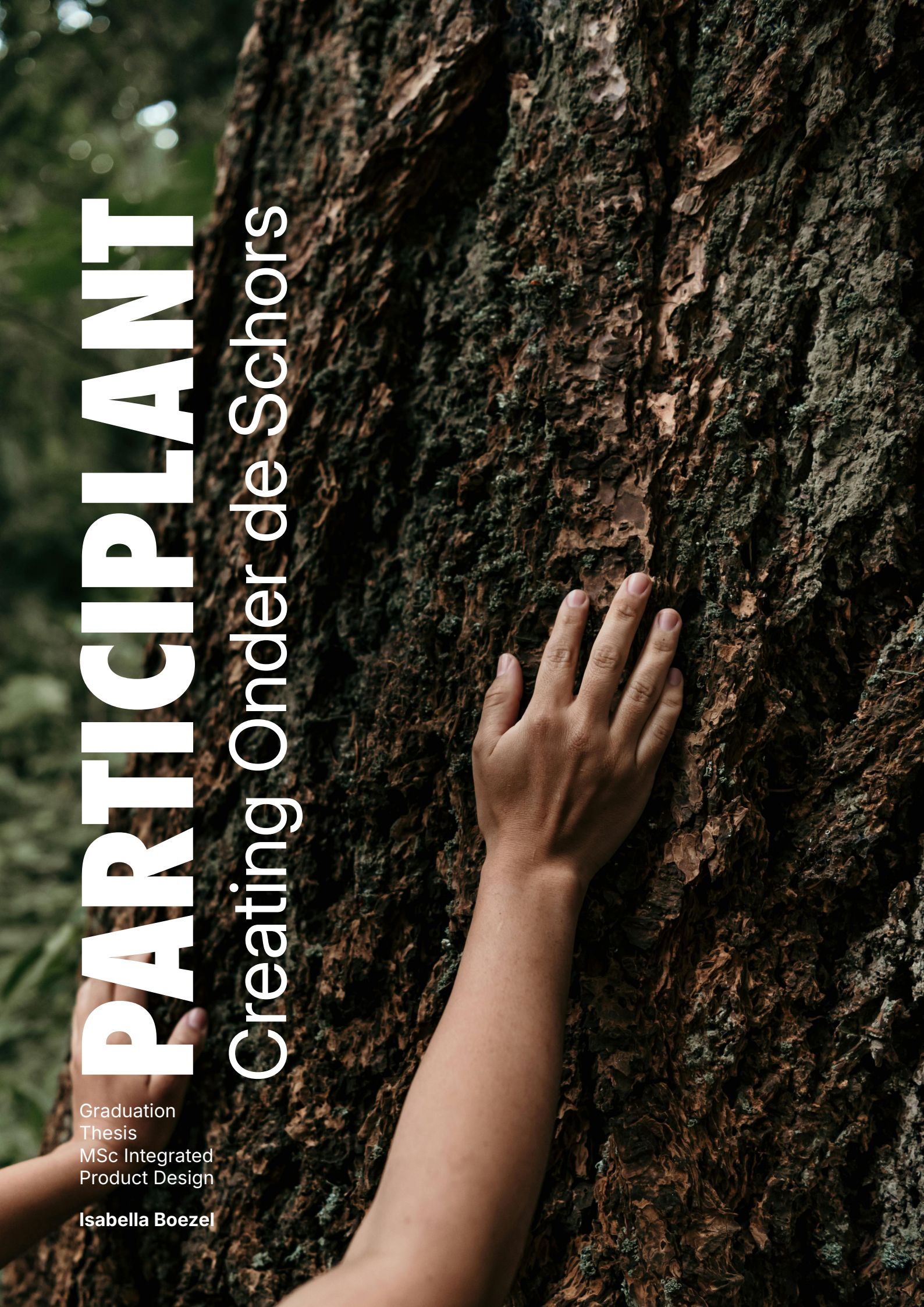

PARTICIPLANT

Creating Onder de Schors

Graduation
Thesis
MSc Integrated
Product Design

Isabella Boezel

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Abstract

This thesis investigates how an interactive, public-park installation can strengthen Connectedness with Nature (CWN) by reducing Plant Awareness Disparity (PAD), the tendency to overlook plants as active, meaningful living beings. Building on literature and various research acitivites the project frames a core design hypothesis: Through experientialising systemic electrical signalling in plants, this installation will foster attention towards plants and information gain about plants, lowering guest's Plant Awareness Disparity, which enhances their Connectedness with Nature.

The work first maps drivers of Disconnection to Nature and then empirically selects PAD as the most effective driver to address to reduce CWN through 11 anecdote-based interviews. This also forms a designable framework that describes how reducing PAD fosters CWN, called the Designable Framework for Reducing PAD to improve CWN using Affective Mechanisms. Further research activities define design requirements to achieve the framework. This creates the final installation: Onder de Schors: a modular installation that physically frames a tree and translates real-time plant electrical signals into synchronised audio and whole-body haptic feedback, enabling visitors to feel and hear plant responsiveness and support fostering Connectedness with Nature.

The final in-situ evaluation (n=18) demonstrated significant improvements on both target outcomes: CWN increased from 4.57/7.00 to 5.97/7.00 ($p<.001$) and PAD improved from 5.02/7.00 to 5.95/7.00 ($p<.001$). PAD change and CWN change were positively related ($r\approx.66$), supporting PAD as a designable driver of reconnection. Mechanism analyses further refined the framework: Attention was the strongest contributor to PAD reduction ($r\approx.73$), while Calmness (physiological restoration) and perceived Liveliness showed stronger relevance for CWN than attention or information alone, indicating that PAD reduction is necessary but not sufficient for deep connection.

Based on these results, the thesis adapts Zylstra's framework into a staged, designable hierarchy: calmness functions as a state-setting condition for receptivity; attention and experiential information gain reduce PAD by making plants noticeable and interpretable; and liveliness functions as the affective bridge that transforms noticing into relational CWN. Theoretically, this research contributes a measurable path from "plant as static background" to "plant as living agent," bridging botanical social science with affective interaction design. Practically, it offers a viable blueprint for repeatable, public-park deployments that enable visitors to re-experience plant liveliness over time.

Contents

Abbreviations and Terminology

Connectedness with Nature - The affective, cognitive, and experiential feeling of belonging and relatedness to the natural world.

Disconnection to Nature - The physical, emotional, and cognitive detachment from the natural world.

Plant Awareness Disparity (PAD) - The cognitive and emotional bias leading humans to ignore or undervalue plants and their ecological significance.

Plant liveliness - The perception of a plant being alive, including having agency and responsiveness. This is defined as an important element required to address PAD in the research activitiy of Chapter 4.

Plant social behaviour - Specific behaviours portrayed by plants that were defined by the participants in the research activity of Chapter 5 to be social behaviours. This includes systemic electrical signalling, nutrient sharing, competition and collaboration, and VOC communication.

Pro-environmental behaviour - Actions undertaken by individuals that contribute to environmental conservation or sustainability.

Nature Connectedness Index (NCI) - A metric assessing the degree of individual connection with nature (Richardson et al., 2019).

Three Phased Journey - The temporal journey of the installation, contsisting of the (1) Preparing phase, (2) Interaction Phase, (3) Reflection Phase.

Three Step Journey - A self-defined conceptual model describing the progression from Connectedness with Nature to environmental responsibility and finally to pro-environmental conservation action.

The West - Western societies or cultural traditions rooted in European Enlightenment thought, often characterised by dualistic worldviews that separate humans from nature.

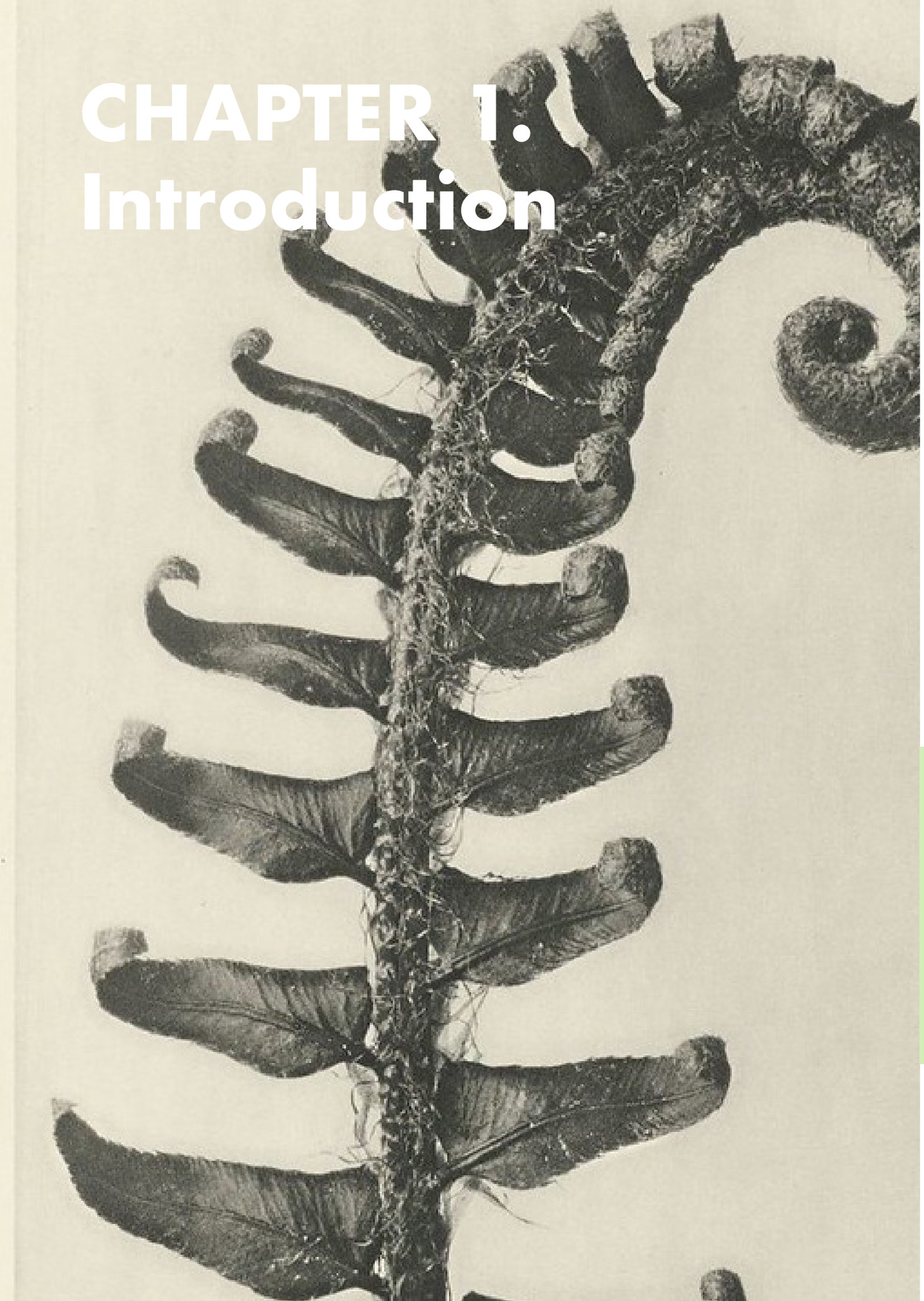
Westerners - People that live in or have majority cultural values from The West.

Indigenous communities - Cultural and social groups with ancestral ties to specific lands, whose worldviews often emphasise relationality, reciprocity, and interdependence between humans, animals, plants, and ecosystems.

Personal Motivation

This project started from an aim to use my designerly skills to enhance conservation action. I grew up in a small town surrounded by nature. In my free time I would love playing outside and walking in the Heide, exploring new parts and the different landscapes with my friends. When I went to my university, the TU Delft, the scenery around me changed too. Rows of trees embracing the streets were swapped out for a historic cobble stone town centre, and so my time in nature was swapped with time spent doing the usual student activities. My Connectedness with Nature had dropped, but I did not know it yet. Until I went on a hiking trip on Guatemala's Acatenango Volcano. Surrounded by the trees and animals in the mountain, my fellow travellers and I noticed a change. We felt calm, positive, and connected. Being in nature again revived this Connectedness with Nature. As we left the mountain and reality set back in, I realized how disconnected I had become from nature in everyday life.

As a Dutch-Brazilian woman I am aware of the deep impacts of deforestation, but with my renewed feeling of connection, this news evoked me more. I wondered how I could get more people to feel this sorrow for deforestation by feeling this connection they might also have been losing. It was then that I became motivated to use my designerly skills to reduce deforestation and increase the so desperately needed climate action through my MSc Thesis Project.



CHAPTER 1: Introduction

1.1 Introduction

People often visit parks and green spaces, yet still overlook plants as active, responsive forms of life, often viewing them as a backdrop. This tendency is described as Plant Awareness Disparity (PAD): a bias in which plants receive less attention and appreciation than animals, limiting what people notice and learn about plant life and how connected they feel to plants. While there are no statistics for how prevalent PAD is in society, along with other factors of Disconnection to Nature it adds to the mere 61% society scored on the Nature Connectedness Index scale (Richardson et al., 2019). This matters because a stronger Connectedness with Nature (CWN) is consistently associated with more pro-environmental and conservation-oriented behaviour (Guazzini et al.,2025).

Currently, many interactive installations aim to foster CWN through a holistic approach. However, as CWN is hindered by many different drivers, a more specific approach may achieve more effective results. While there is much research into the different drivers of CWN, practical applications on how to address these, especially in interaction design and HCI, is limited. This thesis aims to add knowledge where this gap lays.

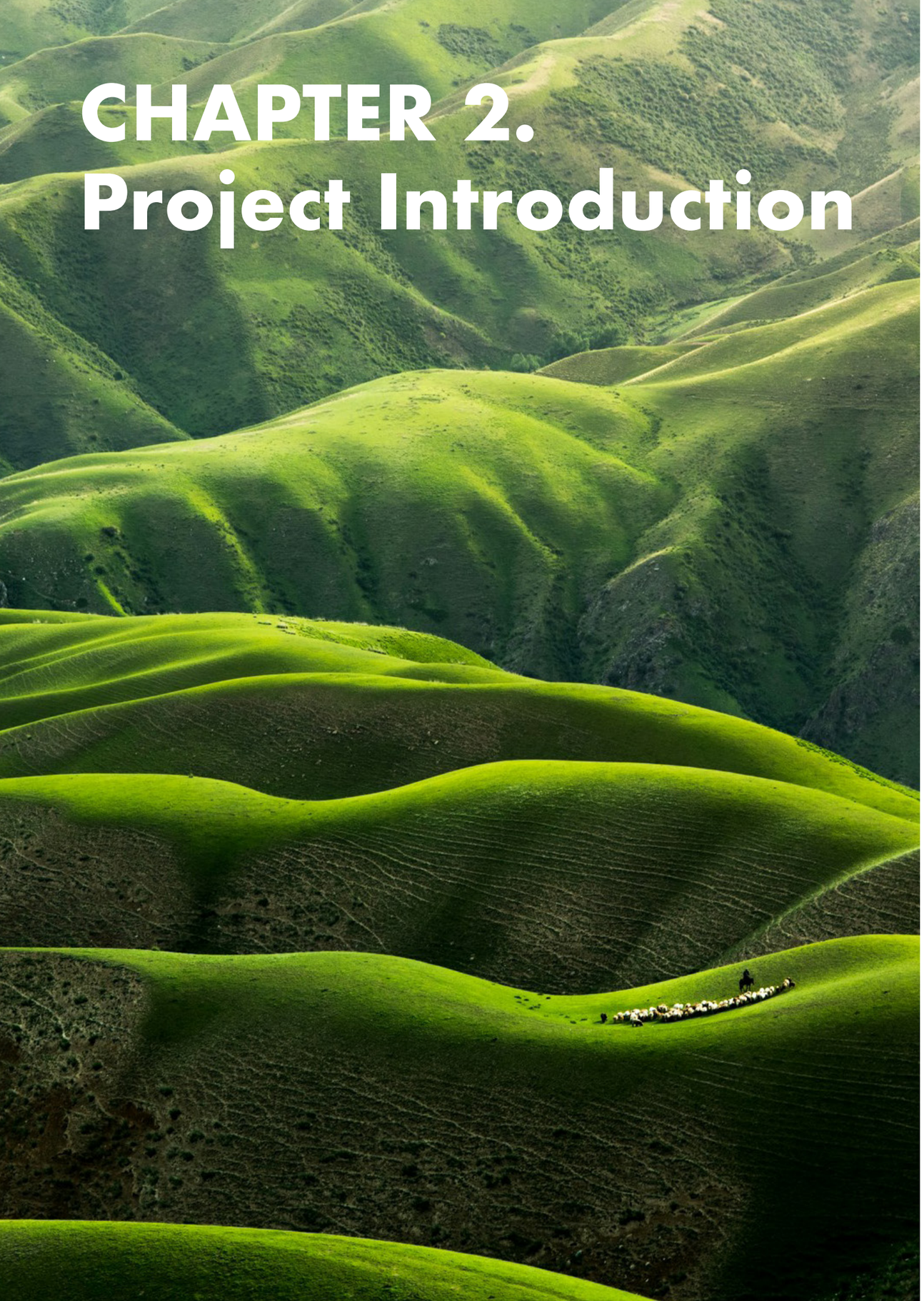
This thesis therefore investigates how an interactive installation can foster CWN by reducing a specific driver of Disconnection to Nature. Through research, this is determined to be PAD. The core design hypothesis is:

Through experientialising systemic electrical signalling in plants to represent plant liveliness, this installation will foster attention towards plants and information gain about plants, lowering guest's Plant Awareness Disparity, which enhances their Connectedness with Nature.

This thesis aims to design an installation that enables me to evaluate this hypothesis.

Through the research activities, this thesis defines a Why, What, How framework to establish the goal and scope of the project, a 'Designable Framework for Reducing PAD to improve CWN using Affective Mechanisms' to establish the mechanisms to

achieve the research objective and design objective, and design requirements that define how this thesis' installation can achieve this goal. I first establish the theoretical framing (CWN and PAD) and translate it into design requirements, the designable framework, and a three-phased experiential journey. Then I present preparatory research into measurable plant biodata and design principles from a related projects analysis, which guides the ideation process. This leads to three meta-concepts. Comparative prototyping and iterative refinement is used to select and develop the final direction. The thesis concludes with reflections, limitations, and recommendations for further development.



CHAPTER 2. Project Introduction

2.1 The Problem

Connection with Nature is low, at a mere 61% for adults on the Nature Connectedness Index (NCI) (Richardson et al., 2019). This diminished sense of connection may lead to the legitimisation of destructive practices, such as the overexploitation of nature by viewing humans as separate from dominant over nature, devaluing nature and its role in our ecosystem (Plumwood, 2002). Strengthening human–nature relationships therefore presents a crucial opportunity to enhance pro-environmental action, as increased connectedness has been shown to foster pro-environmental attitudes and behaviours (Guazzini et al., 2025).

Within the fields of design and Human-Computer Interaction (HCI), many projects have explored the theme of human–nature connection. In HCI, works such as Synplant by Youyang Hu et al. (2023) and PlantMate (Luo et al., 2025) create interactive experiences that allow participants to perceive how plants sense and respond to their environments, such as wind, rain, and touch, through visualization and muscle stimulation, respectively. In contrast, Experience Design projects such as Biomodd [BRG13] by SEADS & Musea Brugge (n.d.) and Akousmaflore (Lasserre & Met Den Ancxt, n.d.) invite participants to experience and influence plants' responses to stimuli such as light and tactile interaction. These projects aim to cultivate a deeper understanding of plant behaviour and environmental perception, fostering empathy and a renewed sense of connection between humans and the natural world.

While such projects aim to foster awareness and empathy toward plant life, the underlying causes of Disconnection to Nature remain complex and multifaceted. Contributing drivers, such as Dualist worldviews (Gameau, 2022), Plant Awareness Deficit (Parsley, 2020)(Guerra et al., 2024), andthe reduction of botanical education (Stroud et al., 2022) each contribute to this divide, yet cannot be comprehensively addressed within a single design. Existing projects tend to approach the issue holistically, aiming to foster a general sense of connection between humans and nature rather than targeting specific causal factors (Hu et al., 2023) (Luo et al., 2025) (SEADS & Musea Brugge, n.d.) (Lasserre & Met Den Ancxt, n.d.). To design effective experiences that cultivate connection, this thesis therefore explores the diverse cognitive, physical, and affective factors shaping both connection and disconnection in order to explore opportunities for an interactive installation that enhances CWN by addressing one of the drivers of disconnection to nature that, when addressed, best enhances a feeling of connection.

2.2 Project objective

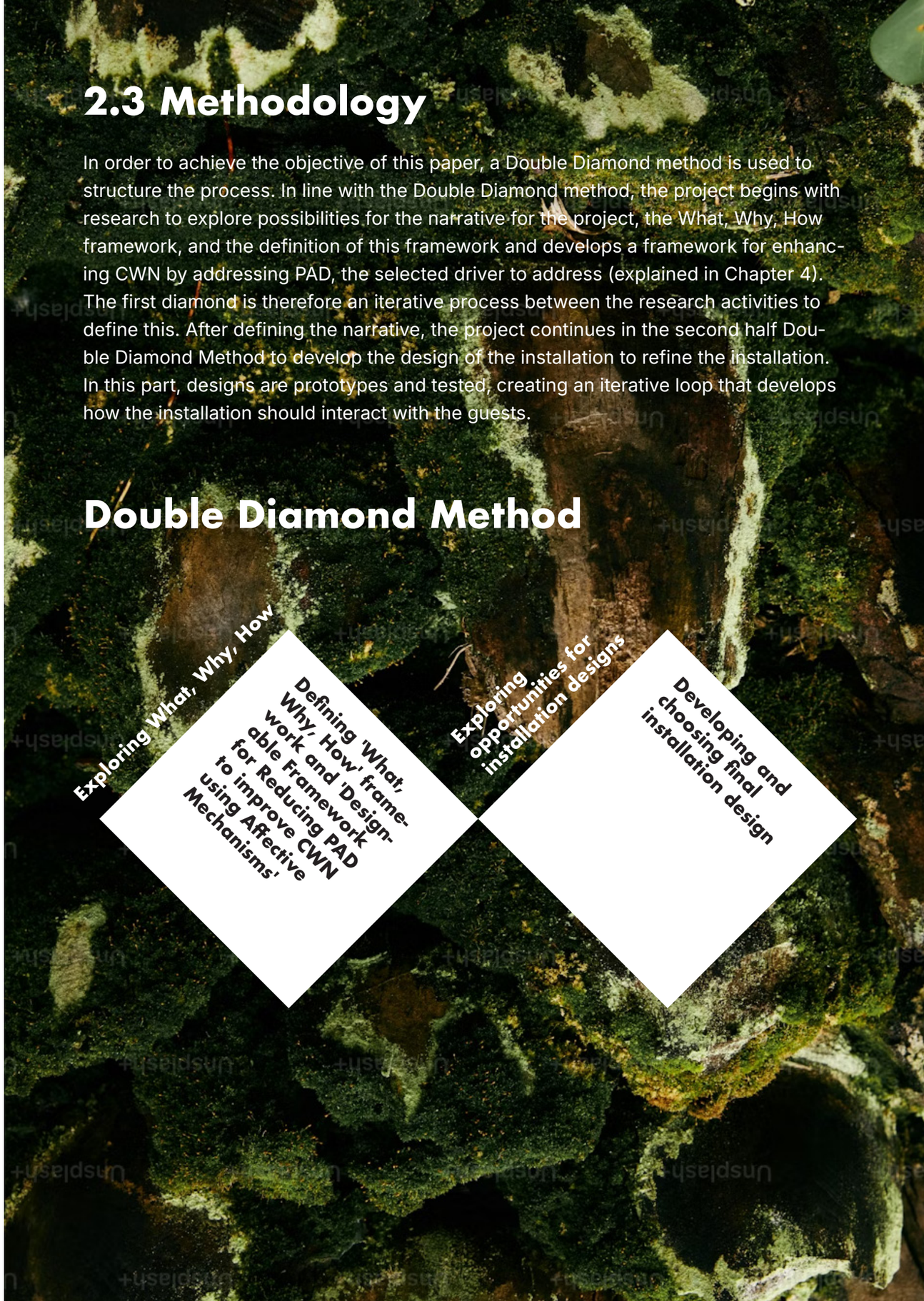
The overarching goal of this research is to contribute to conservation action for plants. This project sees this as occurring over a Three Step Journey from increasing Connectedness with Nature, to enhanced Environmental Responsibility, and ultimately to more Conservation Action, explained in depth in chapter 3.2. To achieve this journey, this project focusses on the first step: fostering a stronger Connectedness with Nature. As established in the previous chapter, this project focusses on achieving this by addressing the research gap, focusing on exploring practical implementations to enhance CWN by addressing a specific driver. The objective of this research is therefore:

To explore opportunities for interactive installations to foster Connectedness with Nature by addressing a specific driver of Disconnection to Nature.

To achieve the thesis objective, two types of sub-objectives are defined throughout this thesis: research objectives and sub-design objectives. The sub-research objectives focus on what needs to be researched in order to achieve the core objective of this paper. The sub-design objectives focus on what the installation design must represent or include in order to effectively enhance CWN.

2.3 Methodology

In order to achieve the objective of this paper, a Double Diamond method is used to structure the process. In line with the Double Diamond method, the project begins with research to explore possibilities for the narrative for the project, the What, Why, How framework, and the definition of this framework and develops a framework for enhancing CWN by addressing PAD, the selected driver to address (explained in Chapter 4). The first diamond is therefore an iterative process between the research activities to define this. After defining the narrative, the project continues in the second half Double Diamond Method to develop the design of the installation to refine the installation. In this part, designs are prototypes and tested, creating an iterative loop that develops how the installation should interact with the guests.



2.4 Research Activities

In total, 5 research activities were conducted in order to develop the design objective, Designable Framework for Reducing PAD to improve CWN using Affective Mechanisms, and design requirements. The outcomes of these activities, design requirements, context, Three Phased Journey, design principles, and selected behaviours and senses to highlight formed the ideation and development of the installation design. The figure below gives an overview of the research activities.

Literature review (Chapter 3)
Defines the problem, Three Step Journey to conservation action, drivers of DTN, the context of the installation and a framework on how PAD (the selected driver) reduces CWN.

Anecdote-based interviews (Chapter 4)
Selects the driver of DTN to address (PAD), defines how PAD can be addressed in the framework of the literature review to foster CWN, and defines a three phased temporal journey for the installation.

Co-creation user tests (Chapter 5)
Defines what senses to engage in the first phase of the installation and what plant behaviour to show in the second phase of the temporal journey.

Technical literature review (Chapter 6)
Defines how the plant behaviours can be measured.

Analysis of related projects (Chapter 7)
Defines design pricniples that guide ideation and selection of concepts.

Why, What, How framework for the installation narrative

Designable Framework for Reducing PAD to improve CWN using Affective Mechanisms

Design requirements

Ideation (Chapter 9)
Ideates concepts and creates and evaluates three meta-concepts, selecting one interaction (and its represented plant behaviour) to further develop.

Refinement (Chapter 10)
Creates final implementation improvements for the final installation design.

Final evaluation (Chapter 12)
Evaluates the final design through an in-situ user test.

Discussion (Chapter 13)
Discusses the results of the final design and refines the Designable Framework for Reducing PAD to improve CWN using Affective Mechanisms

CHAPTER 3. Influences of connection and disconnection

3.1 Introduction

Fostering a stronger CWN is multifaceted. Literature describes many different pathways through which CWN can develop, and many different drivers that sustain Disconnection to Nature. To design an intervention that meaningfully strengthens CWN, the problem therefore needs to be scoped to a specific, addressable driver.

For this reason, this chapter defines the following research objective that it aims to answer:

To establish a comprehensive inventory of the drivers of Disconnection to Nature (DTN) and Connectedness with Nature (CWN) in order to identify actionable intervention points for design.

This establishes the conceptual foundation needed to select the specific, addressable driver. This selection is done through the research activity in Chapter 4.

3.2 The Problem

The deforestation and fragmentation of the natural world are accelerating at an unprecedented rate. In 2024, approximately 30 million hectares of forest was lost glob-

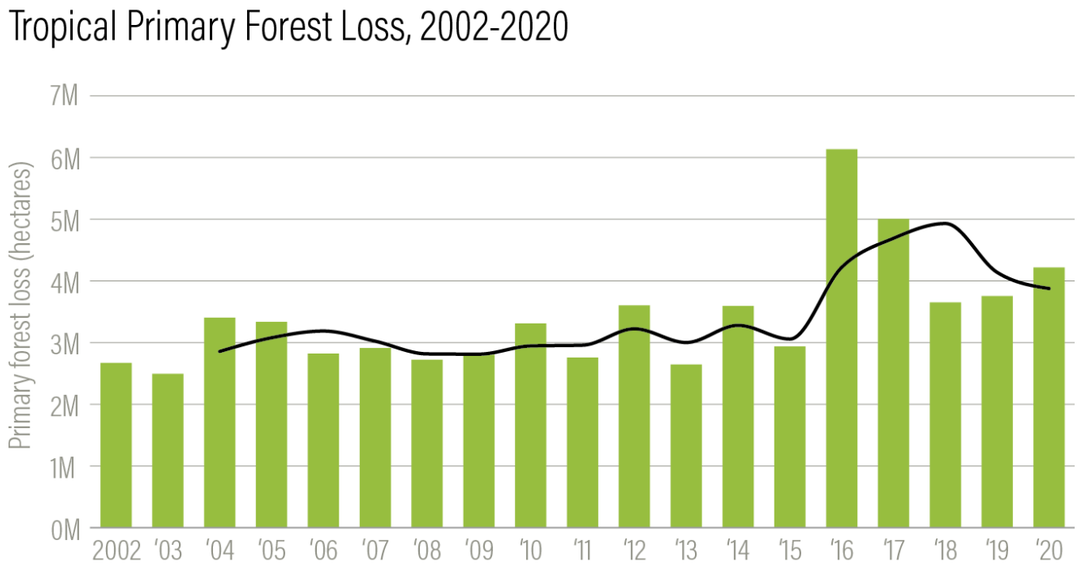


Figure 1, Tropical Primary Forest Loss 2002-2020 (Global Forest Watch, 2024)

ally (Global Forest Watch, n.d.), see figure 1, with over 50% of the world's forests fragmented between 2000 and 2020 (Erickson-Davis, 2025). This process generates ecologically fragile systems that are increasingly susceptible to disease (TED, 2016), spread of zoonic disease (World Wildlife Fund, n.d.), biodiversity loss (Cochard, 2011) and the emission of greenhouse gasses (TED, 2016). Conservation projects show that targeted conservation strategies have a great impact on improving global ecology. This is evidenced by projects such as the recognition of conservation areas and Indigenous territories in Brazilian Amazonia, reducing deforestation by up to 73% in 2023 (Esg, 2024), and reforestation initiatives that protect the forest from threats (wildfires, logging) while it naturally regenerates restoring roughly 9.5 million hectares of forest in the Amazon since 2008 (Matsumoto et al., 2021).

In enhancing these efforts, fostering a connection between humans and nature should be a focus point. Research by Guazzini et al. (2025) indicates that a greater feeling of connection with nature (CWN) significantly enhances individuals' willingness to engage in pro-environmental behaviour. However, in Western societies, the average connection to nature is a mere 61% on the Nature Connectedness Index (Richardson et al., 2019), which focusses on the affective relationship of humans and nature. This disconnection leads to an inability to see oneself as a part of nature and the denial of our dependency on nature, which is recognized as a crucial contributor in progressing environmental destruction, demonstrating the urgent need for interventions that strengthen human–nature relationships (Global Forest Watch, n.d.). This is summarized well by Balmford and Cowling in their research on the future of conservation biology:

"there is a great need for interdisciplinary efforts to tackle perhaps the most pervasive underlying threat of all by reconnecting people and nature... even if all the other building blocks of effective conservation are in place, we will not succeed unless the gener- al public cares, and they are unlikely to care enough if they no longer experience nature directly."

This problem constitutes the Why of the What, Why and How framework of this research.

WHY

Stimulating conservation efforts through fostering a feeling of connection

WHAT

HOW

3.3 Three Step Journey

Naturally, this is not a one-step solution. The study by Guazzini et al. (2025) on the relationship between Connection with Nature and pro-environmental behaviour establishes that CWN does not automatically transfer into the implementation of pro-environmental behaviour. Social pressures, costs, lack of information or time, and negative affective emotion such as feelings of helplessness, amongst other factors, hinder this progression into action. Yet, research does support Balmford and Cowling's claim defining the need for CWN to achieve pro-environmental behaviour (Guazzini et al., 2025) (Tam, 2013) (Straka et al., 2025). In order to facilitate this transition, this paper proposes a Three Step Journey. This is based on research by Jaiswal & Bihari (2020), which shows that a stronger feeling of connection leads to a stronger feeling of Perceived Environmental Responsibility, which in turn leads to more engagement in pro-environmental behaviours, as mentioned in chapter 3.1. To start this transition, this project focusses on the first step: creating a connection with nature.

3.4 Defining Connectedness with Nature and Disconnection to Nature

The establishment of a comprehensive understanding of influences creating a disconnection between humans and nature requires a definition of both connectedness with nature and disconnection to nature.

The concept of Connectedness with Nature (CWN), as used in this report, draws on the framework for CWN and Committed CWN developed by Zylstra et al. (2014), shown in figure 2. CWN is defined as a stable state of consciousness encompassing cognitive, affective, and experiential dimensions. These dimensions collectively foster a sustained awareness of the interrelatedness between humans and nature and enables a lasting sense of appreciation, empathy, and mindfulness toward all life, beyond mere contact or superficial enjoyment. Thus, CWN represents a holistic and personal process that may lead to conservation outcomes.

This framework proposes CWN as evolving along four primary drivers:

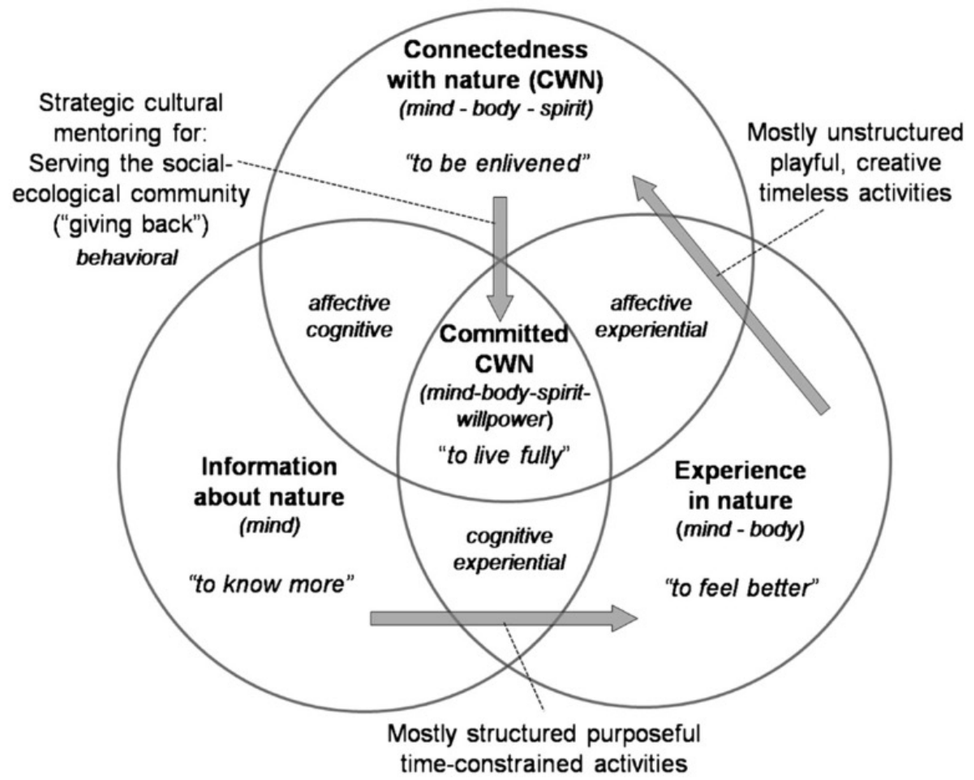


Figure 2, Framework of Connectedness with Nature by Zylstra et al. (2014)

- **Information about Nature:** This dimension is primarily cognitive, emphasizing the gain of understanding and knowledge about nature. It satisfies curiosity and expands one's knowledge of ecological systems.

- **Experience in Nature:** This refers to direct engagement with natural environments through activities such as outdoor recreation, sports, or field excursions. These experiences are typically structured or time-bound and are often pursued to facilitate experiential learning or enhance physical and psychological well-being.

- **Connectedness with Nature (CWN):** This represents a stable state of consciousness often attained inadvertently through unstructured, affective experiences such as prolonged immersion in natural settings. Such experiences may awaken a deeper sense of inspiration or 'spirit', fostering a profound emotional bond with nature.

- **Committed Connectedness with Nature (Committed CWN):** This dimension is the long-term integration of the cognitive, affective, experiential, and spiritual dimensions into a coherent behavioural orientation. It focuses on transformative forms of leadership directed toward pro-environmental behaviours. This level of connectedness requires humans to balance mind, body, and spirit.

Using this framework as the foundation for designing an intervention to enhance Connectedness with Nature, the project must engage the cognitive, experiential, and affective dimensions of users in the interaction in order to effectively foster CWN. Accordingly, this defines the following design requirement:

To foster Connectedness with Nature, interactions must engage the affective (emotional) and experiential, and informational dimensions of CWN.

In contrast to CWN, Disconnection to Nature (DTN) is the physical and psychological separation of humans from the natural world, undermining the cognitive, affective, and experiential dimensions that form CWN. DTN is sustained by a range of drivers that restrict opportunities to gain knowledge about nature, limit direct experiences in natural environments, weaken positive emotional responses toward non-human life, and more.

To effectively strengthen users' CWN, it is therefore essential to identify and understand the primary drivers of DTN. By doing so, this project can focus the installation on addressing a specific, effective hindering factor (Curll et al., 2024; Tam, 2013; Straka et al., 2025), thereby reducing complexity and increasing impact by targeting a driver that obstructs all three dimensions of CWN.

3.5 Drivers of Disconnection to Nature: An Overview

Disconnection to Nature does not have a 'root cause', with drivers spanning across environmental psychology, ecology, education, philosophy, and HCI. To effectively design an intervention that fosters Connectedness with Nature (CWN), it is first necessary to understand the drivers that inhibit it. To identify the barriers preventing Connectedness with Nature in order to scope the project, a mapping review was conducted (Snyder, 2019), generating an inventory of 62 distinct drivers of Disconnection to Nature (see Appendix A for the full research method and driver inventory). These drivers are interconnected, distinct mechanisms that reduce CWN on physical, psychological and perceptual levels.

To establish an understand of the different drivers, this sub-chapter presents 3 drivers based on the framework proposed by Ives et al. (2018), who argue that interventions must address disconnection across multiple scales ranging from shallow leverage points (physical parameters) to deep leverage points (intent and worldview). Therefore, the most commonly described factor in literature for each of the following categories is described:

1. Physical/Experiential Drivers: Barriers related to the lack of tangible interaction with nature.
2. Psychological/Cultural Drivers: Barriers related to deep-seated worldviews and beliefs.
3. Cognitive/Perceptual Drivers: Barriers related to how the brain processes (or ignores) natural stimuli.

3.5.1 Driver 1: The Extinction of Experience (Physical/Experiential)

The most frequently cited driver in conservation psychology is the "Extinction of Experience" (Pyle, 1978; Soga & Gaston, 2016). This phenomenon describes a feedback loop where rapid urbanization reduces the opportunity for daily interactions with nature. Soga & Gaston (2016) identify this loss of direct experience as the primary cause of 'emotional apathy' toward the environment. For this project, this driver confirms the necessity of situating the intervention in an urban context to physically restore this lost contact.

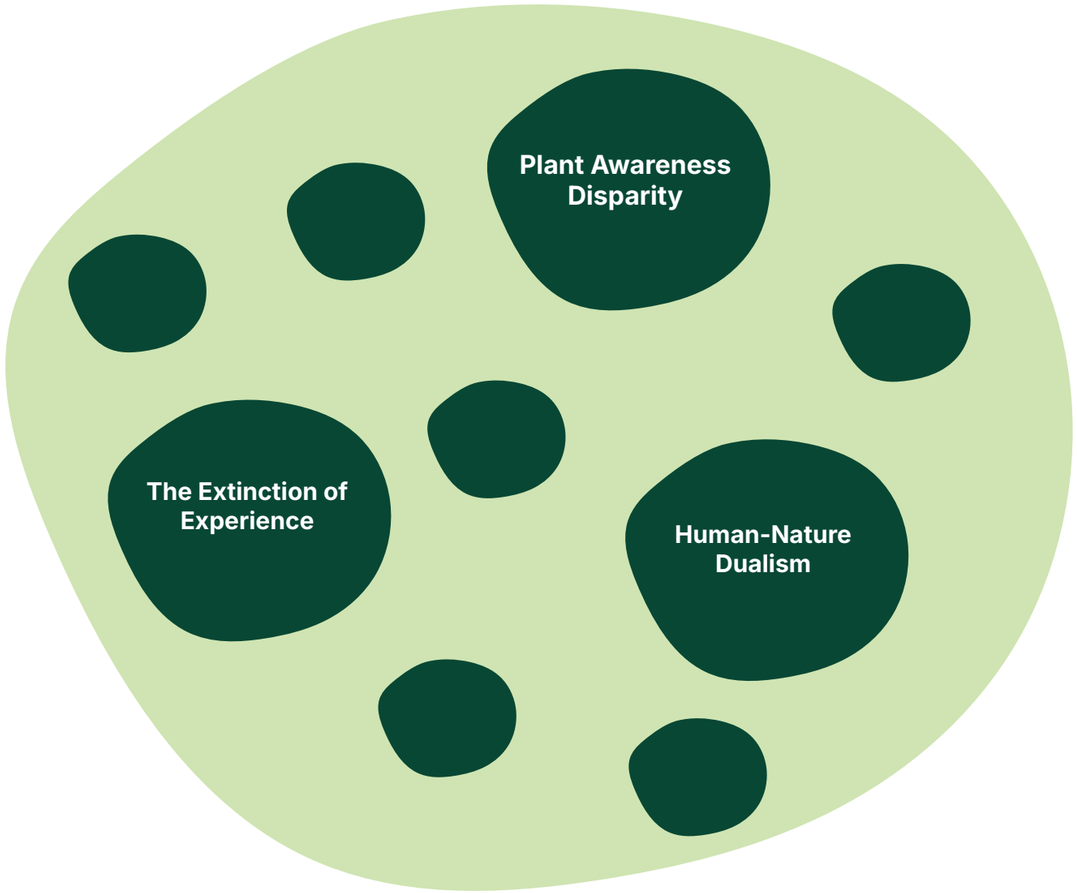


Figure 3, Drivers influencing DTN

3.5.2 Driver 2: Human-Nature Dualism (Psychological/ cultural)

At a deeper leverage point lies the perspective of Human-Nature Dualism. This is the Western cultural belief that humans are separate from and superior to nature. Ives et al. (2018) identify this as a 'deep' cultural driver of DTN. This internal framework acts as a barrier to true connection, as it positions nature as a resource to be observed rather than a community to join.

