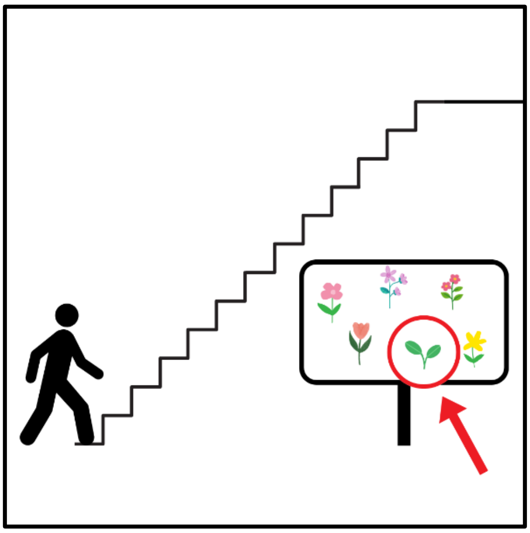


FIGURE 3. NEW SPROUT AS THE USER STARTS CLIMBING THE STAIRS

However, even though this idea aimed to encourage users to reach the top, additional features were considered to keep them engaged from the start of the climb. One concept of such a feature involved a plant sprouting when a user touched the first step (Figure 3), which would grow into a full plant when the user reached the top. To implement this idea, another display would be needed next to the bottom of the stairs to allow the user to see the sprout. The displays would be synchronised so that the users can see their sprouts grow into bigger plants upon reaching the top of the stairs.

An alternative approach involved an LED strip leading from the bottom of the stairs to the screen located at the top. Every time a user stepped on the first step, the strip would activate, sending a travelling light to the top display and bringing the user's attention to it, as illustrated in Figure 4. This approach would also include a counter at the top, showing how many users have stepped on the bottom step and, therefore, how many plants are awaiting to appear.

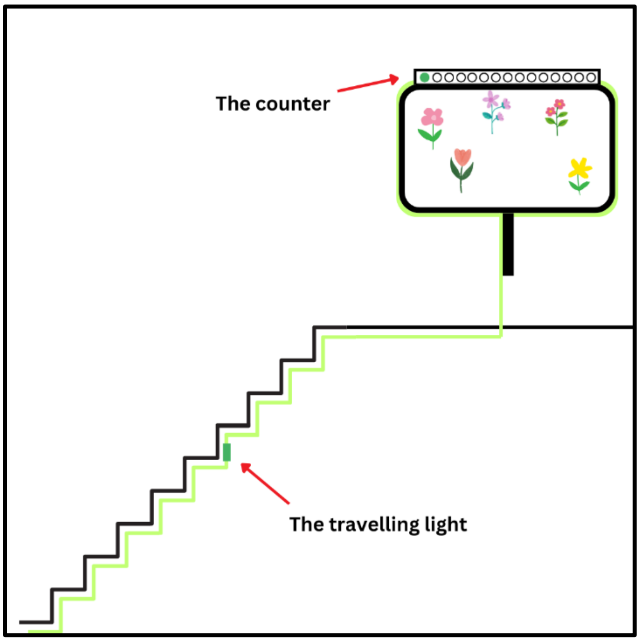


FIGURE 4. THE LIGHT TRAVELLING FROM THE BOTTOM STEP TO THE SCREEN AT THE TOP OF THE STAIRS, TRIGGERED BY THE USER STEPPING ON THE FIRST STEP. A COUNTER AT THE TOP SHOWING HOW MANY PLANTS ARE AWAITING TO APPEAR.

Both options were evaluated for feasibility to decide which one should be implemented in the final product. The specification of the idea is described in Chapter 5: Specification.

As for the long-term functionality of the Digital Garden, it was planned to measure how many users use the stairs daily on average and, based on that information, determine a reset period for the garden. If the garden became too full, it would reset, allowing the users to start creating a new one. To keep the users interested, it was planned to change the design of the garden with each reset by having multiple different sets of plants.

Besides aiming to motivate the users to climb to the top of the stairs, the Digital Garden idea was chosen for several other reasons. First of all, it would work with multiple users using the installation at the same time, which was a potential issue with many other ideas. Furthermore, it would allow the users to collaborate, as they would collectively contribute to the growth of the garden. This shared experience feature would account for the need for relatedness, one of the psychological needs that can enhance intrinsic motivation. This idea also aimed to preserve user autonomy since it did not appear to put any external pressure or influence on the users' choice, allowing them to still opt for the elevator. The need for competence would also be satisfied, as the Digital Garden would not increase the difficulty of regular stair-climbing. Moreover, it would provide positive visual feedback in the form of growing plants and a flourishing garden, which should support the feeling of competence. This positive and nature-themed feedback was also intended to generate a joyful and relaxing atmosphere.

The concept of Digital Garden seemed to be an effective way of fostering intrinsic motivation, as it strived to make the experience of stair-climbing more interesting and enjoyable. Moreover, it was aimed at eliciting the emotion of curiosity by making the user wonder what would happen upon reaching the top of the stairs and how the garden would change over time. Additionally, it was meant to fulfil all three needs that support intrinsic motivation: autonomy, competence, and relatedness. It also followed the design strategies proposed by Tromp et al. (2011), as it provided the users with a different motivation to climb the stairs than just reaching the next floor and strived to elicit positive emotions to encourage stair use. Moreover, the Digital Garden aimed to add a sense of personality to the stairs, which was a different approach than triggering sounds, as used by the Piano Staircase and the Social Stairs.

Chapter 5: Specification

After selecting the preferred concept, it had to be refined into a concrete specification. This chapter presents the functional and non-functional requirements for the installation, as well as the evaluation of the design alternatives.

5.1. Functional and Non-functional Requirements

Based on the user requirements and constraints from the Ideation chapter, this section outlines the functional and non-functional requirements, specifying how the installation will work.

Functional requirements:

Regarding the interaction logic:

- The system must detect each user who steps on the first step.
- The system must detect each user who reaches the highest step.
- The system must respond with visual feedback to each user starting to climb the stairs.
- The system must respond with visual feedback to each user reaching the top of the stairs.
- The system must distinguish between those ascending and those descending the stairs and only react to the former.

Regarding the garden visualisation:

- A sprout must appear in the visualisation (or an LED animation must play) for each user who starts climbing the stairs.
- A plant must appear or grow in the visualisation for each user who reaches the top of the stairs.
- The garden must reset when it gets too full.
- The theme of the garden must change after each reset.

Nonfunctional requirements:

- The system must work with multiple users simultaneously by correctly handling individual detections and responses.
- The system's visual response to user detection must be instant (with no noticeable delay).
- The system's visual response to user detection must be easily noticeable to the user.

- The garden visualisation must be clear and uncluttered to make sure that the system responses are visible.
- The installation must be safe and unobtrusive:
  - It must not increase the risk of stumbling.
  - It must not obstruct the path of the stair users.
  - It must not use bright lights or loud sounds that could startle the users.

5.2. Envisioned Product Specification

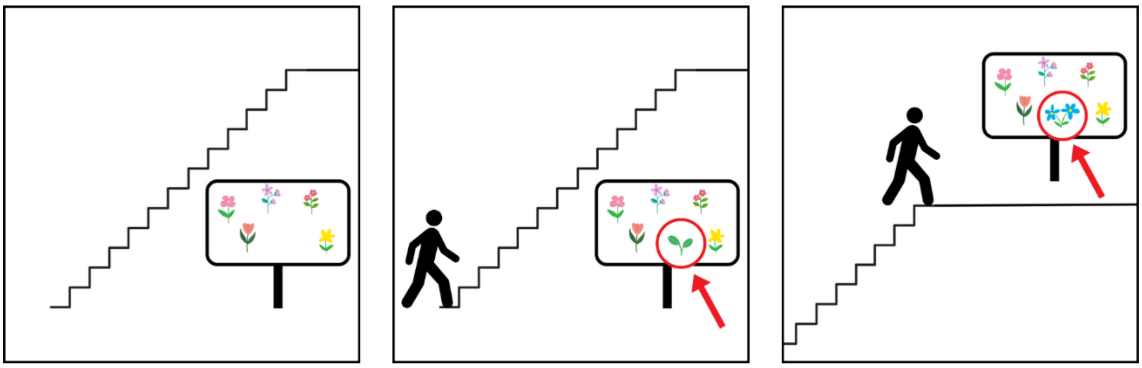
To communicate with project supervisors and convey the envisioned functionality of the installation, scenarios along with storyboards were developed to illustrate the two considered alternatives for user interaction.

The first scenario describes the idea of engaging users with the Digital Garden from the moment they start ascending the stairs by making a sprout appear in the garden.

Scenario 1:

A university student walks into a building on his way to a class on an upper floor. He notices a display showing a digital garden placed next to the stairs, as well as one more at the top. Driven by curiosity, the student decides to take the stairs. As he starts to climb, he notices a sprout appear in the displayed garden. The intrigued student climbs all the way up and, upon reaching the last step, sees the sprout transform into a full plant. He watches as new sprouts appear and turn into different plants each time someone climbs the stairs.

Storyboard 1:



The user sees the display showing a garden at the bottom of the stairs.

The user stars climbing the stairs - a sprout appears in the garden.

The user reaches the top of the stairs – the sprout turns into a full plant.

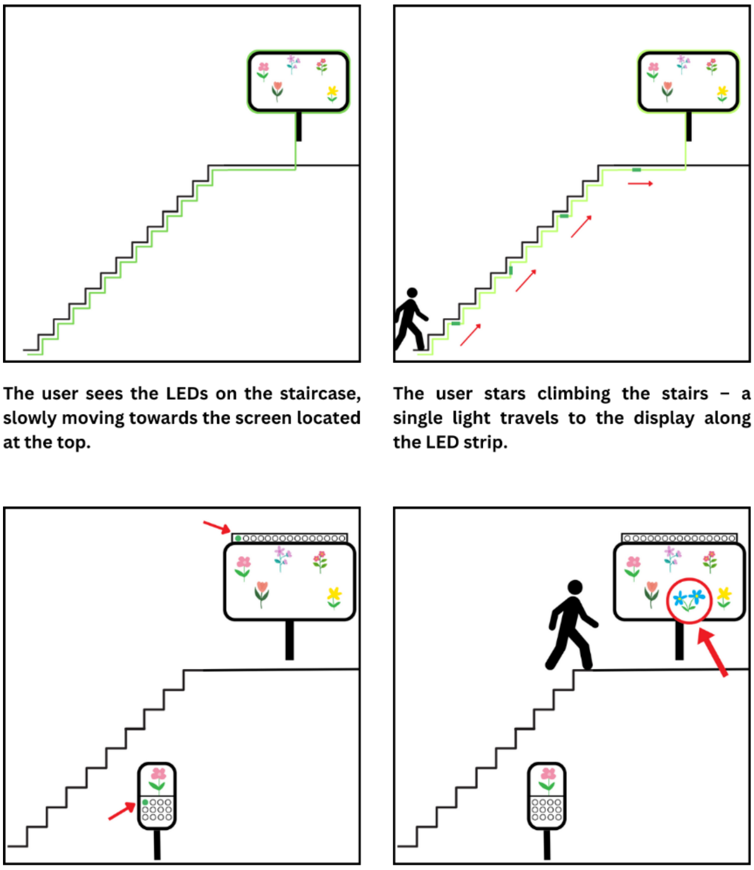
FIGURE 5. A STORYBOARD ILLUSTRATING USER INTERACTION IN SCENARIO NR.1

The second scenario describes an alternative idea for engaging users at the bottom of the stairs, which involves an LED strip placed along the staircase and a counter at the top.