3.5.3 Driver 3: Plant Awareness Disparity (Cognitive/Perceptual)

While the previous drivers explain why people are disconnected from nature broadly, Plant Awareness Disparity (PAD) explains the specific disconnection from plants (Parsley, 2020). PAD is the human tendency to under-appreciate and under-perceive plants compared to animals (Guerra et al., 2024). This is a perceptual bias: the human brain filters plants out of conscious attention, rendering them as a static green backdrop

rather than distinct, living organisms (Parsley, 2020). This inattention causes people to not see plants as active agents, failing to form the emotional or empathetic bonds necessary for Connectedness with Nature (Vining et al.,2008; Wandersee & Schussler, 1999; Amprazis & Papadopoulou, 2020). Consequently, even when people are physically present in nature, PAD can maintain a psychological disconnection, as the living environment remains unacknowledged and unvalued (Achurra, 2022).

This thesis focusses on a specific driver to address to enhance effectiveness in fostering CWN. The selected driver is Plant Awareness Disparity (justification can be found in Chapter 4). Through this inventory and identification of actionable intervention points, the research objective of this research activity has been achieved.

3.6 Driver of Disconnection to Nature: Plant Awareness Disparity

This thesis focusses on addressing Plant Awareness Disparity to effectively foster CWN. The selection of this driver is elaborated in Chapter 4. To understand how to address PAD this chapter presents what it is, why it occurs, and how it relates to fostering CWN.

3.6.1 Why PAD Occurs

Scientific literature generally frames PAD as emerging from a combination of perceptual and attentional factors, knowledge and categorisation limits, and cultural–educational framing.

3.6.1.1 Perceptual and attentional factors

Human visual attention is strongly shaped by cues such as movement and rapid change. Animals often provide such cues on a human timescale, whereas many plant processes unfold slowly or subtly, making plants easier to process as a background object. This contributes to an attentional bias where plants are present but not focal (Achurra, 2022).

Research by Guerra et a. (2024) suggests that when plant movement is made observable on a human timescale, attention and engagement shift. The experiment showed that observing plant movement on a human time scale changes how people attend to plants, supporting the role of perceptual factors in plant neglect.

3.6.1.2 Knowledge and categorisation limits

A second factor is a difficulty in differentiating and interpreting plants. Low plant lit-

eracy and plant-specific knowledge reduces skills such as species identification or understanding plant function, causing plants remain cognitively flat (Jose et al. 2019; Stroud et al., 2022). They become harder to see as individuals or interpret as agent, strengthening their position as a 'green background'.

3.6.1.3 Cultural and educational framing

Finally, PAD is reinforced by a tendency toward zoocentrism in education and media, where animals become the foreground while plants are treated as scenery or resources. This framing shapes attitudes and interest over time and can reinforce both Attention and Memory Disparity and Information Disparity (Jose et al., 2019).
Together, these mechanisms form a reinforcing pattern: low attention reduces learning opportunities, low knowledge reduces interpretability, low interpretability reduces interest, and low interest further reduces attention.

3.6.2 The Four Components of PAD

Parsley et al. (2020) define PAD as comprised of four components:

Attention and Memory Deficit

Humans' visual attention naturally favours animals (Guerra et al., 2024), leading to plants being perceived as an undifferentiated green backdrop rather than distinct living organisms (Parsley, 2020). As visual attention drives emotion and interest, overlooking plants inhibits the sensory and emotional engagement required to form strong CWN (Parsley, 2020).

Knowledge Deficit

PAD involves a lack of specific knowledge of plant biology and the critical roles plants play in ecosystems and human life (Guerra et al., 2024), often due to zoocentric educational systems (Parsley, 2020). Knowledge, especially in species identification, is a strong predictor of Connection with Nature (Straka et al., 2025). A deficit in plant knowledge thus constrains the emotional engagement necessary to motivate pro-environmental behavior.

Attitudinal Disparity

This factor reflects low interest (Parsley, 2020) and negative attitudes (Guerra et al., 2024) toward plants, shaped by anthropocentric worldviews that regard plants as inferior to animals. As empathy and respect are central to Connection with Nature (Straka et al., 2025), negative attitudes weaken emotional engagement and thereby diminish the psychological basis for conservation intentions (Vining et al., 2008).

Relative Interest

People tend to find animals more engaging than plants as their movement captures attention and curiosity. By contrast, plants' apparent immobility causes them to fade into the perceptual background as static beings (Parsley, 2020) (Guerra et al., 2024). This lack of interest reduces motivation to learn about plants (Parsley, 2020). As nature-relatedness is the strongest predictor of pro-conservation behaviour, low relative interest undermines both awareness and motivation (Straka et al., 2025). This bias is reflected in conservation funding priorities: while plants collectively receive only 6.6% of funding, 40% is allocated to just 47 animal species (Straka et al., 2025).

3.6.3 Relevance of PAD to foster CWN

In the framework by Zylstra et al. (2014), CWN does not arise from passive exposure to nature alone. Instead, it develops through the meaningful integration of Information about Nature, Experience in Nature and a positive affect towards nature. For design interventions, this implies that the design must not only place people in nature. It must strengthen the conditions under which information and experience becomes noticed, information becomes interpretable, and both can become personally meaningful

Plant Awareness Disparity (PAD) is relevant in this context because it systematically undermines those conditions. PAD can be seen as a bottleneck: if plants do not enter awareness as distinct, living beings and people do not gain information about nature, they cannot contribute to the experiential, informative, and affective processes through which CWN is formed.

This theory is represented in the 'Framework of the Effect of PAD on Zylstra's Framework of CWN' in figure 4.

Empirical research supports the view that overcoming this attention gap is a prerequisite for connection. Richardson et al. (2021) demonstrate that "actively noticing nature" accounts for substantially more variance in nature connectedness than the duration of exposure alone. If plants remain processed as background, unnoticed and unacknowledged, the attentional pathway to connection is constricted, regardless of time spent in the park.

Similarly, research on interventions for nature-connectedness suggests that information alone is insufficient to foster connection. A meta-analysis by Barragan-Jason et al. (2021) reports stronger effects for contact-based and attention-based approaches than for environmental education alone. This supports the interpretation that CWN emerges when information and experience are affectively integrated.
This supports the interpretation of Zylstra's framework used in this thesis: CWN emerges when information and experience become affectively integrated, rather than when either occurs in isolation. PAD restricts the conditions under which this inte-

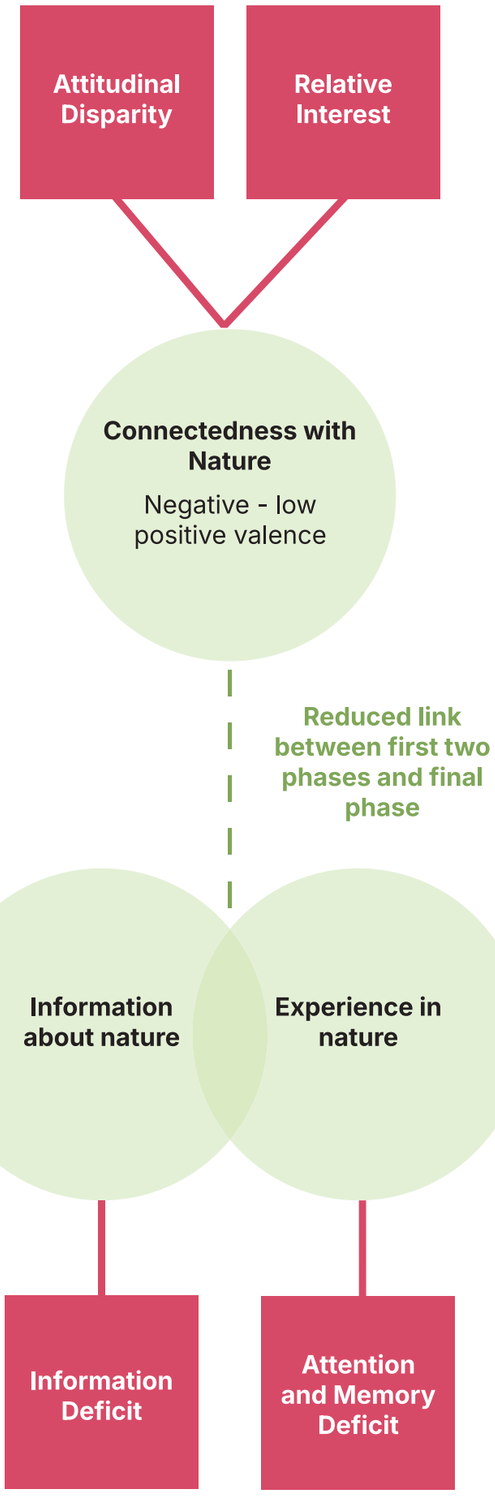


Figure 4, 'Framework of the Effect of PAD on Zylstra's Framework of CWN'

gration can become meaningful. Low attention for plants reduces the likelihood that plant-related information is sought or retained, and low information gain reduces the likelihood that experience produces meaning. Consequently, this lowers posititve attitudes towards plants and relative interest in plants and restricts the ability for the first two phases of CWN to grow.

This forms a design requirement:

> Installations must address Attention and Memory Disparity and Information Disparity to enable experiences in nature to produce a positive affect, improving posititve attitudes towards plants, interest in plants, and CWN.

This thesis therefore proposes the 'Designable Framework Reducing PAD to Improve CWN' illustrated in figure 5. This framework shows how addressing PAD through an installation allows the development of the aspects and strenthens the opportunity for the affective state of CWN to grow.

A formal, widely established causal link explicitly connecting PAD reduction to the psychological construct of CWN remains limited in the current empirical literature. Nevertheless, the project's logic is derived from an evidence-based pathway in which noticing is empirically linked to nature connectedness (Richardson et al., 2021), and combined with Zylstra's theory that CWN arises through integration of experience, information, and affect. Therefore, this thesis treats PAD reduction, particularly by removing the cognitive bottleneck of inattention and enabling interpretability as a theoretically grounded and empirically motivated contributor that can unlock the conditions under which connection is more likely to form.

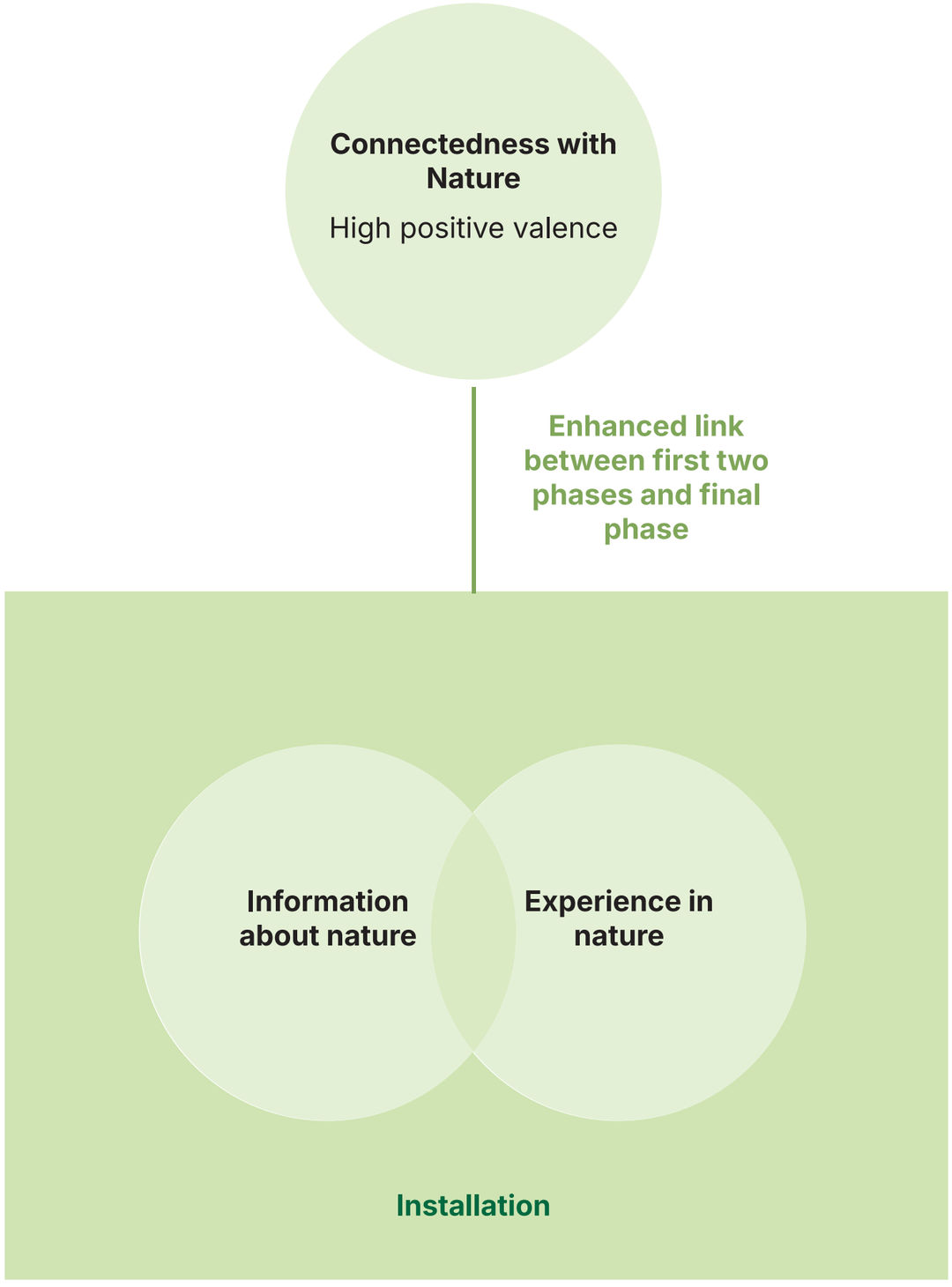


Figure 5, 'Designable Framework Reducing PAD to Improve CWN'

3.7 Installation Location

Connectedness with Nature (CWN) develops through repeated affective experiences rather than one-off activities (Zylstra et al., 2014; Soga & Gaston, 2016; Soga et al., 2016). Therefore, when addressing PAD, it is important to enable a repetition of the experience, to strengthen CWN over time (Richardson et al., 2022; Richardson et al., 2020). Thus, this installation needs to be situated where such experiences can realistically reoccur. This implies that the installation should not be designed only for a first encounter, but for multiple encounters that allow connection to strengthen over time (Zylstra et al., 2014). Therefore, installations aiming to enhance CWN should be situated in a publicly accessible location that guests may frequently visit. This defines the following design requirement:

Installations must be placed in a publicly accessible natural location to provide repeated experiences that strengthen CWN over time.

This project implements this design requirement by placing the installation in a local public park. Parks provide ongoing access to living systems in everyday life, which supports the required repeated exposure and repeated noticing for the installation to enhance its success.

This creates a reinforcing loop that matches the intended mechanism of change in this thesis, see figure 6.

To further maximise the effect of the installation, the installation in this thesis will be designed as a temporary installation that can travel across different parks. This enables the installation to reach the most amount of people and allows it to be moved to experience it by different trees, to enhance the connection to not only one tree, but multiple trees. This is an implementation of this thesis' design and not defined as a designr requirement.

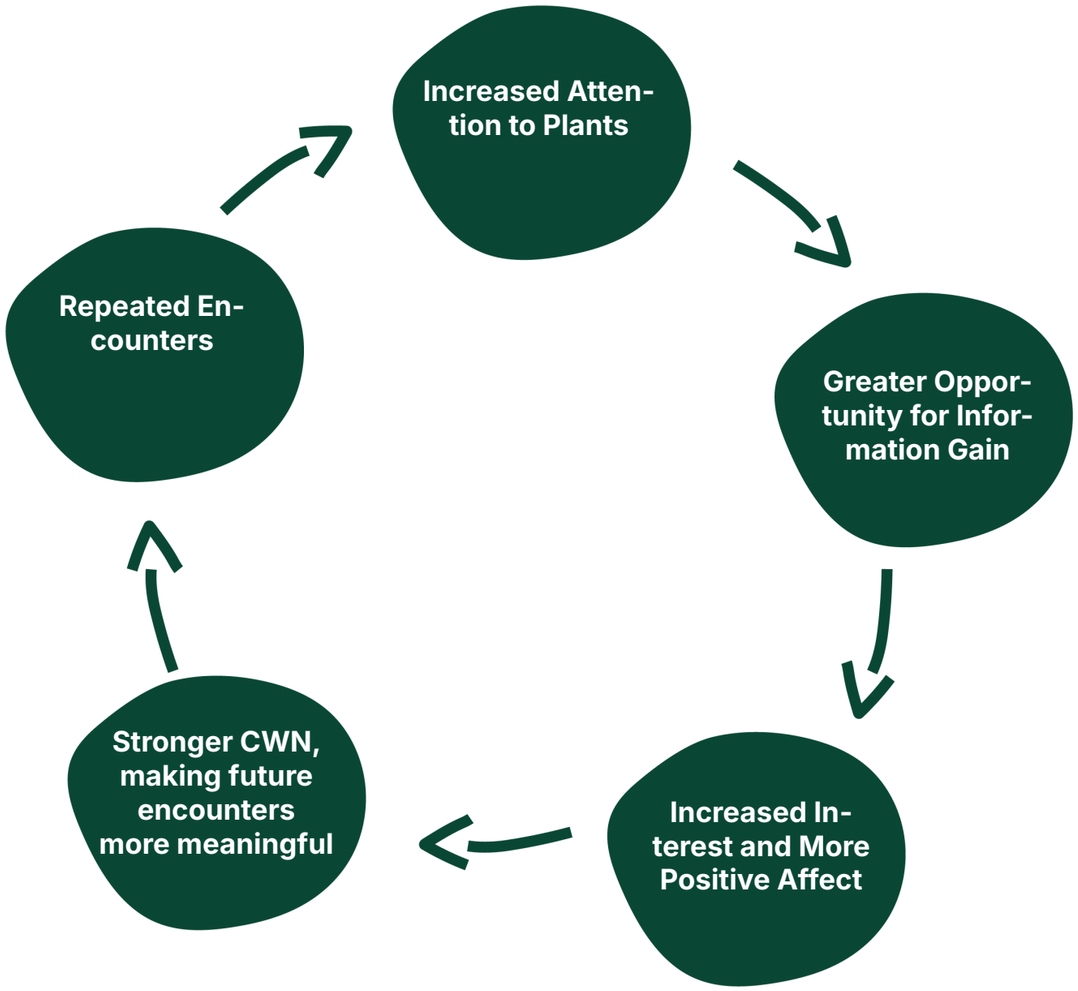


Figure 6, Reinforcing loop of addressing PAD

CHAPTER 4. Selecting a Driver of Disconnection to Nature

4.1 Introduction

The literature review in Chapter 3 established that Disconnection to Nature (DTN) is sustained by a complex set of drivers that undermine the dimensions of CWN. While this inventory defines the context of the problem, no single design intervention can address all drivers simultaneously. The literature largely approaches disconnection from quantitative or theoretical perspectives, offering limited insight into how connection is actually lived and remembered. To select one, the following research objective is defined, which this chapter aims to answer:

To investigate the causal factors triggering moments of strong Connectedness with Nature and identify which driver of Disconnection is effectively mitigated during these instances, in order to select the most actionable lever for design intervention.

Through interviews, concrete experiences of CWN and the mechanisms that enabled this were explored with a diverse group of participants. In particular, the research sought to understand what sensorial, environmental and affective factors were central in fostering the strengthened CWN.

Through a thematic analysis these experiential prerequisites were compared to the list of drivers of DTN to select the single most effective driver to address for the installation. The driver selection is therefore not a direct objective outcome of the interviews, but a reasoned interpretation step: the themes describe how connection happened, and comparing this to the driver inventory provides a validated lens that explains what barrier was being overcome in those moments. In addition, the analysis defined design parameters and a temporal journey for the installation.

4.2 Study Design and Procedures

To ground the driver selection in empirical research, qualitative interviews were conducted with 11 participants spanning a diverse range of ages, backgrounds, and self-reported levels of CWN. The study uses the Anecdote-Based Exploration through Dialogue method (Hamilton-Jones & Schröder, 2025).

This method was used to anchor the conversation in a specific memory to explore experiences that are embodied, emotional, and relational, and that are often difficult for participants to articulate through conventional, structured questioning. The interviews followed the method described in figure 7, where participants were invited to explain a specific anecdote of a moment they felt a strong Connectedness with Nature. This was

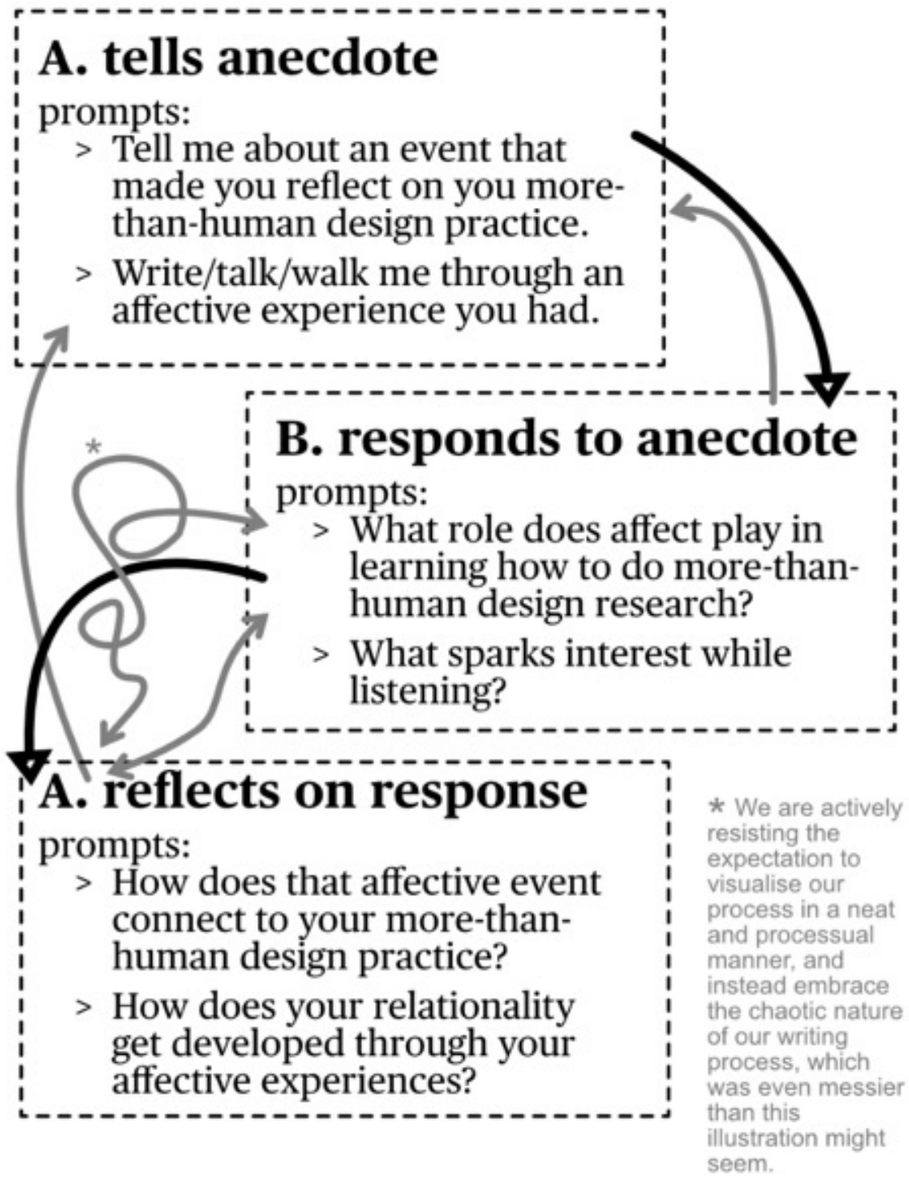


Figure 7, Prompting sequence of Anecdote-Based Exploration through Dialogue (Hamilton-Jones and Schröder, 2025)

followed by reflective prompting focused on unpacking the:

- Sensory Focus: What were they paying attention to, and through which senses?
- Environmental Cues: Which specific elements of the environment triggered the shift?
- Affective State: How did the experience manifest emotionally and physically?

4.3 Analysis

To translate these individual experiences into a grounded driver selection, the data were analyzed using Reflexive Thematic Analysis (Braun & Clarke, 2021). A hybrid inductive–deductive approach was applied. Initial coding focussed line-by-line on experiential elements such as attention, perception, and sensory engagement. These codes were then clustered into broader themes and interpreted through the lens of the DTN drivers identified in Chapter 3.

Counts of occurrences are used to select the final driver because the most important criterion was transferability across participants rather than the emotional intensity of a small number of accounts. Intensity can reflect highly personal life histories, rare contexts (travel, extreme landscapes), or individual sensitivities and can significantly impact outcomes within a small participant number as this activity has. In contrast, mechanisms that recur across many participants are more likely to represent a robust, design-relevant entry point that can work for a broad public in a park setting.

4.4 Outcome

The analysis revealed a consistent pattern: moments of strong Connectedness with Nature were consistently explained by deep attention and information gain about the plant, causing the participant to view the plant as lively and agent. Interpreting these mechanisms through the DTN driver inventory from Chapter 3, they align most directly with Plant Awareness Disparity (PAD), specifically addressing PAD's attention and memory deficit and information deficit. While all four components contribute to diminished plant awareness, the interview data suggest that moments of strong CWN most frequently emerged when participants first overcame habitual inattention and then engaged in sense-making about the plant's behaviours. In 9 out 11 interviews this was subsequently followed by increased relative interest and more positive attitudes toward plants through reflection and repeated experience, rather than these dimensions functioning as initial drivers.

4.4.1 Selection of Plant Awareness Disparity

4.4.1.1 Attention and Memory Deficit

Directed attention toward plants was described by nine out of eleven participants. They explicitly described a shift from habitual inattention toward active noticing of plants: 5 Participants contrasted these moments with everyday situations in which plants remained unnoticed.

Rather than describing connection as an automatic consequence of being in nature, participants emphasised that connection arose when plants were actively noticed. As one participant mentioned,

“Normally trees are just there, but then I really started looking at them, at the details, and that made it feel different” (P3, translated).

This pattern maps onto PAD’s Attention and Memory Deficit. It marks attentional focus as a first step in reducing PAD, because it brings a plant into conscious awareness as a distinct living being rather than as undifferentiated green background.

4.4.1.2 Information Deficit

In addition to attention, eight out of eleven participants described a second mechanism: gaining information about the plant deepened their sense of connection. This information was not only factual. Participants also described recalling prior knowledge, deducing plant processes, or imagining how the plant survives and responds in its environment. This directly addresses PAD’s Information Deficit. Importantly, the interviews suggest that what matters is not only factual transfer, but whether information becomes experientially meaningful through direct noticing and reflection. As one participant explained:

“When you start thinking about how a plant grows or what it needs to survive, you don’t just see it anymore, you understand it” (P1, translated).

Together, these findings indicate that attention creates the opening for experience, while information gain makes that experience interpretable and meaningful. This makes attention and information the most actionable PAD components for the installation to target.

4.4.1.3Attitudinal Disparity and Relative Interest

The remaining two PAD components, Attitudinal Disparity and Relative Interest, were not described as initial drivers of connection. Instead, positive attitudes toward plants and increased interest appeared to follow over time from increased attention and knowledge through reflected and repeated positively affective experiences. This pattern suggests a plausible temporal sequence shown in figure 8.

Within the scope of this project, this supports treating attention and information deficits as the primary intervention targets, through which attitudes and sustained interest may develop over time and repeated engagement.

The selection of PAD defines the ‘What’ of the ‘Why, What, How’ framework of this thesis and therefore achieves the research objective of this research activity.

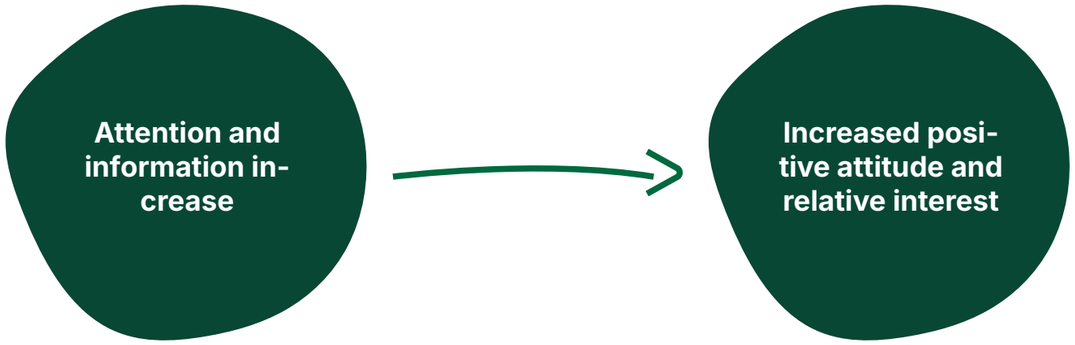


Figure 8, Sequence of reduction of PAD deficits, attention and information increase leads to increase positive attitude and relative interest over time

WHY

Stimulating conservation efforts through fostering a feeling of connection

WHAT

Fostering a feeling of connection by aiding Plant Awareness Disparity

HOW

4.4.2 Relation to Zylstra et al.'s framework

This pattern aligns with the rationale developed in Section 3.6.3, where PAD was framed as a bottleneck within Zylstra et al.'s (2014) model of Connectedness with Nature. CWN emerges through integration of Experience in Nature, Information about Nature, and positive affect, and this integration is less likely when plants remain unnoticed and uninterpretable. In the interviews, CWN was repeatedly described as emerging when the first two pathways combined: attention enabled experience to become more vivid and present, while information gain turned that experience into something interpretable and meaningful.

These findings support prioritising PAD's attention and memory deficit and knowledge (information) deficit as the primary intervention focus. Both are actionable through interaction design: the installation can guide noticing, sustain focus, and enable interpretation through meaningful plant responsiveness and accessible information cues. In doing so, the intervention directly strengthens the Experience in Nature and Information about Nature pathways in Zylstra et al.'s CWN framework, consistent with the literature-based argument developed in Section 3.6.3. At the same time, the participant accounts also showed that attention and information alone were not sufficient to explain the full feeling of connection: a positively valent affective emerged when the plant was experienced as alive and agentic. This is elaborated in the next sub-chapter.

4.4.3 Plant liveliness as the mechanism for reducing PAD

Within the theme of PAD, the analysis revealed a recurring affective mechanism through which PAD was reduced: participants described stronger connection when the plant was perceived as lively, and agentic, with eight out of eleven participants supporting this mechanism. This did not foster one single emotion for all participants, but caused a perceptual-affective shift in which the plant was no longer experienced as static background, but as a living other.

Participants described that once they perceived the plant as actively responding, growing, adapting, or interacting with its environment, their attention was sustained, their interpretation deepened, and their emotional response became more positive and relational. As one participant noted:

“I realised the plant was actually doing something, reacting to its environment, and that changed how I saw it” (P2, translated).

This is a critical distinction in the framework of this thesis. Plant liveliness functions as this project’s affective mechanism within Zylstra’s model with which information gain and attention is sustained and a positive affect is fostered. It bridges the first two pathways of Zylstra’s framework (experience and information) with the third pathway (positive affect).

In the framework therefore:

- Attention and information reduce PAD by making the plant noticeable and interpretable.
- Perceived liveliness helps transform that noticing and interpretation into a positive affective response (e.g., curiosity, respect, care, fascination).

This positive affect then strengthens the likelihood that the experience becomes a felt form of CWN.

This defines a second design objective for the installation:

> The installation must translate the plant’s biological activity into perceptible signals of liveliness, so that the plant can be experienced as a responsive, agentic, and living entity, fostering a positive affect.

This defines the 'How' of the 'Why, What, How' framework: the installation aims to reduce PAD and support CWN by experientialising plant liveliness. Chapter 5 further specifies what kinds of plant behaviours participants perceive as lively and how these can be translated into interaction design.

WHY

Stimulating conservation efforts through fostering a feeling of connection

WHAT

Fostering a feeling of connection by reducing Plant Awareness Disparity

HOW

Showing plant liveliness through experientialising the social behaviours of plants

4.4.4 Calmness as a state-setting mechanism

In addition, to this framework the interviews also indicated a preperatory phase that induced a feeling of calmness and slowed pace. 9 out of 10 participants described an initial phase of calming or slowing down, followed by increased attention.

> **"But by truly pausing, both literally and figuratively, and looking, you truly connect with a plant at that moment. Because your full attention is focused on it, and you're not just glancing at it. You're really looking with a kind of profound gaze, or something."**

This was not directly related to why they felt more connected, but was seen as a necessary state-setting mechanism that supported attention and information gain. By slowing pace and reducing sensory/cognitive noise, calmness increases receptivity for plant-centred attention, makes interpretive sense-making more likely, and strengthens the conditions in which perceived plant liveliness can evoke a positive affective response.

4.4.5 Framework of this project

When mapping the findings with Zylstra's framework, I revise the 'Designable Framework Reducing PAD to Improve CWN' and propose the 'Designable Framework Reducing PAD to Improve CWN using Affective Mechansisms' framework, shown in figure 9.

In the theorised PAD situation, Attention and Memory Deficit and Information Deficit addresses the Information about Nature and Experience in Nature deficits which weakens the link towards a positive affective state, while Attitudinal Disparity and Relative Interest negatively impact the affectie state of CWN. The theorised installation situation solves this by using an installation to foster attention and information gain and using liveliness as a mechanism to strengthen the link between Information about Nature and Experience in Nature with the affective state of CWN.

This framework leads to the following design objective:

The installation ruces PAD by addressing

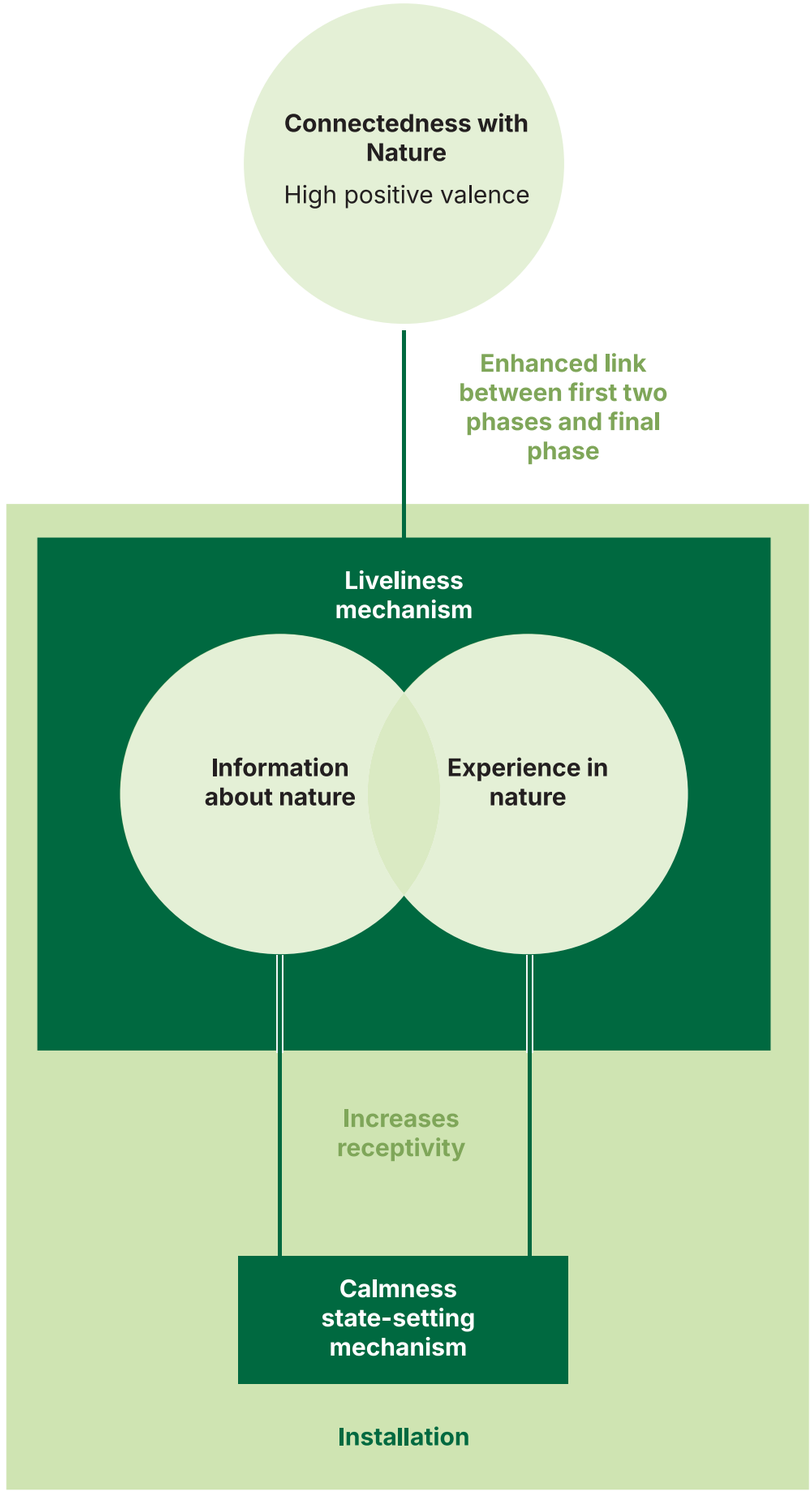


Figure 9, 'Designable Framework Reducing PAD to Improve CWN using Affective Mechansisms'

the Attention and Memory Deficit and Information Deficit by translating plant behaviour into perceptible signals of liveliness to improve CWN.

This can be subdivided into the following sub-design objectives:
Primary sub-objective: Fostering a stronger feeling of Connectedness with Nature.
Secondary sub-objective: Reducing PAD by addressing the Attention and Memory Deficit and Information Deficit
Tertiary sub-objective: Enhancing the guest's perception of plant liveliness

4.5 Defining the Temporal Journey

The analysis further revealed that these mechanisms unfolded over time in a consistent experiential journey. 9 out of 10 participants described the preparatory phase of slowing pace and enhancing calmness. Following this, 8 participants explicitly described a subsequent phase of exploration or engagement in which attention and knowledge about plants increased, and 6 participants mentioned a final phase of reflection in which the experience was integrated and remembered.

This pattern was interpretated as a three-phased temporal journey:
A Preparing phase that enables attentional openness.
An Interaction phase that addresses attention and knowledge deficits central to PAD.
A Reflection phase that supports memory formation and meaning-making.

This temporal journey aligns with how participants naturally experienced moments of strong CWN, increasing the likelihood that PAD is reduced for a sustained amount of time beyond the immediate interaction. Thus, a third design requirement is:

The installation must be comprised of three phases: a preparing phase that slows pace through focusing on different senses, an interactive phase that focusses attention on the plant and allows the user to engage with the plant, and a reflective phase that supports memory formation and an increase in

CHAPTER 5. Defining Plant Liveliness and Sensory Engagement

5.1 Introduction

The previous chapter identified Plant Awareness Disparity as the driver of Disconnection to Nature addressed in this project and established that experiencing plants as living and agentic beings is the mechanism through which PAD can be reduced. This is done in a three phased temporal journey. While this defines the conceptual focus of the installation, it does not yet define how this mechanism should be translated into an experiential interaction of the second phase of the temporal journey. Furthermore, it is unclear how plants can be used to stimulate a calming feeling in the first phase of the temporal journey.

In particular, two design-relevant questions remained open:

1. Which sensory modalities should be engaged in the first phase of the temporal journey to slow users down and induce a calm mental state?
2. Which plant behaviours should be highlighted in the second phase to make users perceive plants as lively and agentic?

These questions concern subjective, embodied experience and emotional interpretation, and could not be sufficiently answered through literature alone. To address this gap, a series of individual co-creation sessions was conducted. The research objective of this activity is:

To co-create with users to define the specific sensory modalities required for the Preparing Phase and the plant behaviours perceived as lively in the Interaction Phase.

Due to the low number of participants (n=4) in this research activity, the findings are not presented as Provisional Design Requirements. These serve as a starting hypothesis for the ideation phase.

5.2 Methodology

5.2.1 Session Structure

The co-creation sessions were a combination of two established design research methods: generative co-design for interaction ideation as defined by Sanders and Stappers, (2008) and the Material Driven Design (MDD) experiential characterisation method by Karana et al. (2015). The adaptation, explained in Appendix C, focusses on the emotional and connective experience, rather than a scientific lens on a material.

All 4 co-creation sessions were conducted one-on-one with individual participants to support introspection, emotional awareness, and calm engagement, and to avoid social influence on subjective experience.

Each session followed a fixed structure consisting of five parts, aligned with the temporal journey defined in Chapter 4:

1. Sensory exploration (preparing phase)
2. Emotional mapping of the preparing phase
3. Behavioural exploration (interaction phase)
4. Emotional mapping
5. Co-creation

5.2.2 Analysis methodology

The co-creation sessions generated two main types of data: sensory scoring graphs and plant behaviour scoring graphs.

The analysis focused on identifying patterns across participants, rather than absolute values.

5.3.1 Quadrant Based Analysis
For both sensory and behavioural evaluations, participants plotted experiences on two-dimensional graphs. Analysis focused on identifying which senses or behaviours appeared most often in:

- the top 50% of scores on each axis, and
- the top 25% on both axes simultaneously (top-right quadrant).

Items in the top-right quadrant were interpreted as most relevant for design focus, as they combined strong experiential impact with sustained interest.

5.3 Sensory Engagement in the Preparing Phase

5.3.1 Procedure

To determine which senses should be engaged in the first phase of the temporal journey, participants interacted with the same plant five times, each time focusing on a different sense, as explained in **figure** 10:

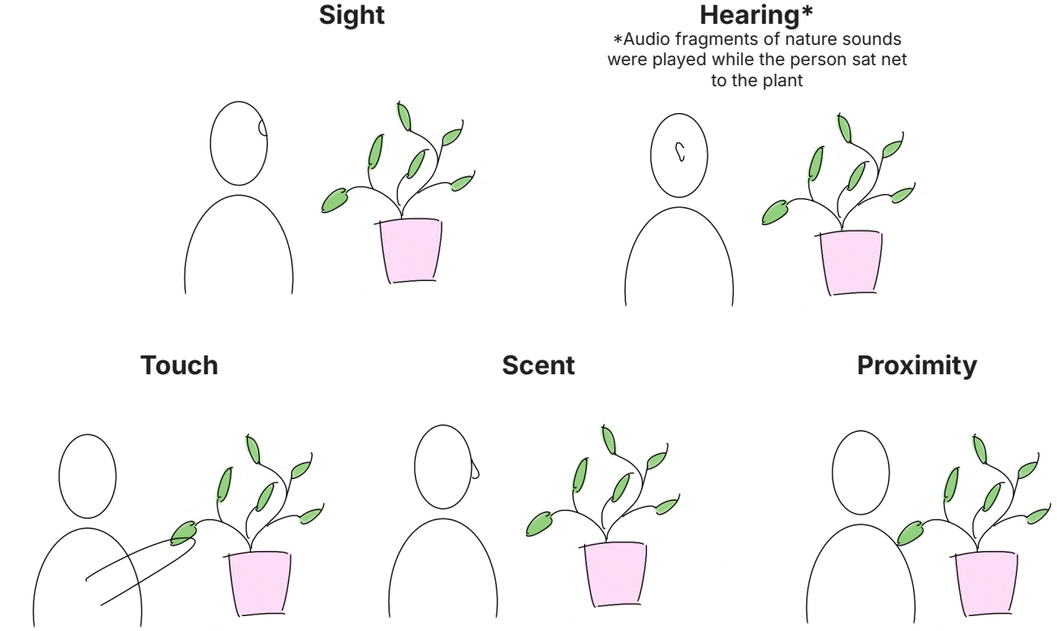


Figure 10, Participant interaction with the plant in the co-creation sessions

After each interaction, participants scored the experience on a graph, shown in figure 11 with:

- Y-axis: how calming the interaction felt
- X-axis: how interesting the plant felt through that sense

5.3.2 Outcomes and analysis: Scent, Sound, and Sight

Analysis of the sensory scoring data shows a preference for scent, sound, and sight. The outcomes are represented in figure 12.

Scent emerged as the sense most frequently placed in the top-right quadrant, meaning it was most often perceived as both highly calming and highly interesting. This indicates that olfactory engagement with plants is particularly effective in slowing participants down while maintaining attention.

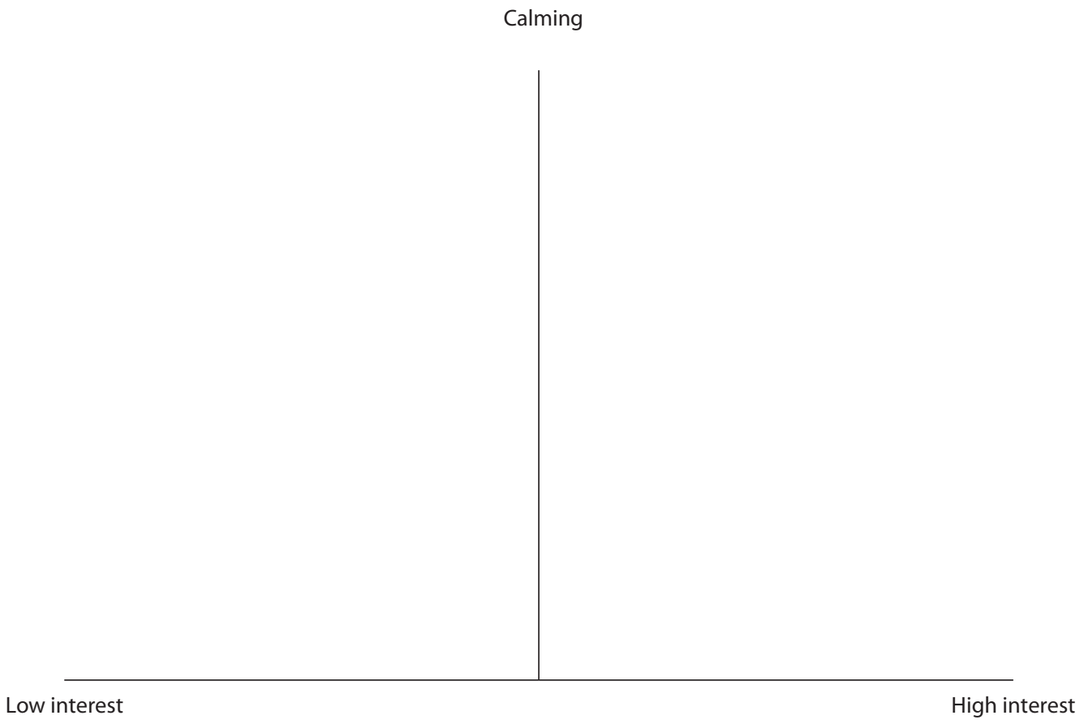


Figure 11, Scoring graph to rate senses on how calm they made the participant and the level of interest it created

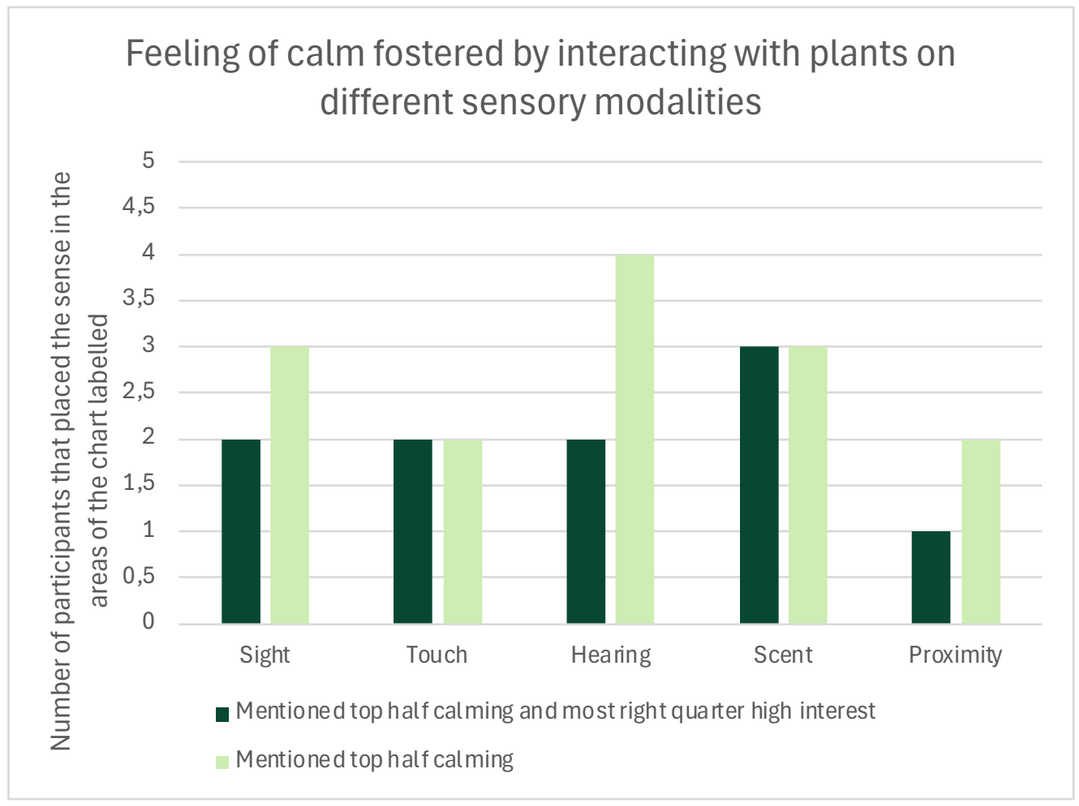


Figure 12, Sensory outcomes co-creation sessions

Hearing was most frequently scored in the top half of calming, suggesting that auditory engagement strongly supports calmness, although it was slightly less consistently associated with high interest.
Sight and touch were moderately represented in both calming and interest, indicating that they support engagement but are less effective as primary calming modalities on their own.

Together, these outcomes indicate that the preparing phase should prioritise scent and sound, supported by visual and tactile engagement, to effectively induce calm while sustaining attentional openness. The Provisional Design Requirement defined by these outcomes therefore is:

Provisional

✱

Users should be stimulated to focus on scent, hearing and sound in the Preparing Phase to induce a calm mood while keeping interest in the installation high.

5.4 Plant Social Behaviour in the Interaction Phase

5.4.1 Procedure

To determine which plant behaviours should be highlighted in the interaction phase, participants were introduced to a range of behaviours exhibited by Dutch plant species, reflecting the local context of the installation.

Each behaviour was explained verbally while participants viewed real-time footage of the plant exhibiting that behaviour. Footage was shown at natural speed to simulate direct observation in nature.

Participants then scored each behaviour on a graph, represented in figure 13, with:

- Y-axis: perceived liveliness of the plant
- X-axis: interest in the plant

5.4.2 Outcomes and analysis

Analysis of the behavioural scoring data revealed that a small number of behaviours

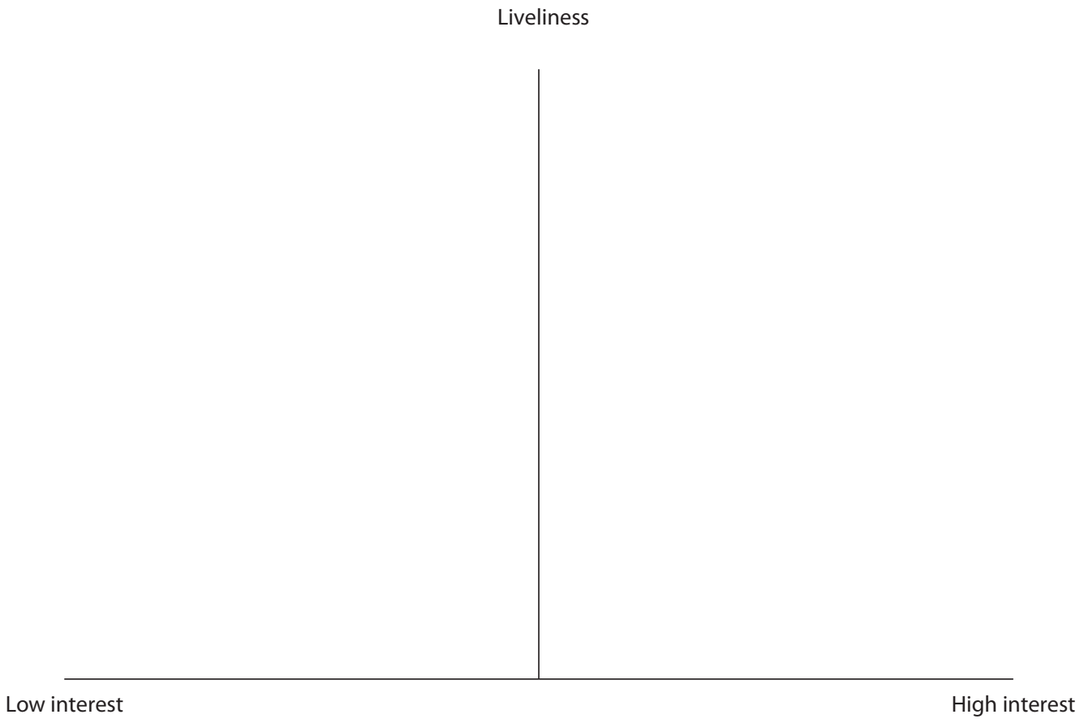


Figure 13, Scoring graph for how much the behaviour made the participant view the plant as lively and the level of interest in the behaviour

were consistently placed in the top-right quadrant, scoring high on both perceived liveliness and interest.

Crucially, all participants independently described the behaviours they perceived as most lively as social behaviours. The highest-scoring behaviours were all interpreted as behaviours in which the plant responds to, communicates with, or adapts to its environment or other organisms. These behaviours behaviours reactiveness to its environment (through systemic electrical signalling, habituation, and conditioning and acoustic/behavioural snesitivity), collaboration and competition (through territoriality), and rapid movement.

Behaviours that were less clearly interpretable as relational or adaptive were scored lower in liveliness, even when they were scientifically complex. This indicates that perceived sociality, rather than complexity or novelty alone, is central to how people view plants as agent.

This finding directly supports the mechanism identified in Chapter 4: reducing PAD by enabling people to perceive plants as living, responsive, and socially embedded beings.

These outcomes define the following Provisional Design Requirement:

Interactions must representing plant social behaviour to allow users to interpret the plant’s liveliness as 'agentic responsiveness'.

5.5 Co-creation and Transition to Ideation

The sessions concluded with co-creation ideation in which participants explored how plant social behaviours could be experientially represented, how calm could be induced using plants in a natural setting, and how reflection might be encouraged. This achieves this research acitivty's objective. The ideas produced served as input for the ideation phase, translating analytical findings into ideation guidance and inspiration.

5.6 Discussion

The findings of this chapter form an important basis for developing the installation’s first two phases: which senses can plausibly support a calming preparing phase, and which plant behaviours most reliably evoke perceived liveliness and agency in the interaction phase. However, because the co-creation activity was conducted with a small sample (n = 4), the results should be interpreted as indicative design guidance rather than generalisable evidence. A larger and more diverse participant pool, with greater variation in age, cultural background, and level of CWN, would likely reduce the influence of individual preferences and produce a more unbiased selection of modalities and behaviours.

A second limitation is potential order bias. The sensory explorations and behaviour scorings were conducted in the same sequence for all participants, which could have shaped responses through comparison effects, learning, or fatigue. For example, once participants learn the intent of the session (to notice and interpret plants), later senses or behaviours may be evaluated more generously because participants become more attuned to subtle cues. In future iterations, this could be improved by counterbalancing

the order (e.g., Latin square) or randomising the sequence, especially if the method is repeated with more participants.

Finally, the co-creation setting differs from the intended park context. Calmness and sensory immersion are strongly shaped by environmental conditions (soundscape, weather, social presence, time pressure). What felt calming or interesting in a controlled session may shift when people encounter the installation while walking through a park. For this reason, the outcomes of this research activity are treated as early design requirements that will guide ideation: the preparing phase must work under distraction, and perceived liveliness must remain legible without heavy explanation.

These limitations do not undermine the value of the activity. They clarify how the results should be used. The chapter provides a grounded starting point for sensory modalities and behaviours which will be translated into prototypes and evaluated in context to confirm which elements reliably produce calm, sustained attention, and perceived plant agency.

CHAPTER 6. Biodata Measurements

6.1 Introduction

As preparation for the ideation phase, it was necessary to establish what plant biodata can be measured in situ and what those measurements practically require. This literature review serves two purposes. First, it defines design parameters: which plant processes can realistically be sensed in a park setting, at what level of invasiveness, and with what robustness. And, it sets the technological design space: which sensing approaches are feasible to integrate into the installation to experientialise the biodata. Together, these considerations provide a foundation to ideate with: instead of designing an experience around abstract plant signals and theoretical opportunities, the ideation can build on a known set of feasible methods and constraints. The research objective of this literature review is therefore:

To identify measurable plant biological signals (biodata) that can be translated in real-time to represent the social behaviour defined in Chapter 5.

6.2 Biodata measurements

Through a literature review, multiple biodata measurement options were identified across different regions of a plant: the leaf, stem and branch, root zone, and surrounding air. Figure 13 summarises the resulting overview, including the type of plant behaviour each signal can indicate and an initial direction for how the signal could be measured.

The final concepts of Round 2 of the ideation phase, in Chapter 8.5, focus on three biodata measurements described in figure 14 as opportunities to experientialise the social behaviour of plants.

Together, these measurements formed the technical basis for ideation. They clarified which biodata channels could credibly support an experiential narrative of plant responsiveness and interdependence, and which channels carried practical constraints (invasiveness, calibration demands, interpretability) that would shape concept development and prototyping decisions.

Leaf electrical potential (electrophysiology) (leaves, branches and stem)
Electrical potential signals can indicate stress and systemic signalling, including communication processes and circadian rhythms (Fromm & Lautner, 2007; Choi et al., 2016; Kozlova et al., 2025). Touch causes an ion influx of Calcium cells in the plant, sending Variation Potentials that travel systemically through the plant (Liu et al., 2025). Proximity also causes a change in electrical potential by creating a static field between the person and the plant (Gloor, 2025). In practice, this can be measured using electrodes combined with a microcontroller (e.g., Arduino) and a high-impedance amplifier (Volkov, 2006; Volkov, 2012; Kernbach, 2022). The main implication for design is that the signal can be treated as a dynamic responsiveness channel, but it demands careful handling of noise, grounding, and stable electrode placement (Volkov, 2006; Armada-Moreira et al., 2023).

VOC emissions (air around leaves)
VOCs are relevant to plant defence and signalling processes, including interactions with other organisms (Holopainen & Gershenzon, 2010; Loreto & Schnitzler, 2010). This can be measured with MOS gas sensors (e.g., MQ5) with sampling via pump, or more compact sensors (e.g., SGP40) with a microcontroller (ESP32) (Wilson, 2013; Rasekh et al., 2020). A key constraint is specificity: low-cost sensors detect broad changes rather than distinct compounds, so the signal is best framed as a coarse indicator of chemical activity rather than a precise message (Rasekh et al., 2020). VOC emissions can also be extracted from the air if it is adsorbed onto a headspace collection substrate in a closed environment (Park et al., 2020).

Figure 14, Explanation of biodata measurements of plants describing leaf electrical potential, VOC emissions, and soil conductance ad soil moisture

Soil conductance and soil moisture (root zone)
Soil conductance (EC) can be linked to nutrient availability and root-zone conditions (Rhoades et al., 1999; Corwin & Lesch, 2005), measurable via a DIY two-probe EC meter (AC excitation). Soil moisture reflects water content essential for hydration and nutrient transport, measurable via a capacitive sensor (with calibration) or a dielectric sensor (White & Zegelin, 2018) (Fülöp et al., 2025). These root-zone measures, however, are indirect. They describe conditions affecting the plant rather than plant signalling itself, so they should be communicated as contextual drivers of plant state.

CHAPTER 7. Analysis Related Projects

7.1 Introduction

To understand what enables biodata and nature based installations effectively support plant-focused attention and information gain and when this is undermined, I analysed existing artworks and installations that bring attention to plants or translate bio-signals from plant social behaviour into an experience. These insights were then transformed into a set of reusable design principles that guided ideation and supported concept pre-selection.

The analysis of precedent designs method used by Blandford et al. (2010) was used to comparatively extract mechanisms that keep attention anchored to the plant and support information gain about plant social behaviour. The resulting design principles are treated as intermediate-level knowledge: not universal theory, but grounded, reusable guidance that can directly shape new concepts and critique emerging ideas.

7.2 Project Summaries

17 different artworks and installations were used for this research acitivity. Examples of artworks that were highly influential in the development of the design principles are:

The Plants Sense (Castellanos & Valverde, 2018–)

The Plants Sense is an interactive garden installation that captures plant systemic electrical signalling activity and translates it into an embodied experience of low-frequency sound and haptic feedback via a wearable and objects in the garden.

Plant-centred, screenless modalities, sound and haptics, hold attention without a screen

The wearable and objects in the ground and its novelty can become the main object of attention rather than the plant, so I need to reduce focal points.

Clarify signal-output connection mapping to support information gain.

Figure 15, analysis of The Plants Sense (María Castellanos, n.d.)

The Tree Listening Project (TreeListening.co.uk)

The Tree Listening Project makes internal tree processes audible through sensitive sensors/microphones, letting visitors listen to a specific tree through a simple, familiar interface: headphones.

The act of listening is spatially tied to the trunk (you listen at this tree), so attention stays on the tree, not on a separate object.

Add an explanation for how the output relates to a real measured process, so people understand what the sound represents and do not treat it as solely entertainment.

Figure 16, analysis of Tree Listening Project (Tree Listening Project, 2025)

One Tree ID

One Tree ID translates a tree's VOCs into a wearable, perfume-like artefact. This creates a bodily, olfactory way of carrying the tree's presence.

Figure 17, analysis of One Tree ID (One Tree ID – How to Become a Tree for Another Tree, n.d.)

Urban Wood Web

Urban Wood Web is an interactive light artwork that visualises the underground tree network through illuminated 'roots' and an immersive light environment, changing based on visitors' presence, time, and proximity.

Figure 18, analysis of Urban Wood Web (Oomen, 2025)

7.3 Design Principles from Analysis

The analysis resulted in a set of design principles that were used in two ways during the next phase: as building blocks to design with and as a screening lens, screening concepts for known risks before investing in prototyping. These principles are:

1. Keep the plant as the primary focus.
If the experience remains compelling without the plant present, attention and meaning drift to the installation. This principle is used to critique concepts where the objects became the attraction, and to prioritise interactions in which the plant remains the object of attention and interpretation.

2. Reduce manipulable objects and competing focal points.
Projects with graspable, visually distracting elements risk shifting interaction into focus on the objects rather than bringing attention to the plant. This informed ideation by favouring minimal interfaces.

3. Use plant-centred sensory modalities to hold attention without screens.
Sound, scent, and touch can sustain attention while keeping gaze available for the plant and its environment. This guided the generation of concepts that rely on screenless feedback and that centre the output near the plant.

4. Support legibility through contextual coupling and attribution.
People understand plant responsiveness more easily when changes may also be created by the surroundings (wind, light, rain, proximity of people), rather than to unclear input-output mappings. This principle guided ideation toward signals and representations that remain interpretable without heavy instruction and can be influenced by the environment, not only the guest.

5. Clarify the connection between measured signals and output.
Clear connections between the input and output of the biosginals enhance understanding of what the output represents. This better enables the installation to achieve information gain in the guest. This principle guided ideation towards showing clear connections.

Together, these principles created a grounded platform for ideation: they narrowed the solution space in productive ways, helped generate concept variations that stayed plant-centred under real-world constraints, and provided explicit criteria for early convergence decisions before prototyping.

Chapter 8. Design Requirements and Synthesis onto Framework

8.1 Introduction

This chapter functions as a synthesis of all seven design requirements and the design implementation of findings onto the 'Designable Framework Reducing PAD to Improve CWN using Affective Mechansisms', see figure 19. These form the basis of the design objective:

The installation reduces PAD by addressing the Attention and Memory Deficit and Information Deficit by translating plant behaviour into perceptible signals of liveliness to improve CWN.

8.2 Framework Implementation

To foster the calmness mechanism, the installation will stimulate an attentional focus on sight, sound, and/or scent.

In the second phase, the installation fosters information gain, reducing Information Deficit, about plants through experientialising plant social behaviour. This behaviour is represented in order to fit with the mechanism of liveliness. In this same phase, Attention and Memory Deficit is addressed by creating an interaction between the person and the plant in the second phase, allowing this Experience in Nature to become meaningful through the representation of plant liveliness. Through this mechanism of liveliness, these two phases of CWN are made meaningful which enhances the development of these phases to a positive affective state forming CWN.

The path from the installation enhancing Information about Nature and Experience in Nature towards the affective state of CWN is further emphasised through the stimulation for reflection in the third phase.

Finally, the park context of the installation enables the further strengthening of CWN over time by enabling guests to re-experience the liveliness of the plant, addressing their Information Deficit and Attention and Memory Deficit, and therefore enhancing Information about Nature and Experience in Nature, and improving their Attitudinal Disparity and Relative Interest, fostering the positive affective state of CWN.

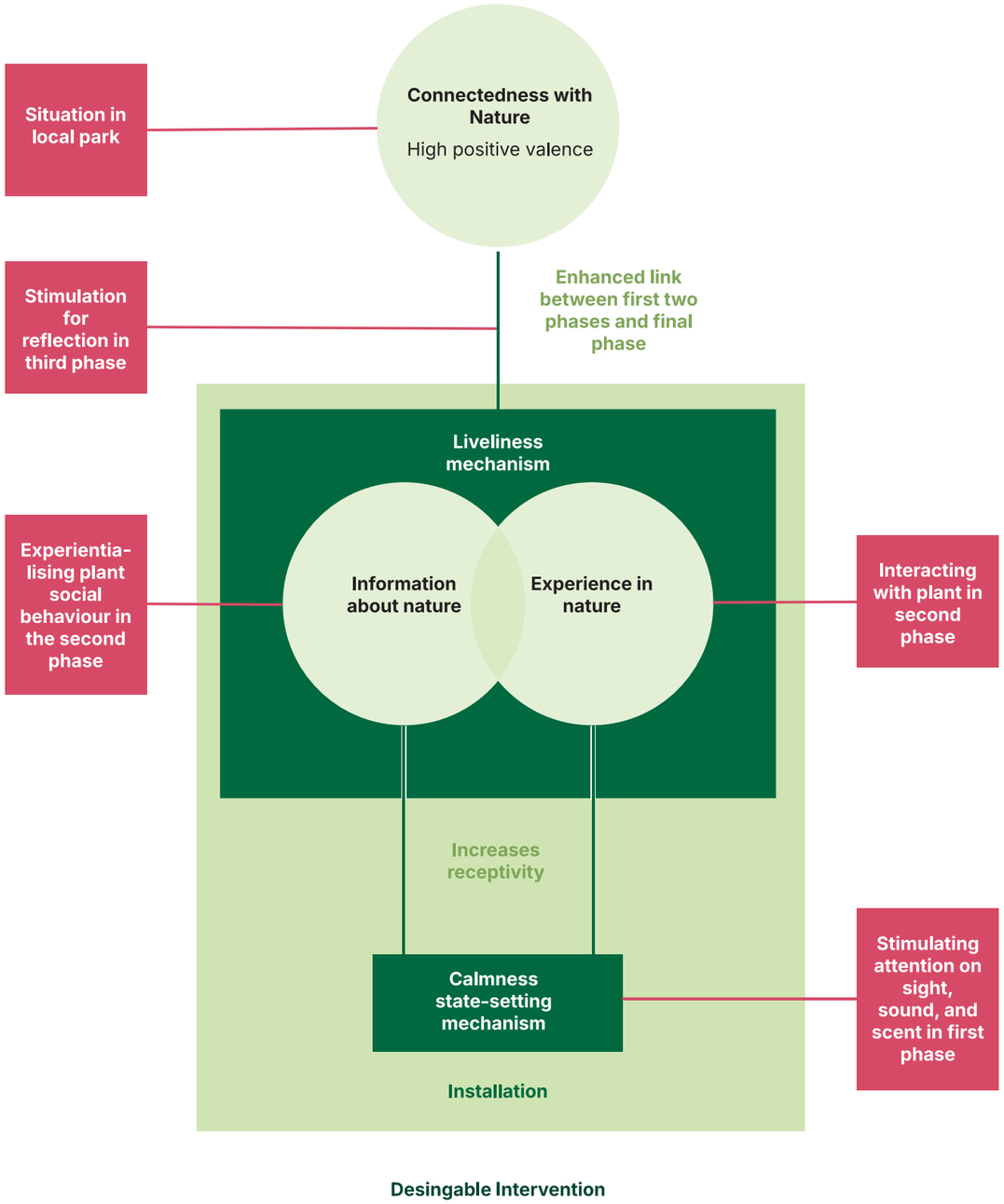


Figure 19, effect of implementation on 'Designable Framework Reducing PAD to Improve CWN using Affective Mechansisms'

Design requirement 1

To foster Connectedness with Nature, interactions must engage the affective (emotional) and experiential, and informational dimensions of CWN.

Design requirement 2

Installations must address Attention and Memory Disparity and Information Disparity to enable experiences in nature to produce a positive affect, improving posititve attitudes towards plants, interest in plants, and CWN.

Design requirement 3

Installations must be placed in a publicly accessible natural location to provide repeated experiences that strengthen CWN over time.

Design requirement 4

The installation must translate the plant's biological activity into perceptible signals of liveliness, so that the plant can be experienced as a responsive, agentic, and living entity.

Design requirement 5

The installation must be comprised of three phases: a preparing phase that slows pace through focusing on different senses, an interactive phase that focusses attention on the plant and allows the user to engage with the plant, and a reflective phase that supports memory formation and an increase in attitude and interest.

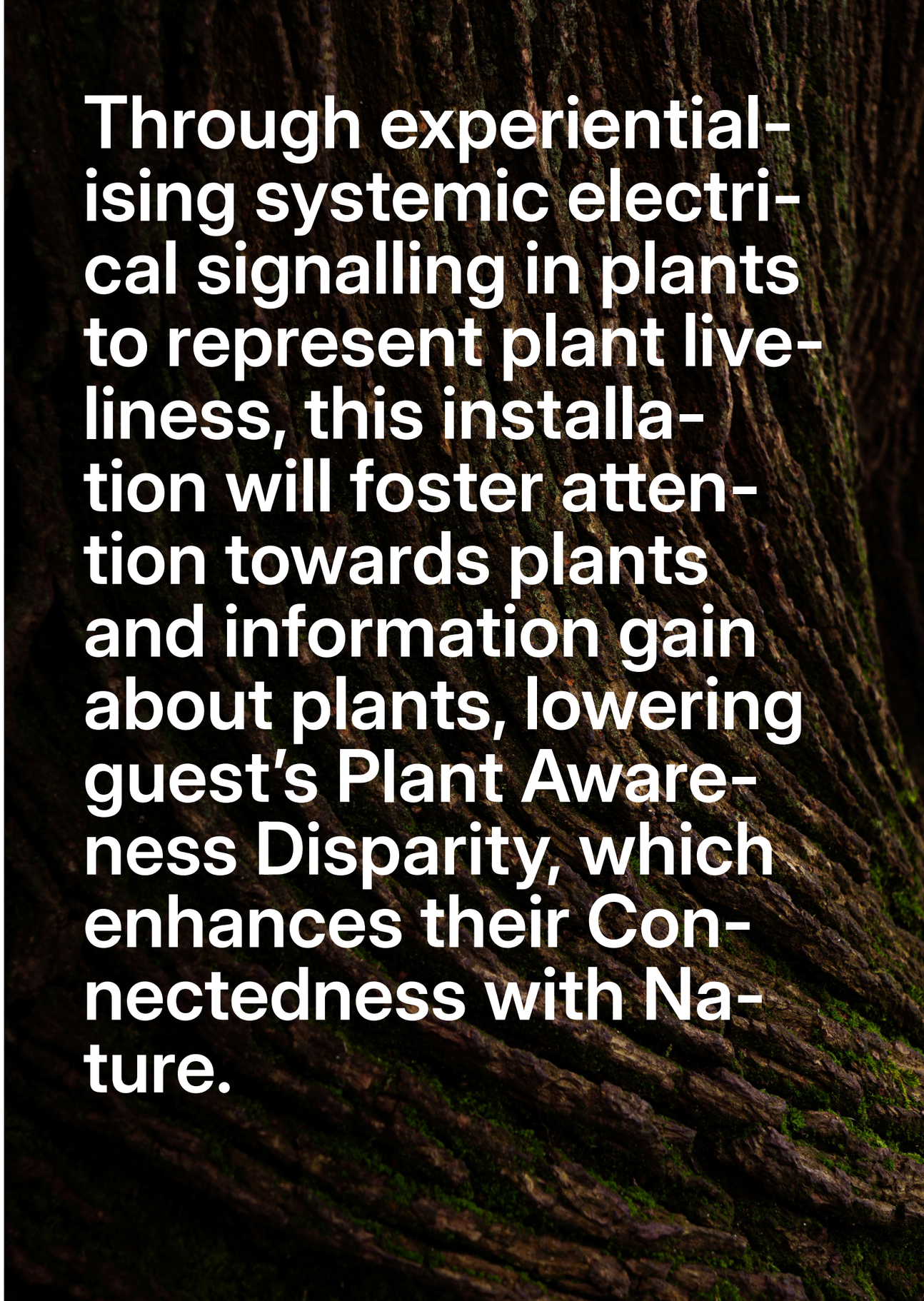
Design requirement 6

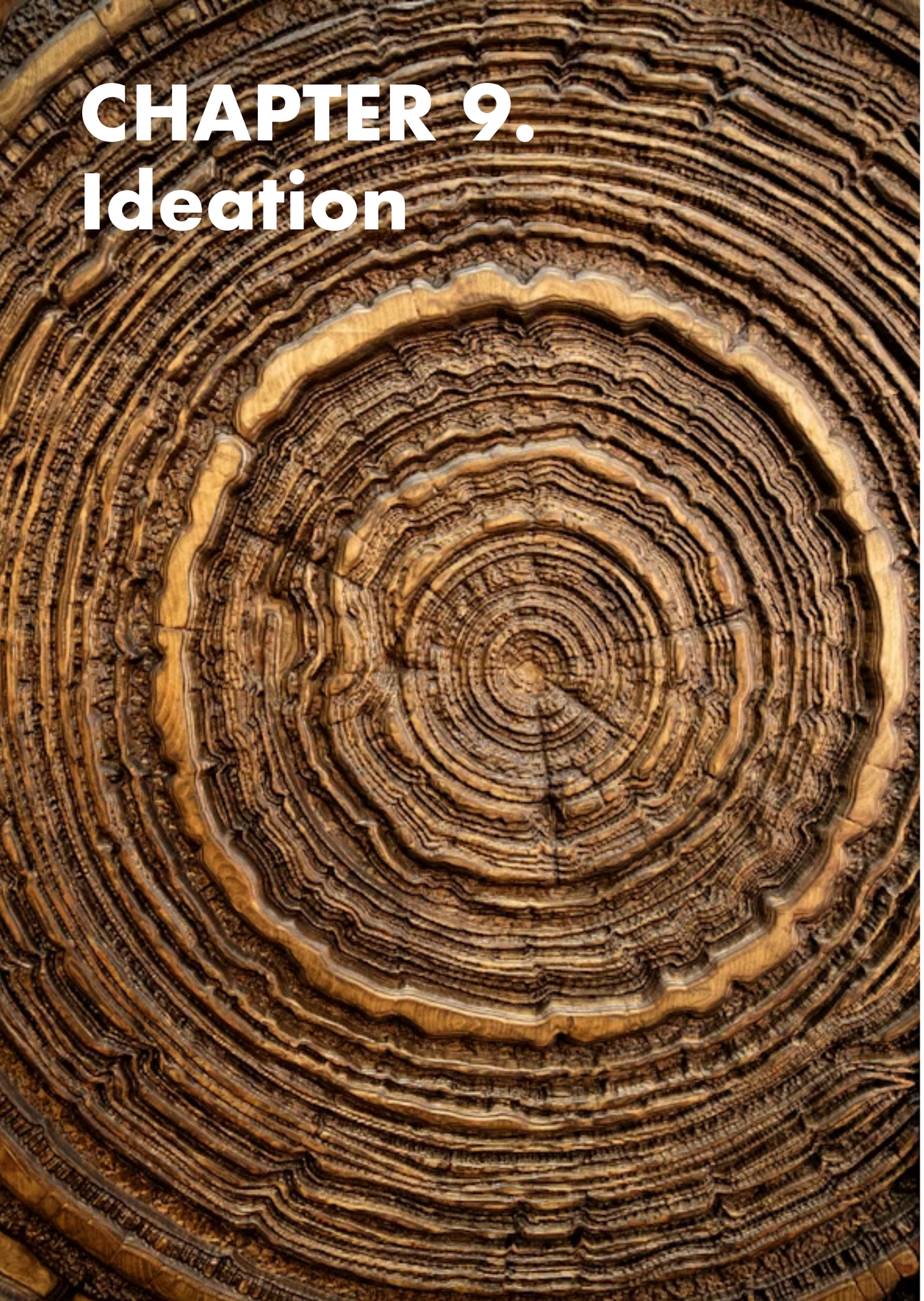
Users should be stimulated to focus on scent, hearing and sound in the Preparing Phase to induce a calm mood while keeping interest in the installation high.*provisional

Design requirement 7

Interactions must representing plant social behaviour to allow users to interpret the plant’s liveliness as 'agentic responsiveness'.

Together, the framework and design requirements define the research hypothesis.





CHAPTER 9. Ideation

9.1 Introduction

The preceding chapters established the framework of this project: to foster Connectedness with Nature (CWN) as a first step in a wider Three-Step Journey toward conservation action, by addressing Plant Awareness Disparity (PAD). In order to achieve this, three different opportunities for measuring plant biodata in order to achieve this framework were established. To select the best plant biodata measurement and develop the installation to represent this, this chapter focusses on achieving the following objective:

To ideate different concepts that implement this thesis' implementation of the 'Designable Framework Reducing PAD to Improve CWN' (described in Chapter 8) and evaluate different conceptual meta-concepts to determine which represent of plant biodata best fosters attention and perceived learning"

Ideation was treated as a structured exploration and convergence process in four iterative rounds. First early exploration focuses on the two fundamental parts of Plant Awareness Disparity to address: how to draw attention to plants, and how to make plant social behaviour experiential. With this broad range of concepts, analogies were explored to ensure the installation also effectively addresses the affective aspect of Connectedness with Nature. These explorations were synthesised into three 'meta-concepts' that each represent one of the biodata measurement options. The final direction was selected through comparative prototyping and user evaluation.

9.2 Ideation Evaluation

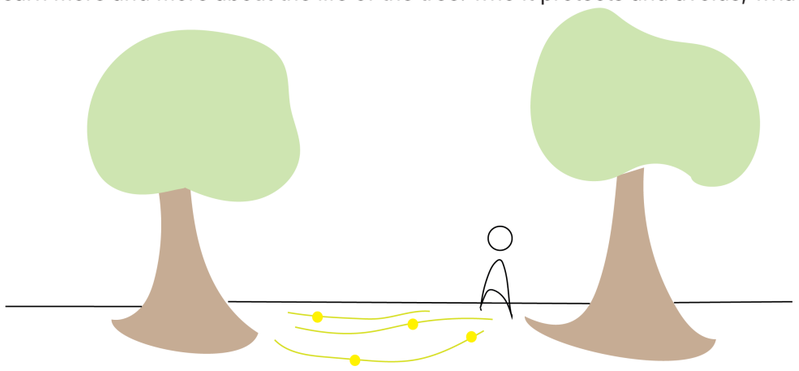
The evaluation of concepts was based in the design requirements, listed all together in the following pages, and an evaluation of feasibility in a park setting. These criteria were used first to guide exploration (what to ideate toward), and later to support convergence (how to justify decisions) to align to the project goal and the three phases.

9.3 Round 1: Exploring Attention and Experientialising Plant Social Behaviour

To effectively address PAD, the installation must gain attention for nature and enhance information about nature. Therefore, Round 1 developed ideas that addressed these

aspects of PAD. The broad set of ideas for both aspects were clustered and combined into many concepts. An evaluation based on the design requirements and feasibility selected 6 concepts to further develop, see figure 20 to 22.

Journey of Care - Nutrients: Guests walk the route of nutrients shared between trees in the park. While walking, they learn more and more about the life of the tree: who it protects and avoids, what is shared, etc.



Sharing/Seing: Guests walk through the park guided by an object, which shines brighter near its kind and less bright by different trees, allowing people to experience the social relations in of the plants in the park.

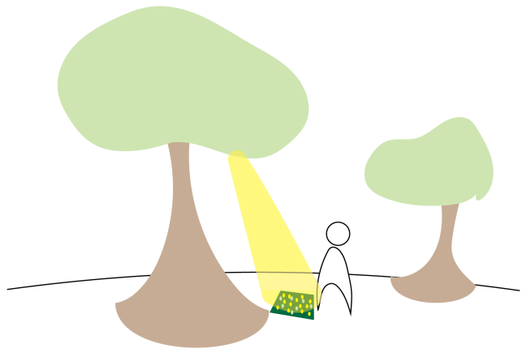
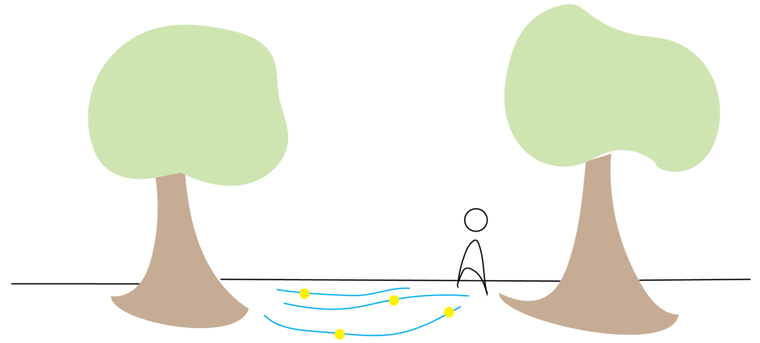


Figure 20, Concepts round 1 ideation

Journey of Care - VOCs: Guests walk the route of VOCs shared between trees in the park. While walking, they learn more and more about the life of the tree: when it emits VOCs, what the VOCs do in other trees, etc.



Harmonising relationships: People are guided through a walk in the park with an amulet playing a poem about the social behaviours of plants. The sounds of the social interactions between the plants are sonofied, with kin harmonizing and differing from other tree families. As you interact with trees, forming a connection with them the amulet to emits a sound, harmonising with the sounds of the trees, representing a relationship being formed between you and the tree.