Scenario 2:

A university student walks into a building on his way to a class on an upper floor. He notices an LED strip on the staircase, a flower icon with a counter next to the first step, as well as a display showing a digital garden at the top of the stairs. Driven by curiosity, the student decides to take the stairs. As he starts climbing, a light activates and travels along the LED strip to the top display. Additionally, an LED lights up under the flower icon. The intrigued student climbs all the way up and, upon reaching the last step, sees a plant appear in the garden on the screen. He notices that for every person who starts climbing the stairs, an LED light travels to the top display and stays lit until that person reaches the top, when the LED turns off and a random plant appears in the garden.

Storyboard 2:



The user sees the LEDs on the staircase, slowly moving towards the screen located at the top.

The user stars climbing the stairs – a single light travels to the display along the LED strip.

Additionally, one LED lights up under a flower icon placed next to the bottom of the stairs, as well as above the display at the top of the stairs.

Upon reaching the top, the LEDs turn off and a plant appears on the screen.

FIGURE 6. A STORYBOARD ILLUSTRATING SCENARIO NR. 2.

Garden ideas:

Apart from the alternatives for user interaction with the installation, different ideas were also considered for the design of the Digital Garden. A pixel art style (Figure 7) and an isometric 3D design (Figure 8) were chosen upon conducting online research for inspiration.

FIGURE 7. PIXEL ART GARDEN DESIGN.

FIGURE 8. 3D ISOMETRIC GARDEN DESIGN.

Final choice:

Both interaction ideas were evaluated with the project supervisors. The second idea was ultimately rejected due to feasibility concerns of placing an LED strip along the staircase raised by its length and durability concerns. Additionally, it was deemed less intuitive for future users since it was not as consistent with the theme of digital garden as the first idea. Therefore, the first idea, where sprouts and full plants appear based on the users' location, was chosen.

Regarding the visualisation, the 3D isometric design was chosen based on its more aesthetically appealing and professional look, as confirmed by several potential users asked for their opinion.

Chapter 6: Realization

After evaluating and choosing between the interaction and design alternatives, the final idea had to be brought to life. The distinction could be made between the two main parts of the Digital Garden: the digital visualisation of the garden and the hardware and interaction part. These two parts were initially worked on separately and then combined to form the installation as a whole.

6.1. Visualization

After deciding on the design of the visualisation, a plan was made for executing the digital part of the installation:

1. Design the garden in Blender.
2. Transfer the visualisation to Unity.
3. Design animations for the sprouts and plants spawning in.

The garden was modelled as a circular island with a water body, bridges, and rocks to make the environment more interesting. Afterwards, free online plant assets were added to the visualisation. All the assets were taken from Sketchfab and the Unity Asset Store (Sketchfab, n.d.; Unity Asset Store, n.d.). The result, as shown in Figure 9, was a 3D model of a garden with a variety of plants.

FIGURE 9. A 3D MODEL OF THE GARDEN IN BLENDER.

After modelling the garden in Blender, it was transferred to Unity. Unity allowed for easy integration of animations and gamification of the whole scene, making it possible to trigger changes in the garden based on the output of physical sensors.

Upon transferring the model to Unity, several assets were removed or replaced due to difficulties in importing their textures. Additionally, the plants were rearranged and strategically placed to increase visibility and allow users to easily notice which plants they triggered to appear. The final result is presented in Figure 10.

FIGURE 10. THE GARDEN MODEL IMPORTED TO UNITY.

Next, animations were created to bring the users' attention to the changes happening in the garden.

First, an animation that would play with the appearance of each sprout was designed. This animation was made using a Particle System component from Unity, resulting in an array of particles coming out of the sprout, as presented in Figure 11.

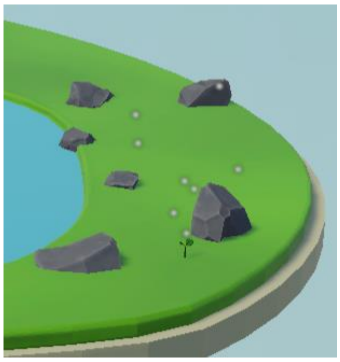


FIGURE 11. SPROUT PARTICLE ANIMATION.

The second animation, which would play upon the sprout's transformation into a full plant, was also intended to make use of the Particle System. However, this approach was rejected since too many particles on the screen could introduce confusion, especially with several users triggering the animations. Instead, a highlight animation was used, creating an outline around the plant, which would disappear after several seconds. This animation is presented in Figure 12.

FIGURE 12. PLANT HIGHLIGHT ANIMATION.

6.2. Hardware and Interaction

Implementing the hardware and interaction part of the system was a more demanding task than designing the visualisation. It required choosing appropriate sensors, writing a code for person detection, obtaining the necessary components, securing a testing location at the university, and more.

The plan made for executing this part of the project was to:

- Decide which sensors to use.
- Decide how to display the visualization.
- Secure a testing location at the university.
- Obtain the necessary components and equipment.
- Code the person detection logic.

1. Choosing the sensors

To start with the hardware and interaction part of the system, a decision had to be made on which sensors to use to detect people taking the stairs. After a brainstorming session, the possibilities included IR sensors, pressure sensors, capacitive proximity sensors, and a camera with computer vision, as these appeared to be the most feasible options.

Using a camera with computer vision was initially rejected due to privacy concerns. Also, permission from the Ethical Committee to carry out the research without the use of a camera was already obtained. Therefore, first, the other sensors were considered.

The decision of which sensors to choose was guided by several main challenges which had to be accounted for:

- The sensors had to detect multiple people stepping on the same step at the same time.

- The sensors had to be placed in a way that does not obstruct the path of the users and does not introduce the risk of stumbling.
- The sensors had to be connected to a microcontroller and a power source, resulting in a large number of wires that must be strategically placed.

First, the pressure sensors were rejected due to the durability factor. Since the pressure sensors work based on physical contact, they could quickly wear out as they would be frequently stepped on. Therefore, the choice was left between the IR or capacitive proximity sensors. These would have to be placed in a grid, dividing the step into smaller detection zones to allow for detecting multiple people. This would increase the number of necessary components, since at least eight sensors would be needed per step, and the number of wires to be managed. Additionally, even with each step divided into several detection zones, a person could still step in between the zones or skip the step, making it difficult for the system to correctly handle the detection. Due to these potential difficulties, using a camera with computer vision was reconsidered.

Using a camera would allow to get rid of most of the issues with other sensors. First, it would eliminate the problem of strategic sensor placement and cable management. Additionally, it would significantly reduce the number of necessary components, as only one camera would be needed. This would simplify the setup of the installation and lower the overall costs since a camera was available, whereas the sensors would have to be bought. Furthermore, using computer vision would allow to easily handle simultaneous detections, as an object detection algorithm would be able to distinguish between individuals. People skipping steps when climbing the stairs would also be detected by the camera. Another aspect which would be significantly simplified by the use of computer vision would be distinguishing between those who are ascending and descending. An object detection algorithm would be able to keep track of each individual in the frame, allowing to determine the direction in which that person is going, which would be difficult to achieve with other sensors.

As using a camera would simplify the setup of the installation, lower the costs of the components, decrease the risk of the participants stumbling on the sensors or cables, and allow for more precise person detection, a second application was filed to the Ethical Committee. It was later approved; therefore, the project proceeded with computer vision.

2. Computer vision

Upon conducting research into computer vision, an open-source algorithm called You Only Look Once (YOLO) was determined to be a promising solution. YOLO was designed for real-time object detection, which made it ideal for detecting people taking the stairs. The necessary files were downloaded from YOLO's GitHub repository (AlexeyAB, n.d.), and a Python program was developed to implement person detection. The code successfully recognised individuals using a live video feed from a laptop's camera and a pre-trained YOLO model; however, it was computationally intensive on the CPU, resulting in a low frame rate and slow performance. The solution was to enable GPU acceleration to run the computations, but configuring YOLO to utilise the GPU proved to be a challenging task. As an alternative, an open-source YOLO framework developed by Ultralytics (Ultralytics, 2024) was used, which provided built-in GPU support, allowing to easily increase the system's performance. The Ultralytics framework also included a pre-trained YOLO model, which was used for person recognition.

After switching to the Ultralytics framework, the program began to run smoothly, allowing for further development of the code. At this point, it used a YOLOv8 model for real-time object detection and tracking individuals on a live video feed from the computer's camera captured by OpenCV. OpenCV was also used to draw the bounding box for each individual along with its centre as well as the detection zones. The first detection zone would be used for detecting people at the bottom of the stairs and spawning in the sprouts, whereas the second zone would allow to detect individuals at the top of the staircase to turn the sprouts into full plants. Initially, for testing purposes, the zones were simply drawn on the sides of the frame, as shown in Figure 13.

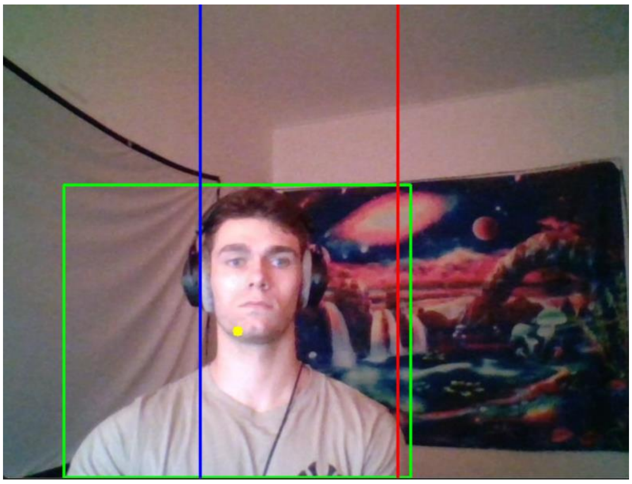


FIGURE 13. DETECTION ZONES AND THE BOUNDING BOX FOR PERSON DETECTION.

To distinguish between individuals, the code utilised a unique identifier assigned by YOLOv8 to each detected person. This functionality would allow to track people and maintain their IDs for as long as they remain in the frame. This would make it possible to trigger each animation only once per person and to determine the direction of each user by checking which detection zone they entered first. For people who entered the second (top) zone first, no animations would be triggered, as those people would be descending the stairs. Figure 14 illustrates the flowchart diagram of the code's functionality.