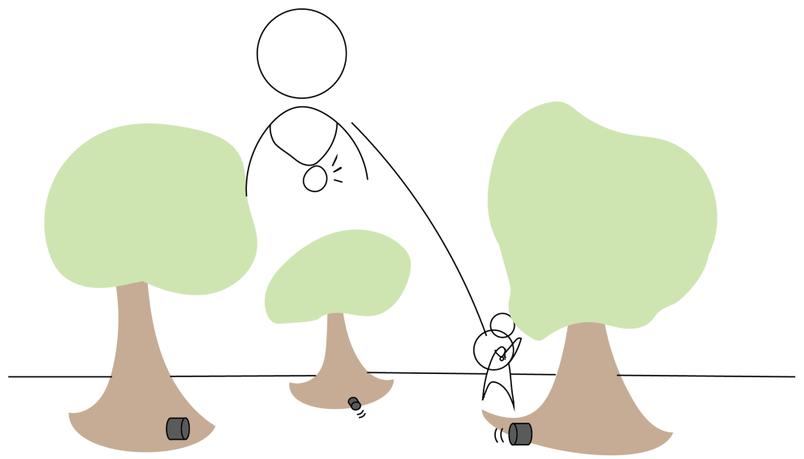
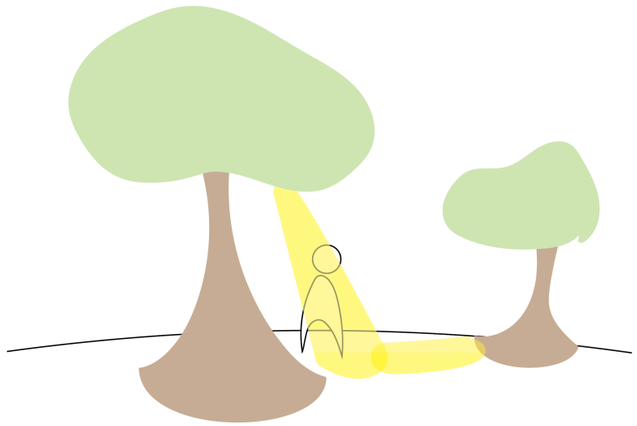


Figure 21, Concepts round 1 ideation

Sharing/Leading: Guests are free to walk in the park. When they stand by a tree, a light shines at them, as if the social relational network between them starts to grow. Meanwhile, a poem about this social relationship is shared through directional speakers. As the person stands longer, the relationship of the tree with other trees is shown through lights, sharing more intimate information with them.



Nutrient recreations: A ‘recreation of the forest’ is made with plants in a basin.. Through fluorescent dyes the nutrient sharing pathways of the plants are shown. As guests touch the plants, ‘giving the plant nutrients’, a projection of the journey of the nutrients in the basin and in scale for the trees is projected.

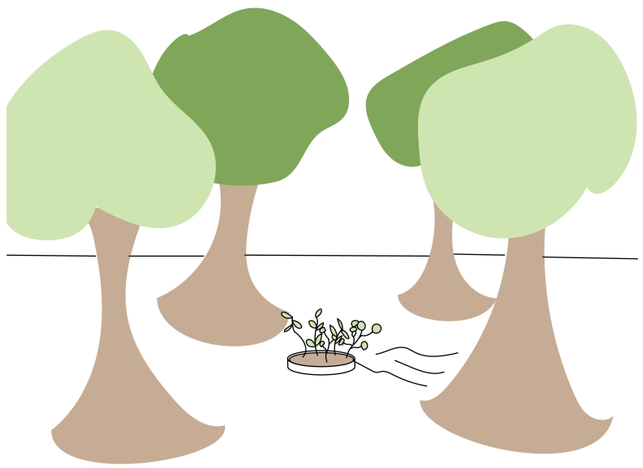


Figure 22, Concepts round 1 ideation

9.4 Round 2: Affective Layer Through Analogies

Round 2 aimed to enhance the affective dimension of Connectedness with Nature through strengthening the experience of liveliness. To do this, this round focuses on adding the affective design layer through analogies to the concept generation process.

For most people, liveliness is well-understood in the context of human-to-human contact. Therefore, interpersonal analogies were used to translate these experiences into interaction principles that represent the interaction elements that effectively foster a positive affect. This moves the ideation beyond experientialising biodata towards designing an experience that evokes connection and the experience of liveliness while keeping the engagement with the plant as the focus.

Each analogy was analysed on the role and actions of the participants and the affective outcome it tends to produce in order to define interaction principles. These were used to develop the final concepts of round 1 to more effectively foster a positive affect and experientialise liveliness.

The four interpersonal analogies used in this round are summarised as follows:

1. Sharing thoughts:

Two friends talk in a familiar, safe setting. One person opens up about something personal, worries, dreams, or an experience, and the other responds warmly, listens attentively, and makes them feel accepted. The exchange feels mutual and supportive. Outcome: the person feels heard, calmer, and emotionally supported; they leave with a stronger sense of closeness and empathy because they were met with receptiveness and care.

2. Sharing silence:

Two people sit together in silence, looking at each other for an extended time. Because of the stilness, attention shifts to subtle details: small changes in expression, breathing, posture, and micro-movements. The longer the silence continues, the more comfortable and intimate it becomes. Outcome: calmness and connection grow through sustained attention; curiosity is directed toward subtle change; the relationship deepens because the other person becomes more present and fully noticed.

3. Being welcomed and introduced:

Someone enters a space where they know one person and are unfamiliar with the rest. The friend greets them warmly, makes them feel safe, and introduces them into the

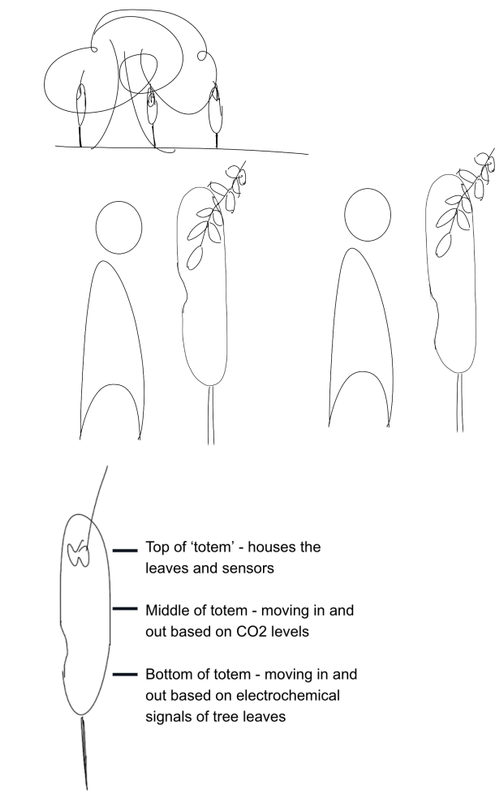
group, giving context and helping them find their place. The social world becomes accessible and less intimidating. Outcome: the newcomer feels included, reassured, and open; curiosity increases; connection forms faster because the interaction is guided and the environment feels hospitable rather than overwhelming.

4. Getting to know someone:
Two people who only know each other slightly start a conversation in a public context (train, street, café). It begins with introductions and small talk. As they continue, they share more personal or meaningful information, and the conversation becomes richer. When they part, the person reflects on what they learned and feels they understand the other better. Outcome: connection strengthens gradually; empathy increases through accumulating information and responsiveness; the interaction is memorable because it unfolds over time and ends with reflection and meaning-making.

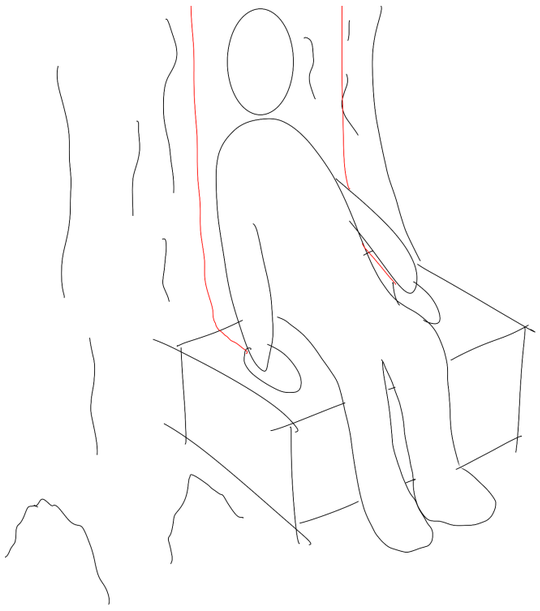
A limitation in this approach may be the human-centered focus of the analogy. The connection felt in these contexts may not translate as intended into a connection with nature. By using the interaction principles as opposed to mimicking the interaction, I aimed to minimize the effect of this.

9.4.1 Expert selection with client advice

This round of ideation developed 6 concpets, see figures 11 to 15. Because this project was conducted for Tellart, a selection of 3 concepts was done after a meeting with the Design Director of Tellart. These 3 concepts will be developed into meta-concepts. The critique was grounded in the same evaluation lens established earlier: compliance to the project logic and goal of the project, and outdoor feasibility.



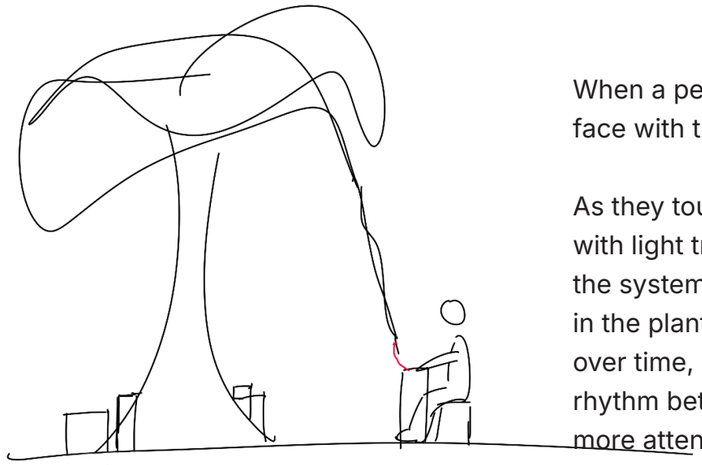
When someone stands before the totem, their breath warms the leaves and raises CO_2. The CO_2 makes the totem's middle pulse in and out, while the heat boosts the plant's electrochemical signals. Together, these responses create a rhythmic motion between the base and center, emphasizing the quiet symbiosis between human and plant.



Speakers beneath the tree play sounds of its underground communication. The bench has two pads that slowly expand and contract in sync with the leaves' slow waves, inviting guests to sit and observe nature more closely. Resting their back against the tree encourages calm, while the pads set a gentle pace and reveal the tree's quiet liveliness.

Figure 23, Concepts round 2 ideation

A stand with fertilizer and a speaker playing a sonofication of the earth's conductance stand by the tree. When the person is near the tree, a poem about the trees relation to other plants in the park is shared and invites them to join the underground network by adding fertilizer, causing the sound to change. The sound spreads to other trees, welcoming the guest into their world.



When a person sits, they are face to face with this part of the tree.

As they touch the plate it begins with light trembling, representing the systemic electrical signalling in the plant, and becomes greater over time, allowing them to feel the rhythm better as they give the tree more attention.

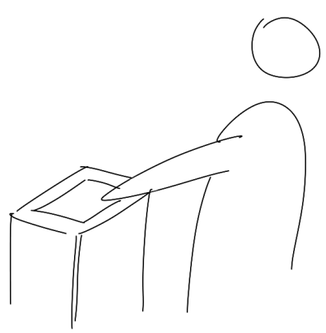
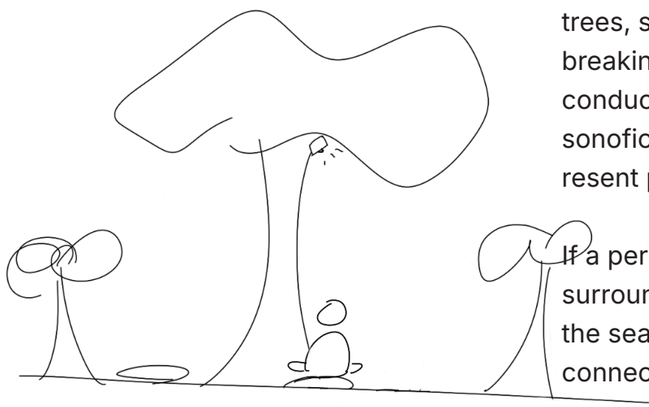


Figure 24, Concepts round 2 ideation

Speakers around the tree lead the guest under the canopy towards the tree trunk while learning about what the tree has experienced.

At the tree trunk, the poem invites the audience to share their worries and experiences with the tree, allowing the underground network to take in the worries for the guest, represented by a sound moving from the tree towards other trees.



A tree plays the sounds of different natural events that happens to trees, such as storms and branches breaking and a sonofication of soil conductance. At intense events, the sonofication becomes louder to represent plant to plant collaboration.

If a person sits on one of the seats surrounding the tree the speaker in the seats sonifies their conductance, connecting them to the trees.

Figure 25, Concepts round 2 ideation

9.5 Round 3: Meta-Concepts

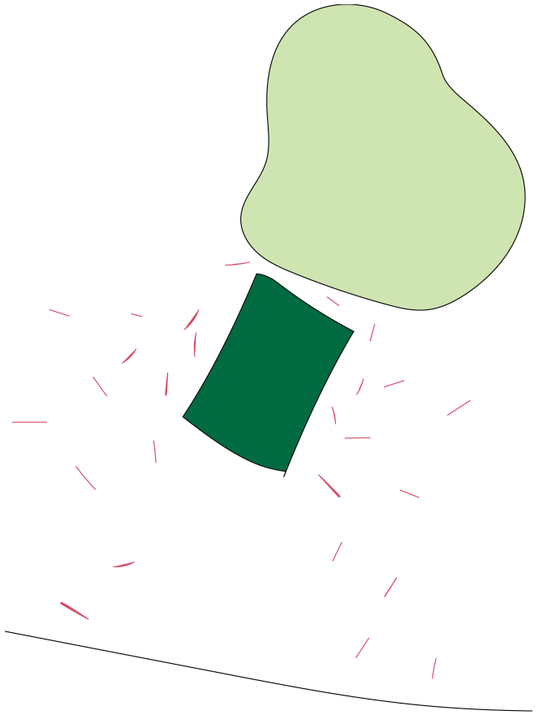
The selected directions from Round 2 were developed into three meta-concepts that could be compared at the interaction level through prototypes. The development of concepts from Round 2 to Round 3 focussed on enhancing feasibility and connecting the biodata to the interaction. The final product of Round 3 was a prototype for each installation at an equal level of development, which enabled equal comparison between prototypes.

The aim of prototyping at this stage to create sufficient experiential fidelity for participants to meaningfully compare how each concept affects attention to the plant, perceived information about the plant, and felt connectedness.

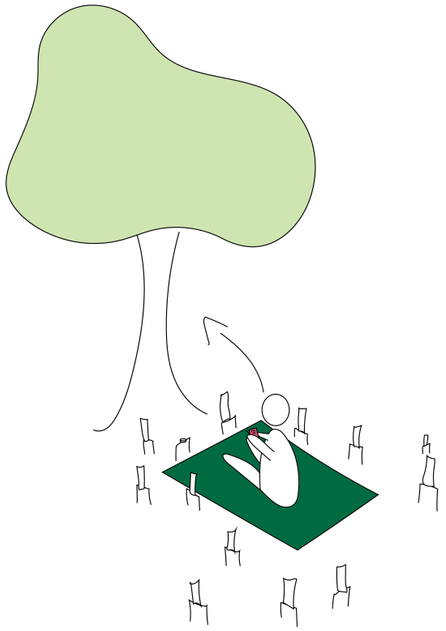
To improve the validity of the comparison, prototypes were designed so that certain aspects, the setting, approximate interaction duration, and instruction level, were held constant. This enables the interpretation of differences as stemming from the concept rather than from unintended biases.

9.5.1 Meta-Concept 1: Sharing Thoughts

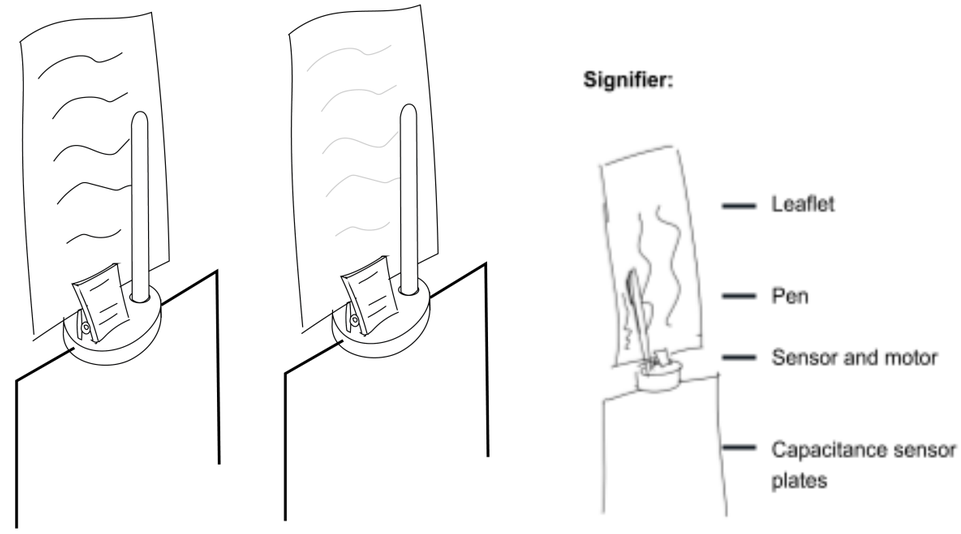
Sharing Thoughts experientialises **nutrient sharing in the underground network of plants**, see figure 26 and 27. Multiple small signifiers are placed in the ground around a tree and move based on soil conductance readings, arranged to create a path toward a blanket. When a visitor enters the path, the nearby signifiers stop moving to invite them inward. At the centre, the visitor can write on a leaflet and clip it back onto a signifier. The signifier's capacitance then triggers gentle warming that erases the heat-sensitive ink, suggesting the message has been taken in and redistributed through the unseen system.



Leaflets shape a path towards a blanket in fron of the tree. The leaflets move based on the capacitance of the earth.



By the blanket the guest can see a text on the leaflets that invites them to share something with the tree root network, fostering connection.



When the person puts the leaflet back on the 'signifier', it sends electrical signals based on the earth capacitance through the metal on the back of the leaflet, causing the heat-reactive ink to disappear.

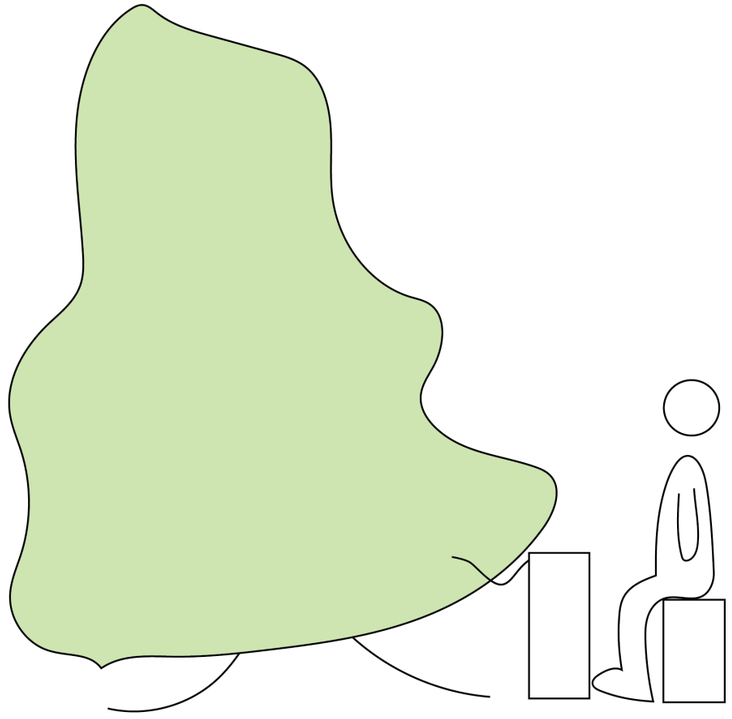
Figure 26, Storyboard of Meta-Concept 1

Figure 27, Prototype of Meta-Concept 1

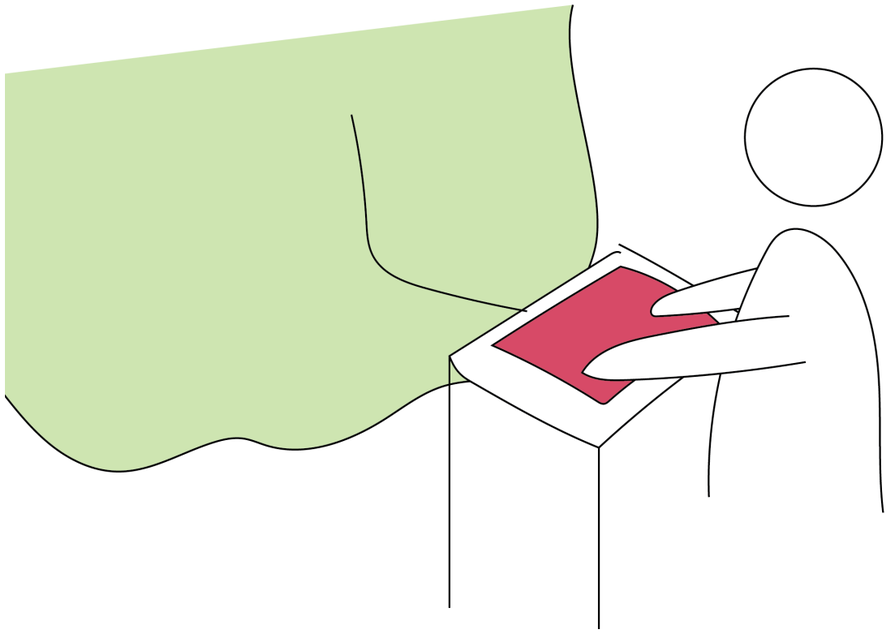
9.5.2 Meta-Concept 2: Sharing Silence

Sharing Silence represents the **systemic electrical signalling of plants**, see figures 28 and 29. Guests sit on a stool in front of the plant's leaf, 'standing eye to eye with each other'. In front of each stool, a tactile plate translates that part's activity into a tremble. When the visitor places their hand on the plate they can feel the tremble. As they touch the leaf of the plant, this changes the signal and therefore the tremble in the box.

Figure 28, Prototype of Meta-Concept 2



Seats are placed around the tree inviting people to sit face to face with the tree.



As they put their hands on the table, the conductance of the leaf is represented through trembling. The longer they sit, the more trembling they experience, stimulating a long, connective face to face moment.

Figure 29, Storyboard of Meta-Concept 2

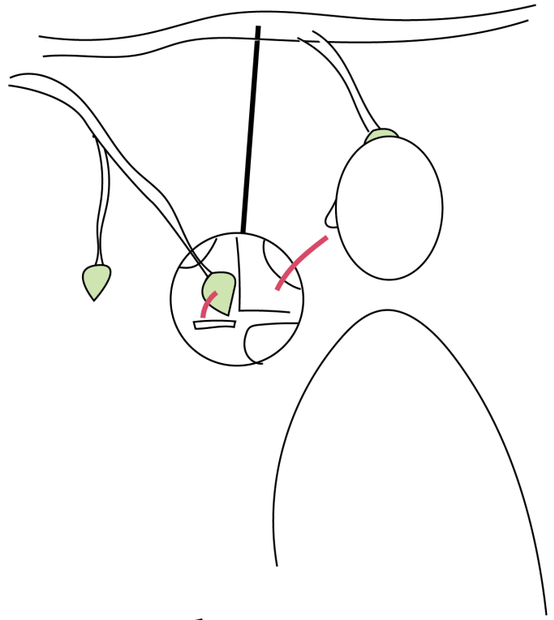
9.5.3 Meta-Concept 3: Sharing Breath

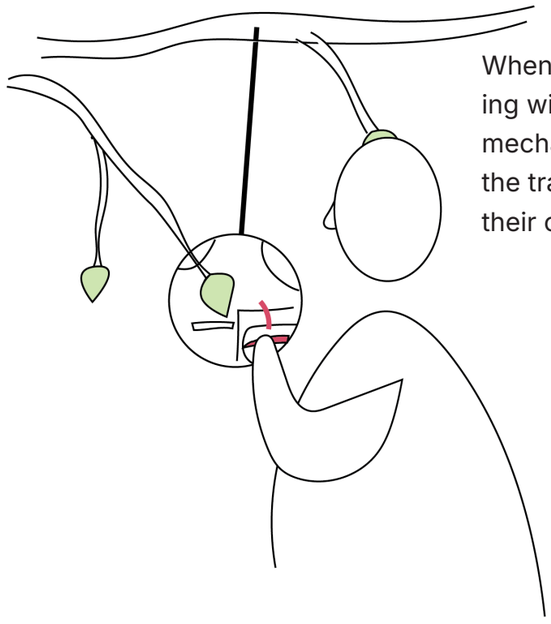
Sharing Breath represents the tree's **volatile organic compounds (VOCs) as a medium of communication**, see figures 30 and 31. A small scent source is positioned in/near the tree canopy so that, when a visitor approaches and pauses beside the tree, they receive a gentle release of the tree's natural scent. The experience is designed to be calming, shifting the visitor's breathing and attention. As they breathe into the ball, a paper captures VOCs from the person while a bowl with alcohol captures the VOCs released by the tree. By turning a lever, the guest can dip their paper into the bowl, receiving a memroy of their 'communication' with the tree.

Figure 30, Prototype of Meta-Concept 3

Transparent scent balls hang from the tree. An audio describing the relationship between humans and trees through scent plays, inviting the guest to come closer.

As the guest breathes by the opening, some VOC particles go onto the perfume paper. Meanwhile, a tray with alcohol on it collects VOC emissions from the leaf.





When the person is done breathing with the leaf, they can turn the mechanism so the paper dips into the tray, creating a scent memory of their communication.

Figure 31, Storyboard of Meta-Concept 3

9.6 Analysis Approach and Selection

A within-subject study was conducted in which each participant experienced all three prototypes. Order effects were controlled using a Latin square counterbalancing scheme so that each prototype occurred in each position across participants. Nine participants took part in the evaluation (n = 9).

The evaluation focused on three outcomes that directly correspond to the project mechanism established earlier: attention toward plants (addressing PAD's attention deficit), information gain (addressing PAD's knowledge deficit), and a state-like measure of connectedness to nature elicited by the experience. To evaluate this, three methods were used: a Likert scale rating of Connectedness with Nature, an interview on its ability to address PAD, and a visual analysis based on Hartmann et al. (2006)'s method to find key points of improvement.

Participants experienced the three prototypes in their assigned order and were then interviewed. They were asked to complete Likert scale rating on Connectedness with Nature and participate in a semi-structured interview. The interview focused on what supported or hindered attention to the plant, what participants felt they learned or understood about the plant, and what created or blocked a feeling of connection.

9.6.1 Analysis Approach for Selection

Because the evaluation compared three prototypes within the same participants and used Likert-type ratings with a small sample size, quantitative differences between prototypes were analysed using a Friedman test. Post-hoc comparisons were required, pairwise tests were interpreted and corrected for multiple comparisons to reduce inflated Type I error.

Interview data were analysed through thematic analysis, focusing on recurring patterns in what participants described as connecting, attention-directing, or informative. This improved the selection of a final concept by evaluating the lived experience of the prototypes and how well it addresses PAD.

9.7 Outcomes and Selection of Final Direction

9.7.1 Quantitative Outcomes

The average connectedness ratings for each prototype were as follows: Prototype 1 scored 3.44, Prototype 2 scored 2.67, and Prototype 3 scored 3.78. In this sample, the quantitative analysis did not indicate a statistically reliable difference between Prototype 1 and Prototype 3, while Prototype 2 consistently underperformed. Given the small sample size (n = 9), these results are interpreted as suggestive rather than definitive. They indicate that both Prototype 1 and Prototype 3 have potential to support connectedness, but they do not establish a clear superiority of one over the other on the connectedness rating alone.

9.7.2 Qualitative Outcomes

Although Prototype 1 and Prototype 3 achieved comparable connectedness ratings, participants described different experiential mechanisms through which this connection emerged. Prototype 1 was repeatedly described as enabling participants to feel what the plant is experiencing and to interpret plant change as a response to its surroundings. This supported the project's core goal: focusses attention toward the plant while making its liveliness experiential as agency through representing social behaviour.

The interviews suggested that Prototype 1 kept the plant as the centre of focus, sustaining attention and supporting interaction with the plant rather than with the interface.

In Prototype 3, participants frequently described a calming experience centred on breathing and awareness of shared breath with the plant. While this contributed to a reflective and self-regulatory feeling, it also tended to move attention toward the participant's internal bodily state rather than toward interpreting plant social behaviour. As a result, Prototype 3 aligned less directly with the project's stated How: experientialising plant social behaviours through biodata to reduce PAD.

On this basis, Prototype 1 was selected as the final direction. Prototype 1 more consistently supported the desired chain from attention and information gain to perceived liveliness and agency, which is the mechanism through which PAD is aimed to be reduced.

9.8 Refining the Selected Concept

A subsequent round of thematic analysis and a visual evaluation was performed on Prototype 1 with the goal of refinement: discovering what aspects of the prototype to improve in order to best achieve the goal of the installation.

Video footage were reviewed to identify moments in which participants were confused on what to do, misinterpreted the aimed interaction, or shifted attention away from the

plant. The analysis focused on: problem indicators (confusion, hesitation, disengagement), major user actions and recurring interaction patterns, and points that supported or hindered connection, attention, and information gain. This reflective analysis concluded with three design changes aimed at strengthening intuitiveness of the installation, clarity of responsiveness cues to enhance information gain and attention, and the calmness evoked in the preparing phase.

The questions defined to answer are:

1. What should the form of the interaction output object(s) be to make interaction and sensory engagement intuitive?

2. How can I make clear how and where to touch the plant to interact with it?

3. How can I use the bio-signals and its expression to calm people before their interaction with the tree?

The next phase, described in chapter 8, focusses on answering these questions through refinement iterations of prototypes evaluated through user testing in order to achieve an installation that intuitively and effectively addresses PAD. Question 2 is specified in Chapter 9 through a visual analysis of the preceding prototype.

9.9 Discussion of Evaluation Method

9.9.1 Attention and Plant-Centredness

A key lesson from the prototypes is that attention is shaped less by the intended narrative and more by what the interaction affords. Prototype 2 illustrates this clearly. Although it appeared promising on paper, its physical setup pulled attention away from the tree. Participants became distracted by the papers themselves and oriented toward manipulating or controlling them, rather than using them to attend to the plant and interpret responsiveness. The interface became the primary object of engagement and the plant became secondary.

This does not necessarily mean the narrative concept of Prototype 2 is invalid. Rather, it shows how easily form can overshadow meaning-making. When a component is visually appealing and/or interactive, participants will naturally explore it as an object to interact with. For an installation aimed at countering Plant Awareness Disparity, this undermines the intended shift from plants as background to plants as foreground. A direct implication for subsequent iterations is to minimise manipulable objects and keep cues and feedback perceptually and spatially anchored to the plant itself.

9.9.2 Limitations and Interpretation

The findings should be interpreted cautiously due to three constraints. The sample size was small (n = 9) and relatively homogeneous (predominantly young university educated students), limiting generalisability and statistical sensitivity. In addition to this, although a Latin square was used, the within-subject design likely introduced a learning effect: after the first prototype, participants better understood the framing (biodata, responsiveness, connection), which likely increased understanding of later prototypes and may have elevated baseline connectedness during the session. Finally, the experience of the first phase, by situating the installation in a park, was constrained by the practical requirements of access to electricity, which prevented testing the preparing phase as a true park-based journey. Because this phase relies on the calming experience of walking into and being in nature, the evaluation may underestimate the impact of the complete three-phase experience when placed in the middle of the park.

CHAPTER 10. Concept Refinement

10.1 Introduction

The previous chapter identified a set of open questions that must be resolved to refine the chosen concept. The refinement work focuses on three interrelated aspects: developing the interaction and output modalities so that bio-signal changes are legible as plant responsiveness, addressing usability issues that prevented participants from understanding how to interact, and strengthening the preparing phase so that the experience reliably supports a calm, receptive state before interaction.

10.2 Current Interaction Concept

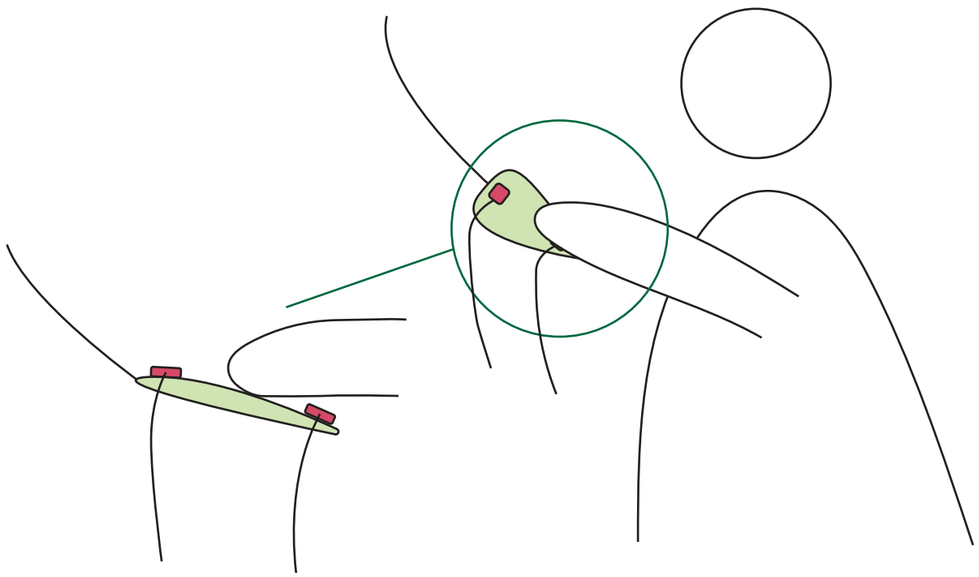
10.2.1 Interaction

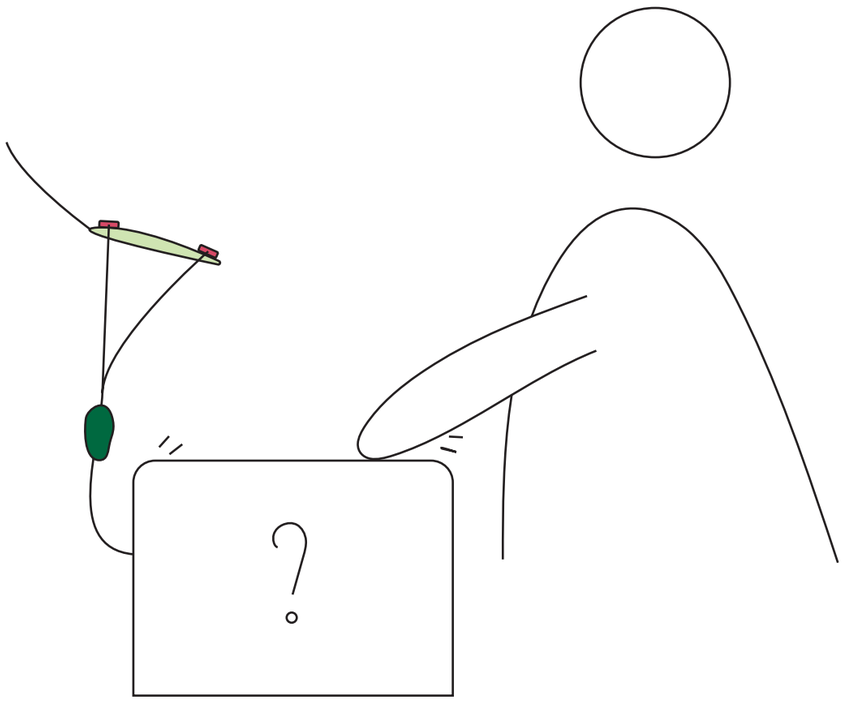
In the current interaction concept, guests can explore the systemic electrical signalling of plants through a biofeedback loop that transforms the plant's conductance into sound and haptics. When a guest comes in close proximity to the plant's leaf connected to the biotron (at roughly 10cm from the plant) or touches this leaf, the conductance of the leaf changes. Guests can hear this through the sound and feel this through the haptic interface. This enables a tactile interaction between the person and the tree.

The interaction is based on the Playtronica Biotron, which measures changes in the plant’s systemic electrical signalling through the conductance of the leaves. Electrodes are attached to a leaf, and the Biotron translates these conductance changes into a digital signal.

This signal is then processed through the Playtronica software environment (synth.playtronica.com), where it is translated into sound and haptic output. In the current prototype, the DX7 Synth was used as the sound engine. The resulting sound is played through a speaker, while low-frequency output is sent to a bass shaker, allowing participants to feel the plant signal as vibration.

As a result, the interaction creates a real-time sensory translation of the plant’s activity: participants can hear and feel changes in the plant signal while being physically near or interacting with the plant. At this stage, the prototype primarily functions as a proof of concept for plant-based sensory feedback. The following sections describe how this interaction was evaluated and refined to better support the project’s goals of reducing Plant Awareness Disparity and fostering Connectedness with Nature.





10.3 Refinement questions: Ideation and testing

For refinement questions 1 and 2, multiple concepts were prototyped to the same fidelity and tested in the intended context, with similar duration and instruction level. The prototypes differed only in the specific intervention, so observed differences could be attributed only to the design change. These prototypes were then tested by 7-9 participants in within-subject user studies so that participants could directly compare alternatives and articulate differences in perceived clarity and meaning. To reduce order effects and learning bias across conditions, the presentation order of prototypes was counterbalanced using a Latin square.

10.3.1 Question 1: How should the tremble + sound element be designed to make understanding the output intuitive?

For the first refinement question, ideation focused on form and output clarity., addressing two key usability issues:

Unclear output cues: participants were uncertain how to interact with the installation to cause changes and interpret the trembling sensation. Two misinterpretations were often made: that the audio was the main interaction or that the electronics or box were the interactive elements, with the physical trembling experienced as a secondary side effect rather than a meaningful channel. This created confusion about what to touch, where to focus, and what counts as part of the experience.

Ambiguous signal causality: participants were not always sure what changed the signal, having difficulty differentiating whether the reaction was driven by wind, movement, or touch. This led participants to struggle to form a clear information gain of plant electrical signalling.

This was developed into two concepts:
Concept 1: Chair with bass shaker in the back area which trembles in response to plant's biosignal, shown in figure 32.
Concept 2: Table between person and tree, as if they are sitting at the table with the tree. The table top trembles based on the plant's biosignal, shown in figure 33.

Figure 32, Prototype of Question 1 Concept 1

Figure 33, Prototype of Question 1 Concept 2

Figure 34, Prototype of Question 2 Concept 1

Figure 35, Prototype of Question 2 Concept 2

Figure 36, Prototype of Question 2 Concept 3

10.3.2 Question 2: How can interaction with the plant be made clear (where to touch and how)?

The user tests of Question 1 defined that the core issue in this question was that participants did not consistently understand which branch or leaf to touch and what constituted a correct or meaningful interaction. Ideation therefore focused on physical guidance and invitation: how to direct the body and hand toward the intended interaction point, while maintaining a plant-centred experience and avoiding artefacts that would become the new focal object. Thus, Question two was split into two questions:

- How can it be intuitive that the branches are a part of the interaction?
- How can it be intuitive how to interact with the branch to change the signal?

This was turned into three concepts:
Concept 1: The same setup as Concept 2 of Question 1, but with a more sensitive reaction to touch and proximity. This concept is shown in figure 34.
Concept 2: The same setup as concept 1, but preluded by a poem that tells about haptic communication and the reactiveness between humans and plants, sensitising the guest to touch the plant and understand the input-output connection. This concept is shown in figure 35.
Concept 3: Same setup as concept 1, with an additional stand that physically frames the connected leaf's branch. This guides the user to touch the correct leaf and invites engagement. This concept is shown in figure 36.

10.3.3 Question 3: How can I use the bio-signals and its expression to calm people before their interaction with the tree?

The user tests of Question 1 and 2 proved that the preparing phase needed development to more effectively foster a calm and slow-paced state, stimulate guests to enter the installation and walk towards and engage in the interaction phase. These findings became design requirements, see Chapter 9.4.3. With this knowledge, Question three was specified into the following sub-questions:

- How can the guest actively focus on and engage in their senses to get to know the specific features of the tree?
- How can the first phase downshift arousal and pace so people are stimulated to feel comfortable, receptive and curious as they enter the second phase?
- How can the preparing phase engage people to enter the installation and go to the interaction phase?

10.4 Measurements and Analysis

In the concept refinement tests, evaluation combined quantitative and qualitative measures to capture both interaction clarity and the underlying reasons why an intervention supported or hindered plant-centred interaction.

10.4.1 Question 1 analysis

The first refinement test used a qualitative analysis focused on two aspects: the extent to which the installation reduced Plant Awareness Disparity, measured through an adapted Plant Awareness Disparity-Index (PAD-I) (Parsley et al., 2022), and perceived intuitiveness and clarity of interaction cues. To assess the interaction cues, a questionnaire approach was used combining principles from semantic differential measurement (Osgood et al.) and perceived affordance/intuitiveness perspectives informed by Norman (1999)'s literature on affordances and interpretation. In addition, a visual analysis following Hartmann et al. (2006) was performed, focusing on:

- Problem indicators (hesitation, confusion, disengagement)
- Major user actions (recurring behaviours and workarounds)
- Points that hinder or support causing bio-signal change and interpreting bio-signals as plant responsiveness expressed through sound and trembling
  This approach enabled both comparative scoring and the evaluation of why a prototype succeeded or failed.

10.4.2 Question 2 analysis

For the second refinement test, evaluation assessed usability cue clarity. A semi-structured interview explored what elements provided clear invitations and what created confusion, and an adapted QUESI survey measured perceived intuitiveness and ease-of-use. Again, visual analysis was used to identify remaining problem indicators and opportunities for improvement.

10.4.3 Design Implementations

Based on the thematic and visual analysis of the user tests for question 1 and 2, the following design implementations were formulated to address specific usability hurdles and cognitive barriers observed during testing:

Observation	Design Implementation
Participants frequently misinterpreted visible wiring and patches as buttons, pressing the hardware rather than touching the plant.	Sensing patches shall be visually unobtrusive and blend into the tree's material palette to prevent them from becoming a competing focal object.
Users in the test for questions 1 and 2 were often unsure where to touch, leading to hesitation or random interaction with non-connected leaves and branches	The interaction shall physically frame and direct attention to a specific leaf or leaf cluster as the primary point of engagement.
Passers-by in the test for question 2 expressed social discomfort to engage in the interaction (e.g. "Am I allowed to sit here?") due to the lack of an artistic framing of the installation, causing them to avoid the installation entirely.	The first phase shall include an explicit but gentle invitation (e.g., specific signage or spatial cues) that signals permission to enter and sit without social pressure.
Participants felt socially exposed due to the open area in which the interaction phase is placed, which prevented the relaxation required for the Preparing Phase.	The interaction phase must limit direct sightlines from high-traffic routes and create an off path pull to attract passers-by from the main walking path into the preparing zone and guides them along a route to the chair.
In early concept testing, participants associated the electrode patches with heart-rate monitors, intuitively linking the signal to a signal of the plant. However, during the user test for question 2, this association proved inconsistent. Participants frequently failed to understand that the plant was reacting and changing the input, often interpreting the change as attributed to touching the patches which changed the signal.	The interaction shall physically frame and direct attention to a specific leaf or leaf cluster as the primary point of engagement.

10.5 Question 3 Selection

Three concepts were developed to solve question 3, see figures 37 to 39. All concepts were scored on how well they achieve the design requirements for the first phase, Appendix F.

For this, three concepts were developed:

Concept 1: Fabric arches with questions about the senses, stimulating people to focus on their sensory perception of the tree.

Concept 2: A wood chip path, causing people to slow pace due to the change in texture, with speakers playing a soundscape that hints at different senses (eg. wind for scent and movement, sounds of leaves crackling and moving in the wind for touch)

Concept 3: Wooden 'stepping stones' guiding guests towards the chair. Every other 'stepping stone' has a question on it, guiding people to focus on their senses.

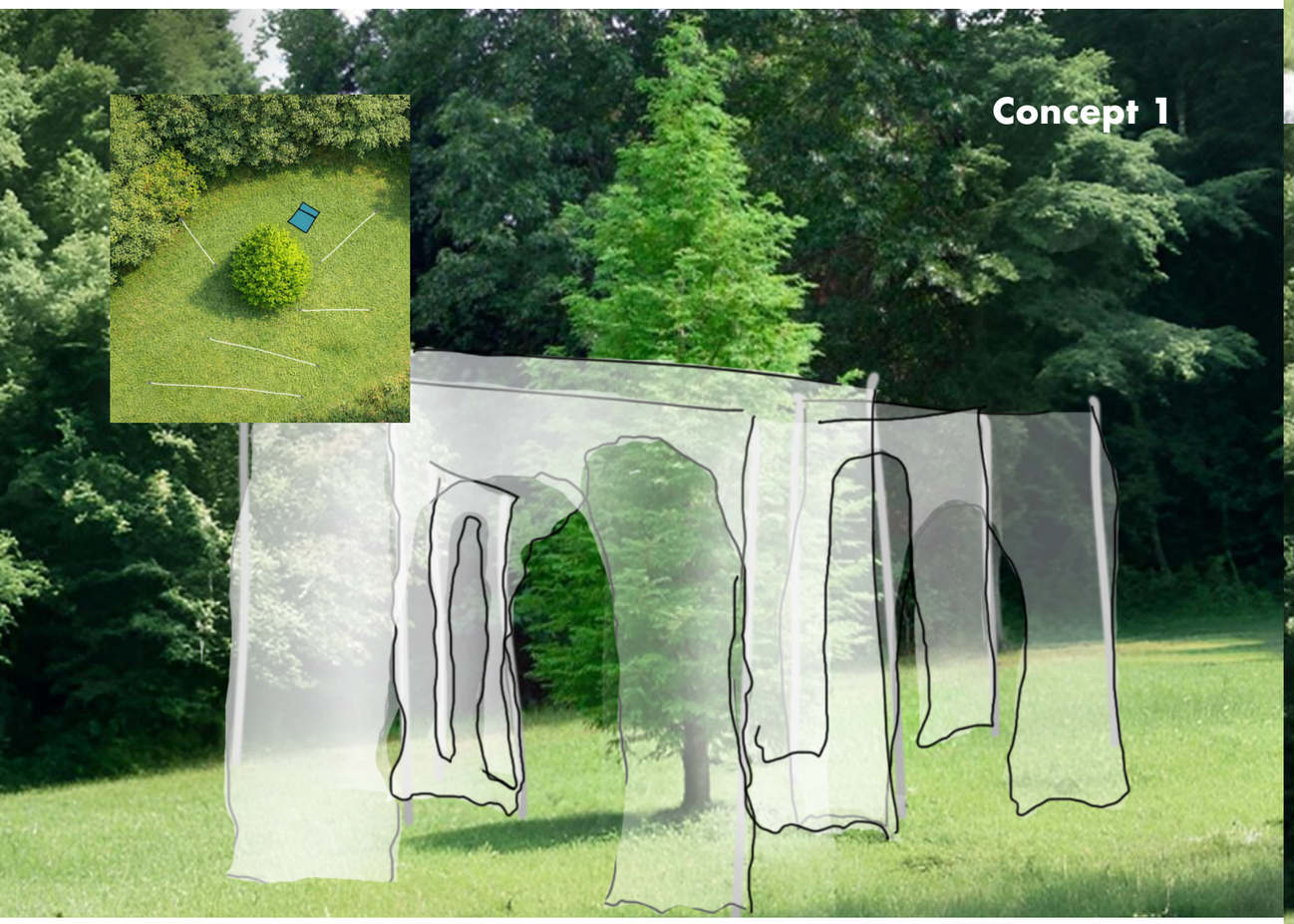


Figure 37, Visual of Question 3 Concept 1

Figure 38, Visual of Question 3 Concept 2

Figure 39, Visual of Question 3 Concept 3

I scored the concepts on all design requirements to evaluate which best achieved calmness in the first phase. Concept 1 was selected, as it scored highest among the design requirements because it effectively pulls people off the path and frames the tree through its unique visual qualities, uncommonly found in parks. Furthermore, the privacy created by the fabric best enhances the feeling of social safety that strengthens guest's feeling of comfort and slow pace in the preparing and interaction phases.

10.6 Improvements Made

Through this iterative process, final design improvements were made to the installation. The interaction of the installation can be found in figure 41.

10.6.1 Setup

The setup of the interaction of the installation, illustrated in figure 40, consists of electrode patches that measure the bio-signal of the plant's systemic electrical signalling, connected to a laptop that converts these signals into an audio and haptic output. The audio is played by a speaker while the haptics tremble the chair's seat through a bass shaker.

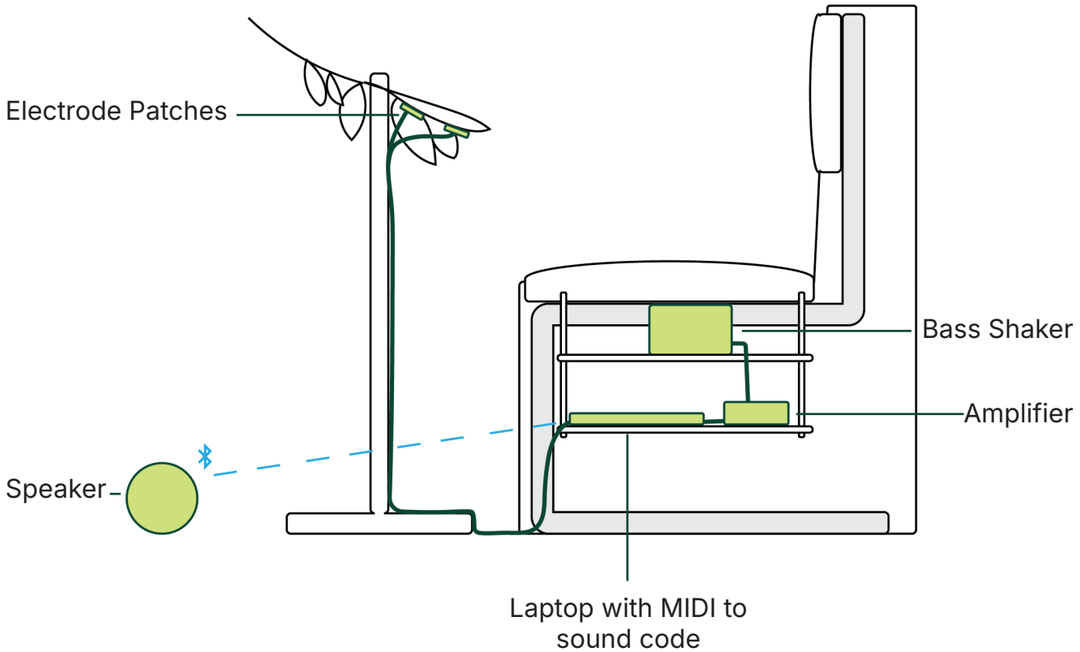


Figure 40, Setup of interaction phase design

Figure 41 shows the final installation interaction.

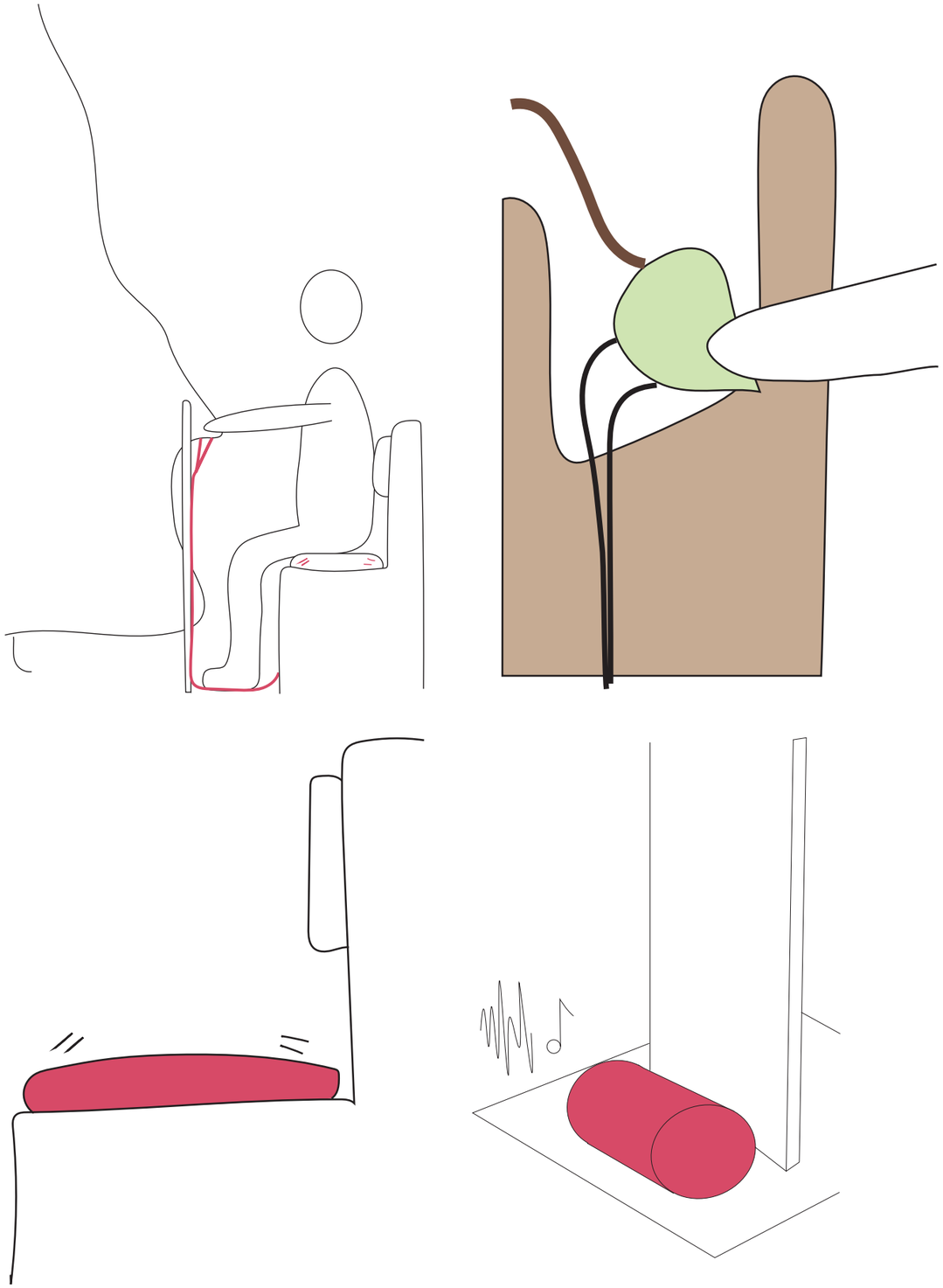


Figure 41, Interaction visual of interaction phase design

10.6.2 Interaction form: Haptic-Acoustic output

Problem: During testing, interfaces requiring the hand to touch to feel the output competed with physically interacting with the plant. In addition, interfaces between the person and the plant competed with the plant for the user's attention. Finally, users struggled to perceive the changes in the bio-signal through haptics alone.

Improvement: The final design is a chair with a synchronized audio-haptic system. Audio is delivered via external speakers to ensure all guests can experience the plant's liveliness, even if the chair is occupied or people are not able to sit on the chair. The hands-free form of the chair physically relaxes the user and allows the haptic vibrations to be felt through the entire body, creating an engulfing sensation of the plant's signals.

10.6.3 Affective Audio Design

Problem: The Problem: The standard biosignal-to-audio software of the Playtronica Biotron (sensor for systemic electrical signalling) often produces high-pitched, synthetic tones that users associated with plant stress, triggering negative affective responses.

Improvement: A custom Logic Pro programme was developed to translate MIDI signals of electrical conductance into stretched, flowing base tones for baseline water flow and bubble popping sounds for proximity and touch.

10.6.4 Camouflaged sensing and physical framing

Problem Identified: During testing, the visible sensing patches were interpreted by users as buttons, causing them to press the technology rather than touch the plant. Furthermore, without clear framing, users were unsure which branch to interact with.

Improvement: The sensing patches were redesigned using hard foam and a covering material to visually blend into the leaf's material palette and remove interaction cues, signaling they are not interaction points. Simultaneously, a specific interaction branch is placed on a wide, minimalist stand. This provides a physical frame that invites touch while keeping the leaf free-moving and uncaged. These improvements are visualised in figure 42.

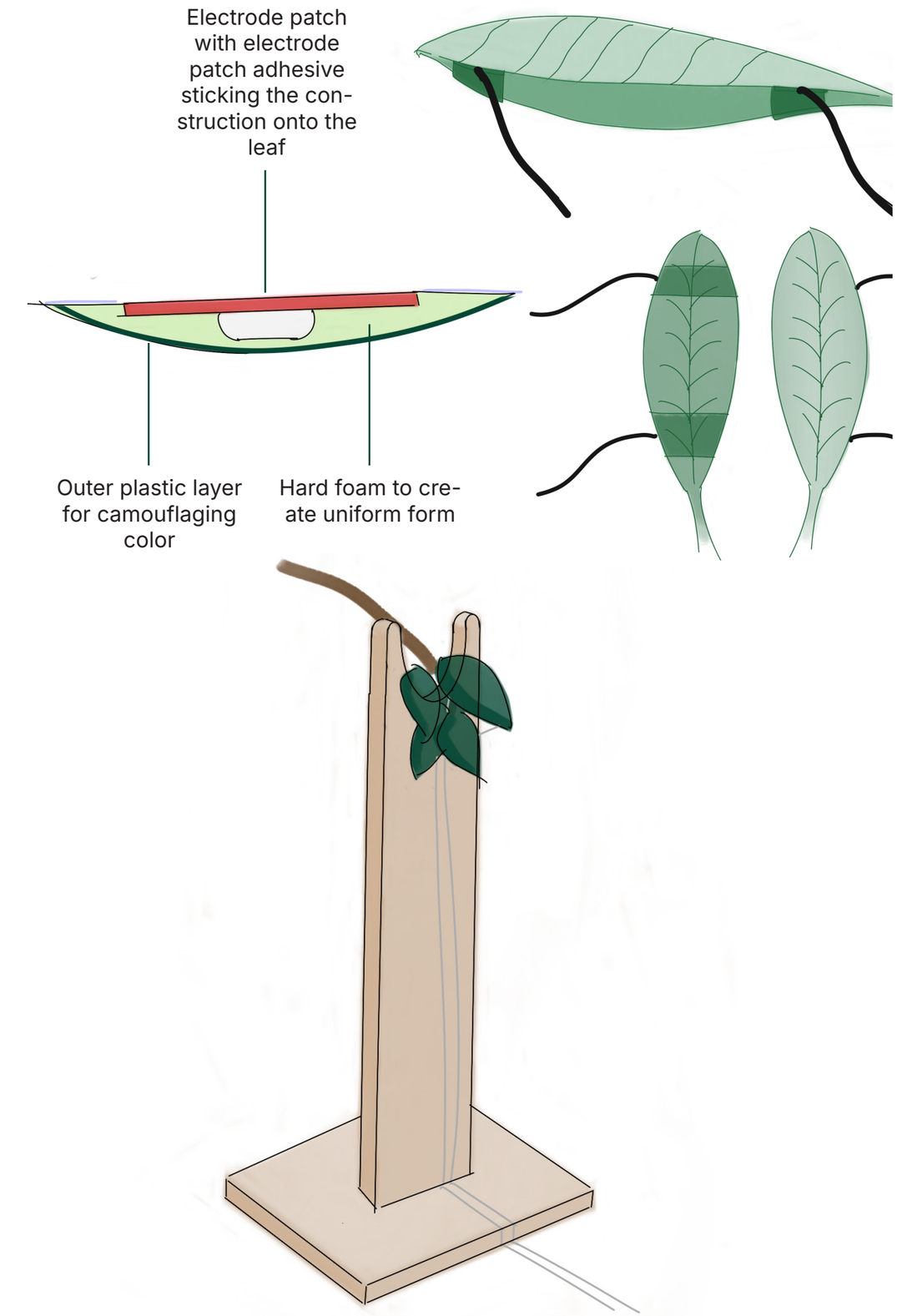


Figure 42, Improvements for interaction with plant

10.6.5 Sensitising First Phase

Problem: In a public park setting, the open nature of the interaction phase and proximity of the installation by the tree caused social discomfort, or view it as a closed experiment, making passers-by hesitant to enter or engage. Users felt exposed and rushed, preventing the slowing down required to notice nature.

Improvement: A series of modular fabric arches was created to frame the tree and create a dedicated path. These arches act as an off-path pull and provide privacy. Text on the arches guides users to focus on specific senses (scent, ground texture) before they reach the interaction, stimulating slowing down. Figures 43 to 45 illustrate this concept.

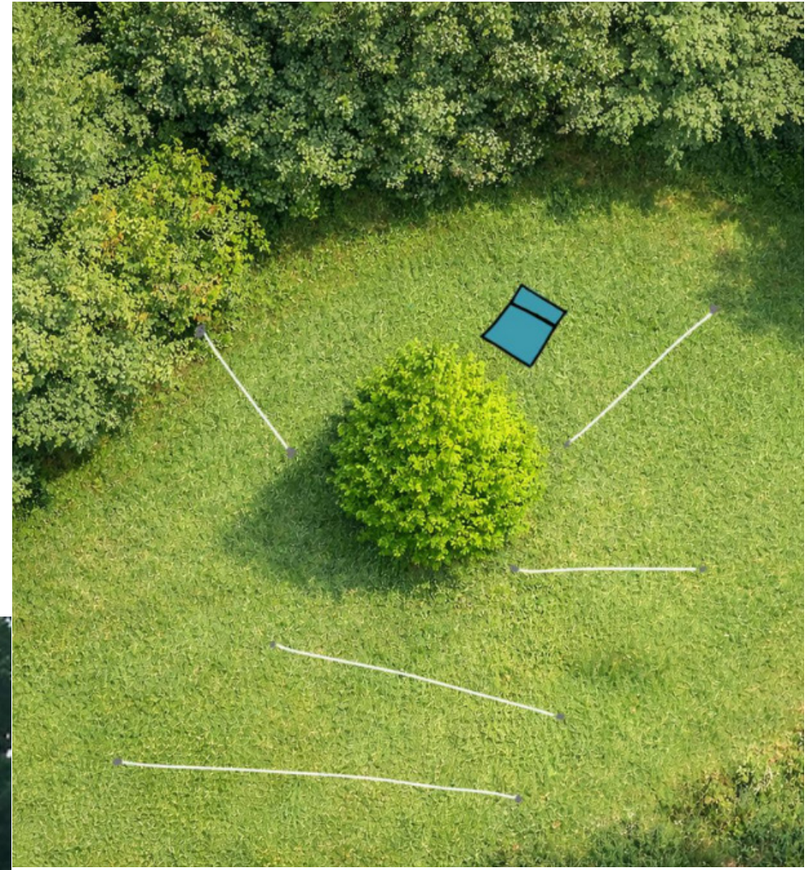


Figure 44, Spatial mapping of preparing phase concept

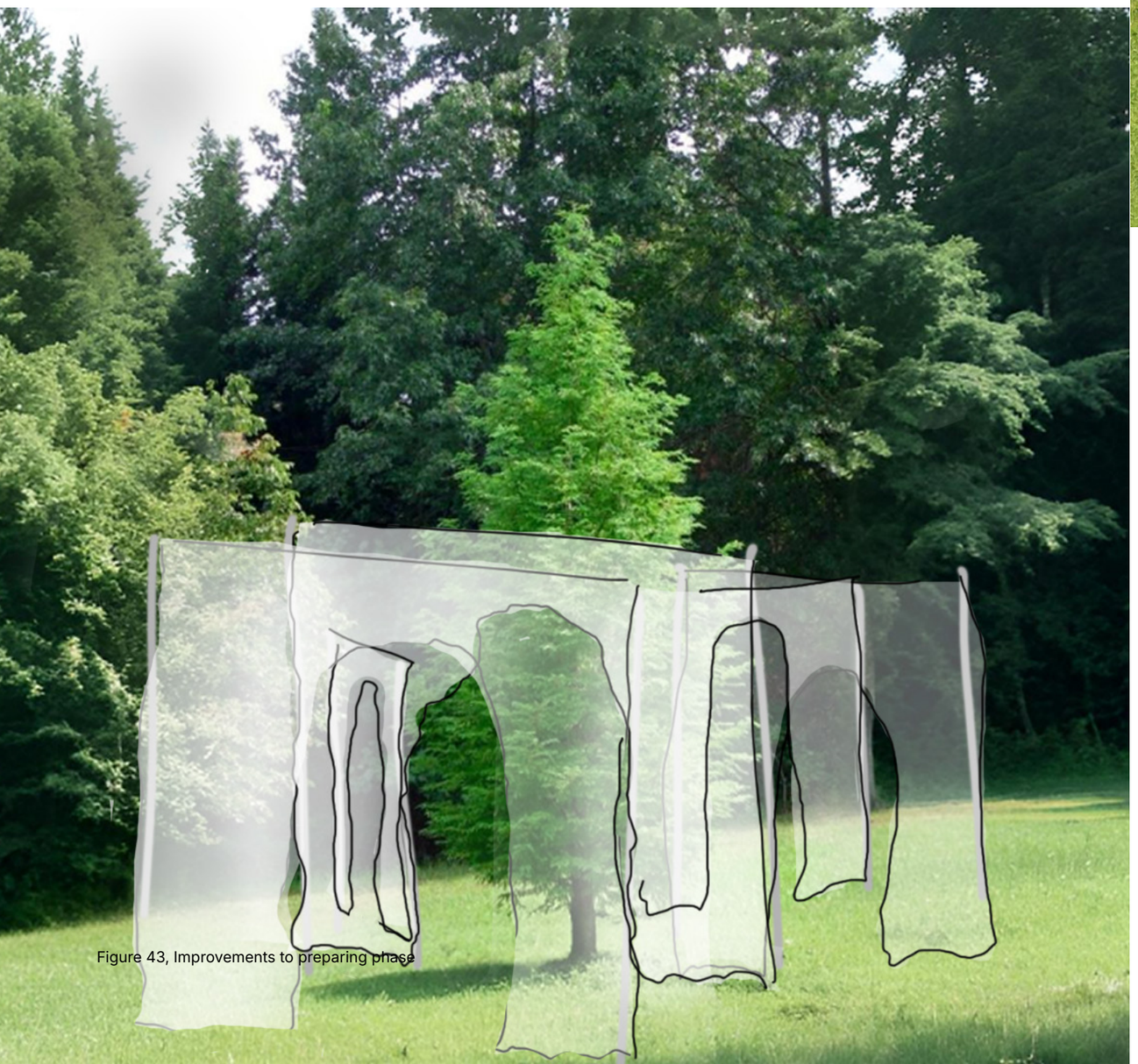


Figure 43, Improvements to preparing phase

Figure 45, Inspirational image to illustrate design of preparing phase concept (Oele, n.d.)

10.6.6 Structural Design: Modularity and Safety

Problem: As the installation will be temporary, with the intention of being placed in different parks, the design for the preparing phase must be transportable and moduilar to fit varying park layouts and tree sizes.

Design Improvement: The design, shown in figure 46, is a modular, weighted fabric arch structure is adaptable, allowing the installation to fit different tree geometries and path widths by simply swapping the fabrics while retaining the core structure. The structure was selected guided by a civil engineer and stage builder based on structural integrity in outdoor conditions and transportability, enabling the installation to move to different parks. This concept allows the structure to withstand winds up to 7 on the beaufort scale, tested through simulations (see Appendix B), while keeping the appearance of the structure minimal nor requiring much weight to keep the structure stable.

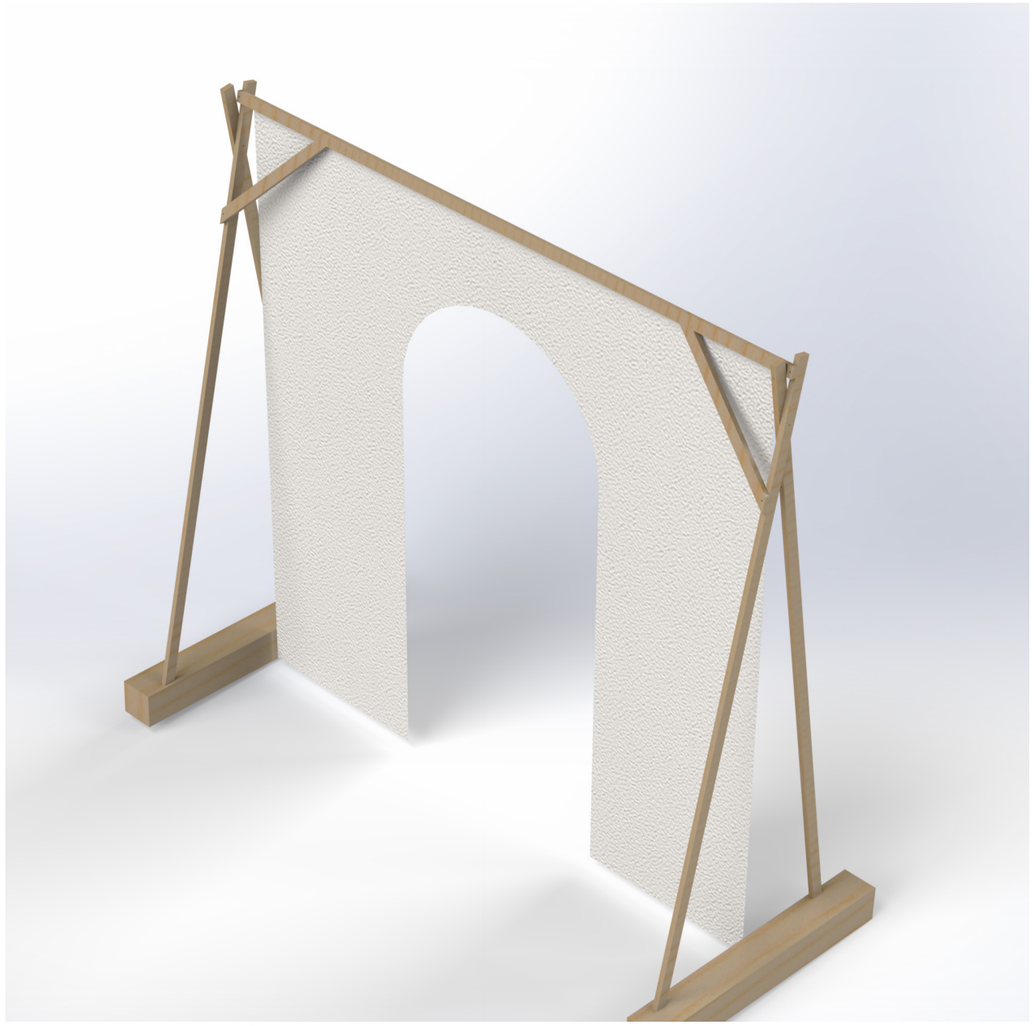


Figure 46, Structural design of preparing phase

10.7 Discussion

A key learning was that interaction legibility depends on context and the specific tree. In Chapter 8, wind-driven movement helped participants understand that the plant responds to its environment and that touch can plausibly change the output. In the refinement tests, the trees moved less, and participants had fewer environmental hints to interpret what they should do. This makes clear that the final experience cannot rely on environmental cues (like wind) to teach the interaction. Instead, the installation needs consistent, plant-specific guidance: where to touch, what kind of touch is appropriate, and how long to sustain it, without adding distracting objects.

The tests also confirmed that a small amount of explanation is necessary to stimulate information gain. In the user test of question 2, only one participant recognised the patches as measurement-like (associating it with a heart-rate patch), and 6/7 participants did not understand what was changing the sound/vibration. In the test for question 1 and the test of Chapter 8, in total 14 out fo 17 people had this association, allowing them to interpret the change in output as a reaction of the plant. When a short explanatory text was integrated into the poem concept of question 2, participants became noticably more engaged. They shifted from appreciating the effect as interesting to actively exploring the tree's responsiveness and linking changes in output to their touch. This indicates that the design needs an explanation to make this translation understandable, after which curiosity and exploration can take over.

10.7.1 Limitations

Several limitations shape how these outcomes should be interpreted. Participant numbers were small (n = 7–8 per test) and the Q2 group was relatively homogeneous (mostly university-educated, 21–25 years old). A larger and more diverse sample would likely reveal misconceptions, such as not all participants associating of the patches with the heart rate monitor, earlier and strengthen confidence in the conclusions. Learning effects were also present: once participants discovered how to influence the output through longer engagement causing them to explore more and touch the plant, they evaluated that prototype more positively, suggesting first-time clarity remains a central design constraint. Finally, early refinement could not fully include the intended preparing-phase journey due to practical constraints around electricity. This reduced the effect of the first phase and without downshifting arousal before interaction, participants were less sensitised for the intended plant-centred experience. Future iterations should therefore be tested fully in-context or preceded by a brief sensitising exercise that approximates the intended preparatory state.

CHAPTER 11. Final Design: Onder de Schors

We often overlook plants because they seem static and silent compared to animals, a bias known as Plant Awareness Disparity (PAD). This lack of attention and understanding makes it hard to feel empathy for them. To foster a true Connectedness with Nature, we need to bridge this gap. Onder de Schors addresses PAD by making the invisible visible. By translating hidden electrical signals into human-perceivable auditory and haptic feedback, the installation proves that plants are active and responsive. This shifts the tree from a passive background object into a living protagonist, capturing our attention and teaching us about its liveliness to build a lasting connection.

Onder de Schors is an interactive installation that allows you to physically feel and hear the internal life of a tree. Through a set of fabric arches, you are guided off the main path and invited to slow down and tune into your senses. This guides you towrds the interaction phase, where you can sit and physically interact with a living branch through touch. This contact changes the installation's feedback: the sound in the tree and haptic feedback in the chair change. This is done through bio-signal sensors on the leaves, audio speakers, and haptic bass shakers embedded in the seat.

By creating a direct, multimodal feedback loop where the plant visibly and tangibly responds to human presence, Onder de Schors facilitates the Information Gain and Attention required to address PAD to foster a sustained Connectedness with Nature (CWN).

11.1 Three Phased Journey

The three phases of the user journey are design as follows:

1. The Priming Zone (Phase 1): A series of modular fabric arches physically frames the tree and sensitises the user to slow down, directing attention to sensory details (scent, ground texture, sight) often filtered out by PAD.

2. The Interaction Zone (Phase 2): The core interface is a haptic-acoustic chair positioned before a specific branch. Non-invasive sensors on the leaves measure real-time changes in electrical potential caused by the tree’s water flow and reaction to external stimuli. These signals are processed into a synchronized soundscape and vibrational feedback loop.

3. The Reflection Zone (Phase 3): As the user exits, the final arch facilitates the integration of this experience, prompting a cognitive re-evaluation of their relationship with nature.

Figures 47 to 50 show the final prototype of each of these phases.

Phase 1

Figure 47, Image of the first phase of the final prototype

Phase 2 - Interaction

Figure 48, Image of a person interacting with the installation in the second phase of the final prototype

Phase 2 - close up

Figure 49, Close-up image of the second phase of the final prototype

Phase 3

Figure 50, Image of the third phase of the final prototype

11.2 Storyboard

The storyboard of figure 51 shows how the guest is guided through the three phases of the installation, fostering a stronger Connectedness with Nature by bringing their attention towards the tree and experientially learning about its behaviour.

The fabric arches pull people into the installation, bringing attention and anticipation towards the tree through its framing of the tree. Through the first phase, the guest is guided to focus on how their different senses perceive the tree and are invited to touch the to touch the plant. This leads to the second phase, in which they explore the reactiveness in the audible and tactile bio-signal output of the physical communication between the guest and the plant. The final arch provides the third phase, inviting guests to reflect on their experience and their Connectedness with Nature.

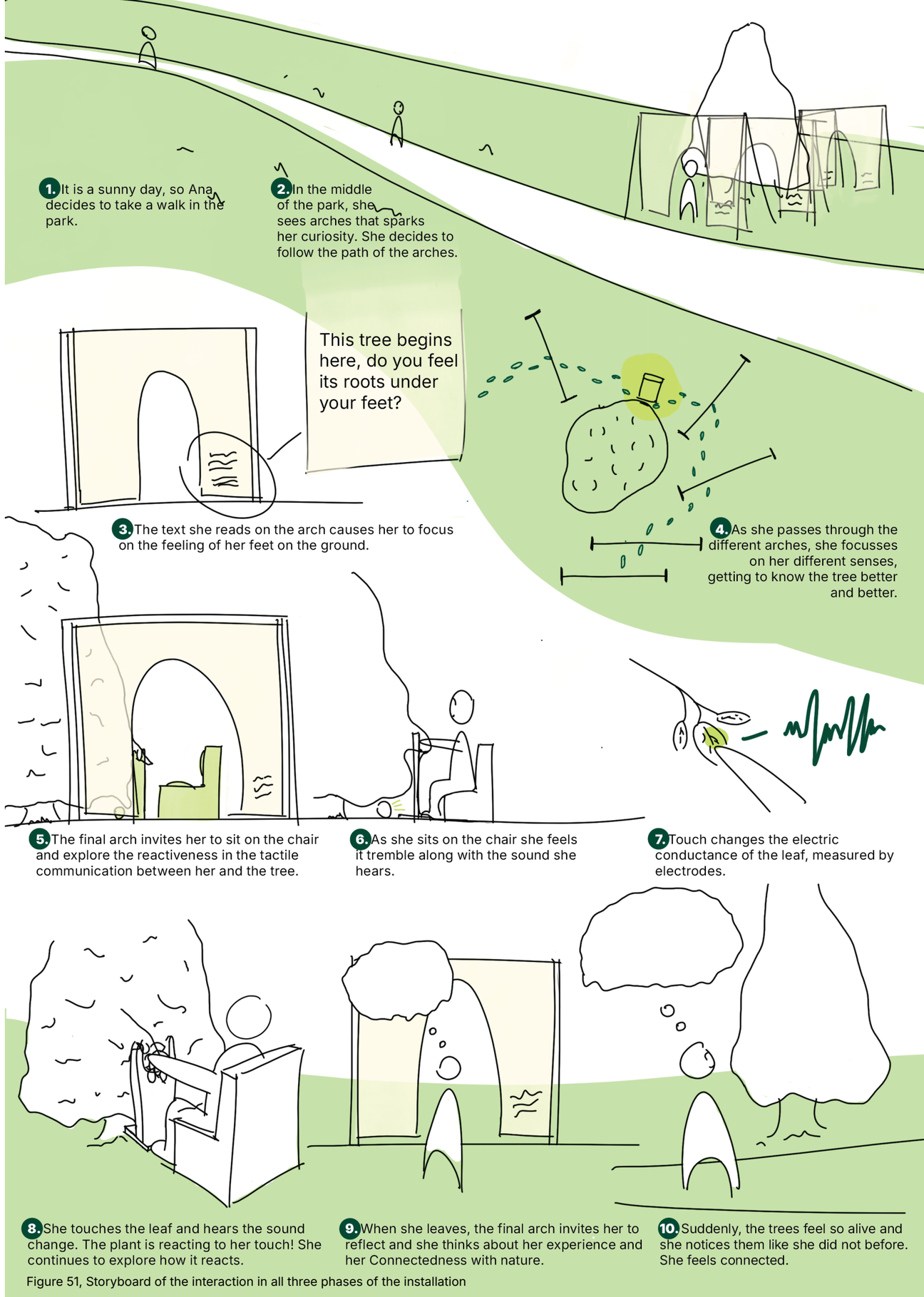


Figure 51, Storyboard of the interaction in all three phases of the installation

11.3 Spatial Mapping and Sensory Priming

To achieve the calm, receptive state defined as a requirement for the Preparing Phase, the spatial layout utilizes a sequence of five modular arches. These arches serve two functions: controlling the physical flow of the user and orchestrating a psychological transition from the public park mindset to a plant-centric focus. The layout and sensory narrative is represented in figures 52 to 55.

11.3.1 Arch Size Progression and Flow Control

The arrangement of the arches creates a directed walking flow that mitigates external distractions. By guiding the guest along a path hidden by the fabric, the design reduces the cognitive load of navigation and minimizes visual interference from other park visitors.

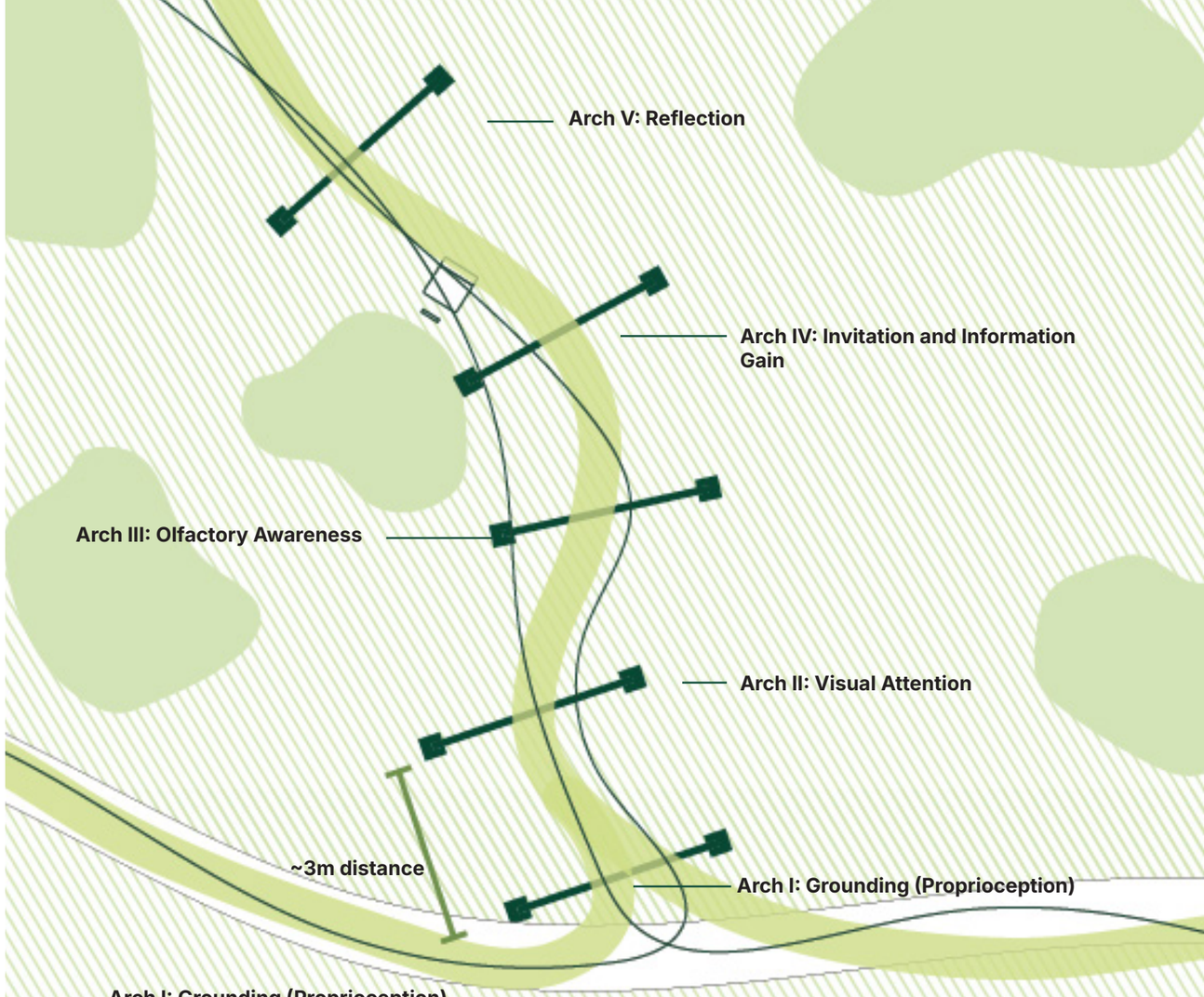
The scale of the arches is modulated to support this emotional journey:

- Immersion (Arch 1-2): The second arch is larger than the first. This volumetric expansion creates a feeling of stepping into the tree's world, framing the canopy and capturing Visual Attention.
- Intimacy (Arch 3-4): The fourth arch contracts in size. This physical narrowing fosters a sense of privacy and safety, which is essential for the user to feel comfortable enough to engage in the intimate interaction of the next phase.

The arches are placed at a minimum of 3 meters apart. This gives the guests the breathing space between each question to slow down, engage their senses, and reflect.

11.3.2 The Sensory Narrative

Each arch features text prompts designed to guide the guest to focus on their senses. Based on the co-creation outcomes of Chapter 4, these texts focus on specific sensory modalities, proprioception, sight, and scent, to slow the user's pace and ground them in the present moment.