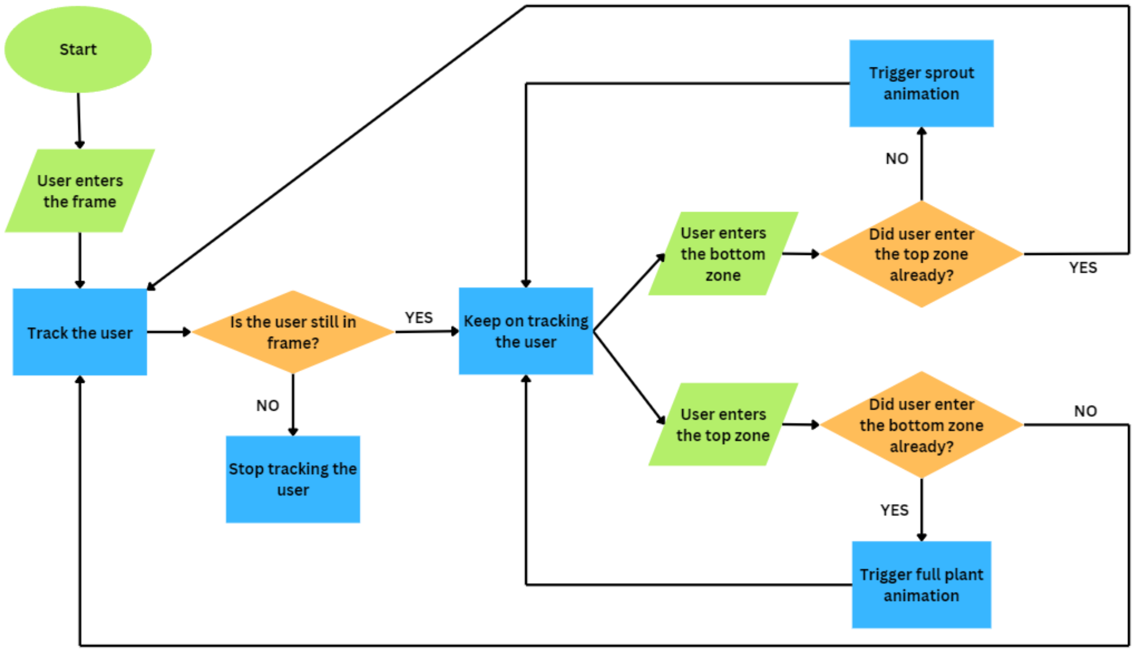


FIGURE 14. FLOWCHART DIAGRAM OF THE SYSTEM'S FUNCTIONALITY.

3. Components, equipment and experiment location

Once the main parts of the system were developed, the required hardware had to be obtained to bring the installation to life. The main component necessary for the proper execution of the installation was a computer capable of running the person detection algorithm and Unity at the same time. Additionally, an external camera was needed to provide the video feed for the algorithm. Both of these components were borrowed from the Interaction Lab at the University of Twente.

In addition to the components necessary to run the system, suitable equipment was required to display the visualisation at the staircase. The optimal solution would be to use two large mobile displays, one placed at the top and the other at the bottom of the stairs. Their large size would ensure the visualisation's visibility for users, whereas the mobile aspect would allow for an easy setup of the installation. However, even though such displays are commonly used around the university, obtaining them was one of the biggest challenges of this project.

Initially, two potential locations were considered for the installation: Ravelijn and Horst, both located at the University of Twente campus. These two buildings were chosen because they both featured a staircase next to an elevator, which would be perfect for conducting an experiment assessing whether the installation increases the number of stair users. Additionally, both staircases had an optimal amount of space at the top and bottom to place the displays. After meeting with the building managers and discussing the possibilities, Ravelijn was chosen due to a convenient availability of a power outlet, which was lacking in Horst. Additionally, the staircase in Ravelijn was larger and more open, providing more space for the displays.

Once the location was secured, the next step was to obtain the two displays which will be placed there. However, after contacting the Ravelijn's service desk as well as the university's mobile display manager, it turned out that such displays are not available for rent in Ravelijn due to being frequently in use. Attempts to borrow the displays from other places on campus, with the intention to transfer them to Ravelijn, were also unsuccessful. Therefore, the options were to either change the location of the installation or to obtain other means of displaying the visualization. The latter would require a use of smaller displays, such as computer monitors or TVs, which would not be big enough for the users to clearly see the visualisation and would require constructing special stands for proper placement. Alternatively, projectors could be used; however, this approach would be more complex, as it would require obtaining two projectors as well as projector screens and placing them strategically so as not to obstruct the users' path, which would be a challenging task due to limited space around the staircase. Therefore, it was first attempted to find another location at the university where two mobile displays would be available.

After consulting several places on campus, the Design Lab was identified as the most suitable location for borrowing the displays due to a large number of mobile displays at their disposal. Additionally, it was directly connected to the Gallery building, which provided a wide, open staircase with enough place to put the displays and multiple power outlets to power the installation. With permissions granted from the Design Lab coordinators and the Gallery service desk, the displays and testing location were secured.

The final challenge was to connect the displays to the computer. Since the laptop had only one HDMI port, while two were needed, the solution was to connect one display to the laptop's HDMI port and use an USB-C to HDMI converter to connect the other display. Additionally, a method was needed to connect the display placed at the bottom of the stairs to the computer located at the top. As finding an HDMI cable of the necessary length proved to be a challenging task, the initial solution was to get an adapter allowing to connect two shorter HDMI cables. However, since this approach would require extensive cable management to avoid obstructing the staircase, a wireless HDMI transmitter was found to be the best solution. This method allowed to solve the problems of the long distance between the display and the computer and cable management. Both the transmitter and USB-C to HDMI converter were borrowed from the Interaction Lab.

6.3. The Final Product

Once both the visualisation and interaction logic were completed, they had to be combined into a working installation. This required finding a way to trigger changes in the garden visualisation by person detections done by the computer vision algorithm.

To achieve this, real-time communication was set up between Python and Unity. This was done using a TCP socket, allowing Python to send messages to Unity. If a person entered the first (bottom) zone, drawn on the lowest step of the staircase, a message spawning in the sprout would be sent. Once the person entered the second (top) zone on the highest step, a message would be sent to deactivate the sprout and spawn a full plant in its place.

6.4. Usability Testing

Before conducting the final experiment, a usability test was conducted to gather feedback and identify potential flaws and aspects to improve.

First, the setup had to be installed at the location and adapted to it. Therefore, after the installation was placed at the staircase in the Gallery, the detection zones were adjusted to match the camera angle and the staircase's structure. The result of these adjustments is illustrated in Figure 15.

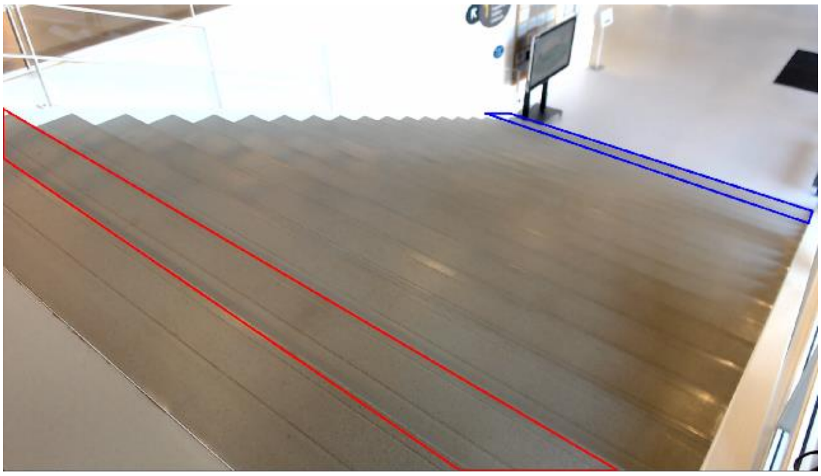


FIGURE 15. THE DETECTION ZONES. BOTTOM IN BLUE, TOP IN RED.

After ensuring that the installation works properly, the usability test was conducted with four fellow students who were asked to:

1. Read the information letter and provide written consent.
2. Climb the staircase with the installation.
3. Scan a QR code leading to a questionnaire asking for feedback about the design of the visualisation and the animations, the safety and unobtrusiveness of the installation, as well as general feedback and suggestions. The questionnaire is presented in Appendix C.

In addition to the survey, the participants were observed to see whether the components of the installation worked as intended and if any malfunctions occurred. After the test, the results were analysed, and appropriate changes were made to the installation.

The feedback regarding the design of the Digital Garden was positive, as all four users liked it. However, several aspects of the visualisation needed improvement. First, the users found the garden too static and suggested adding some dynamic elements to make it more interesting. For that reason, since the garden resembled a floating, moving clouds were added to the background, as shown in Figure 16.

FIGURE 16. THE GARDEN VISUALISATION WITH CLOUDS ADDED TO THE BACKGROUND.

Half of the users also indicated that the animation accompanying the appearance of the sprout should stand out more to make it easier to spot. To achieve that, a light was added in front of the sprout, which would turn on for a few seconds after it spawns, as shown in Figure 17.

In addition, one user noted that the animation playing when the full plant grows could be more appealing. Since the original highlight was also not appearing properly around some of the plants, it was removed. It was replaced by a light turning on when the plant appears and off after a few seconds, as presented in Figure 18.

FIGURE 18. NEW SPROUT ANIMATION WITH THE ADDED LIGHT.

FIGURE 17. NEW FULL PLANT ANIMATION.

Aside from the mentioned aspects, all the users were pleased with the design of the visualisation. Moreover, they found the installation safe and unobtrusive, requiring no changes to the setup. The users also suggested modifications such as adding sound effects or informative signs. However, it was required by the Gallery management for the installation to remain silent. Additionally, informing users about the purpose of the installation was not desired to ensure that it fosters intrinsic motivation, encouraging stair use by sparking interest and curiosity without any external influence.

In addition to user feedback, it was observed that the system triggered sprout animations for users descending the stairs; therefore, the issue was debugged and fixed.

Chapter 7: Evaluation

After refining the prototype based on the information gathered from usability testing, an experiment was conducted to evaluate the effectiveness of the product. The goal of the experiment was to find out whether the installation makes the stair-climbing experience more interesting or enjoyable by fostering intrinsic motivation. This chapter presents the study's design, methods, and results, revealing the impact the installation had on the participants' experience and behaviour.

7.1. Experiment Design

Research Questions and Hypotheses

Research Question 1: Does the installation make climbing the stairs more enjoyable or interesting?

H1.0: The interactive installation does not make stair climbing more enjoyable or interesting for university students and employees as compared to climbing the stairs without the installation.

H1.1: The interactive installation does make stair climbing more enjoyable or interesting for university students and employees as compared to climbing the stairs without the installation.

Research Question 2: Does the installation increase intrinsic motivation to take the stairs?

H2.0: The interactive installation does not increase the intrinsic motivation of university students and employees to climb the stairs as compared to climbing the stairs without the installation.

H2.1: The interactive installation does increase the intrinsic motivation of university students and employees to climb the stairs as compared to climbing the stairs without the installation.

Study Design

The dependent variables to be measured in the experiment were the interest/enjoyment of taking the stairs and the motivation to climb the stairs. The independent variable was the presence of the installation. Therefore, there were two conditions, one with and one without the installation, and the results between the conditions were compared.

The design used in the study was a within-subjects design. This design was chosen to help control for individual differences, such as the participants' regular attitude towards taking the stairs. Comparing the results from the same individuals between conditions ensured that any differences in results are caused by the installation and not other factors. This was especially important as the measurement tool used in the experiment, the Intrinsic Motivation Inventory (IMI), evaluates the participants' subjective experience (Intrinsic Motivation Inventory, n.d.).