Arch I: Grounding (Proprioception)
Text: "This tree begins here, can you feel its roots under your feet?"
Purpose: This immediately shifts attention from the visual horizon to the immediate physical sensation of walking, grounding the guest in the present location.

Arch II: Visual Attention
Text: "How does this tree move with its environment?"
Purpose: This addresses the Attention Deficit component of PAD by explicitly directing the gaze toward plant movement, countering the tendency to view plants as static background objects.

Arch III: Olfactory Awareness
Text: "How does the scent change from one breath to the next?"
Purpose: Scent was identified in the co-creation sessions as a key modality for inducing calmness. This prompt encourages deep breathing, which physiologically regulates arousal.

Arch IV: Invitation and Information Gain
Text: "Sit, relax, and touch the plant to form a connection. Can you notice how it reacts to your touch?"
Purpose: This serves a critical Information Gain function. By explicitly stating that the plant reacts, it frames the subsequent bio-feedback as a causal communication, not random noise.

Arch V: Reflection
Text: "How did you experience communicating with the plant? Did you feel more connected?"
Purpose: Positioned at the exit, this ensures the experience concludes with the Reflection Phase, aiding in the consolidation of the memory and the feeling of Connectedness with Nature.

Figure 52, Spatial mapping of the fabric arches and sensory guidance in the installation

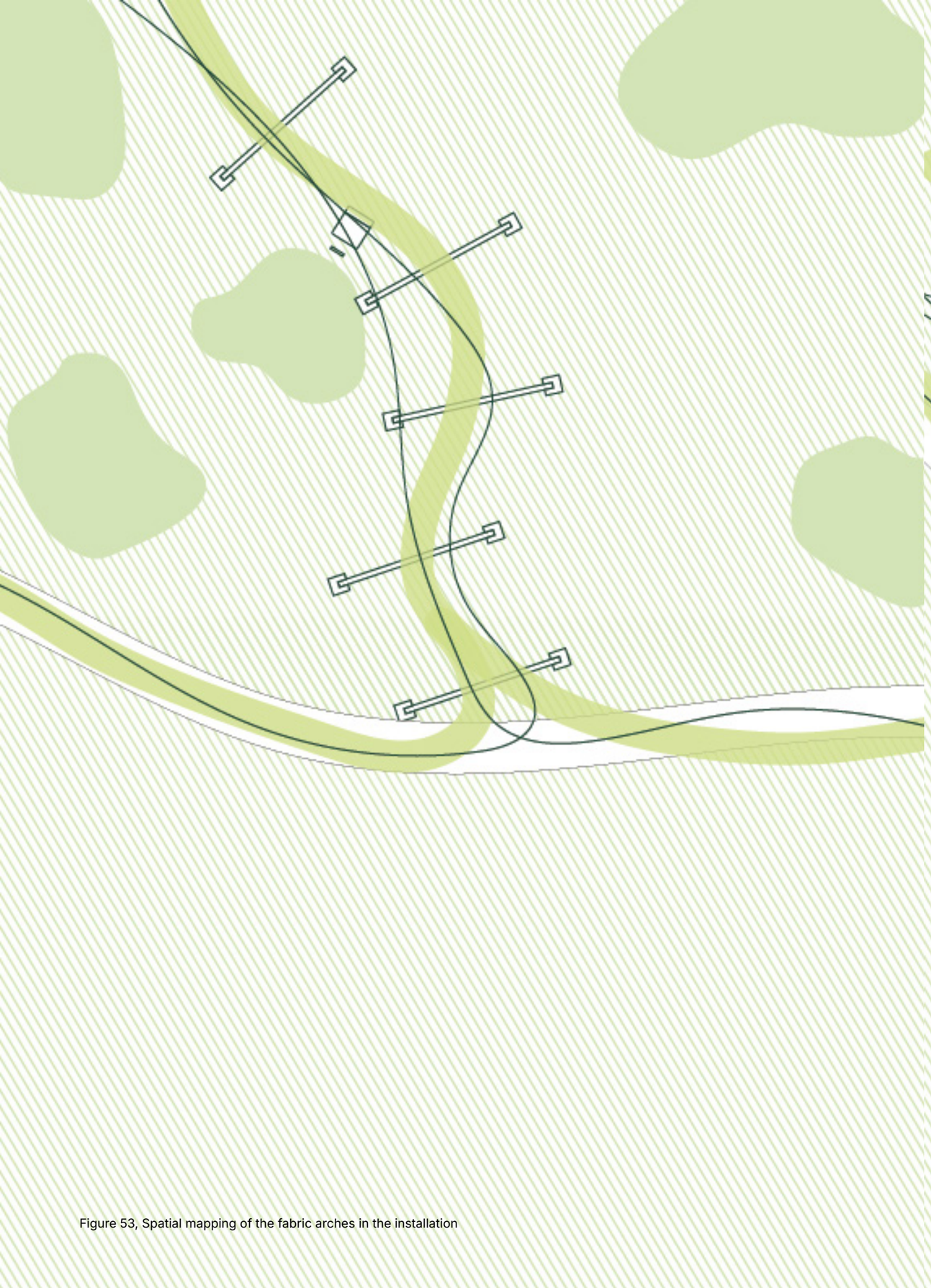


Figure 53, Spatial mapping of the fabric arches in the installation

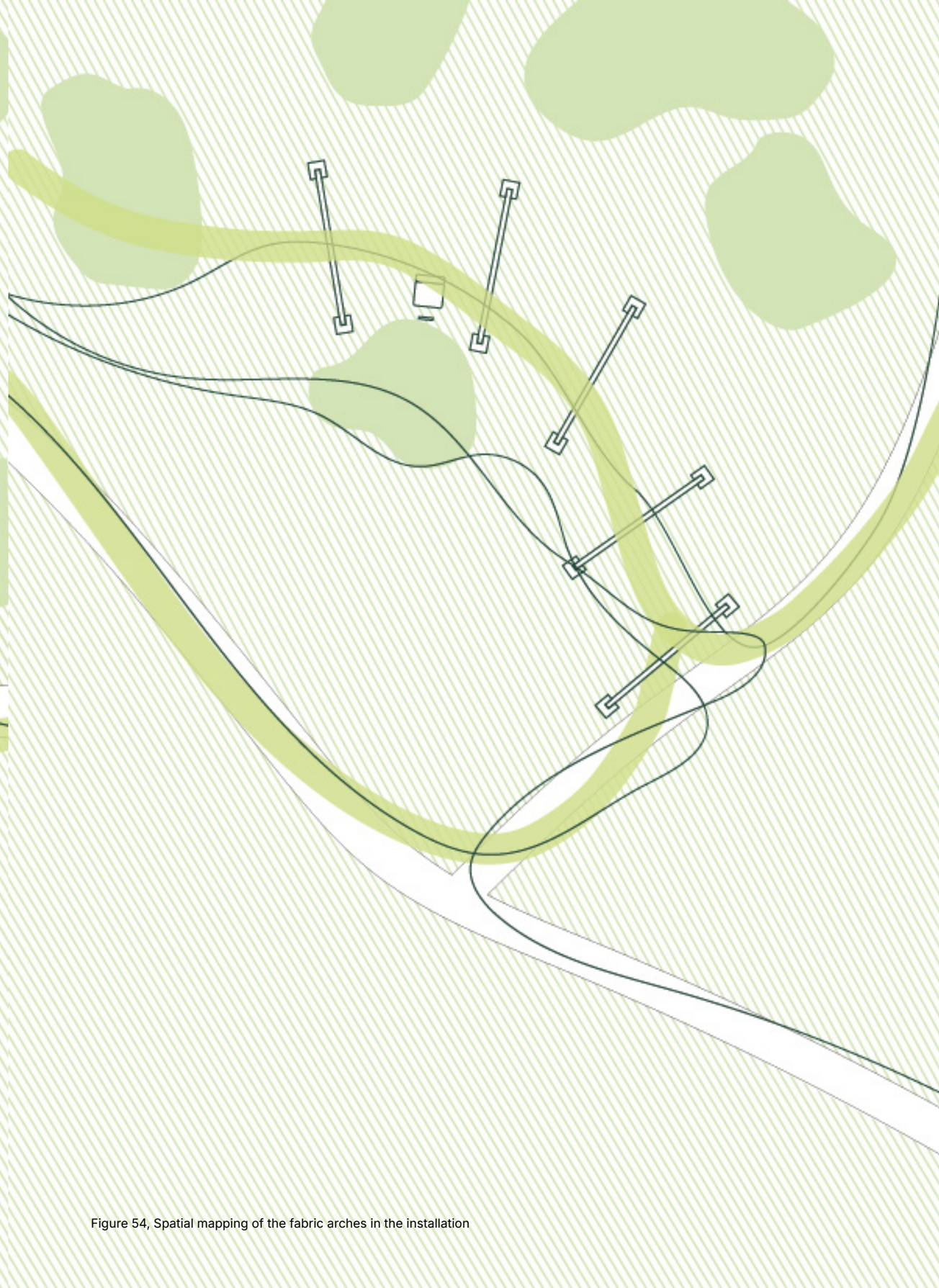


Figure 54, Spatial mapping of the fabric arches in the installation

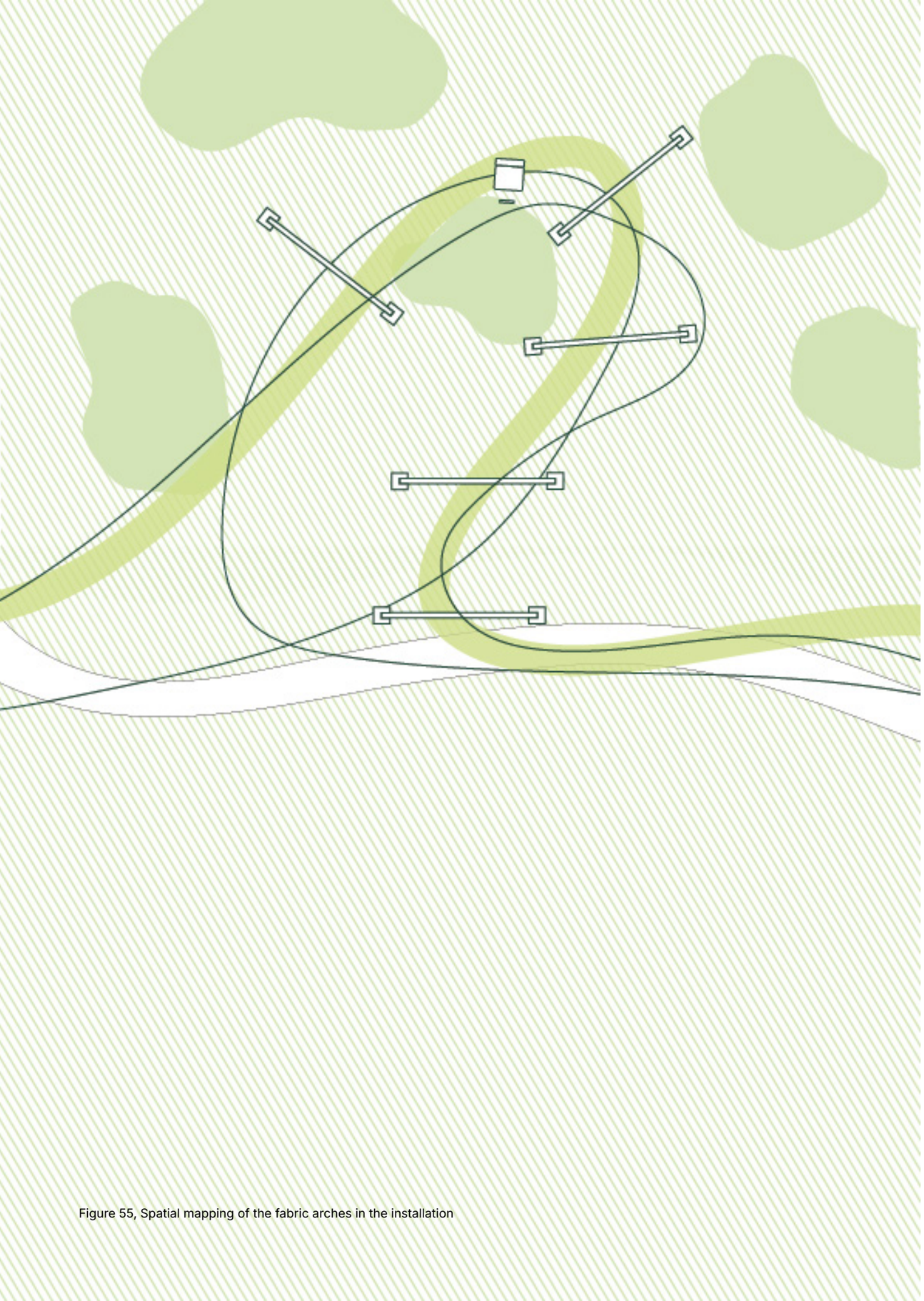


Figure 55, Spatial mapping of the fabric arches in the installation

11.4 Connected Electronics

The electronics configuration is a real-time bio-feedback loop, translating the plant's internal physiological state into human-perceivable modalities. This is done in three distinct stages, as represented in figure 56.

Stage one is the sensing (input) stage, in which non-invasive electrode patches measure the conductivity of the plant's leaf. In the processing (translation) stage, the data from the patches are transformed by a Playtronica Biotron processer into Midi data. This midi data is then processed in Logic pro, three sounds to the signals. Two sounds sonify the long wave signals, from the plant's water flow, and the short signals, from the plant's reaction to its environment. One other sound represent the reaction to environmental stimulation (touch, proximity, wind, rain) in a low bass tone, which is not audible in the speakers but do cause the bass shaker in the chair to vibrate. The final actuation (output) stage plays the sounds from a speaker placed by the trunk of the tree and a bass shaker in the chair.

The power supply for the Playtronica Biotron is the computer battery, the power supply for the bass shaker is a power station connected to the amplifier, and the speaker is powered by an internal battery.

11.5 Sonification and Haptic Translation of Plant Activity

A key aim of the sonofication was not only to make the plant signal perceivable, but to make different types of plant activity experientially meaningful to participants.
In the final design, the plant signal (received as MIDI through the Playtronica Biotron) was translated into three output tracks, each with a different role in the experience:

1. A long-wave ambient sound layer
2. A short-wave touch-reaction sound layer
3. A haptic vibration layer in the chair

Long-wave ambient layer: continuous plant presence
The first track sonifies the slower, long-wave plant signal of water flow as a continuous ambient soundscape. This layer was designed to communicate that the tree is active even when the participant is not touching it. Rather than sounding event-based or fragmented, it was shaped into a sustained, meditative auditory texture.

This contributes to a calm and slowed-down atmosphere and helps frame the tree as a continuously active organism, supporting the perception of plant liveliness.

Short-wave touch-reaction layer: legible and friendly interaction
The second track sonifies the faster, short-wave signal changes that occur in response to environmental stimulation (proximity, touch, wind, etc.). This layer was designed as a distinct touch- and proximity-reaction sound so that participants can clearly perceive when the plant signal changes in real time.

A soft bubble pop sound was used for this layer. This sound was chosen intentionally

because it is affectively supportive by making the response friendly to support engagement and a positive affect.

Haptic vibration layer: embodied plant reactivity
The third track translates touch-related signal changes into a low-frequency (inaudible) vibration in the chair through a bass shaker. This haptic layer allows participants to feel the plant's response in addition to hearing it. The vibration was included to make the interaction more embodied and intimate. It increases attentional focus, strengthens the sense that the plant is reacting in the moment, and reinforces the experience of the tree as a lively and responsive presence.

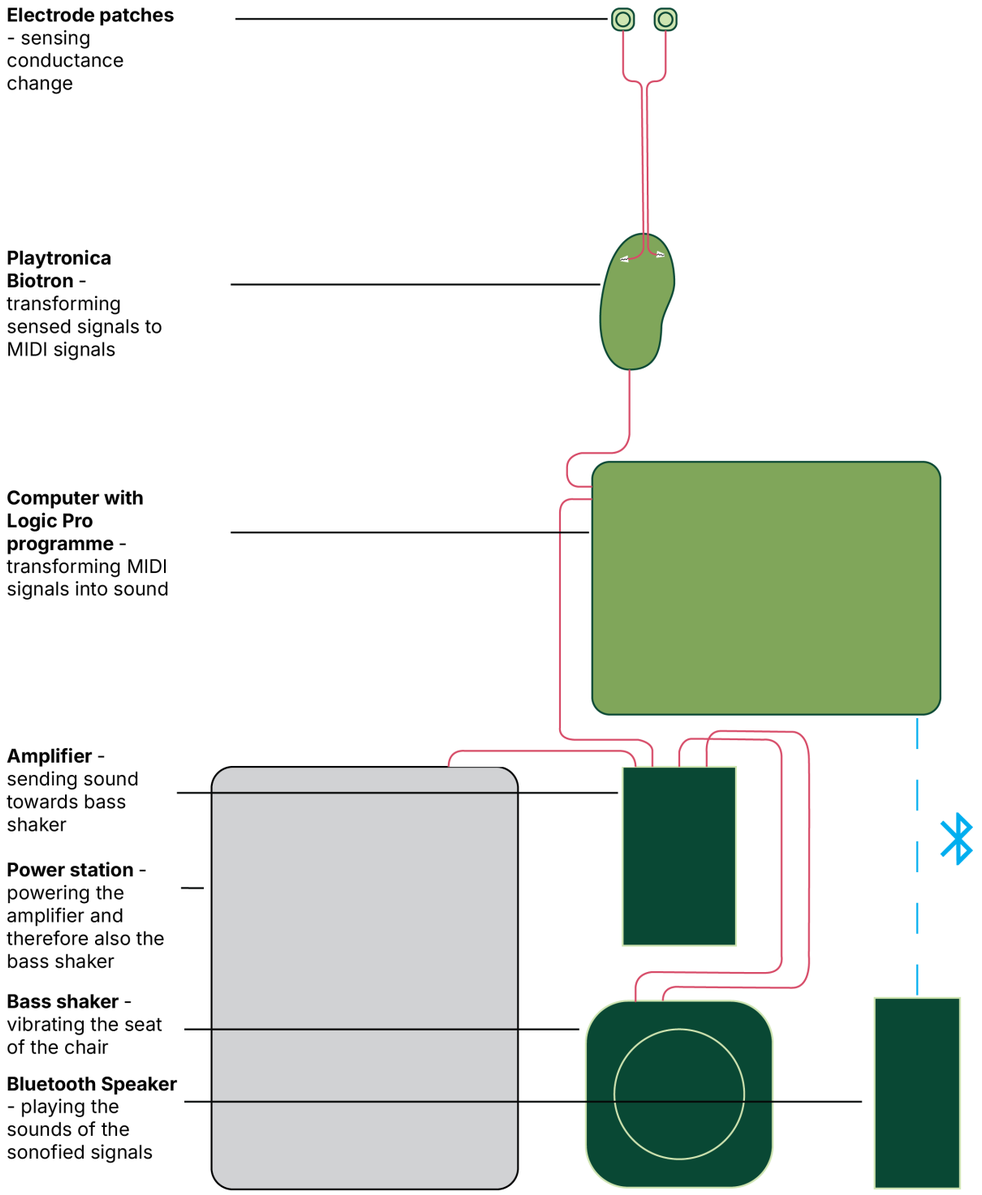


Figure 56, Technical diagram of the components for the interaction phase of the installation

11.6 Structure

To ensure the installation's viability in a public park context, the structural design of the fabric arches was developed through iterative prototyping and professional consultation.

11.6.1 Structural Logic and Assembly

The architecture utilizes a modular A-frame system constructed from spruce wood beams (22mm x 44mm), see figure 57. This geometry was chosen in collaboration with a professional stage builder to achieve a high strength-to-weight ratio while maintaining a minimal aesthetic. By using a traverse beam reinforced with two diagonal struts to create a triangular pressure distribution, the structure achieves high rigidity without the need for bulky external bracing. This minimalism is a functional requirement: it reduces visual clutter, thereby supporting the Calmness Mechanism and focusing user attention on the sensory cues of the Preparing Phase.

11.6.2 Technical Specifications and Materiality

Dimensions: Each arch stands 2600mm tall and 2700mm wide, providing a grand yet intimate portal for the user.

Materiality: Lightweight cotton was selected for the cladding. The semi-transparency of the cotton allows for a diffused, "open" feeling that prevents a sense of claustrophobia while still demarcating the transition into the interaction space.

Portability: The use of bolt-and-nut connections allows the structure to be fully collapsible. The traverse beam detaches, and the A-frame legs rotate into a single linear profile, resulting in three compact components per arch for efficient transportation.

A technical drawing of the structure can be found in Appendix G.

11.6.3 Simulation and Stability

To verify safety, a SolidWorks Simulation was conducted to test wind load resistance. The results confirmed that the structure remains stable in winds up to Beaufort Scale 7. Stability is further enhanced by anchoring the legs within wooden ballast boxes (1200mm x 150mm x 150mm) filled with sand, providing a low center of gravity and high resistance to tipping without damaging the park's ground surface. The simulation can be found in Appendix C.

Figure 57, Visuals of the structural design of the fabric arches of the installation

11.7 Viability

In a real-world deployment, viability of the installation is achieved by combining a robust outdoor setup with a clear maintenance model and a plant-safe protocol.
The current prototype already demonstrates core viability: it was successfully deployed in a public park, the biofeedback loop runs in real time, and the system works locally (without internet), which improves its reliability in outdoor contexts. The installation is also understandable in public space through the invitation and sound output, so both seated users and bystanders can engage. The durability of the system is enabled by the modular setup, enabling the swapping of all electronics when they require replacement.

For full-scale deployment, the current multi-battery setup would be replaced by one central LiFePO4 power station integrated into the seating, powering the processing device, speaker, and vibration setup. A practical target is a 1 kWh-class power station (approximately 1024 Wh) with pure sine wave AC output, such as the EcoFlow Delta 2, charged nightly by the host organisation. This size is suitable for a full park day, provides a stable, simple power strategy, and offers a long cycle life (around 3000 charge cycles to 80% capacity), which supports long term operation (EcoFlow DELTA 2 Portable Power Station | DELTA 2, n.d.).

In the full-scale version, viability is further achieved by implementing the electronics as a weather-protected, low-maintenance system with: sealed housings for both the electronics and speaker to protect it against rain and protected cable routing. For the audio output, a marine-grade passive speaker, such as the Fusion XS 6.5'' is used for long-term outdoor use.

To ensure operational viability, the installation will be hosted together with municipalities, park organisations, and/or nature conservation organisations. These partners would be responsible for daily operation: charging the power station, connecting/disconnecting the electronics, and performing basic checks. This makes the installation maintainable without requiring continuous researcher presence.

Plant wellbeing is an essential part of the sustainable viability of this project. In real deployment, the measured leaf would be switched every morning to reduce stress on the leaf, and the installation would remain connected to the same tree for a maximum of one week before moving to another tree. This reduces impact on a single plant and supports the project's aim of helping visitors connect with multiple trees over time.
To ensure safety and long term viability under various weather conditions, the structure of the fabric stands are placed in wooden bases filled with water to heighten its structural integrity. This enables the structure to stand in winds of up to 7 on the Beaufort scale.

Finally, the installation is viable in terms of long-term public value because it supports repeat encounters, which are central to building CWN over time in a park context. Rotating the installation to a different tree each week creates new experiences of plant reactivity and encourages visitors to return and compare, rather than treating the installation as a one-time novelty.

11.8 Cost

Table 1 gives an itemised and categorised cost overview of the installation. The estimated total cost of the installation is €5,242, including labour (~100 hours). The largest cost category is electronics (€2,617 of which €1,600 are for the power station and computer), followed by labour (€2,000 for 100 hours). The remaining costs are comparatively limited and consist mainly of the fabric arches (€355), transport (€150), and physical interaction parts (€120). This shows that the project is primarily driven by the cost of the sensing, processing, audio-haptic system, and power infrastructure, rather than the physical framing itself.

This total includes one-time material and labour costs for one installation unit. Recurring operational and maintenance costs are excluded.

Category	Component	Price
Fabric arches	Wooden beams	200
	Bolts and nuts	20
	Fabric	50
	Round wooden sticks	20
	Wooden sheets	40
	Text on fabric	25
Electronics	Playtronica Biotron	110
	Electrode patches	12
	Cover electrode patches	10
	Dayton Audio BST-1 bass shaker	90
	Fosi Audio M02 amplifier (for bass shaker)	80
	Fusion XS-F65CWB speaker	100
	Fosi BT20A Pro amplifier (for speaker)	85
	EcoFlow DELTA 2	600
	Computer	1000
	Weatherproof housings + cable glands + sealing materials	200
	Protected cabling / connectors / strain relief / mounting hardware	100
	Software license Logic Pro	230
Physical interaction parts	Seat	100
	Physical framing stand	20
Transport	Rent of trailer and gas	150
Labour	Labour (roughly 100 hours)	2000
Total		**5242**

Table 1, Itemised and categorised costs of the installation

CHAPTER 12. Evaluation and Results

12.1 Evaluation Setup

The final prototype was evaluated through a user test involving 19 participants experiencing the full installation in a park setting. The study followed a pre-test/post-test design to assess the installation's effectiveness against its objectives:

1. Core Objective: To increase Connectedness with Nature (CWN) by addressing Plant Awareness Disparity (PAD).
2. Secondary Objective: To decrease PAD specifically by increasing Attention for the plant and Information about the plant.
3. Design Mechanisms: To achieve this through a Calming First Phase (Preparing) and by demonstrating Liveliness (Interaction) in the Second Phase.

12.2 Methodology

Participants completed a survey measuring their baseline connection to nature and plant awareness before entering the installation. After experiencing the three phases of the installation, they completed a post-test survey (found in Appendix H) measuring their connection to the specific tree and their perceived changes in awareness.

Survey questions were taken from the:

- Plant Awareness Disparity (PAD) Scale: To measure attention, attitude, and interest toward the tree.
- Connectedness to Nature Scale (CNS): Adapted to measure connection to the specific tree.
- Restoration Outcome Scale (ROS): To measure calmness and restoration.

12.3 Results

12.3.1 Participants and Outliers

A total of 19 participants took part. One participant (P7) was excluded from the final analysis due to clear signs of survey fatigue and unreflective responses, resulting in an effective sample size of n = 18.

12.3.2 Outliers and incomplete responses

Participant 7 was excluded from the quantitative analysis because the questionnaire was not completed reliably (rushed responses without reflection). The effective sample for the pre–post analyses was therefore n = 18.

For several post-test mechanism questions, such as "How much did information gain help increase your Connectedness with Nature?", the number of valid responses was lower (n = 14–17) due to incomplete item responses. These varying sample sizes are reported where relevant.

12.3.3 Primary objective: Increasing Connectedness with

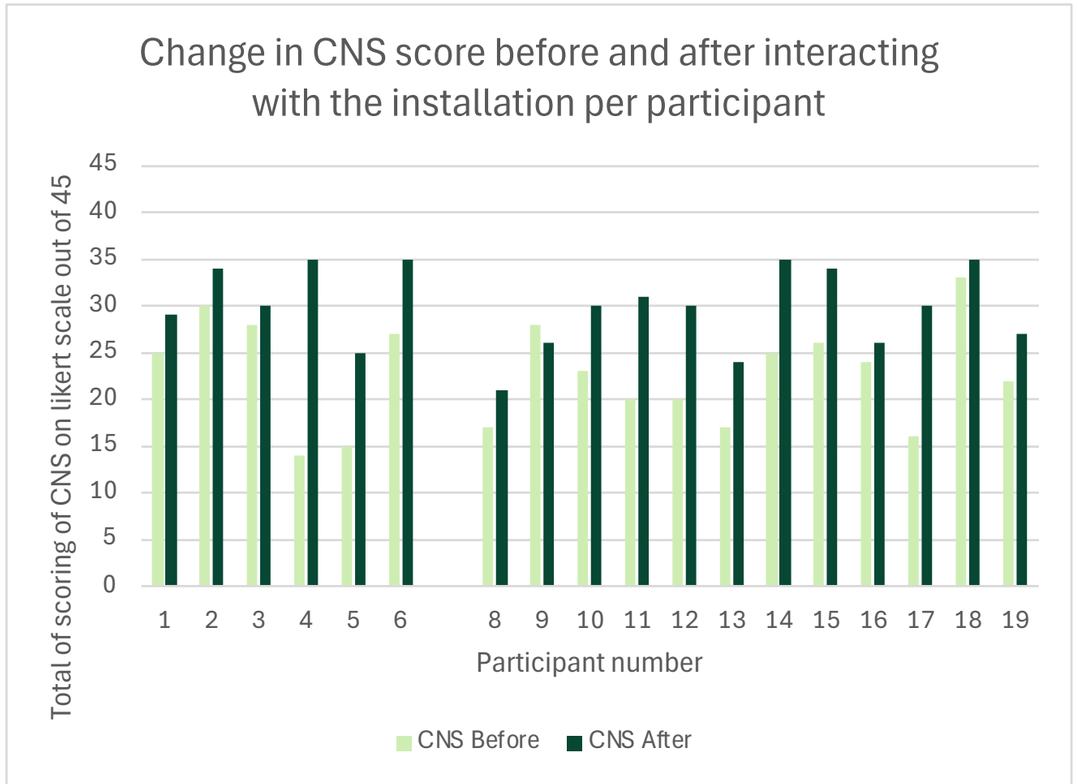


Figure 58, Change in CNS score before and after interacting with the installation per participant

Nature

The primary objective of the installation was to foster a stronger Connectedness with Nature (CWN). A paired-samples t-test showed a significant increase in CWN after the experience. Mean CWN increased from 4.56 before the installation (SD = 1.10) to 5.97 after the installation (SD = 0.86), $t(17) = 5.65$, $p < .001$. Figure 58 shows the change per participant.

This indicates that, overall, the installation successfully strengthened participants' felt connection with nature. However, while the general trend was positive, a closer analysis reveals a distinction based on baseline connectedness. 12 out of 18 participants (67%) experienced a statistically significant transformation, P3, P9, P14, P16, P18 and P19 had did not have a significant change. Participants with lower baseline scores showed the most dramatic growth, whereas 6 participants with high initial scores had a lower increase that was not deemend significant and 2 (P7 and P9) had a decrease.

Qualitative interviews indicated this could be caused by experienced a ceiling effect, as many of the participants who did not have a significant increase described having a high initial CWN (3 was a biologist and 16 was a researcher in ecology), describing the experience as an affirmation of their existing bond rather than the formation of a new connection.

12.3.4 Secondary objective: Reducing Plant Awareness Disparity

The secondary objective was to reduce Plant Awareness Disparity (PAD) by addressing Attention and Memory Deficit and Information Deficit. A paired-samples t-test showed a significant improvement in PAD scores after the installation. Mean PAD increased from 5.01 before (SD = 1.15) to 5.95 after (SD = 0.78), $t(17) = 5.69$, $p < .001$. Figure 59 shows the change in PAD score per participant.

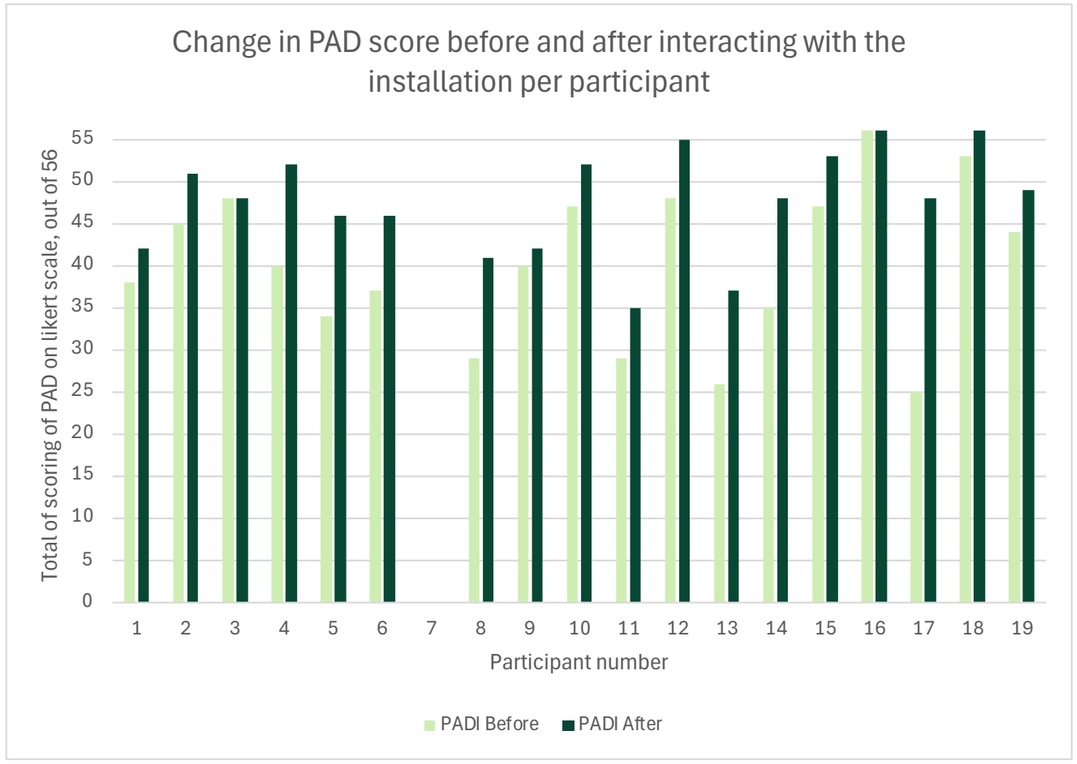


Figure 59, Change in CNS score before and after interacting with the installation per participant

This indicates that participants became significantly more aware of plants after the experience.

As with CWN, the individual patterns varied. 12 participants showed significant improvement, while 7 did not have a significant change. In some cases, this also appears related to high baseline scores (ceiling effects). In other cases, participants improved more strongly on one PAD-related mechanism such as attention or affective attitude than on another.

Qualitative topical analysis

Therefore, a topical analysis of the qualitative data was conducted. In the topical analysis 2 patterns were found:

- 10 participants mentioned feeling a strengthened CWN from interacting with the plant which enhanced their information about the behaviour and liveliness of the plant. Out of these participants, 5 specifically mentioned their increased awareness of the liveliness of the plant as attributing to their CWN.
- The other 8 participants attributed their CWN to the sensory attention gained in the preparing phase. Out of these 8 participants, 5 mentioned an increase in calmness having a positive influence on their CWN, but at a lower level than the attention gained. Furthermore, 5 of these 8 participants also attributed CWN to the reflection

stimulated by the questions and their changing awareness on their senses. Participants therefore did not all reach connection through the same mechanism combination. Instead, the installation functioned as a mechanism ecosystem with at least two valid pathways toward stronger CWN:

- Attentional pathway (calmness + attention)
- Informational interest pathway (liveliness + experiential information/curiosity)

These two pathways may cause participants to note a significant change in one aspect of PAD but less in another aspect of PAD. Comparing the results of the participants that did not have a significant increase shows an alignment with this pattern, where one pathway of PAD reduction (information gain or attention increase) had an increase while the other remained relatively the same, see figures 61 to 63. Participant 16 had no change, but had an initial score of 7/7, confirming the ceiling effect theory.

12.3.5 Validating the link: CWN increase due to PAD reduction

To test the central project hypothesis that reducing PAD is associated with stronger connectedness, a Pearson correlation was calculated between PAD change scores and CWN change scores. The analysis showed a significant positive relationship, $r = 0.68$, $p = 0.002$ ($n = 18$).

This means that participants who showed a larger reduction in PAD also tended to show a larger increase in CWN. This is statistically consistent with the project's core thesis: reducing the Plant Awareness Disparity directly leads to a stronger feeling of connection.

This aligns with the qualitative data, in which participants described their CWN increase through the interaction with the plant and the subsequent information gain, while 10 attributed it to the questions focussing their attention on the plant in the preparing phase.This proves the correlation between PAD and CWN to be causal, while the significance of each aspect of PAD to vary amongst participants.

12.3.6 Mechanism outcomes in relation to the framework

Following the framework developed in Chapter 4, the results were analysed in terms of four mechanism clusters in the installation:

1. Attention
2. Information
3. Liveliness (affective mechanism in the interaction phase)
4. Calmness (state-setting mechanism in the preparing phase)

This analysis combines objective pre-post shifts in validated scales, post-test mechanism ratings, and correlations with PAD and CWN outcomes. This enabled an analysis of the achievement of the secondary and tertiary sub-design objective.

Attention as the strongest mechanism for reducing PAD

The PAD Attention subscale increased significantly, from 4.89 before (SD = 1.37) to 6.14 after (SD = 0.68), $t(17) = 4.76$, $p < .001$.

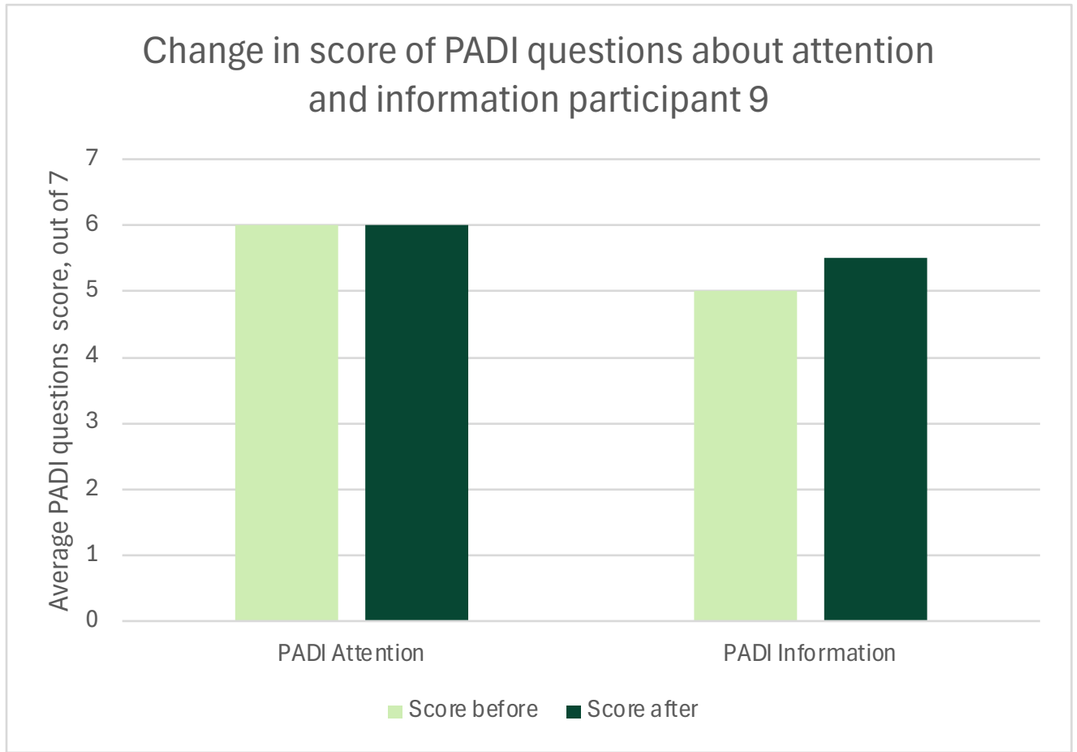


Figure 60, Change in score of PADI questions about attention and information participant 9

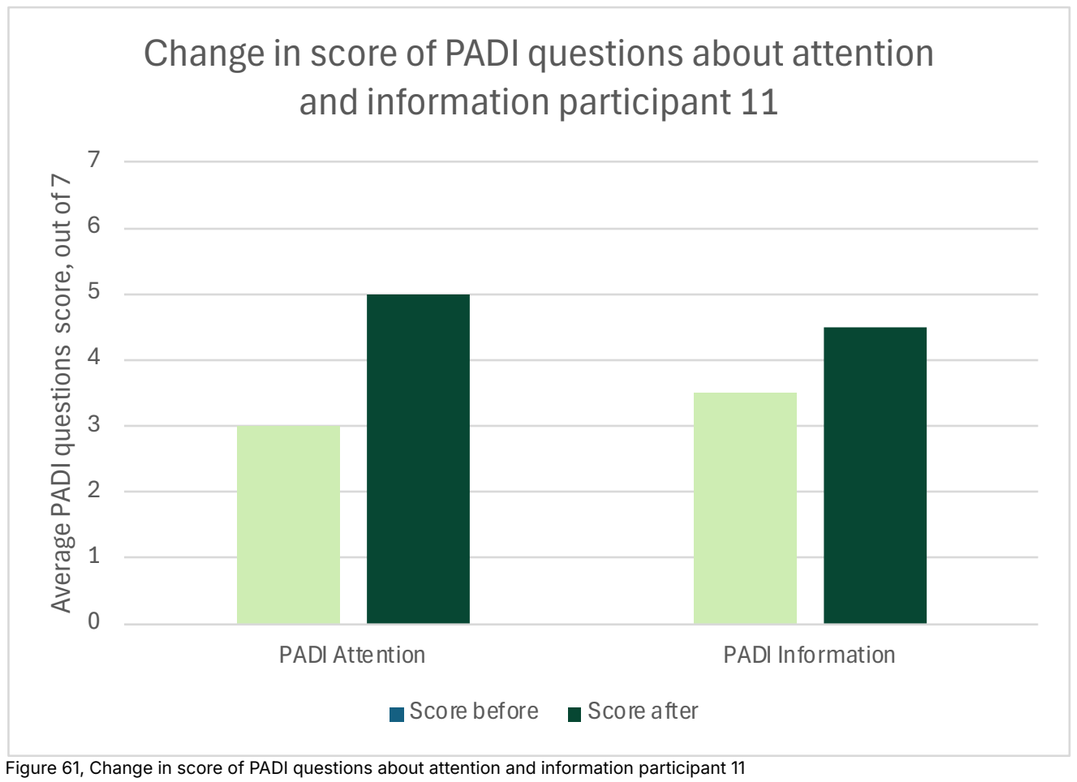


Figure 61, Change in score of PADI questions about attention and information participant 11

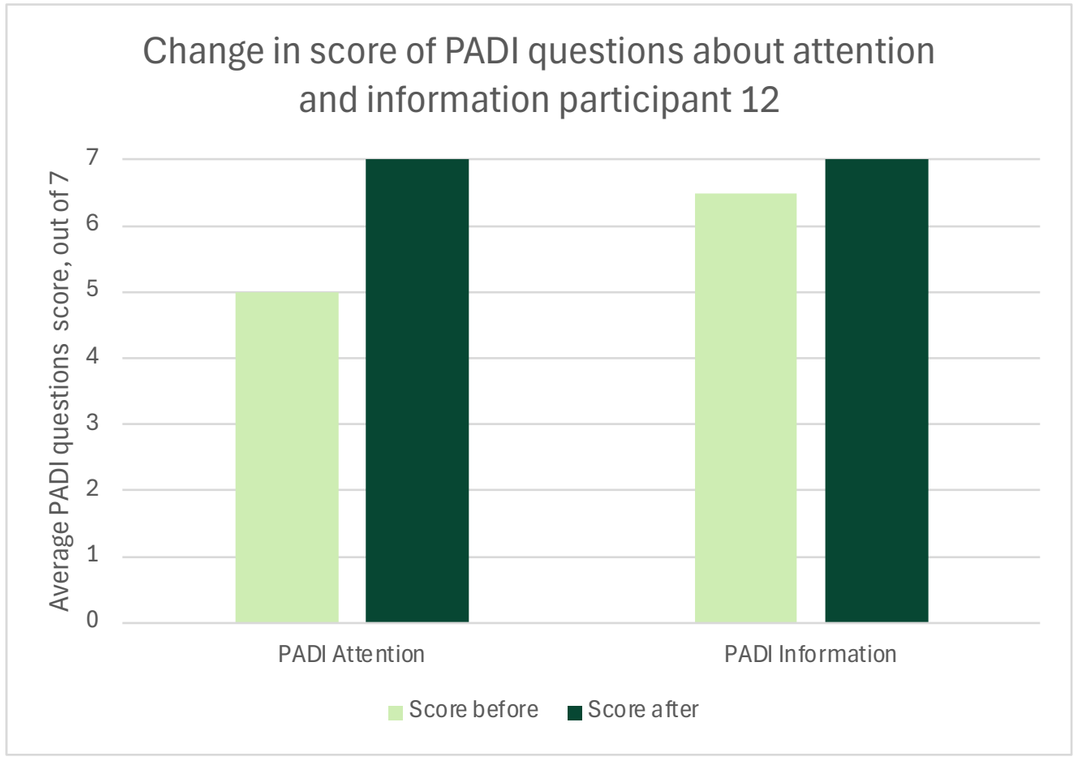


Figure 62, Change in score of PADI questions about attention and information participant 12

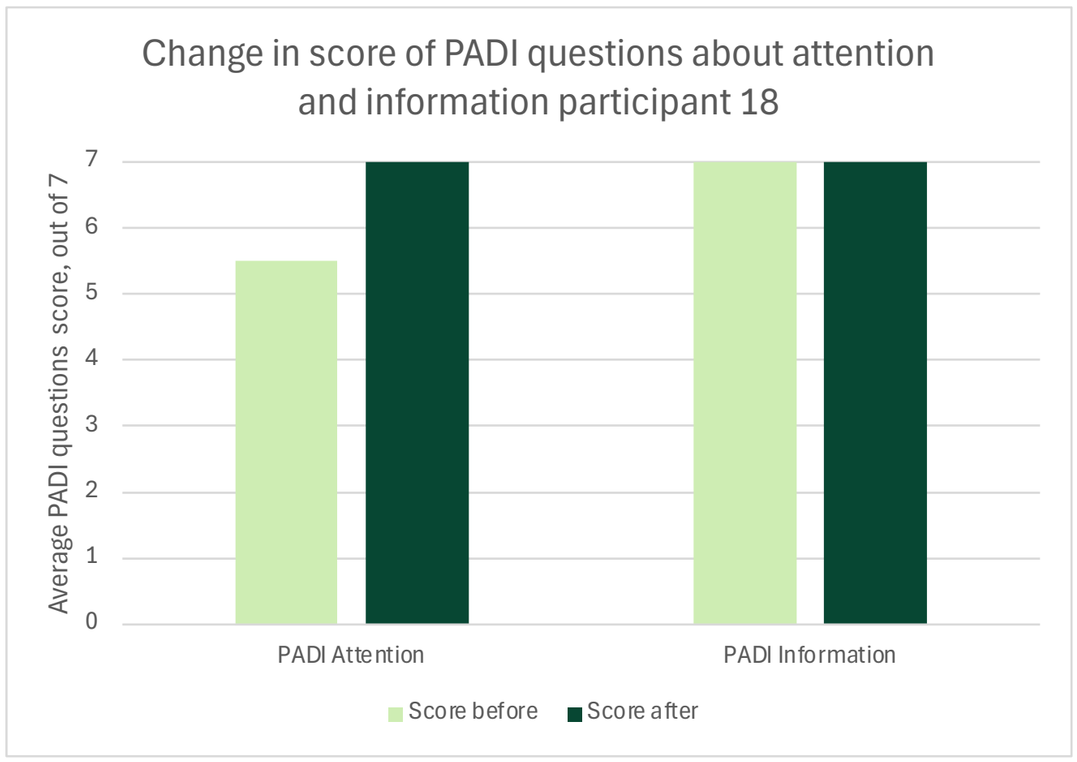


Figure 63, Change in score of PADI questions about attention and information participant 18

Participants also reported a strong perceived increase in attention toward the tree in the post-test mechanism items (M = 6.00 / 7, SD = 0.87, n = 17).
Attention emerged as the strongest quantitative predictor of PAD outcome:

- Self-reported attention increase was strongly associated with post-test PAD (r = 0.73, p = .001, n = 17)
- "Attention helped me connect" was also strongly associated with post-test PAD (r = 0.64, p = .010, n = 15)

These findings indicate that the installation was particularly effective at addressing the Attention and Memory Deficit component of PAD. In practical terms, the installation successfully moved the tree from the perceptual background into the participant's foreground of attention.

12.3.7 Information: significant increase, but mainly as experiential meaning-making

The PAD Information subscale also increased significantly, from 5.00 before (SD = 1.21) to 6.11 after (SD = 0.85), t(17) = 4.75, p < .001.

In addition, participants reported a clear subjective increase in information about the tree (M = 5.15 / 7, SD = 1.37, n = 17).

However, the role of information requires careful interpretation. The direct self-reported information increase item showed only a weak relationship with the overall PAD and CWN outcomes. By contrast, the PADI Information questions (which reflects interest in learning more about plants, such as epistemic interest) was much more strongly related to CWN (see Section 11.4.5).

This suggests that the installation's contribution was not primarily factual knowledge transfer. Instead, it appears to have supported experiential meaning-making: participants interpreted plant behaviour, inferred responsiveness, and became more curious about the plant.

12.3.7.1 Plant liveliness as the affective mechanism in the interaction phase

Participants reported a strong perceived change in how lively/agentic the tree felt:

- Perceived liveliness change: M = 6.18 / 7 (SD = 1.01, n = 17)
- "Liveliness helped me connect": M = 6.29 / 7 (SD = 0.61, n = 14)

Perceived liveliness change was positively associated with both key outcomes:

- Post-test PAD: r = 0.48, p = .050 (n = 17)
- Post-test CWN: r = 0.51, p = .038 (n = 17)

These results support the framework's proposition that perceived plant liveliness is a central affective mechanism. Liveliness appears to help transform noticing and interpretation into a more relational and emotionally meaningful experience of the tree. Notably, liveliness was more strongly related to CWN than to PAD, which supports its role as an affective bridge rather than a purely perceptual mechanism.

12.3.7.2 Calmness as a state-setting mechanism in the preparing phase

The Preparing Phase was designed to create a calmer, more receptive state before interaction. This was supported by both restoration and self-report measures.

First, the Restoration Outcome Scale (ROS) increased significantly:

- ROS before: M = 4.39 (SD = 1.13)
- ROS after: M = 5.57 (SD = 0.97)
- t(17) = 3.87, p = .001

Second, participants reported:

- Calmness change: M = 5.62 / 7 (SD = 1.19, n = 17)
- "Calmness helped me connect": M = 5.40 / 7 (SD = 1.24, n = 15)

Perceived calmness change showed positive trend-level associations with:

- Post-test PAD: r = 0.47, p = .058 (n = 17)
- Post-test CWN: r = 0.45, p = .069 (n = 17)

Although these correlations did not reach the .05 significance threshold, the pattern is consistently positive and supports the intended role of calmness as a state-setting mechanism. Calmness appears to support receptivity, rather than functioning as the primary driver of change by itself.

12.3.7.3 A hierarchy of mechanisms for CWN: epistemic interest, liveliness, calmness, attention

When correlating mechanism indicators with CWN outcomes, a clear hierarchy emerged.

Among the project-specific mechanism items, the strongest associations with CWN were:

- Liveliness change: r = 0.51
- Calmness change: r = 0.45
- Attention increase: r = 0.34
- Self-reported factual information gain: low association

A particularly important finding emerged for the PADI Information subscale, which showed the strongest relationship with CWN (approximately r = 0.80 in the dataset). This subscale reflects not only knowledge, but also interest in learning more about plants (epistemic interest). This suggests that the strongest "engine" of CWN in the installation was not factual learning alone, but the activation of curiosity and desire to know more.

Taken together, these results indicate a layered mechanism structure:

- Attention is most important for breaking the PAD bottleneck,
- Liveliness and calmness shape the affective quality of the encounter,
- and epistemic interest appears to be the strongest driver of deeper CWN.

12.3.7.4 Qualitative attribution of change: Two pathways to connection

To understand how participants themselves explained their increase in connectedness, the post-test interviews asked them which part of the installation contributed most to their experience. The responses revealed a clear two-pathway split.

Informational Interest Pathway (n = 10):
Ten participants primarily attributed their increased connection to the Interaction Phase. They described the experience of perceiving the tree as responsive or agentic and interacting with it as the key reason they felt more connected.

This pathway aligns with the quantitative pattern in which liveliness and epistemic interest were strongly associated with CWN.

The Receptive Pathway (n = 8):
Eight participants primarily attributed their increased connection to the Preparing Phase. They described slowing down, increased sensory focus, and being more present/attentive as the main drivers of their shift in connection.

This pathway aligns with the quantitative cluster around attention and calmness.
The qualitative attribution data helps explain the variability in individual outcome patterns. In the post-test interviews, 10 participants primarily attributed their increase in connectedness to the Interaction Phase, describing the plant's reactivity and the information they gained through interaction as the key driver. In contrast, 8 participants primarily attributed their increased connectedness to the Preparing Phase, particularly the increase in sensory focus and attention. In addition, 5 participants explicitly mentioned that reflection prompted by the preparatory questions contributed to their CWN increase.

This pattern helps explain why some participants showed stronger change in one mechanism cluster (e.g., attention/calmness or liveliness/information) than in another. In other words, participants did not all move through the same mechanism sequence with equal strength. The participant-level score patterns are consistent with this interpretation (see Figures 60 to 63), where some participants show marked improvement in one pathway while remaining relatively stable in another.

A ceiling effect also appears plausible in several cases. For example, Participant 16 showed no measurable change but had a baseline score of 7/7, which leaves little room for further increase. This supports the interpretation that the installation was more transformative for participants with lower initial scores, while functioning more as affirmation for participants with already high baseline connectedness.

The two-pathway pattern helps explain why some mechanism correlations are weaker or more variable than expected. This qualitative result strengthens the overall framework, because it shows that the installation's mechanisms are complementary rather than strictly linear.

12.4 Results conclusion

The final evaluation shows that the installation successfully achieved its two main objectives: it significantly reduced Plant Awareness Disparity and significantly increased Connectedness with Nature. The positive correlation between PAD reduction and CWN enhancement supports the project's core hypothesis that these outcomes are closely linked.

At the mechanism level, the results indicate that:

- Attention is the qualitatively strongest measured aspect for reducing PAD
- Information was qualitatively low correlated with PAD reduction, but the epistemic interest fostered by the information gain was most effective in enhancing CWN
- Perceived plant liveliness is an effective affective mechanism for strengthening CWN
- Calmness supports the receptive state needed for the interaction to work.

Finally, the qualitative two-pathway split shows that participants connected through different routes, confirming that the installation does not operate as a single mechanism, but as a structured combination of complementary mechanisms.

These results provide the empirical basis for the discussion in Chapter 12, where the findings are interpreted in relation to the PAD literature and Zylstra et al.'s CWN framework.

CHAPTER 13.
Discussion

13.1 Evaluation Results Discussion

13.1.1 Overview of the main finding

The central finding of this thesis is that the installation fostered Connectedness with Nature (CWN) (CWN of 4.57/7.00 to 5.97/7.00 ($p<0.001$)) by reducing Plant Awareness Disparity (PAD) (5.02/7.00 to 5.95/7.00 ($p < .001$). Participants reported significantly higher CWN and significantly lower PAD after the experience, and participants with stronger PAD reduction also tended to show stronger CWN increase ($r=0.66$). The qualitative results, in which participants attributed their enhanced CWN with information gain, experiencing liveliness, and increased attention confirm that this correlation was a causation. This supports the design objective of the thesis:

The installation reduces PAD by addressing the Attention and Memory Deficit and Information Deficit by translating plant behaviour into perceptible signals of liveliness to improve CWN.

Therefore, the research objective of this thesis,

To explore opportunities for interactive installations to foster Connectedness with Nature by addressing a specific driver of Disconnection to Nature.

is achieved.

At the same time, the results also refine the framework developed in the thesis to achieve the research objective and design objective. The installation did not work through one single mechanism. Instead, the results indicate a layered mechanism structure: attention was most important for reducing PAD, while liveliness, calmness, and especially epistemic interest (captured in the PAD information-related subscale) were more strongly associated with CWN enhancement. The qualitative attribution data strengthens this interpretation by showing that participants did not all describe the same route to connection. Rather, some participants grounded their shift in the Interaction Phase (reactivity, liveliness, meaning-making), while others grounded it in the Preparing Phase (slowing down, sensory focus, receptivity). This mechanism-system view is essential to interpret both the consistency of the overall effects and the variability between individuals. This extends the Chapter 4 framework by clarifying which mechanisms matter and how they differ in function within the pathway from PAD reduction to CWN.

A key contribution of the discussion is that the results support this thesis' framework but also refine it. In particular, they suggest that Zylstra et al. (2014)'s three pathways

(Information about Nature, Experience in Nature, and positive affect) did not operate with equal influence at the same moment in this installation. Instead, the findings support a staged hierarchy of influence: attention and experiential information primarily reduced PAD, while affective mechanisms (especially liveliness, with calmness as preparation) were more decisive for the strength of CWN.

13.2 PAD Reduction as the Perceptual Gateway to Connection

A central contribution of this thesis is the empirical support for PAD as a designable gateway to CWN. In Chapter 3, PAD was positioned as a perceptual and interpretive bottleneck that prevents plants from becoming meaningful participants in human experience. The final evaluation supports this framing: participants became significantly more plant-aware, and those with stronger PAD change also tended to show stronger CWN change. This aligns with the literature-based argument developed earlier, where PAD was treated not as a guaranteed cause of CWN, but as a condition-shaping barrier whose reduction makes connection more likely.

The mechanism results strengthen this interpretation. Attention was the strongest quantitative driver of PAD outcomes, which is highly consistent with Parsley's PAD framing and with Guerra et al.'s work on perceptual bias toward plants. PAD is not only a lack of information; it is first a failure of perception. In that sense, the installation's strongest success was not "teaching" plants, but making the plant perceptually present enough to be noticed, interpreted, and engaged with. This also supports Richardson et al.'s argument that actively noticing nature matters more for connectedness than exposure duration alone: the installation did not simply place participants near a tree, it structured their attention toward it.

This is an important distinction for HCI and experience design. It suggests that plant-centred interventions should be evaluated not only on whether they deliver information, but on whether they successfully produce a perceptual shift from plant-as-background to plant-as-foreground.

13.3 Information vs. epistemic interest

The results also clarify an important nuance in the role of information. In Chapter 4 and Chapter 3.6.3, the thesis argued that information supports CWN only when it becomes experientially meaningful. The final evaluation supports this, but with a more precise distinction: information" needs to be treated as two distinct constructs:

1. Factual information gain (eg. "I learned information about this tree")
2. Epistemic interest (eg. "I am interested in learning more about plants," captured within the PAD information-related scale items).

Self-reported information gain was clearly present, but it was not the strongest predictor of either PAD reduction or CWN enhancement. In contrast, the PADI information-related subscale (which includes items closer to interest in learning more about plants) showed the strongest association with CWN. This suggests that the installation's key contribution was not simply knowledge transfer, but the activation of curiosity. Thus, the installation's informational strength appears to lie in making the plant interpretable and worth understanding, rather than functioning as an educational tool that transfers facts. This aligns with the design requirement of experientialising plant social behaviour. Through experientialising it, they can understand and experience the information they receive, which may increase epistemic interest.
This is represented in the qualitative data, in which 10 participants attributed their enhanced CWN with their interaction with the plant and how they suddenly perceived the liveliness of the plant. This change in perception indicates an information increase. However, as this is experiential and therefore not textbook information increase, this explains why participants may have not scored the attribution high but did mention this as influential in their CWN.

This finding aligns well with Zylstra et al.'s framework, but it also refines how the Information about Nature pathway can be used in design. The current results suggest that the most effective form of information in this context is not detached instruction, but experientialised interpretability: participants notice a signal, infer plant activity, and become interested in what it means. This directly supports this thesis design requirement 4, where information supports CWN when it becomes experientially integrated rather than detached. The installation did not deliver a lesson about trees, it created a perceptual and affective situation in which participants began to wonder about the plant and interpret its signals. That is a critical design insight for CWN-oriented HCI: the goal is not simply more information, but the activation of meaning-making through experientialised information gain.

This interpretation is also consistent with the intervention literature by Barragan-Jason et al.), discussed in Chapter 3.6.3, which found that contact- and attention-based approaches tend to outperform education-only interventions for strengthening nature connectedness. The present results suggest one reason why: contact and attention do not replace information, but make information relationally and affectively active.

For the thesis framework, this strengthens the original claim that PAD should be addressed through attention and information, but it sharpens "information" into a more design-relevant concept: experiential information gain fosters curiosity and sense-making.

A further implication is that future iterations should measure these constructs more cleanly. While Parsley et al.'s (2020) framework of PAD describes Information Deficit as having little knowledge about plants, the questions in the PADI test focus on epistemic interest. So, to test experiential information gain as a pathway, the evaluation should separate: "I learned facts," "I inferred meaning," and "I want to learn more.". The current findings already point to this, however more specific research through making this divide explicit increases scientific clarity and enables a better definition of causation.

13.4 Plant Liveliness as the Affective bridge to CWN

Perceived plant liveliness emerged as a central affective mechanism. Participants rated liveliness as highly helpful, and perceived liveliness change was positively related to CWN. Furthermore, 5 participants mentioned liveilness in the qualitative interviews, suggesting a causal link. This supports the claim that liveliness is the affective mechanism between reducing PAD and enhanced CWN. It also proves the final design achieved the fourth and seventh design requirement. It is important to note that no questions were asked about viewing the plant as social, however as this is a representation of liveliness and its significant effect on CWN, I conclude that this requirement has been achieved.

This acts as an affective bridge from PAD towards CWN, in which the plant becoming perceivable as lively and responsive supported a positively valent affect towards the tree. This supports the Chapter 4 interpretation that plant liveliness bridges Zylstra's first two pathways (Experience in Nature and Information about Nature) with the third pathway (positive affect). It is the mechanism through which noticing and interpretation become emotionally resonant.

This also helps explain why the installation could enhance CWN within a relatively short encounter. A brief experience may be enough to produce noticing and curiosity, but what makes it feel like connection rather than observation is the affective shift: the tree is no longer passive scenery but a responsive being. In this sense, the project contributes a concrete HCI operationalisation of affective integration in CWN design: translate biological activity into perceivable signals of liveliness.

At the same time, the liveliness mechanism should be interpreted carefully. The term 'liveliness' may have been understood differently by different participants (eg. as biological activity, personality, responsiveness, or aesthetic vibrancy). This could add noise to survey responses and partly explain why liveliness does not always correlate linearly with every other mechanism metric. This measurement precision should be strengthened in future testing in order to better investigate the role of liveliness.

13.5 Calmness as a State-Setting Mechanism

The role of calmness should be interpreted carefully. In the final evaluation, calmness increased significantly, and participants generally rated it as helpful for their sense of connection. At the same time, the correlations between calmness and PAD and CWN outcomes were moderate and consistently positive, but did not reach the conventional 0.05 significance threshold in the current sample. This means that the results do not provide strong quantitative evidence that calmness, by itself, directly predicts CWN enhancement.

This pattern is nevertheless meaningful for this thesis' framework. It supports the interpretation that calmness functions primarily as a state-setting mechanism: rather than acting as the sole driver of connection, calmness may increase receptivity by lowering arousal and helping participants become more present, attentive, and open to the later interaction.

Importantly, the significant increase in calmness and the consistently high subjective ratings of calmness as helpful supports the design validity of the temporal journey, especially the Preparing Phase. Even if calmness is not statistically isolated as a direct predictor of CWN in this sample, the findings indicate that Phase 1 is functionally relevant acting as a mechanism to foster connection. This is supported by the qualitative attribution data, in which a 8 group participants identified the Preparing Phase as the part of the installation that most shaped their experience of connection.

At the same time, calmness may also contribute to CWN more directly as part of the positive affective quality of the installation. The current study cannot fully disentangle these roles. Future evaluations should therefore include more specific interview and survey questions to determine whether calmness functions primarily as a preparatory condition, as an affective contributor, or as a combination of both.

Overall, the results support retaining calmness in the framework: calmness is a state-setting mechanism in the Preparing Phase that supports receptivity for plant-centred connection, while also validating the temporal design logic of the installation. And it proves the final design succesfully achieved the 6th design requirement.

13.6 Two Pathways to Connection

The qualitative attribution results indicate that participants did not all experience the same primary route to Connectedness with Nature. Instead, they described two recurring phase-based pathways through which the installation supported connection. These pathways can be understood as experiential patterns of perceived connection, not as statistically isolated causal pathways.

The first is the Attentional Pathway, in which participants primarily attributed their increased connection to the Preparing Phase. In this pathway, the thematic analysis showed that connection emerged through slowing down, focusing on the senses and the plant, and in some cases reflection. The shift in attention and calmness are the biggest influences in this pathway.

The second pathway is Informational Interest, in which participant mainly attributed their increased CWN to the Interaction Phase. In this pathway, the thematic analysis showed that connection emerged through perceiving the plant as reactive and lively, and through the information and meaning participants gained from interacting with it. The qualitative data helps explain the low correlation between the scores of the aid of information gain in fostering CWN and the increase in CWN scored, as described in 13.3. It is important to note that this phase was also designed to keep attention on the plant. While this was not described as a main influential factor in this phase, this may be caused by a heightened influence of information gaina and experienced liveliness. However, this designed attention may describe the significant correlation between attention and PAD (0.73) even if it is not a main attributed factor in the qualitative study. This pathway is therefore shaped by a combination of liveliness and experiential infor-

mation gain and likely attention increase.

As the informational pathway also heightened attention, this could be viewed as the attentional pathway having a reduced impact in the second phase, perhaps due to not understanding what is going on. However, no systemic evidence could be found for this in the quantitative or qualitative data. This thesis therefore does not adhere to this theory. This phase-based interpretation could, however, explain why some individual mechanism correlations are uneven or weaker than expected. The installation did not function as one fixed route in which every participant moved through the same sequence with the same intensity. Instead, it functioned as a structured interaction system in which different participants reached connection through different dominant mechanism combinations.

Importantly, this strengthens the validity of the installation's Three-Phased Journey. This temporal journey supports multiple ways of fostering CWN, and the final evaluation suggests that this design resulted in more participants experiencing an increased CWN. Future work can build on this by testing the pathways more directly, for example by isolating specific mechanisms within each phase.

13.7 Implementation Evaluation

The installation was placed outside in a park for testing and exhibiting. In total 70 people interacted with the installation. The test was not done longitudinally, therefore the achievement of strengthened CWN over time could not be tested. However, it does prove succesful outside implementation which enables access to multiple people, therefore achieving design requirement 3.

13.8 Explaining variability

Two variability factors appear in the final evaluation:

Ceiling effects
Several participants started with high baseline CWN and/or high baseline PAD scores, leaving limited room for measurable improvement. In these cases, participants often described the experience as affirmation rather than transformation. This does not undermine the effectiveness of the installation. It indicates that its measurable impact is strongest for those who are more nature-disconnected at baseline, while its value for highly connected individuals may be more confirmative or reflective.

Pathway differences
The qualitative data indicates that participants did not all connect through the same mechanism emphasis. Some participants primarily connected via the Interaction Phase, describing liveliness and information gain, while others primarily connected through the Preparing Phase, focussing on attention and calmness. Importantly, attention was also increased and kept in the Interaction phase, which helps explain the high effect attention has on PAD (r = 0.73). This helps explain why some individuals show strong change in one cluster but weaker change in another. The installation should therefore be interpreted as enabling multiple routes to CWN, rather than enforcing a single universal sequence.

A third and important validity consideration concerns measurement interpretation. Participant 9's CWN decreased in one statement, "I feel a sense of oneness with the natural world / this tree". Such broad CWN statements can be interpreted differently pre- vs post-intervention, especially when an intervention shifts the participant from an abstract nature-concept toward a more differentiated or relational perception of plants. A person might feel less oneness in a philosophical sense while simultaneously feeling more relational engagement with a specific living tree. This it indicates that the intervention may shift interpretive frames. I suggest including a short description in the survey to better describe item semantics.

13.9 Adapting the Framework Based on the Final Evaluation

The final evaluation supports the overall framework developed in Chapters 3 and 4 and implemented in the final design, but it also indicates three refinements that improve explanatory precision. This proves that the final design achieved the first and second design requirement. Figure 64 shows the adapted framework.

13.9.1 From equal pathways to a staged hierarchy

Zylstra et al.'s (2014) framing treated Experience in Nature, Information about Nature, and positive affect as equally influential. The final mechanism results suggest a more differentiated structure:

- Experientialised information gain supports the perception of liveliness and fosters epistemic interest
- Attention functions as the gateway, breaking the PAD perceptual bottleneck
- Affective mechanisms, as liveliness and epistemic interest function as the integration mechanism, transforming the encounter into a positively valent affective connection, deepening meaning-making and sustaining engagement

Therefore, the affective state of CWN has most influence, while Interest and Attention have a lower interest. The updated framework can be found in figure 65. This is not a replacement of the underlying CWN framework, it is a project-specific operationalisation supported by empirical outcomes.

13.9.2 From a single chain to a mechanism ecosystem

The final evaluation supports representing the framework as a mechanism ecosystem with multiple valid pathways:

- Attentional pathway fostering CWN through calmness and attention
- Informational interest pathway emphasising liveliness and experiential information gain enhancing epistemic interest but including attention

These routes describe different dominant pathways through the same designed system towards heightened CWN. This refinement strengthens the framework because it explains why the installation can succeed across diverse users with different baseline connectedness and different preferred modes of engaging. In figure 64, these path-

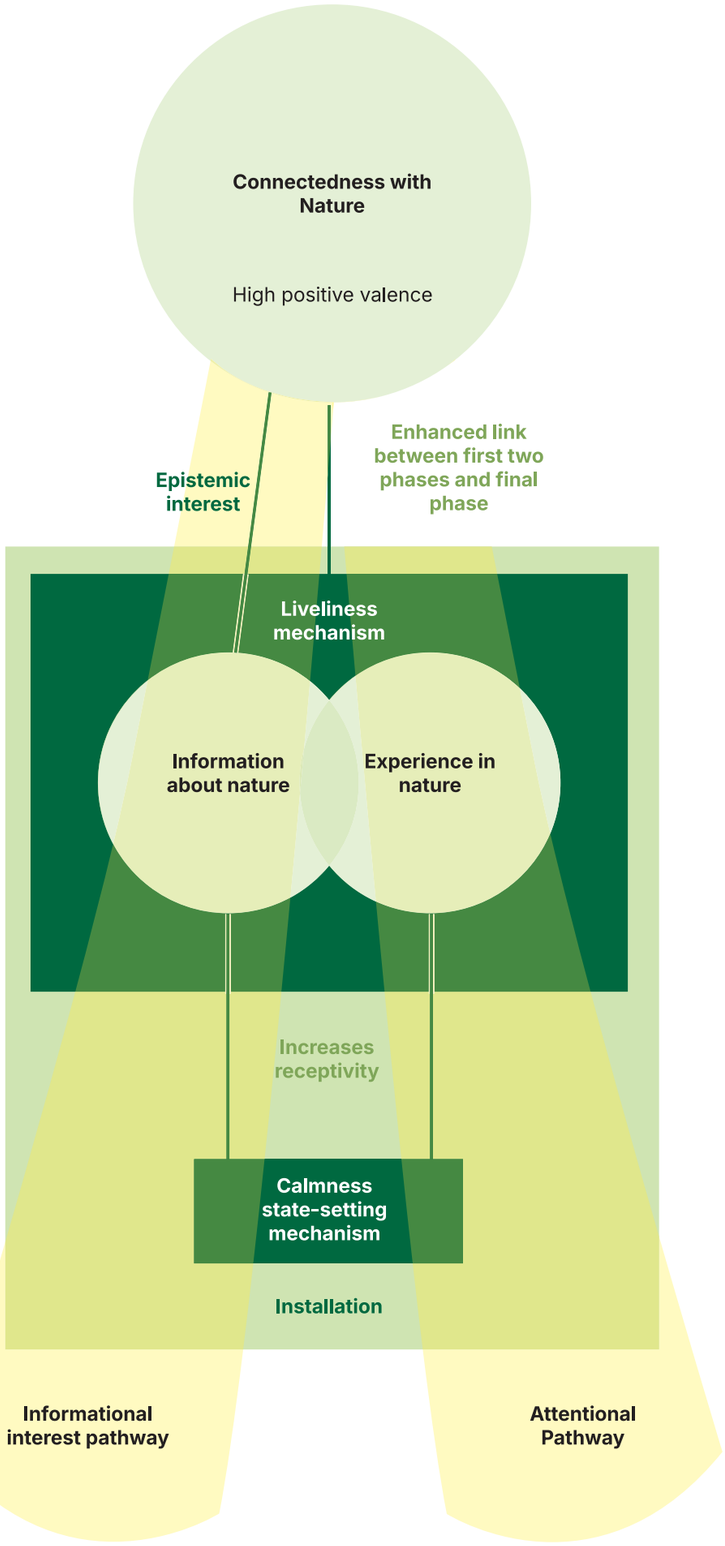


Figure 64, Improved 'Designable Framework Reducing PAD to Improve CWN using Affective Mechansisms'

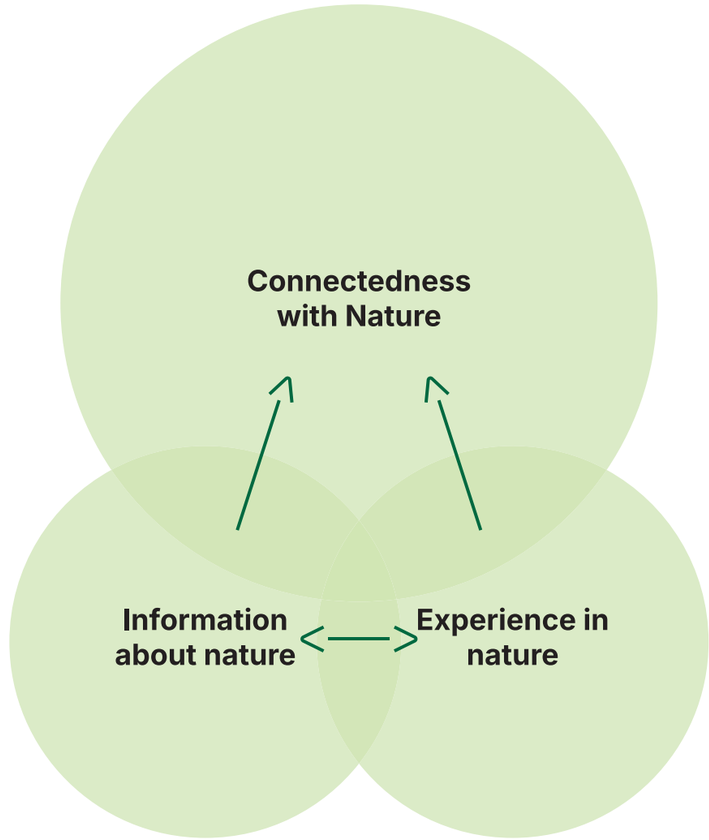


Figure 65, Proposed improvement of Zylstra et al.'s (2014) framework of CWN

ways are represented by the yellow paths.

13.10 Implications for Design and Evaluation

The results indicate design implications for plant-centred public installations:

1. Prioritise attention before education. If the plant remains background, informational content alone is unlikely to matter.
2. Design for interpretability and curiosity, not only facts. The strongest CWN links appear when users want to know more and can infer meaning.
3. Make liveliness perceivable. Translating plant activity into sensory signals supports relational meaning and affective engagement.
4. Include a state-setting entry. Calmness and slowing down help users shift into a receptive mode in urban contexts.
5. Treat outcomes as multi-pathway. A good public installation should allow different users to connect through different dominant mechanisms.

For evaluation, the findings indicate that future work should:

- include more specific interview questions on calmness and liveliness,
- experimentally isolate mechanisms (e.g., comparing versions with/without liveliness cues, or with/without calmness phase), and
- improve scale alignment by using plant-specific connectedness measures and clarifying interpretive ambiguity in certain CWN items.

13.10.1 Theoretical Contributions

1. Restructuring Zylstra's CWN Framework
This r10search empirically refines Zylstra et al.'s (2014) Connectedness with Nature framework. While the framework presents Information, Experience, and Positive Affect as equal aspects, this thesis indicates that in plant-centred installations, they operate as a hierarchy. Attention and information (PAD) acts as the gateway but the strongest descriptor of CWN is affective enhancement, such as perceived liveliness or an increase in curiosity for plant information.

2. Advancing PAD Literature: The Epistemic Shift
By extending recent Plant Awareness Disparity (PAD) literature (Parsley et al., 2020; Guerra et al., 2024) into designable interventions, this thesis reframes the "Information Deficit." It suggests that PAD is best reduced by experientialising information gain, generating the affective state of Epistemic Interest (r = 0.80), transforming a plant from a background object into a subject worthy of curiosity.

3. Environmental Identity and the Ceiling Effect
Supporting Clayton's (2003) theory of Environmental Identity, the data supported the finding of a ceiling effect among participants with high baseline CWN. This contributes a valuable nuance to interaction design: plant-centred interventions function as a transformative experience for the disconnected, but as an affirming space for those with pre-existing ecological identities.

13.10.2 Practical Contributions

1. Designing for Curiosity over Knowledge
The thesis provides a clear mandate for environmental HCI: design for interest, not just information. The r = 0.80 correlation between epistemic interest and CWN change indicates that interactive installations should use high-affect mechanisms to evoke questions and spark a "desire to know."

2. Operationalizing Liveliness through Systemic Signalling
The project demonstrates that translating invisible biological processes, specifically a tree's systemic electrical signalling, into perceptible haptic feedback is a highly effective design strategy. The data suggest that the physical translation of biodata successfully broke the static bias of PAD (r = 0.48) and serves as the primary relational catalyst for users to perceive plants as active social agents.

3. The Three-Phased Journey as a Spatial Architecture
Finally, the project contributes the Three-Phased Journey (Preparing, Interacting, Reflecting) as a validated temporal journey for high-arousal environments. The data indicates the Preparing Phase is a physiological necessity to reduce urban distraction through stimulating calmness, rendering subsequent interactive mechanisms ineffective.

12.9 Limitations and boundary of claims
This study provides strong evidence of immediate, in-situ effects in a real-world park context, but several limitations bound the claims.

First, the sample size limits statistical power for mechanism correlations, particularly for calmness. The consistent positive trend is meaningful but should be treated as supportive rather than definitive.

In addition, the evaluation measured short-term change. Some PAD components, especially Relative Interest, are plausibly slower-moving and may require repeated exposure over time. This suports the theory proposed in Chapter 3.6.3 and suggests that long-term change should be tested longitudinally.

Finally, measurement ambiguity, including the terms liveliness and oneness indicates that future evaluations should strengthen construct clarity and triangulation between scales and qualitative interpretation.

These limitations define next steps required to strengthen generalisability and causal specificity.

13.11 Methodological discussion

Throughout the iterative design process, evaluations relied on relatively small participant groups. For instance, the sensory inputs for calmness and the plant behaviours representing liveliness were initially defined in a co-creation session with only 4 participants. Because these elements were established as provisional requirements, their true efficacy in fostering a positive affective state across a diverse public remained unverified until the final evaluation.

This reliance on small sample sizes directly impacted the contextual validity of the interaction design. A clear example occurred during the prototype refinement phases. In early testing, 14 out of 17 participants associated the installation's electrode patches with medical heart-rate monitors, which successfully helped them understand that a biological signal was being measured. However, in a subsequent refinement test with a different small group, only 1 out of 7 participants made this association. This stark variance demonstrates that small samples in early design phases can create false confidence in interaction legibility. Increasing the participant count and demographic diversity during early prototyping would have yielded a more robust, universally intuitive installation to address Plant Awareness Disparity (PAD).

Finally, the in-situ evaluation methodology introduced an unforeseen selection bias. The final user test only interviewed participants who completed the full Three-Phased Journey. However, due to the public nature of the park setting, there were instances where the interaction chair was occupied, causing some guests to only experience the fabric arches (Phase 1: The Preparing Phase) without engaging in the biological interaction (Phase 2).

Not interviewing these partially engaged users represents a missed methodological opportunity. These bystanders effectively formed a natural control group. Evaluating

their experience could have isolated the specific influence of the Preparing Phase (fostering calmness and attention) from the Interaction Phase (fostering information gain and liveliness). Understanding the difference in PAD reduction and CWN enhancement between these two groups would have yielded invaluable insights into the independent strengths of each phase within the temporal journey.

Finally, significant methodological assumption in this project was focusing early prototype evaluations almost exclusively on the ultimate goals, the reduction of PAD and the enhancement of Connectedness with Nature (CWN), rather than isolating the underlying mechanisms. In earlier phases, it was assumed that if PAD was decreasing, the mechanism of liveliness was inherently functioning.

However, the final evaluation revealed that affective layers, specifically perceived liveliness ($r = 0.51$) and epistemic interest ($r = 0.80$), were the primary drivers of the CWN increase. Calmness and liveliness was not deeply investigated in earlier phases. Rather than focussing on liveliness it focussed more on the reduction of PAD and enhancement of CWN, with the thought that liveliness was being shown through the behaviour shown. However, because these affective mechanisms have such a high influence on the installation's success, failing to evaluate liveliness and calmness directly during early prototyping was a missed opportunity. Conducting isolated tests on these specific affective mechanisms earlier in the process would have provided stronger empirical grounding for the framework and allowed for a more optimized interaction design.

13.12 Discussion conclusion

The final evaluation supports the thesis' core claim: a plant-centred interactive installation can foster Connectedness with Nature by reducing Plant Awareness Disparity. The results further refine the project's framework by showing that the installation operates as a mechanism system rather than a single lever. Attention appears to be the perceptual gateway for reducing PAD; epistemic interest and interpretive engagement form the strongest engine for CWN; liveliness functions as the affective bridge that makes the plant relational; and calmness supports receptivity, validating the temporal logic of the Three-Phase Journey.

Together, all evidence proves that the design hypothesis was validated.

Overall, the project contributes a tested, mechanism-based account of how plant-centred HCI can move urban park visitors from passive co-presence with trees to a more attentive, interpretive, and affectively meaningful relation with plant life.

CHAPTER 14. Conclusion

14.1 Core Findings and Synthesis

The central finding of this thesis is that Plant Awareness Disparity (PAD) is a primary and designable driver of DTN, and that reducing PAD is an effective route to fostering Connectedness with Nature (CWN). This thesis therefore has succesfully developed an interactive installation that fosters CWN and provides a framework to develop more opportunities this cause, therefore succesfully achieving the research objective:

To explore opportunities for interactive installations to foster Connectedness with Nature by addressing a specific driver of Disconnection to Nature.

14.1.1 Addressing a specific driver: PAD (Attention and Memory Deficit and Information Deficit)

The interview study of Chapter 4 identified a recurring experiential pattern: participants described stronger connection when plants moved from perceptual background to foreground, and when they could interpret plants as active, meaningful presences. The final evaluation then confirmed this pattern quantitatively and qualitatively: the intervention significantly reduced PAD and significantly increased CWN, and stronger PAD reduction was associated with stronger CWN enhancement. Together, these findings demonstrate identify PAD as an empirically effective design strategy to foster CWN. More specifically, the findings show that PAD is most effectively addressed through addressing:

- Attention and Memory Deficit through focusing noticing and sustained percepion of plants
- Information Deficit, not through information gain solely, but more effectively through stimulating the affective state of epistemic interest

These two mechanisms function as the cognitive-perceptual basis of reconnection. Attention breaks the perceptual bottleneck that causes plants to remain green background. The final evaluation of this thesis indicates that information functions most powerfully as meaning-making and epistemic interest: the activation of curiosity and the desire to understand plant life.

Attitudinal Disparity and Relative Interest are found to be a result from addressing Attention and Memory Deficit and Information Deficit that grows over time through reflection and from posititve affective. Therefore Attention and Memory Deficit and Information Deficit were defined as the designable aspects in an installation that should be represented through an affective mechanism of liveliness to reduce the final two aspects. This thesis finds that setting installations in a publically accessible natural setting enables guests to reduce these disparities over time, further strenghtening the reduction of PAD and enhancement of CWN.

14.1.2 Temporal state-setting: the role of the Three-Phased Journey

Another finding was the development of a Three-Phased temporal journey. This structure reflects the temporal journey that participants described in moment of high CWN, described in Chapter 4. The phases are:

- **Preparing phase**, in which the installation stimulates calmness by slowing pace through bringing attention towards sensory engagement with the plant.This stimulates receptivity in the next phases.
- **Interacting phase**, in which the guest engages with the plant and experientially gains information about the plant. This happens through the representation of plant biosignals in an interaction.
- **Reflecting phase**, in which guests are stimulated to reflect on their experience.