To account for any unwanted carryover effects, the order of the conditions was randomised. A pre-generated list of randomised condition orders was generated using a Python script and used to assign participants as they arrived. Additionally, after each climb, the participants were asked to fill in a questionnaire, which provided an opportunity to rest, allowing to counteract any fatigue caused by the previous climb.

Experimental Setup

The experiment was conducted in the Gallery building at the University of Twente campus, as this was the only location with access to the mobile displays necessary for the installation. The setup consisted of:

- Two such displays for displaying the visualisation, one at the bottom and one at the top of the staircase.
- A camera for real-time people detection.
- A computer running the installation.
- All the necessary cables and connections.
- An audio recording device to capture the interviews.

The setup is shown in Figure 19.

FIGURE 19. THE EXPERIMENTAL SETUP WITH ONE DISPLAY AT THE BOTTOM AND ONE AT THE TOP OF THE STAIRS.

Participant Recruitment

Participants taking part in the experiment were University of Twente students and employees aged at least 18 years, which were the inclusion criteria for the experiment. People physically unable to climb the stairs due to medical conditions or injuries were excluded. Participants were recruited through personal invitations or by approaching passers-by at the location.

To make sure the participants meet the criteria, upon having them sign the consent form and understand the course of the experiment, they were asked their age, occupation and whether they confirm to feel physically capable of participating.

The participants did not receive any incentives or compensation for participating in the experiment.

Methods:

The questionnaire used in the experiment was a customised version of the IMI, a validated measurement tool allowing to assess the participants' intrinsic motivation in controlled experiments (Intrinsic Motivation Inventory, n.d.). The IMI's "Interest/Enjoyment" subscale was used to address both research questions. This subscale, as the name suggests, focuses on measuring the interest and enjoyment coming from an activity, allowing to directly answer the first research question of whether the installation makes stair-climbing more interesting and enjoyable. Additionally, the "Interest/Enjoyment" subscale is specifically aimed at assessing intrinsic motivation and is considered its self-report measure (Intrinsic Motivation Inventory, n.d.); therefore, it also helped to answer the second research question. To collect the responses, the participants were seated at a table where they could scan the QR code and complete the online questionnaires. Both questionnaires, one per each condition, are provided in Appendix D.

To complement the self-reported data, after each stair-climbing session, the participants were asked whether they would like to climb the stairs again. Their choice was recorded to provide objective evidence of whether the installation increases intrinsic motivation. A high rate of participants voluntarily deciding to climb the stairs again with the installation would suggest an increase in intrinsic motivation.

Additionally, semi-structured interviews were conducted to gather qualitative data about the installation. While the IMI questionnaires were used to determine the effectiveness of the installation, the interviews allowed to explore how it influenced the participants and their experiences. The interview questions covered enjoyment, change in motivation, the installation's design, and aspects related to intrinsic motivation, such as perceived autonomy, competence and relatedness. See Appendix E for the interview questions.

Experiment Protocol:

1. Welcome the participant and provide the consent form and the information letter, including a short task description. Do not reveal what exactly is being tested to avoid potential bias.
2. Ask the participant to provide their age, gender, and whether they feel physically capable of participating in the experiment based on the task description.
3. Randomly assign the participant to the order of conditions.
4. Ask the participant to climb the stairs under the first condition.
5. Record whether the participant would like to climb the stairs again.
6. Ask the participant to complete the IMI questionnaire.
7. Repeat steps 4-6 for the other condition.
8. Conduct the interview.
9. Debrief the participant.

7.2. Analysis Plan

The IMI Questionnaire

1. Cleaning the Data

First, the data will be reviewed for completeness and errors, such as missing values or duplicate entries.

2. Calculating Individual Scores

For each participant a mean score for the “Interest/Enjoyment” subscale will be calculated for both conditions.

3. Descriptive Statistics

Overall descriptive statistics, such as means and standard deviations, will be calculated and reported.

4. Statistical Analysis

For statistical analysis, a paired-samples t-test will be conducted since the experiment has one independent variable, two conditions and a within-subject study design. Before conducting the t-test, a Shapiro-Wilk test will be conducted to test for normality, and the data will be checked for outliers. In the case that the assumption of normality or no outliers is violated, a Wilcoxon signed-rank test will be conducted.

Behavioural Measure: decision whether to take the stairs again

1. Descriptive Statistics

The number and percentage of participants who chose to take the stairs again will be calculated and reported for each condition.

2. Statistical Test

A McNemar’s test will be conducted to determine whether the installation significantly affects the participants’ decision to take the stairs again. Since the study has a within-subject design, McNemar’s test is an appropriate choice as it accounts for the paired nature of the data, unlike the Chi-Square test.

The interviews

The qualitative data will be analysed to add depth to the findings. The interview transcripts will be reviewed, and relevant quotes will be identified and assigned to predefined themes, including motivation, enjoyment, engagement, autonomy, competence, relatedness, and the design of the installation. Additionally, any themes that emerge during the analysis will also be included. The frequency of similar responses will be noted to identify patterns and illustrative quotes will be selected to represent the themes.

7.3. Analysis

After the experiment was conducted, the data was analysed according to the analysis plan. To begin with, the IMI questionnaire scores were analysed to find out whether the installation increased the interest and enjoyment of stair-climbing, providing an answer to the first research question and a starting point for answering the second one. Then, the analysis was done on the behavioural measure as well as the interviews, complimenting the results of the t-test and allowing to answer the second research question of whether the installation fostered intrinsic motivation.

7.3.1. Questionnaire Analysis

The first step in analysing the questionnaire answers was to clean the data. This resulted in the removal of two participants from the dataset, as one of them filled in the same questionnaire twice, and the other had missing answers. Therefore, out of the initial n = 20, n = 18 responses were valid for the analysis. Afterwards, a mean score was calculated for each participant under each condition. To be precise, since the Interest/Enjoyment subscale contained seven questions, the numerical answers of each participant were summarised and then divided by seven to obtain the mean value. It has to be noted that before adding the scores, some of the items had to be reverse scored.

Descriptive statistics

Then, the data was imported into SPSS statistical software, and overall descriptive statistics were calculated for the two conditions. Those statistics suggest that stair-climbing with the installation, with the mean score of M = 4.71, was regarded by the participants as more interesting and enjoyable as compared to without it, where the mean score was M = 2.8. Additionally, the variability of the answers with the installation (SD = 1.06) was smaller than without it (SD = 1.22). These findings suggest a more consistently positive experience when climbing the stairs with the installation.

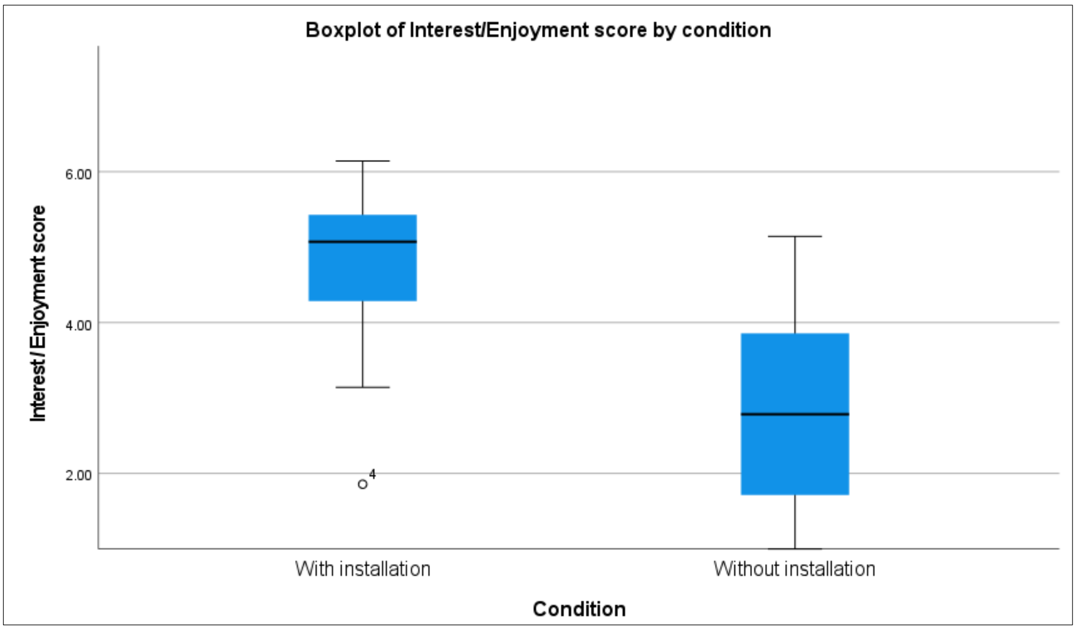


Figure 20. Boxplot comparing the interest/ enjoyment scores between the two conditions.

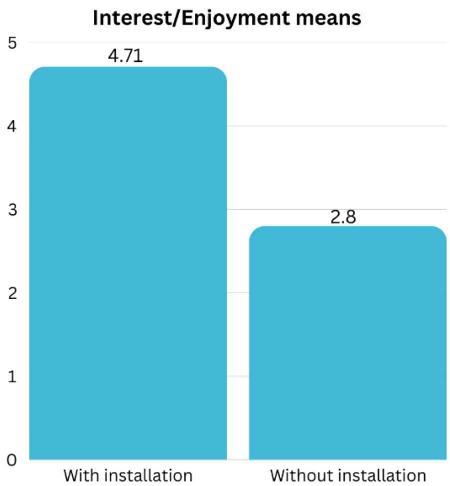


Figure 21. Interest/Enjoyment means for both conditions.

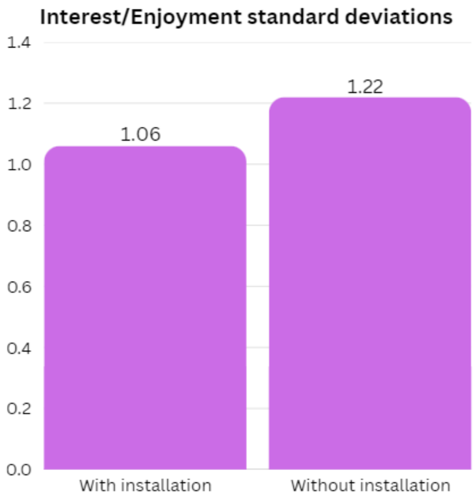


Figure 22. Interest/Enjoyment standard deviations for both conditions.

Paired sample t-test

The next step was to carry out the paired sample t-test; however, first, it had to be checked whether the data met the necessary assumptions of normal distribution and no outliers. A Shapiro-Wilk test was conducted, which indicated that the differences between the paired values are normally distributed (W = 0.959, p = 0.588).

Then, the data was checked for any outliers in the difference between the paired scores. A boxplot and z-score analysis confirmed that the data contains no outliers, as none could be identified visually, and the minimum and maximum z-scores were around -1. 74 and 1.93, respectively, falling within the acceptable range.

After confirming that the assumptions of normality and no outliers are met, a paired samples t-test was conducted to check whether the difference between the conditions is statistically significant.

The results of the t-test indicated that the interest/enjoyment scores with the installation ($M = 4.71$) were significantly higher than without it ($M = 2.8$), $t(17) = -5.96$, $p < 0.001$. The mean difference between the conditions was around 1.91 points lower without the installation (95% CI [-2.59, -1.23]). Those findings indicate that the installation did make stair-climbing more interesting and enjoyable. The difference in scores is unlikely to have occurred by chance since the p-value is smaller than 0.001, which is well below the significance threshold of 0.05.

7.3.2. Behavioural Measure Analysis (Decision to Take the Stairs Again)

While the results of the t-test indicated a statistically significant increase in the interest and enjoyment of stair-climbing caused by the installation, further analysis had to be conducted to confirm whether it truly fosters intrinsic motivation. The next step was to check whether the installation had a significant impact on the participants' decision to climb the stairs again.

First, the total number and percentage of participants who chose to take the stairs again were calculated for each condition. With the installation, 14 out of 20 participants (70%) decided to take the stairs again, while without the installation, 5 participants (25%) chose to do so.

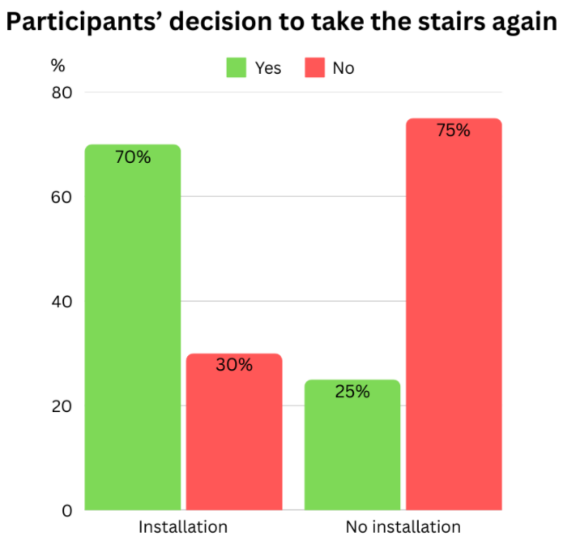


FIGURE 23. PARTICIPANT'S DECISION TO TAKE THE STAIRS AGAIN FOR BOTH CONDITIONS.

Next, a McNemar's test was conducted to check whether the installation significantly affected the participants' decision to take the stairs. The crosstabulation showed that:

- 10 people chose to take the stairs again with the installation but not without the installation.

- 1 person chose to take the stairs again without the installation but not with the installation.
- 5 participants chose not to take the stairs again under both conditions.
- 4 participants chose to take the stairs again under both conditions.

The results of the test indicated that the effect of the installation on the participants' decision was statistically significant, $p = 0.012$, with more people choosing to take the stairs again with the installation than without it. This shows that the installation significantly influenced the participants' likelihood to take the stairs again. The results of the crosstabulation and McNemar's test suggest that the installation fosters intrinsic motivation by making stair-climbing more enjoyable or interesting, confirming the findings of the t-test.

7.3.3. Interview Analysis

While the analysis of the quantitative measures provided statistical proof of the installation's ability to make stair-climbing more interesting and enjoyable by fostering intrinsic motivation, the interviews had to be examined for deeper insights into the participants' experiences, which would enrich the quantitative findings.

It is important to note that, even though a total of 20 participants took part in the experiment, the interviews were conducted with a subset of the first 12 participants. This was done due to limited time available for the transcription and analysis of the interviews.

The interviews were analysed using predefined themes as well as emergent themes that appeared during the review. For each theme, key patterns, as well as diverging opinions, were identified.

Motivation

Most participants (nine out of twelve) indicated that the installation made them feel more motivated to climb the stairs because it made it more intriguing or enjoyable. For instance, one participant said, "I wanted to climb the stairs to see it change and to see what would change. And out of curiosity, even" (ID 1). Others added, "I was excited to see what was on the installation" (ID 3) or "It made me feel more motivated because the journey was more pleasant than usually coming up the stairs" (ID 6).

The remaining three participants reported no change in motivation. One explained, "It's not a change for me. I would rather use the stairs anyway" (ID 5), while two others mentioned not paying attention to the installation: "I didn't pay too much attention. It was just like a small distraction" (ID 10).

These findings suggest that the installation increased the motivation to climb the stairs for most participants. However, its impact may be limited for people who would take the stairs anyway or those not paying attention to the displays.

Interest and Enjoyment

Ten participants found that the installation made climbing the stairs more interesting and enjoyable, where the most popular reason was the interactive aspect. For example, one participant said, “Yeah, it definitely was more fun because of the interactive element” (ID 1). The participants also appreciated having something to look at, making the activity of stair-climbing and the environment less dull and more pleasing. One participant noted, “I think it made it interesting, as when you're going down or walking up the stairs, you had something to look at” (ID 3), and another said, “Because the environment was more pleasing while climbing up the stairs, not the normal environment” (ID 6).

Curiosity about what would happen upon reaching the top of the stairs also made the experience more interesting. For instance, one participant shared, “I would say definitely more interesting because, otherwise, I will just climb the stairs without really even thinking about anything. This made me actually, like, think and be curious of what's going to happen once I reach the top” (ID 8). Another added, “I was excited to be up the stairs to see what would be on the screen” (ID 9).

Another mentioned aspect was the installation being a distraction from the activity of stair climbing. As one participant stated, “It was more fun because I didn't think of climbing the stairs” (ID 5).

These findings indicate the installation’s success in creating a more interesting and enjoyable stair-climbing experience, mostly delivered through its interactivity and visual appeal but also through its ability to spike curiosity and provide a distraction from climbing the stairs.

Autonomy

None of the participants indicated feeling any external pressure or influence from the installation to climb the stairs. This indicates that the installation does not undermine the users’ autonomy, which is important for the intended effect of the installation on the users, as to foster intrinsic motivation, they must retain freedom of choice.

Competence

Three participants reported feeling more confident or capable while climbing the stairs with the installation. One explained, “If I'm climbing the stairs without something like a goal at the end, then I'm just climbing the stairs, I'm focused on that. But if I'm doing it for something else, I feel like it happens more easily” (ID 1).

The rest of the participants did not indicate an increased feeling of confidence or capability. However, none suggested a lower sense of competence, meaning that the installation's impact on that aspect was neutral.

Seven participants confirmed feeling successful or accomplished upon reaching the top of the stairs with the installation due to the visualisation reacting to their actions. One participant shared, “You can say I felt more accomplished because my actions made changes to the display. Like, it felt like I planted a tree, and it made me feel good.” (ID 8), and another added, “When it started from a little plant, and then it turned into a big plant, it was like, yeah, nice” (ID 7).

The rest of the participants did not feel successful or accomplished because they did not notice the interaction aspect of the visualisation. One participant also indicated not paying attention to the installation at all, while another said, “I don't take taking stairs as any achievement for me at all” (ID 6).

These findings suggest that the installation did not directly affect the perceived sense of competence for the majority of participants. Nevertheless, it made most of them feel successful or accomplished, indicating a positive impact on their feeling of competence.

Relatedness

Only one participant recognised the concept of the installation to provide a shared experience where each person can contribute to the growth of the garden. That participant shared, “Yeah, I would say it felt like I was part of a community, where even though I haven't interacted with the other person that has been here before me, they still have their traces. And then now I left my trace, and then the next person will also climb the stairs and leave their trace, and then we collectively make a change to the installation.” (ID 8)

However, a majority of the participants expressed enthusiasm once asked about their opinion about the concept of a shared experience. For example, one participant said, “I think it's a nice way to somewhat have an interaction with someone without meeting them actually” (ID 7), while another added, “Yeah, I think it would be fun. I genuinely think I would grab my friends and be like, let's climb the stairs and see some trees” (ID 9).

The remaining participants were those who did not notice the interactive aspect of the installation; therefore, they could not be asked questions regarding the shared experience, as they were not even aware of the individual experience.

The participants' answers indicate that the shared experience aspect was not obvious due to the nature of the experiment, as they were stair climbing alone. However, their enthusiasm about this idea suggests a potential increase in motivation to take the stairs thanks to this functionality if applied in a real-world scenario.

Interaction aspect

Six participants indicated the visualisation being clear and easy to understand; however, one of them noted being confused during the first climb and figuring out the interaction during their second climb.

Two participants only noticed the animation happening on the bottom screen but could not point out what happened upon reaching the top of the stairs. However, they both highlighted having an eyesight problem and not wearing their glasses during the course of the experiment.

The rest of the participants did not notice the interactive aspect of the installation. Therefore, they were asked to provide reasons for that or suggestions about what could be done to catch their attention.

One participant simply indicated having no interest in the installation and did not like the concept of the Digital Garden. Two participants indicated paying little attention to the displays while climbing the stairs. The last participant who missed the interaction aspect of the installation indicated not being able to focus on a display while climbing the stairs and stated, “The thing is, I was focusing on coming up the stairs. So, I cannot focus on something on the screen” (ID 6).

The suggestions from the participants included placing signs explaining what the installation does at the bottom of the stairs, making the plants bigger or the animation more visible, and adding sound effects. For example, one participant said, “I would say I would like a sentence or something that would like, catch your attention at the beginning of the stairs, being like, “look what grows at the end of your path” (ID 9), while another commented, “Maybe it should be more prominent, so it kind of flashes into your eyes so you like, you are sure that you see that something is happening there” (ID 10).

These findings indicate that animations on the visualisation were mostly noticed and understood; however, they could stand out more for better clarity and to decrease the probability of some users missing the interaction aspect. Additionally, it can also be concluded that individual differences played a role here, as some participants did not pay attention to the displays in general.

Impression

Almost all participants found the design of the visualisation to be appealing. One of them noted, “Yes, that was my favourite part because, because that's what caught my attention. The art style, the garden and everything, and even like the sky box, everything looked pretty good” (ID 8).

Most participants described the atmosphere of the garden as calm, relaxing or chill, with some participants also regarding it as happy, fresh, and charming. Only one participant, who did not like the concept of the Digital Garden, did not have an opinion about the design of the garden and its atmosphere.

Those results confirm the design of the Digital Garden to be visually appealing and prove its success in inducing a calm and relaxing atmosphere.

Impact

Nine participants stated that they would use the stairs more often if the installation was present in a building they frequently use. The reasons included the participants wanting to see their impact on the garden, seeing the trees grow, or curiosity about the garden's growth over time. For example, one participant said: "I want to see how or where my impact would have been on the on the garden, to see where the little flower or the plant will pop up on it" (ID 7), while another noted, "Because I want to see the trees grow. And also, I know that it's going to be like, if it's a building where there's a lot of people, I'd be interested to see how many trees there are in the beginning at the end of the day. If it's a building that I frequently use, then I'd be really excited" (ID 9).

Those findings are a positive indicator of the installation's ability to encourage stair use and suggest it could be effective if applied in a real-world environment.

Chapter 8: Discussion & Future Work

The findings from the IMI questionnaire, behavioural measure, and interview analyses indicated the installation's ability to make the stair-climbing experience more interesting and enjoyable and to foster intrinsic motivation. This chapter focuses on interpreting, discussing and comparing the results to literature, as well as addressing the limitations encountered during the project. It also answers the two key research questions this study investigated:

- **RQ1:** Does the installation make climbing the stairs more enjoyable or interesting?
- **RQ2:** Does the installation increase intrinsic motivation to take the stairs?

8.1. Results and Discussion

Results

The analysis of the IMI scores revealed a significant increase in participants' interest and enjoyment of stair-climbing with the installation compared to without it. Similarly, the behavioural measure analysis showed that more participants chose to take the stairs again with the installation than without it, demonstrating its significant effect on their decision.

The interview analysis provided deeper insights into these findings. The majority of participants noted increased motivation to climb the stairs with the installation, with the key factors being fun and curiosity. Interactivity and visual appeal were commonly mentioned factors in making the experience more interesting and enjoyable, along with curiosity about what would happen at the top of the stairs.

The findings of this study align with the cognitive evaluation theory (CET), where Ryan and Deci (2000b) present three psychological factors that play a role in fostering intrinsic motivation: autonomy, competence, and relatedness:

- **Autonomy and Competence:** As stated by Ryan and Deci (2000b), satisfying the needs for autonomy and competence is essential for intrinsic motivation to work. The installation successfully managed to preserve autonomy, as the participants did not report feeling externally influenced but being motivated by internal factors. This indicates that the installation did not rely on extrinsic motivation, which would occur if the participants wanted to climb to achieve a separable outcome (Ryan & Deci, 2000b; Di Domenico & Ryan, 2017; Ryan & Deci, 2000a). Furthermore, when given a free choice, participants decided to climb the stairs more often with the installation than without it. These findings suggest that if the installation was placed in a real-world environment, its users would most probably perceive their choice to take the stairs as self-regulated.

Similarly, the need for competence was also preserved, and even partially enhanced, as implied by more than half the participants feeling a sense of accomplishment upon reaching the top of the stairs.

- **Relatedness:** The need for relatedness was not found to be satisfied due to the controlled nature of the experiment, where each participant climbed the stairs alone, reducing the likelihood of noticing the shared experience aspect of the installation. However, as stated by Ryan and Deci (2000b), satisfying the need for relatedness is not required to foster intrinsic motivation. Furthermore, once prompted, the installation's shared experience feature was met with enthusiasm, suggesting its potential success in a real-world use scenario.

Since both competence and autonomy were satisfied, it can be said that the installation successfully fulfilled the requirements needed for intrinsic motivation to work established based on the CET (Ryan and Deci 2000b).

The results of the experiment also align with the definition of intrinsic motivation, which states that this type of motivation only works when performing an activity because it is interesting, enjoyable, or satisfying (Ryan & Deci, 2000b; Di Domenico & Ryan, 2017; Ryan & Deci, 2000a). The IMI scores demonstrated that stair-climbing with the installation was found to be more interesting and enjoyable, while the interviews showed increased motivation caused by aspects such as fun and curiosity. Additionally, the installation made the participants significantly more likely to take the stairs again, as shown by the behavioural measure. Together, these findings provided clear answers to both research questions:

- RQ1: The installation increased the interest and enjoyment of stair-climbing.
- RQ2: The installation increased the intrinsic motivation to climb the stairs.

Aligning with the principles of intrinsic motivation has several potential implications for the installation. This is because intrinsic motivation results in higher interest, excitement and persistence in an activity (Ryan and Deci, 2000b). Furthermore, as claimed by Peeters et al. (2013), intrinsically motivated people are more likely to perform and sustain a behaviour. These findings suggest that, in a real-world environment, the installation has a large potential to encourage stair climbing and sustain that behaviour.

Relation to previous work

Unlike many persuasive technology (PT) interventions for encouraging physical activity, which rely on mobile and desktop applications or wearable devices (Aldenaini et al., 2020), this project focused on designing an interactive installation. Furthermore, while most PT interventions try to increase the users' overall physical activity, this project specifically aimed to encourage stair use. It did so by fostering intrinsic motivation, which is an approach rarely used by previous work.

This Digital Garden is a new addition to interactive installations encouraging stair-climbing, joining the Piano Staircase and Social Stairs as the only three solutions identified by this project. However, unlike these projects, which focused on auditory feedback, the Digital Garden provided visual feedback. Additionally, it did not respond to each step of the users but only reacted at the beginning and end of the climb. By doing so, it aimed to motivate the users to reach the top of the stairs instead of playfully interacting with the installation, which was possible with the Piano Staircase and Social Stairs.

While this project builds on the approach suggested by Peeters et al. (2013), the creators of the Social Stairs, to target intrinsic motivation, it adds a novel type of interaction. Moreover, the promising findings of the experiment reinforce the idea that fostering intrinsic motivation can be an effective way of encouraging stair use.

8.2. Limitations and Future Work

Although this study demonstrated the installation's ability to foster intrinsic motivation and its significant and positive impact on stair use, it encountered several limitations which may affect the quality of the findings.

Controlled nature of the experiment

The major limitation of the study was the controlled nature of the experiment, with participants being asked to perform a specific set of tasks. Ideally, the installation should be tested in a real-world setting, where participants' natural behaviour and reactions to the project could be observed. This way, instead of being asked to climb the stairs, participants would only do so if encouraged by the installation, allowing to assess its true impact on their motivation. Additionally, the number of stair users before and after implementing the installation could be compared to check for its effectiveness. An observation-based approach would also help to eliminate potential biases caused by the participants being aware of taking part in an experiment. This awareness may have influenced their behaviour, for example, by making them pay more attention to the displays. However, conducting such an experiment was infeasible due to time constraints, as it would require collecting the data over a long period, for at least a week with and a week without the installation. Additionally, a testing site with equal access to both the stairs and the elevator would be necessary, but no such location with the required mobile displays was available.

Longitudinal data

Another limitation was the experiment's inability to assess the installation's impact on stair use over a longer period of time. Obtaining such data would be crucial to understanding whether the installation keeps encouraging stair use over time and whether it fosters a sustained behavioural change, as suggested by Peeters et al. (2013) and Boldina et al. (2022). Therefore, a recommended direction for future research is to conduct longitudinal studies assessing the long-term effects of the installation.

Shared experience feature

The controlled experiment also did not allow for testing the impact of the shared experience feature of the installation, as participants climbed the stairs individually. This would be particularly important to evaluate in future projects, as satisfying the need for relatedness could further enhance intrinsic motivation fostered by the installation (Ryan & Deci, 2000b).

Sample size

Another important aspect to mention is the sample size, which consisted of 20 participants due to the time constraints of the project. Conducting a study with more participants could increase the validity, reliability, and generalizability of the findings. Additionally, it would minimise the impact of invalid responses, which, in the case of this research, reduced the number of valid IMI questionnaire responses to 18.

System performance

One limitation of the system was the inability to handle users starting to climb the stairs but then turning around and leaving the frame. Although this issue was not encountered during the project, but discovered later, it is recommended to address this limitation in future projects.

Location and resources

Other limitations arose from the location of the experiment and the available resources. For example, the building manager did not give permission to use sound effects, which could have been an effective way of catching participants' attention. Additionally, it was not feasible to place the camera on the ceiling, which would have increased the reliability of the system. A bird's-eye view would have helped to prevent detection overlapping, which occasionally was an issue with the existing setup.

Furthermore, the structure of the staircase, being particularly wide, may have reduced the noticeability of the displays, as they were placed on the sides of the stairs. Additionally, as shown in Figure 23, the bottom screen had to be placed parallel to the staircase, forcing the stair-climbers to turn around to see it. Placing the display to be naturally visible when starting to climb the stairs could have increased the number of participants noticing it and the comfort of the experience. Similarly, utilising larger displays could have enhanced the visibility of the visualisation and animations; however, obtaining such equipment was out of the scope of this project. Future projects are advised to account for these limitations by using larger displays and optimising their placement.

FIGURE 24. THE PLACEMENT OF THE BOTTOM DISPLAY.

Visibility: Participant's suggestions

The limited visibility of the interaction was also a limitation mentioned by several participants, especially those who failed to notice the interactive aspect of the installation. Some suggested placing informative signs about the project at the bottom of the staircase, stating that knowing what the installation does would make them pay more attention to it. This solution, however, could undermine intrinsic motivation, as it is a form of an external cue to the user. Nonetheless, it is recommended to examine the effectiveness of such an approach and its impact on intrinsic motivation in future research. The size of the plants and the design of the animations can also be considered limitations of the installation, with some users suggesting to make the plants bigger and the animations more prominent. Incorporating these changes, along with adding sound effects, is a recommended direction to be explored by future projects building on this one.

Future directions

Despite the limitations, this study provided valuable findings indicating the installation's potential to encourage stair use, offering a solid foundation for future projects. This project also added a novel approach to the existing solutions aimed at encouraging stair use through interactive technology, different from the Piano Staircase and Social Stairs. Future studies should explore the suggested usability improvements, including larger displays, more optimal screen and camera placement, sound effects, as well as bigger plants and more noticeable animations. Furthermore, future research should evaluate the installation's long-term effects in an observation-based experiment.

Chapter 9: Conclusion

Physical inactivity is a growing concern, especially at universities, where students and employees tend to be sedentary for most of their day. This project aimed to address this issue by designing an interactive installation motivating people to take the stairs instead of the elevator. The research question guiding this work was: “How can the stair-climbing experience be modified to increase the number of people taking the stairs instead of the elevator at the university using interactive technology?”

As background research found that out of two types of motivation, intrinsic and extrinsic, the former results in more interest and engagement in an activity while making a person more likely to have a sustained change in their behaviour, the focus of this project was on fostering intrinsic motivation. Further literature review highlighted that to achieve that, the installation must make the stair-climbing experience more interesting and enjoyable while satisfying autonomy, competence, and relatedness, the three needs affecting intrinsic motivation. In addition to these research findings, the ideation process considered ethical guidelines and physical constraints to ensure the installation’s safety and effectiveness in a university setting. Based on these insights, the concept of the Digital Garden was developed. It was then refined through consultations with project supervisors and potential users.

The Digital Garden was an interactive installation that visually responded to people climbing the stairs by growing a virtual garden. The visualisation was displayed on two screens, one located at the top and one at the bottom of the stairs. For each user starting to climb the stairs, a sprout appeared in the garden, which then transformed into a full plant upon the user reaching the top of the stairs. The project combined computer vision for real-time person detection with a visualization in Unity.

The installation was evaluated through usability testing and a controlled experiment. The usability test ensured that the installation was safe and unobtrusive and allowed for improvements based on user feedback. The final experiment measured the system’s impact on the experience of stair-climbing and on intrinsic motivation using the Intrinsic Motivation Inventory (IMI) questionnaire, behavioural measure, and interviews. The results indicated a significant increase in users’ interest and enjoyment of taking the stairs with the installation. Furthermore, the findings showed that participants were more likely to take the stairs again when the Digital Garden was present. Interview insights revealed that the installation satisfied the two needs necessary for intrinsic motivation to work: autonomy and competence. These findings provided affirmative answers to the two research questions guiding the evaluation: “Does the installation make climbing the stairs more enjoyable or interesting?” and “Does the installation increase intrinsic motivation to take the stairs?”.

This research contributes to the field of persuasive technology and encouraging physical activity through interactive installations. It adds a novel approach to motivating people to take the stairs by fostering intrinsic motivation. Unlike the two previously identified solutions, Piano Stairs and Social Staircase, which relied on sounds, the Digital Garden focused on making the stair-climbing experience more interesting and enjoyable through visual feedback. It also aimed to make the users feel a sense of accomplishment and motivate them to reach the top of the stairs. Moreover, it added a sense of personality to the staircase in the form of a garden, which flourishes every time someone takes the stairs, creating a positive and relaxing atmosphere.

Future work should explore the impact of the Digital Garden’s shared experience feature on stair use, as it appears to be a promising way of enhancing intrinsic motivation. Additionally, long-term real-world studies should be conducted to assess the sustained impact of the installation on behaviour in natural environments.

Ultimately, the findings suggest that the Digital Garden has strong potential to encourage stair use if implemented in a real-world environment. By integrating this or similar interactive interventions, universities can take a significant step toward promoting active lifestyles and improving well-being.

Appendix

During the preparation of this work, the author used ChatGPT in order to:

- help to improve the clarity of some sentences,
- help to explain errors and suggest optimizations in the Python code and Unity scripts,
- help to solve technical issues encountered in Blender and Unity when creating the garden visualization, such as importing the textures.

Additionally, Grammarly was used to conduct a spelling and grammar check.

After using these tools/services, the author reviewed and edited the content as needed and takes full responsibility for the content of the work.

Appendix A: Context Analysis Survey

Behaviour related to taking stairs and elevators at the university

You have been invited to participate in this survey, which is a part of a Creative Technology Graduation Project. The goal of this survey is to gain insight into the reasons why do people choose to take the stairs or the elevator and the factors that affect their choice. The results of this study will be used to design an installation encouraging people to take the stairs instead of the elevator and will be included in the final project report.

This online survey should take around 5 minutes to complete. To participate you must be at least **18 years old** and be a **university student or** a part of the **university staff**.

Participation is voluntary and you have the right to withdraw or refuse to answer at any time without any consequences. All the collected responses will be anonymous and no data that can identify you will be recorded. You can request to have your answers deleted at any time without providing any reason.

There are no expected physical or psychological risks associated with this study.

Thank you in advance for your participation. If you have any questions about this survey or further research please contact the researcher, Filip Tatarek, at f.tatarek@student.utwente.nl.

If you wish to contact the Ethics Committee Computer and Information Science, you can reach them at ethicscommittee-CIS@utwente.nl.

1. I have read and understood the study information. I have been able to ask questions about the study and my questions have been answered to my satisfaction. *

   ◯ Yes

2. I consent voluntarily to participate in this survey, and I understand that I can withdraw from the study or refuse to answer at any time without any consequences. *

◯ Yes

3. I understand that the information gathered in this survey will be used to design a prototype and will be used in the researcher's project report. *

◯ Yes

The reasons for taking the stairs and the elevator

4. Why do you choose to take the elevator at the university? (you can provide multiple aspects influencing your decision)

5. Why do you choose to take the stairs at the university? (you can provide multiple aspects influencing your decision)

6. On a scale of 1-5, how beneficial do you think taking the stairs is compared to taking the elevator in terms of health benefits?

1 - Not at all	2 - Slightly	3 - Fairly	4 - Very	5 - Extremely
◯	◯	◯	◯	◯

7. What could be changed about/added to the staircase to make you more eager to take the stairs? (you can provide multiple aspects)

Demographic data

8. What is your age? (provide a number, e.g. 21)

9. What is your gender?

- ◯ Male
- ◯ Female
- ◯ Non-binary
- ◯ Prefer not to say

10. What is your occupation?

- ◯ Student
- ◯ University employee
- ◯ Other

11. How would you rate your fitness level?

- ◯ Very low
- ◯ Low
- ◯ Medium
- ◯ High
- ◯ Very high

Appendix B: Ideas and Their Paper Prototypes from the Ideation Phase

1. Steps light up with colors when stepped on
    a. User chooses a color palette with a button
    b. Stepping on a step lights it up
    c. The nearby steps also light up but less, and gradually fade
    d. Consecutive steps create a color transition effect
    e. the users could choose the color of each step, by stepping on it multiple times, allowing to “paint” the stairs
2. Lights follow the user
    a. A trail of lit up steps behind the users, fading away after a few steps
3. When the user steps on the stairs, a spot on the next stair lights up, leading the user all the way up on a random path
4. User chooses colors, brightness and ambience before going on the stairs
    a. Using a touchscreen or buttons
    b. User can select a color palette and adjust the brightness
    c. The user can also select the style of lighting, such as fading in and out, blinking, etc.
    d. User can also select the ambience sound
5. The user chooses a theme before going on the stairs, then the lights, sounds (and possibly visuals) will adapt accordingly
    a. E.g. Ocean, space, forest, winter
    b. Lights and sounds form an atmosphere of the selected theme
    c. E.g. choosing the ocean theme would result in blue colors, whale sounds, bubble sounds, etc.
    d. Colors could become lighter the higher the step
6. User selects a theme, and then a sound effect from that theme plays with every step
7. Play a funny walking sound effect, different for each journey
    a. Quacks, cartoon sounds, etc.
8. At each step the user can choose from a set of melody loops
        i. Each step would be a different instrument
        ii. E.g. the first step would be a kick pattern, the second step would trigger a snare loop, and the next steps would allow to play sounds such as the bassline, chords, or melody.
        iii. Therefore, the user would be able to make a custom melody from the loops while climbing.

    iv. The users could play together by triggering different instruments, mimicking a band
    v. The loops would be synchronized and in the same key, so that the melody does not fall out of rhythm or key
    vi. Upon triggering a new loop, the old loop would play out until it ends and then the new loop would play.

9. The stairs get brighter the higher the user goes
    a. With multiple users, the colors change and the light patterns intensify
10. Heat map of the stairs
    a. Color gradient or brightness levels showing where people step more frequently
    b. Real-time change
    c. Stronger response with multiple people
    d. The map fades away after some time
11. Pixel art, turning pixels on or off by stepping on them
    a. The user can choose a color and “paint” on the stairs
    b. Pixels either stay on or fade away
    c. People can paint together
12. Pixel art, where the users “reveal” the artwork by stepping on the pixels
    a. After the artwork is fully revealed, a new artwork loads
13. A displayed artwork, which starts empty and gets revealed as the user goes up
    a. For example, a blank canvas is displayed, which starts to get colored from the bottom as the user progresses
    b. With each user, something new could be added to the painting
14. Minigames
    a. Spot a symbol – step on the right symbol
    b. Mystery/puzzle/crossword
    c. There is a question, and the user types in the answer as going up, by stepping on appropriate letters
    d. Rebus
    e. Trivia
        i. With a, b, c answers
    f. A sequence of spots lights up, and the user needs to memorize it and repeat it
    g. User must choose an item that doesn’t match the rest
    h. The user must avoid stepping on a certain moving object
15. A garden, shown on a display or projected
    a. Every time the user takes the stairs, the garden flourishes: A new plant is added, a plant grows bigger, wildlife appears, etc.

16. Similar idea but with an aquarium
    a. Where new plants and animals spawn
17. Evolution show
    a. A certain thing is displayed next to the user as the user climbs
    b. For example an egg
    c. As the user goes up, the egg hatches, the chicken grows, etc.
    d. This could also show an evolution of a certain car model, or of a human, or how Earth changed over time, or a sprouting and growth of a plant, etc. Many different possibilities.
18. A bar is charged as the user goes up
    a. After the user reaches the top of the stairs and the bar is fully charged the user can:
        i. Choose one of the creatures that is displayed and feed it
        ii. Or choose a plant from the garden which they want to grow
        iii. Or add a doodle to a collaborative artwork
        iv. Etc.
19. An interactive wall on the stairs, on which the users can draw
20. A journey though seasons
    a. A forest in a certain season is shown when the user starts climbing
    b. As the user climbs, the forest goes through all the seasons, showing different weather, plants blooming, different animals waking from hibernation, then the leaves falling, etc.
21. A story that is spoken or displayed with text, getting revealed as the user goes up
    a. To hear the next part of the story, the user must keep on moving up
22. Short animated clips which play as the user climbs and stop if the user stops
23. AR creature
    a. The user can select a creature that will accompany the user when climbing
    b. The user can customize the look of the creature after reaching the top
    c. Or feed the creature
    d. Each user can have their own creature which they can interact with every time they take the stairs
24. AR Find an object
    a. A certain object is hidden somewhere in the AR environment on the stairs and the user must find it
25. AR environment
    a. The user can see the environment as if climbing a snowy mountain, or being in a forest, or climbing stairs in the sky, etc.

26. The stairs have a face
    a. When the user starts climbing it is sleeping, then it wakes up and gets happier as the user climbs
    b. With more users more faces could appear

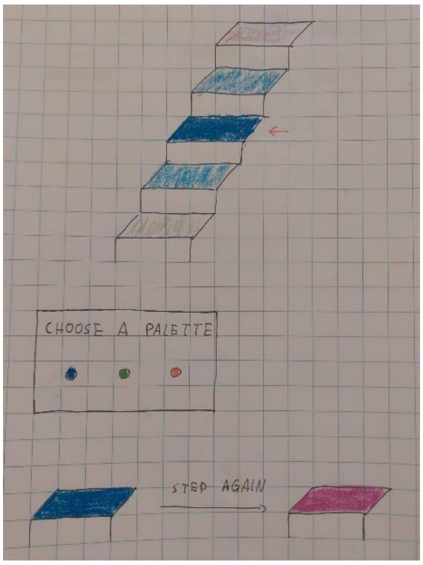


Figure B1. Idea nr. 1.

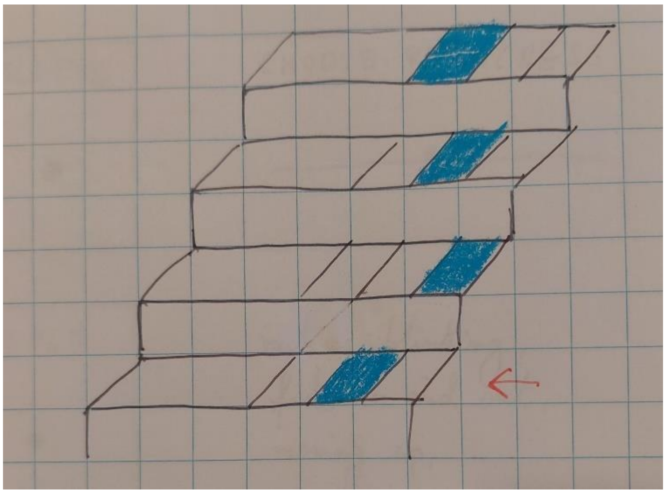


Figure B2. Idea nr. 3.

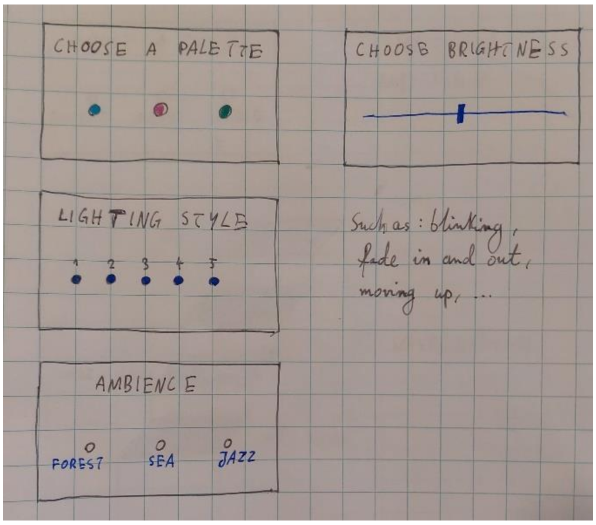


Figure B3. Idea nr. 4.

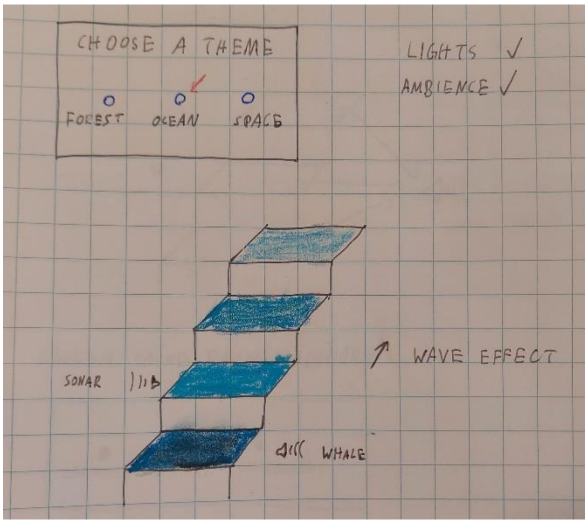


Figure B4. Idea nr. 5.

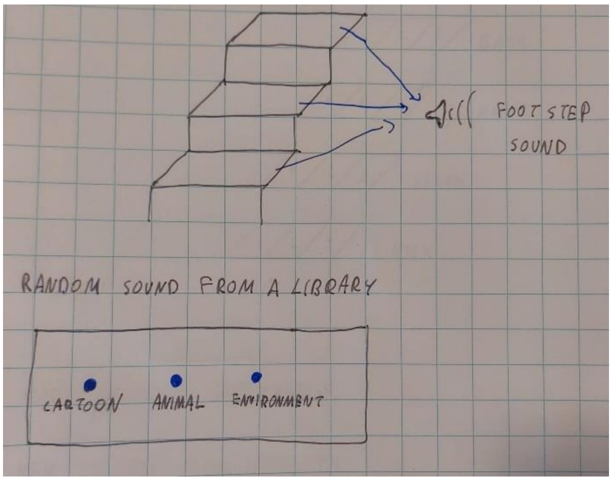


Figure B5. Idea nr. 6 and 7.

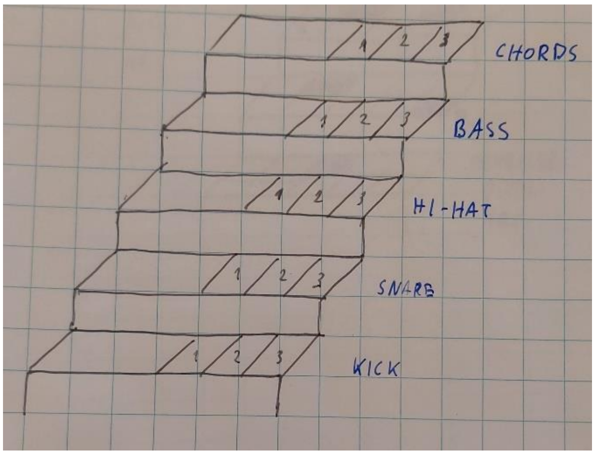


Figure B6. Idea nr. 8.

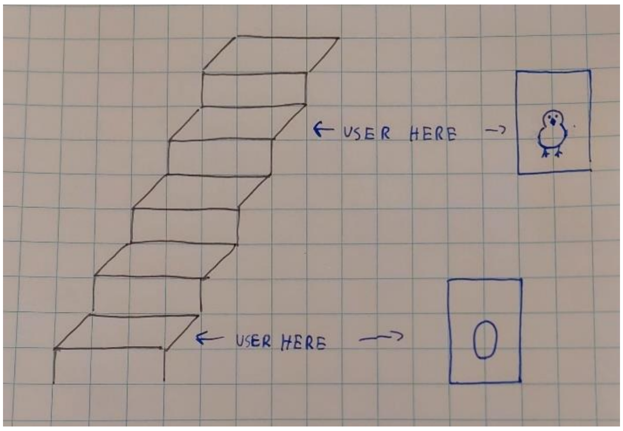


Figure B7. Idea nr. 17.

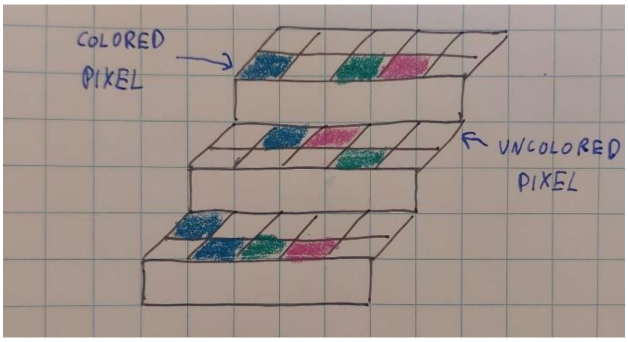


Figure B8. Idea nr. 11.

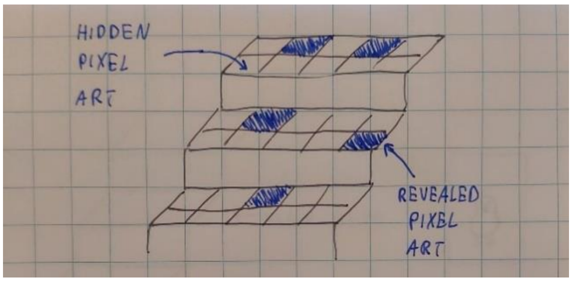


Figure B9. Idea nr. 12.

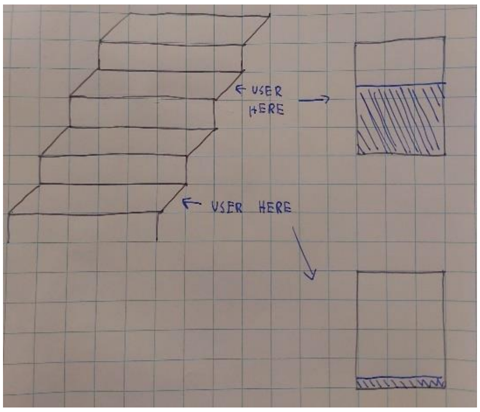


Figure B10. Idea nr. 13.

Appendix C: Questionnaire for Usability Testing

Digital Garden prototype evaluation

Design of the animations

1. Was it easy to notice the sprout appearing?

- ◯ Yes, it was easy.
- ◯ No, it was difficult.

2. If it was difficult to notice the sprout appearing, what made it hard to spot?

3. Did you like the particle animation playing when the sprouts grow?

- ◯ Yes
- ◯ No

4. If not, what would you change about the animation?

5. Was it easy to notice the full plant appearing?

- ◯ Yes, it was easy
- ◯ No, it was difficult.

6. If it was difficult to notice the full plant appearing, what made it hard to spot?

7. Did you like the highlight animation when the full plants appear?

- Yes
- No

8. If not, what would you change about the animation?

Aesthetic appeal

9. Did you like the design of the visualisation?

- Yes
- No

10. Would you change anything about the visualisation to make it more appealing to you?

- Yes
- No

11. If yes, what would you change?

Emotional impact

12. What emotions did the installation trigger in you?

Comfort

13. Did the installation feel safe?

- Yes
- No
- Other

14. If not, why did it not feel safe?

15. Did the installation feel unobtrusive?

- Yes
- No
- Other

16. If not, what was obtrusive about it?

17. Would the installation bother you in taking the stairs if you had no interest in it?

- Yes
- No
- Other

18. If yes, why would it bother you?

Attention and motivation

19. Do you think the displays showing the garden visualisation would attract your attention upon entering a building?

- ◯ Yes
- ◯ No

20. If not, what could be changed about the installation to attract your attention?

21. Do you think that the installation would make you more likely to take the stairs?

- ◯ Yes
- ◯ No

22. If not, what could be changed to encourage you to take the stairs?

23. Did you feel like you were externally motivated or pressured to take the stairs?

- ◯ Yes
- ◯ No

24. If yes, please explain.

General feedback

25. Do you think anything should be improved about the installation?

- ◯ Yes
- ◯ No

26. If yes, what do you think should be improved?

27. Do you have any other remarks about the installation?

Appendix D: Questionnaires for the Experiment

1. Without the installation

Stair-climbing interest and enjoyment

For each of the following statements, please indicate how true it is for you, using the following scale:

1 - Not at all true
2
3
4 - Somewhat true
5
6
7 - Very true

1. I enjoyed climbing the stairs very much.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

2. Climbing the stairs was fun to do.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

3. I thought climbing the stairs was a boring activity.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

4. Climbing the stairs did not hold my attention at all.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

5. I would describe climbing the stairs as very interesting.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

6. I thought climbing the stairs was quite enjoyable.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

7. While I was climbing the stairs, I was thinking about how much I enjoyed it.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

2. With the installation

Stair-climbing interest and enjoyment with the installation

For each of the following statements, please indicate how true it is for you, using the following scale:

1 - Not at all true
2
3
4 - Somewhat true
5
6
7 - Very true

1. I enjoyed climbing the stairs with the installation very much.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

2. Climbing the stairs with the installation was fun to do.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

3. I thought climbing the stairs with the installation was a boring activity.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

4. Climbing the stairs with the installation did not hold my attention at all.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

5. I would describe climbing the stairs with the installation as very interesting.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

6. I thought climbing the stairs with the installation was quite enjoyable.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

7. While I was climbing the stairs with the installation, I was thinking about how much I enjoyed it.

1	2	3	4	5	6	7
○	○	○	○	○	○	○

Appendix E. Interview Questions

Motivation and engagement

1. How did the installation affect your motivation to climb the stairs?

2. Did it make you feel more or less motivated to climb the stairs? Why?

Enjoyment and interest

1. Did you find climbing the stairs with the installation more enjoyable or interesting? Why?

2. Was it more fun? What aspects made it more fun?

3. How was the experience of stair-climbing with the installation different than climbing the stairs without it?

Autonomy

1. Did the installation make you feel like you were freely choosing to take the stairs?

2. Did you feel motivated to take the stairs by any external factors, such as pressure to obtain a reward?

Competence

1. Did the visual feedback make you feel more capable or confident while climbing the stairs? How?

2. Did you feel more successful or accomplished in reaching the top with the installation? Why?

Relatedness

1. Did the installation make you feel connected to others?

2. Like you were a part of a shared experience and contributed with other people to the garden growing and flourishing?

Usability and design

1. Was the visualization clear and easy to understand?

2. Did you like the design of the visualization and the animations?

Impression

1. What atmosphere did the installation give you? (emotion, impression)

2. What did you like the most about the installation?

3. Was there something you did not like?

4. If the installation was present in a building you frequently use, do you think you would take the stairs more often?

5. Do you have any final comments?

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