The qualitative results of the final evaluation suggests two pathways towards CWN with a different combination of mechanisms:

- Attentional pathway (calmness + attention), mentioned by 8 participants
- Informational interest pathway (liveliness + experiential information → curiosity), mentioned by 10 participants

The final evaluation therefore supports the validation that the Three-Phased Journey as a mechanism-supporting structure that enables different participants to enter the experience through different pathways while still contributing to the same overall outcome.

14.1.3 Liveliness as the affective mechanism

The findings further demonstrate that liveliness is an effective affective mechanism through which the reduction of PAD can become positively valent and affectively meaningful.
Liveliness is the moment in which the plant is no longer interpreted as a static object, but as a lively and agentic being. Chapter 5 and 6 defines that liveliness can be represented through the translation of measurable 'plant social behaviours', including:

- Systemic electrical signalling
- Nutrient sharing
- VOC (Volatile organic chemical) communication

By representing these behaviours through interaction, the installation made plant life perceptible as active and relational. This transformed attention and interpretation into affective responses such as curiosity, respect, care, and wonder.

14.1.4 Sensory state-setting: sight, sound, and scent as mechanisms for calmness

Chapter 5 concludes that sight, sound, and scent are effective senses to focus attention towards to foster calmness and prepare participants for the later interaction with the tree. The results show that calmness increased significantly, and 8 participants rated this phase as helpful to their experience. Although calmness was not the strongest statistically isolated predictor of CWN, the findings support its role as a state-setting mechanism.

This is an important design conclusion: in an urban park context, users do not enter an installation in a neutral state. The sensory preparation in Phase 1 may help participants slow down, focus, and become more receptive to plant-centred cues.

14.2 Theoretical Contributions: The Updated Framework

This thesis contributes a designable and empirically tested framework for reducing PAD to improve CWN using affective mechanisms. Its primary theoretical contribution is the integration of botanical social science, ecological psychology, and affective interaction design into one operational model for plant-centred HCI and interaction design.

14.2.1 PAD as the designable driver of DTN

The first theoretical contribution is the evidence of PAD as an effective designable driver of DTN which, when addressed, creates an increase CWN. This creates a more precise starting point for HCI than current holistic interventions.

14.2.2 From Static Object to Living Being: a measurable path

The second theoretical contribution is the articulation of a measurable path from static object perception to living-agent perception. This path, represented by the framework in figure 62, is the mechanism chain through which PAD reduction becomes CWN:

1. Information gain makes the plant interpretable (as experiential meaning, not only facts), while epistemic interest improves affective states
2. Attention foregrounds the plant in perception
3. Liveliness transforms interpretation into affective relation
4. Calmness supports state readiness for this transformation

Based on the final evaluation, the framework by Zylstra et al. (2014) was refined from an equal-pathways model to a staged mechanism framework, with most influence fromt the affective aspect of CWN than Information about Nature or Experience in Nature. In this framework, CWN can be fostered by reducing PAD through increasing attention and experiential information gain. This is done within the mechanism of representing plant liveliness, which strengthens the positive affective state resulting from the decreased PAD. Preluding the installation, the mechanism of calmness is used as a state-setting mechanism to foster receptivity in the installation, strengthening the reduction of PAD.

The updated provides a testable theoretical model linking plant-centred design mechanisms to measurable connectedness outcomes.

14.3 Practical Implications and Viability

This thesis also contributes a practical model for implementing plant-centred recon-

nection in public space. The final installation demonstrates that the framework can be used in a public park context with real users and measurable outcomes.

14.3.1 Practical design implications

The findings create a clear design strategy for future interventions:

- Start with state-setting: use sensory cues (sight, sound, scent) to foster calmness and receptivity
- Design for attention first: make the plant perceptually foregrounded before introducing interpretation
- Enable experiential information gain: prioritise interpretability and curiosity over stand-alone factual education
- Represent liveliness: translate plant behaviours into perceivable signals that communicate agency and responsiveness
- Structure the experience temporally: use a staged journey rather than a single interaction moment

This practical sequencing is a direct contribution to HCI and public-interaction design. It provides a reusable blueprint for how designers can create meaningful human–plant encounters that go beyond awareness messaging and toward affective relation.

14.3.2 Viability in the public park domain

The application of the framework in a park context is itself a practical contribution because it demonstrates contextual viability. Public parks are high-value but challenging settings: users arrive with different intentions, different baseline connectedness, and varying levels of attention and cognitive load. The success of the intervention in this setting indicates that the framework can function under realistic public conditions. The practical contribution is therefore not only the installation artifact itself, but the demonstration that a plant-centred, affective framework can be implemented in a viable public setting where users can repeatedly re-engage with plant liveliness as a living phenomenon rather than a one-time demonstration.

14.4 Final Conclusion

This research establishes that PAD is the critical designable driver of DTN in plant-centred urban interaction, and that reducing PAD is an effective route to fostering CWN. The findings demonstrate that reconnection depends on more than exposure: it requires a designed shift from plant as static object to plant as living agent.

That shift is achieved by addressing attention and information deficits, and by activating affective mechanisms through Liveliness and Calmness. Liveliness creates the relational bridge by making plant social behaviour perceptible; calmness creates the temporal and sensory conditions for receptivity. The resulting framework provides both a theoretical contribution (a measurable, mechanism-based model validated through NCI outcomes) and a practical contribution (a viable public-park implementation that supports repeat engagement).

The thesis therefore advances the domain from holistic ambitions of CWN toward a empirically grounded, designable pathway for fostering CWN in everyday urban life.

Finally, all the core research objective and all sub-research and sub-design objectives have been achieved.

CHAPTER 15. Recommendations

15.1 Recommendations

To improve this project in further studies and further develop this project to better achieve the objectives defined, I have defined various recommendations within the categories installation design, technology, sustainability and methodology.

15.1.1 Installation Design

Through the design process and final evaluation I have defined four improvements for the installation's design.

First, I recommend to explore the opportunities of enabling multiple people to interact with the tree at the same time. In the final evaluation, sometimes people did not interact in the interacting phase because there was already someone sitting in the seat. This causes guests to miss out on the information gain, that had a significant influence on reducing PAD.

In addition to this, I recommend exploring different ways of explaining how the plant reacts to proximity and touch and its influence on CWN and PAD. In the final evaluation, multiple participants asked what was happening. Due to the significant impact of information gain on PAD reduction, investigating if a more informative installation would improve information gain could therefore offer opportunities to further reduce PAD.

To strengthen CWN, I would recommend further exploration on how the first phase can stimulate calmness and a slow pace. Due to limited time, this was not further developed in this project. However, the significant influence of calmness on CWN proves that this is a great opportunity for further strengthening CWN.

Finally, I recommend exploring the influence of different affective states created by the installation on the enhancement of CWN. The current project focused primarily on calmness and perceived liveliness, but the findings suggest that the affective dimension is central to how strongly CWN develops. Future design research should therefore investigate which affective qualities (e.g., calmness, curiosity, wonder, intimacy, empathy, or care) most effectively strengthen CWN, and how these can be intentionally designed through sensory translation, pacing, and interaction.

15.1.2 Technology

To enhance the installation's robustness, strengthen the technical deployability, and clarity I have defined four improvement recommendations.

First, to improve signal robustness, I recommend using silver prongs/electrodes to measure the plant's electrical activity. This would reduce noise and external interference in the signal and improve measurement stability, resulting in a clearer and more reliable translation of plant activity into sensory output. A more stable signal would also make the interaction easier for participants to interpret.

To enhance the clarity of what the plant is reacting to (wind, proximity, touch, rain) which is changing the output, it could be beneficial to explore using machine learning in combination with the silver chloride (Ag/AgCl) electrodes to develop a code that generates different outputs for the different types of interactions with the plant. In the

final evaluation test, people were sometimes confused what the plant reacts to when the output was changing but they were not touching the plant. Therefore, I believe that improving this would enable better information gain about the plant.

Finally, I recommend developing a reactivity guide for different plant species. During the research process, it became clear that plants differ substantially in how strongly they respond and how clearly their signals can be translated into interaction. For example, the leaves of weeping willows appeared highly reactive, while pine needles produced much weaker responses. A structured guide comparing plant species in terms of signal reactivity, clarity, and suitability for deployment would make it easier to select appropriate plants and assess the installation's deployability in other parks or contexts.

15.1.3 Sustainability

In order to achieve the Three Step Journey to more conservation action, I recommend exploring next steps, after interacting with the installation, that can strengthen Environmental Responsibility and conservation action.

I also suggest investigation into the long-term effects of the installation on a tree to define how long the installation can stay at one tree and how often it should change the leaf that is measured. This aims to minimise harm to the tree.

15.1.4 Methodology

To improve the research process and strengthen the validity of findings in future iterations of this project, I recommend four methodological improvements.

First, the final evaluation should be redesigned as a longitudinal field study rather than only an immediate pre-/post-test. A stronger setup would include a baseline measurement in the same park before the installation is introduced (e.g., one week earlier), a post-test directly after the interaction, and a follow-up test after one week or longer. This would reduce expectation bias, control for location effects, and provide better insight into whether repeated encounters strengthen PAD reduction over time, deepen CWN, and produce more durable changes in attitude, interest, or everyday plant noticing. This would also enable the improvement of the reflection phase, which aimed to strengthen long term CWN fostering.

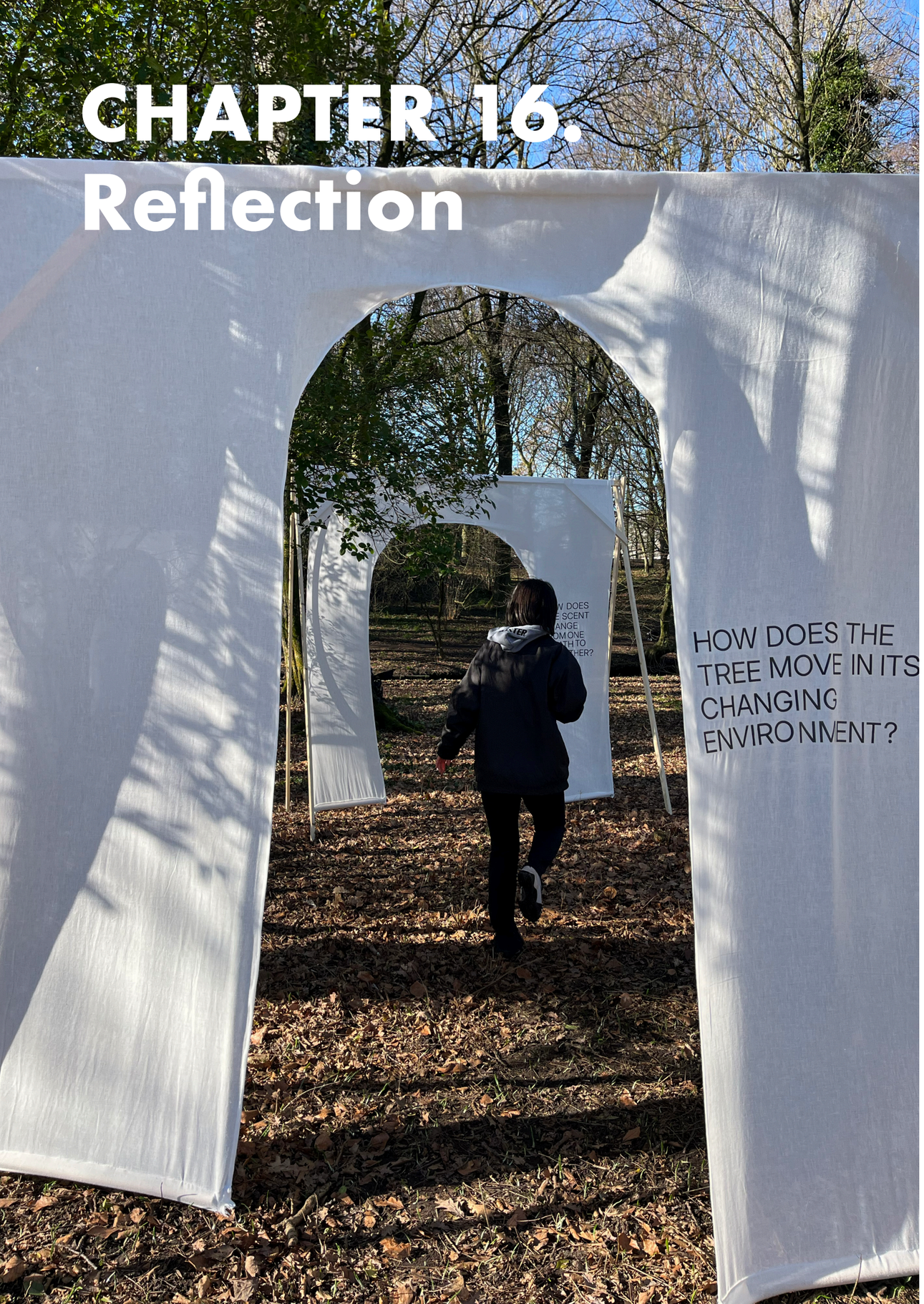
Future research should also include a broader participant group throughout the full design process, not only in the final evaluation. Much of the intermediate testing was done with students, which may have influenced design decisions and findings. Including participants with more varied ages, backgrounds, and baseline connectedness to nature would improve the reliability and generalisability of the results.

And future research should more clearly define liveliness in the tests, as its current use in the interviews and questionnaire was conceptually broad. Such vague constructs reduce interpretability, which may cause participants to respond to different meanings (movement, responsiveness, social presence, etc.), making it unclear what was actually measured. A clearer definition would also support more valid item development and stronger comparisons across conditions.

Interview protocols should also include more targeted questions on specific mechanisms of connectedness with nature. The current interviews produced useful descriptive insights, but their general phrasing limited the ability to identify which mechanisms drove participants' responses. More focused questions would improve analytic precision and help explain how different pathways contribute to connectedness.
In early prototype evaluations, liveliness should be assessed more directly. The initial focus on attention and information focussed on addressing plant awareness disparity with the idea that liveliness arose from the chosen behaviour and affective layer onto the concept, but reduced research in its effectiveness. So, it should be evaluated more explicitly to determine whether it was successfully perceived and whether it contributed to the observed effects.

Because the framework combines multiple mechanisms, future studies should test mechanisms both in isolation and in combination. This is improves causal interpretation. Without isolating mechanisms, it remains unclear whether effects are driven by one mechanism, several independently, or their interaction. Such testing would strengthen conclusions about both the framework's overall effectiveness and the specific contribution of each mechanism.

CHAPTER 16.
Reflection



This was my first fully solo interaction design project, and throughout this process I have grown a lot in the various areas of interaction design, HCI, and ecology.

Beginning this process, I believed I would focus much more on the HCI of plant interaction using systemic electrical signalling. However, my eyes opened to how complex human-nature disconnection was and how many different ways this can be addressed thorugh interaction design. While beginning, the literature felt endless and it was difficult to select a specific area to address. Therefore, defining a direction for the project was quite challenging. This is where I believe I grew the most: strategically defining a narrative and aligning design decisions with this.

Because of the interactive nature of the installation, in the beginning I did not want to scope down too, because there was so much to address. But, I quickly noticed that my ideas were going left and right, losing its direction and therefore its effectiveness. Through my feedback meetings with my coaches and my Tellart mentor, I kept being challenged at what the core issue of my problem was. And from that, my narrative derived. And I noticed that by the end, my ideation was highly aligned with my project and during ideation I began asking myself how my ideas aligned with the strategy.

While evaluating my final results, it all became clearer to me. To explain the results, I had to explain the thoughts I kept having in my head but could not fully explain. This led to the development of my framework - the thoughts I had all along, but now organised for others to understand. This helped me realise that in future projects, I would like to focus on creating a strategic mapping of what I want to achieve, in order to keep checking if my project aligns with my whole strategy and be able to explain this to others.

Besides this, I learned the relevance of combining test results and designerly knowledge in interaction design. In many tests, I often followed what the outcomes indicated, while sometimes this differed from my own opinion. For example, the second and third protoype of the meta-concepts test scored very equally and people indicating they preferred the third because they felt most connected there. First I wanted to continue with that concept then, however, after reflecting on these outcomes with my Tellart mentor, we came to the conclusion that this was mainly because they felt calmer and calmness tends to connect. But, if I want to show liveliness and have people engage with the plant, the second prototype is much more interesting. This had my preference as well, but I was quick in believing the outcomes over my knowledge. However, with iterations and improvements, I believe that this outcome was much more effective than the other prototype. Later in the project, I did this more and more. And I aim to keep a reflective lens on my projects like this in the future: evaluating what exactly caused this and if this aligns with what I believe is best for the strategy.

Finally, even if the installation was a flop (which I am very happy it was not :)), my connection with nature grew immensly during this project. A goal of mine was learning more about plants, and I am fascinated with how much I learned through one project! By being more aware of plants and our connection with them, I noticed that on my walks to and from my internship, I would actively focus on the plants around me. This would relax me on the stressfull days and inspire me on the relaxed days. Not only me, but even my friends who so warmly supported me during my project started noticing them more!

The succes of the final installation was a massive reward. Even though I want to further improve the installation, it succesfully engaged 70 people in nature and improved at least 15 people's CWN.

While one installation may not be the whole solution to the problem, this makes me grateful that within my city, Rotterdam, I have been able to have an influence.

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Appendix A: Drivers of human-nature (Dis)Connection

The Factors Influencing Human-Nature (Dis)Connection

Factor	Explanation	Positive/negative	Source(s)
Experiencing nature enhances connection	Only need a few days in nature to feel connected Increases willingness to experience nature	Positive	https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf
Nature-related activities enhances connection	Doing more nature volunteering leads to visiting nature more often	Positive	https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf
Loss of emotional affinity with, love for, or interest in nature	Decreases further ambition to experience nature	Negative	https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf
Negative feedback loops decreases connection	Not liking nature makes you want to go there less, which makes you have even less affinity with nature	Negative	https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf
Beliefs of surrounding societal members influence yours	Family, friends, and educators beliefs and lifestyles disconnected from nature influence those of others	Negative	https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf
Devaluation of nature	Negative changes in public attitude leads to a loss of opportunity to experience nature	Negative	https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf
Psychological well-being benefits derived from nature	These cause people to have more positive environmental attitudes	Positive	https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf
Shifting baselines syndrome	The baseline of what people view as environmental health shifts through years and generations of it declining	Negative	https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf file:///Users/isabellaboezel/Downloads/s40362-014-0021-3.pdf - https://link.springer.com/article/10.1007/s40362-014-0021-3
Closeness of green infrastructure	"UK government agency Natural England recommends that everyone should have access to natural greenspaces of at least 2 ha in size, located within 300 m of their homes "	Positive	https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf
Confusing noticing nature with being in nature	Many initiatives focus on giving people more ability to be in nature, but this alone does not perse help people feel more connected, they need to also pay attention to nature in order to gain a greater feeling of connection. Therefore, many initiatives do not really aid the cause	Negative	https://findingnature.org.uk/2021/10/19/how-actively-noticing-nature-not-just-time-in-nature-helps-promote-nature-connectedness/
Noticing nature	Noticing nature is key to gaining appreciation for it, not just being in it. It activates pathways like sensory engagement, which is the first step towards other pathways like appreciating nature and feeling emotions or compassion. It also increases the wellbeing of the human " Commonality analysis showed that when considered in isolation, the 'noticing nature' activities accounted for around 50% more of the variance in nature connectedness than time in nature."	Positive	https://findingnature.org.uk/2021/10/19/how-actively-noticing-nature-not-just-time-in-nature-helps-promote-nature-connectedness/https://findingnature.org.uk/wp-content/uploads/2021/10/actively-noticing-nature-ecopsychology-accepted-version-personal-archive.pdf
Noticing sounds and sights of nature	Actively engaging with the sounds and sights of nature is very effective to boost human-nature relationship "watching and taking photographs of wildlife, listening to bird song and noticing butterflies and bees" caused high feelings of nature connectedness In photographing people expose themselves and focus on nature during photographing, editing, etc with close attention being paid to features it also creates a ""highly immediate and highly mediated" kind of knowledge that supports a better grasp of biospheric connections " Naturalist skills like birdwatching and drawing can improve CWN.	Positive	https://findingnature.org.uk/wp-content/uploads/2021/10/actively-noticing-nature-ecopsychology-accepted-version-personal-archive.pdf https://dl.acm.org/doi/pdf/10.1145/3681716.3681729
Biotic vs abiotic	People feel a stronger connection to nature when focussing on biotic elements rather than abiotic elements	Positive	https://findingnature.org.uk/wp-content/uploads/2021/10/actively-noticing-nature-ecopsychology-accepted-version-personal-archive.pdf
Real life exposure vs digital exposure	while both can strength human-nature relationships, real life exposure provides higher levels of sensory engagement and exposure with wildlife.	Positive	https://findingnature.org.uk/wp-content/uploads/2021/10/actively-noticing-nature-ecopsychology-accepted-version-personal-archive.pdf
Perceptions of self and how humanity fits into natural environment	In western countries people see themselves as separate and above nature through our anthropocentric viewpoint. This comes from unconscious socialisation of 16th and 17th century viewpoints. to achieve a human-nature relationship we should extend an individual's sense of self to include nature.	Negative	https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0177186#pone.0177186.ref027
Anthropomorphising nature	Could be important in including nature in the 'self'. "As natural elements are humanised, feelings of similarity and empathy are formed" Enhanced feelings of connection when calling nature Mr Nature in a study or when seeing a poster with human-like characteristics It also leads to a stronger dispositional empathy with nature (feeling of empathy with linked to your personality) Also tends people to feel more of a social connection to and empathy for nature	Positive	https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0177186#pone.0177186.ref042 https://www.sciencedirect.com/science/article/pii/S0022103113000292?casa_token=OtWz1IY0jMkAAAAA:2oH-MDhgGGOUOTLUqmqVLRyzk546VahICPwIUvf2dBinrSbWBBXmkI2Qk3FwdpVcmHaCZPuPHw#bb0250 https://www.sciencedirect.com/science/article/pii/S0272494413000273 https://www.mdpi.com/2071-1050/11/19/5430 https://www.sciencedirect.com/science/article/pii/S0022103113000292?via%3Dihub
Beauty of nature	Interacting with the beauty of nature positively impacts the relationship between connection to nature and wellbeing. But a paper also found it was not a significant independent predictor of nature connectedness	Neutral	https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0177186#pone.0177186.ref042
Symbolism to view nature	Symbolism can help people create positive schemas about nature and the connected self. Enhances "the experience of a connection with nature by expanding an awareness of nature leading to a deeper relationship or connectedness" It can be a "route to connectedness by providing a means to express the transpersonal experiences in a more than human world that connecting with nature provides"	Positive	https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0177186#sec019
Knowledge about and ability to identify species	I	Neutral	https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0177186#sec019
Social connection	Anthropomorphising nature can fulfil a need for social connection and affiliation. This can foster a deeper connection with nature.	Positive	https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0177186#sec019
Empathy	As defined as "the understanding and sharing of another person's emotional experience (Davis, 1983; Hoffman, 2008)" is often seen as the key of altruism. Towards nature this can be called Induced Empathy with Nature. People who take the perspective of the natural element suffering had a stronger compassion for them and desire to help them	Positive	https://www.sciencedirect.com/science/article/pii/S0272494413000273?ref=pdf_download&fr=RR-2&rr=99dd47a15a4a668c
Considering nature to be sentient	The recognition of another being's need it important for empathy, but then you do need to recognise plants as sentient. Studies found that some people find it difficult to empathise with nature when it is not personalised and feel a stronger concern for the environment	Positive	https://www.sciencedirect.com/science/article/pii/S0272494413000273?ref=pdf_download&fr=RR-2&rr=99dd47a15a4a668c

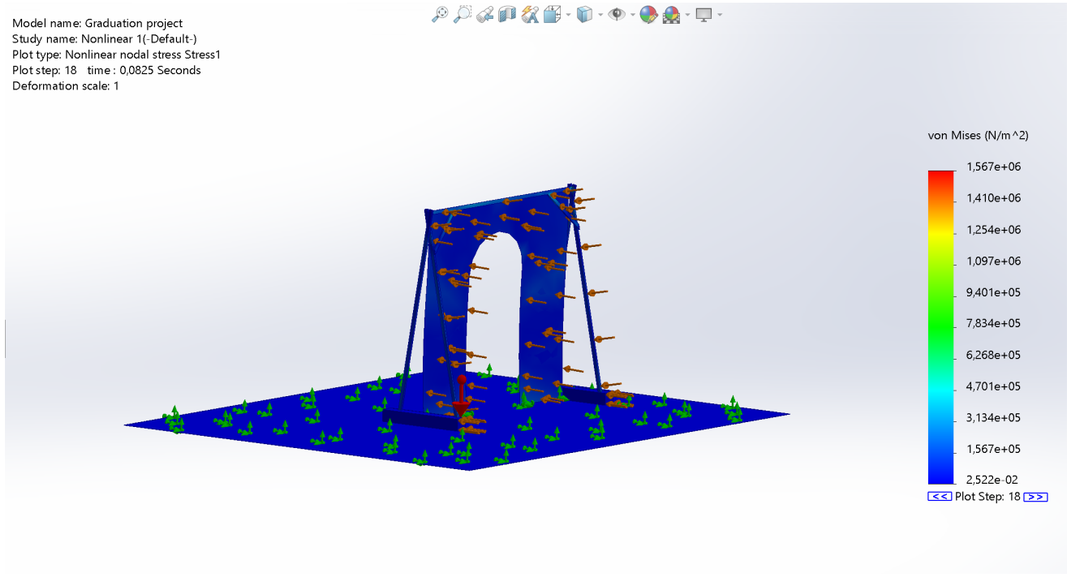
Losing the feeling of dependency on nature	Because we live in an industrialised world where we do not fully grasp where our food comes from and are less and less exposed to nature, we are losing our feeling of dependency on nature.	Negative	https://www.jstor.org/stable/pdf/24707479.pdf?refreqid=fastly-default%3A832ca06dd2e8ebcde8f28b5268c80020&ab_segments=&initiator=&acceptTC=1 https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource007361_Rep10598.pdf
Values and place in nature	The value we place on nature is related to how much we see ourselves as a part of nature	Neutral	https://www.jstor.org/stable/pdf/24707479.pdf?refreqid=fastly-default%3A832ca06dd2e8ebcde8f28b5268c80020&ab_segments=&initiator=&acceptTC=1
Nature is separate from human activity	In a study, people said they felt connected to nature but also described nature as "undisturbed by humans, pure, clean, uninhabited, and not human-made" This suggests that they see themselves as connected but not a part of - nature is still separate from human activity. The feeling of connectedness often came from sharing the same habitat, needing resources from nature or because they are both biological beings and part of a biological system.	Negative	https://www.jstor.org/stable/24707479?seq=10
Connection virtues: connectedness, action, affect, definition	Study found that people feel connected to nature on different virtues: Connectedness: interdependence between humans and nature for resources and we share a habitat. Action: their connection to nature comes from doing outdoor activities. Affect: almost exclusively from people that felt connected and includes emotions like caring, enjoyment and love. Definition: we are, by definition a part of nature. This paper shows that people often see themselves a part of nature while seeing nature as absent of humans.	Neutral	https://www.jstor.org/stable/24707479?seq=10
Cognitive dissonance	Cognitive dissonance can arise from the contradiction of people believing they are a part of nature but that nature is also separate from human activity. This often results in rationalising or denying subsequent thoughts or behaviours. But you can also have the possibility that people feel connected to nature but perform environmentally destructive behaviour which can lead to dissonance.	Negative	https://www.jstor.org/stable/24707479?seq=10 https://therelease.co.uk/the-danger-of-environmental-apathy https://therelease.co.uk/the-danger-of-environmental-apathy
Natural justice	A concept in indigenous communities that is a system of fairness between humans and nature. So it gives a moral responsibility and belief to the actions of both humans and to nature. This might also be because of the stronger reliance that eg. these Colombian Amazonian Letuama people's have on nature for providing them with shelter, etc. and is therefore also a more important cultural value. A feeling of reciprocity is very important for this.	Positive	https://www.jstor.org/stable/pdf/24707018.pdf?refreqid=fastly-default%3A441fb948d52f5b46cefdded66ab771b0&ab_segments=&initiator=&acceptTC=1
Plant blindness/Plant attentiveness disorder	The inability of a person to perceive plants in their environment, acknowledge their importance in the biosphere or appreciate plants' aesthetic and unique biological features. most common characteristics of plant awareness disparity is a deficit of knowledge, followed by an attention or memory advantage for animals compared to plants, and low interest in plants. Also caused by the failure to distinguish between plants and the fact that the perceived slow lifecycles and behaviors of most plants that do not captivate our attention in the same way that animals do (https://www.sciencedirect.com/science/article/pii/S0272494424000197?ref=pdf_download&fr=RR-2&rr=9842811c9fdbb97a#bib60). 4 components of PAD: attitude (disliking plants), attention (neglecting the observation of plant life), knowledge (not understanding plant life and its importance in ecosystems) and relative interest (finding plants less interesting than animals)	Negative	https://www.sciencedirect.com/science/article/pii/S0272494424000197?ref=pdf_download&fr=RR-2&rr=99dd487fbe589718
Reduced botanical education	The reduction of botanical education and rise of zoocentric and zoochauvinistic education is leading people to understand plants less and less teachers that can teach about plants. This contributes to our separation from the natural world, makes us blind to the biodiversity crisis and inhibits our ability to restore it	Negative	https://onlinelibrary.wiley.com/doi/epdf/10.1002/ece3.9019?src=getftr&utm_source=sciencedirect_contenthosting&getft_integrator=sciencedirect_contenthosting
Positive affect in nature	When people have a positive experience in nature - when they feel good in nature - they feel more connected to nature	Positive	https://www.sciencedirect.com/science/article/pii/S0272494424002640#bib51
Negative affect in nature	When people have a negative experience in nature - when they feel bad in nature - they feel more connected to nature	Negative	https://www.sciencedirect.com/science/article/pii/S0272494424002640#bib51
Feeling of awe	This in turn makes people feel more connected to nature and has been conceptualised as a form of self-transcendence	Positive	https://www.sciencedirect.com/science/article/pii/S0272494424002640#bib51
Love and compassion	This is also a self-transcendent emotion that makes people feel more connected to nature	Positive	https://www.sciencedirect.com/science/article/pii/S0272494424002640#bib51
Showing plant agency, needs and forms of creativity	Foregrounding plant agency, needs and forms of creativity is important to decenter humans in the process.	Positive	https://dl.acm.org/doi/pdf/10.1145/3681716.3681729
Evolutionary and physiological difference between human and plant	We are evolutionary further from plants (than animals), so we have more physiological differences in how our bodies work and behave. This makes it easier for humans to 'other' plants.	Negative	https://dl.acm.org/doi/pdf/10.1145/3681716.3681729
Attention Restoration Theory	Looking at nature restores our attentional focus and helps us recover from mental fatigue	Positive	https://www.mdpi.com/1660-4601/16/18/3373
Stress reduction theory	Nature can reduce stress, benefitting well-being.	Positive	https://www.mdpi.com/1660-4601/16/18/3373
Focussing on surroundings	In a study, both focussing on nature and the built environment helped people's wellbeing but most pronounced in people experiencing nature. The groups that benefitted most were people that were not in nature often in the past year and people that were in nature often in their youth.	Positive	https://www.mdpi.com/1660-4601/16/18/3373#B23-ijerph-16-03373
Increase in relaxed positive affect	A rise in a feeling of wellbeing from being in nature comes from a relaxed positive affect. high positive affect is excitement and activation was not a significant predictor for the increased wellbeing. So focus on calming, low-arousal states	Positive	https://www.mdpi.com/1660-4601/16/18/3373#B23-ijerph-16-03373
Water evoking positive relaxing affect	Water "evokes interest, aesthetic pleasantness, and positive feelings, such as tranquility (e.g., Hubbard & Kimball, 1967)" and scenes with water often have high pleasantness		https://www.researchgate.net/publication/232542780_Aesthetic_and_Affective_Response_to_Natural_Environment
Positive affects for exploration	Positive affects in nature incite exploration, staying in location or gaining environmental info		https://www.researchgate.net/publication/232542780_Aesthetic_and_Affective_Response_to_Natural_Environment
Story of Dualism	Humans have for long been told that humans and nature exist in a divide, they are mutually exclusive. And that we are superior to nature. This leads to ecological blindness - the tendency to overlook or willfully ignore environmental destruction because acknowledging our role in it would force us to question the core belief that we are separate from and superior to nature. This also denies our dependency on nature		https://www.tandfonline.com/doi/epdf/10.1080/17524032.2023.2199946?needAccess=true file:///Users/isabellaboezel/Downloads/s40362-014-0021-3.pdf - https://link.springer.com/article/10.1007/s40362-014-0021-3
De-anthropomorphisation of nature	As children we tend to see all things around us as living things and anthropomorphise them. When we get older this is socialised out of us. We should stimulate people to re-anthropomorphise nature in order to connect better with them.		https://www.academia.edu/66826973/Bodies_like_bodies_Multispecies_motherhood_in_the_anthropocene?auto=download&auto_download_source=social-news
Heightened use of screens and advertisements	Continuously takes away our attention from the (natural) world around us. This super stimuli contains more compelling sensory and emotional content		file:///Users/isabellaboezel/Downloads/s40362-014-0021-3.pdf - https://link.springer.com/article/10.1007/s40362-014-0021-3
CWN rituals	Typical CWN processes start with 'loosening up' like bringing awareness to your breath and body, then exploration and awareness of the human senses by directing perceptual focus and attention back to yourself and the natural world, then it can be followed by sitting silently, recording observations and reflecting on the experience. You may be encouraged to interact or commune with elements of nature as search for personal symbolism, messages, and meaning. " Personal rituals or expressions of thanks to nature may be performed and, finally, participants' might be encouraged to share their stories and insights with their fellow learners [166]"		file:///Users/isabellaboezel/Downloads/s40362-014-0021-3.pdf - https://link.springer.com/article/10.1007/s40362-014-0021-3
A feeling of community in nature	"CWN is considered causal in generating psychological benefits because of the "power of the feelings associated with belonging to a community or something 'greater than oneself'" [26,		file:///Users/isabellaboezel/Downloads/s40362-014-0021-3.pdf - https://

Intimate experiences	Allow 'wisdom training' needed to liberate the anger and despair often associated with environmental neglect and destruction		file:///Users/isabellaboezel/Downloads/s40362-014-0021-3.pdf - https://link.springer.com/article/10.1007/s40362-014-0021-3
Short terminism	The focus of institutions on short term improvements, making it hard to achieve change		https://therelease.co.uk/the-danger-of-environmental-apathy https://www.theguardian.com/sustainable-business/2014/nov/10/brain-climate-change-science-psychology-environment-elections
Social distance/optimism bias	The feeling that the consequences of climate change will not affect someone like me or in my area		https://therelease.co.uk/the-danger-of-environmental-apathy
Free rider effect	The bigger a group of people, the less effort individuals contribute to a common cause because they see themselves as dispensable. This undermines the power of the collective.		https://therelease.co.uk/the-danger-of-environmental-apathy
Loss aversion	Because climate change is such a far away and unpredictable issue, we are more afriad of losing what we want in the shot term than surmounting obstacles in the distance		https://www.theguardian.com/sustainable-business/2014/nov/10/brain-climate-change-science-psychology-environment-elections
Uncertainty of climate change effects	Because the effects of climate change are so uncertain we have difficulties to act on what we know for certain, that climate change is happening		https://www.theguardian.com/sustainable-business/2014/nov/10/brain-climate-change-science-psychology-environment-elections
Measurable tools	Carbon footprints have been useful tools to help aid climate change combatting because it allows you to measure improvement and compete. But there should be more, new measures for other aspects.		https://blog.openforests.com/our-disconnect-from-nature-is-key-to-understanding-environmental-destruction/ https://www.theguardian.com/sustainable-business/2014/nov/10/brain-climate-change-science-psychology-environment-elections
Lack of self control	Humans have issues with self control, especially with the uncertainty of climate change and loss aversion, we often seek what we like now, with a consequence for what we like in the future.		https://www.theguardian.com/sustainable-business/2014/nov/10/brain-climate-change-science-psychology-environment-elections
Perceived rarity of plants	This makes people more willing to pay in a study. So should be a significant driver of people's interest in the conservation of livign organisms		https://besjournals.onlinelibrary.wiley.com/doi/full/10.1002/pan3.10775
Temporary relieves	Temporary relieves such as the reduction of global warming through climate engineering is likely to draw attention away from the massive environmental destruction that's happening.		https://blog.openforests.com/our-disconnect-from-nature-is-key-to-understanding-environmental-destruction/
Anxiety from CC news	Because all bad news on CC creates a feeling of powerlessness that causes anxiety (backfiring), people start to ignore or even deny facts to release themselves from pressures on their self-esteem		https://blog.openforests.com/the-core-concept-of-sustainability/
Kinship = morality	Kinship thesis says that what is kind to humans gets a place in the moral universe		https://digitalrepository.unm.edu/cgi/viewcontent.cgi?article=1128&context=cj_etds
Homogenisation and reduction of local flora and fauna	This initiates a cycle of impoverishment of nature, followed by disaffection and apathy. This is progressed by a shifting baseline.		https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.9019
Viewing a plant in action	Triggers a similar level of brain activity as watching a human's action. Suggests that having more knowledge or empathy for plants can alter how our brain physically processes their movements, making them seem less strange. The brain also sees the moving plant not as a boring object but as an actor with a goal, just like an animal. Showing their actions could be a good tool to increase awareness and appreciation for the green world around us.		https://www.sciencedirect.com/science/article/pii/S0272494424000197?ref=pdf_download&fr=RR-2&rr=99dd48d60c889f93

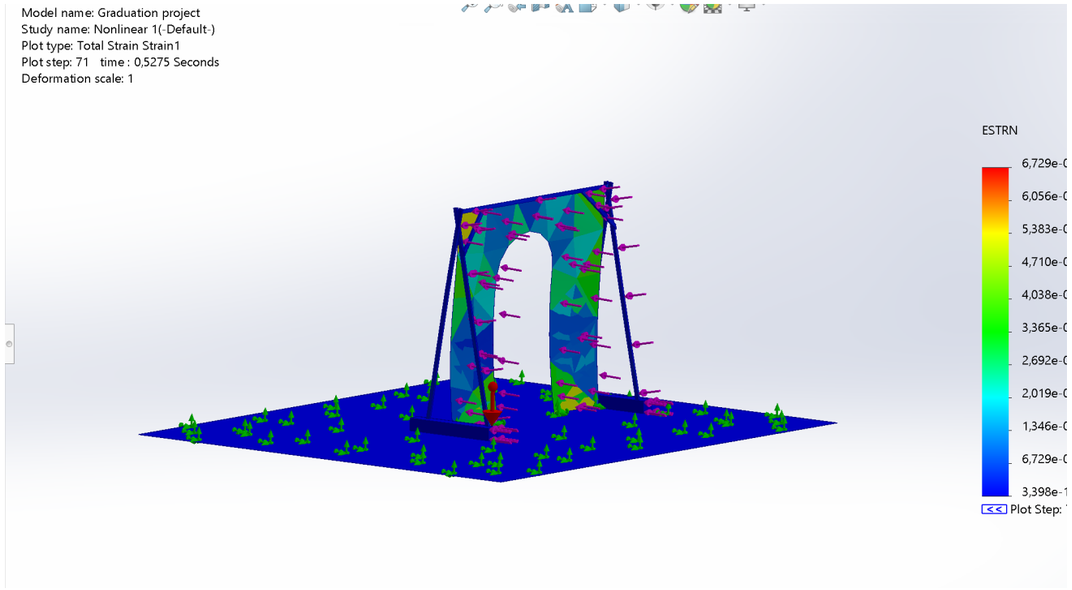
Appendix B: Structure Simulation

To test the ability of the structure to withstand being outside, simulations were done in Solidworks. A pressure of up to 210N/m^2, correlating to wind speeds of up to 69 km/h, were tested to ensure it can handle wind up to a 6 on the beaufort scale. The tests show that the structure itself remains very stiff and will not break under these situations and no large displacement was measured.

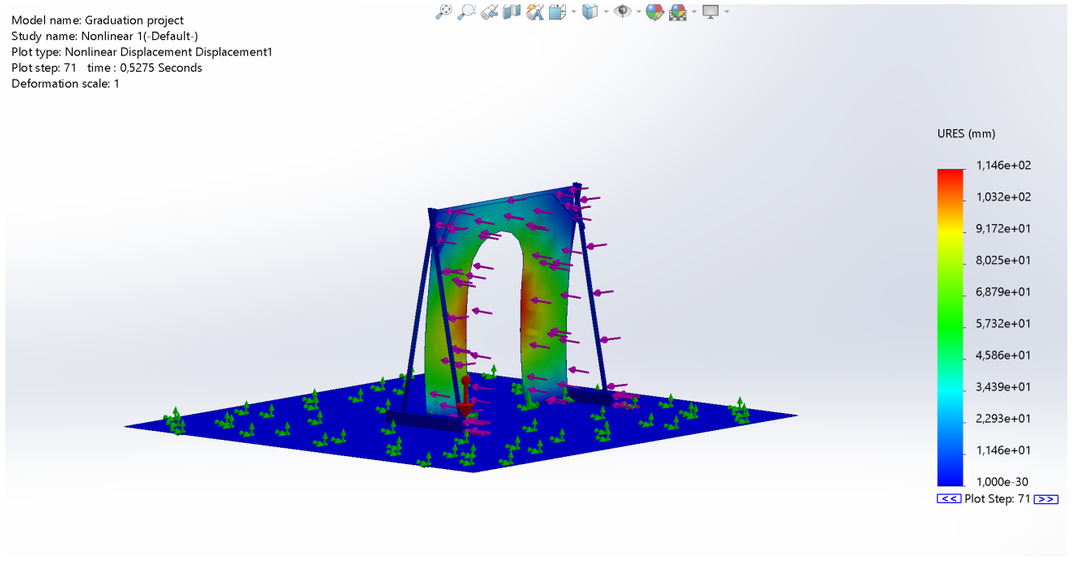
Simulation stress outcome:



Simulation strain outcome:



Simulation displacement outcome:



Appendix C: Co-creation sessions outcome

A pilot session revealed that applying the MDD experiential characterisation method in its original form in the co-creation sessions caused participants to adopt an analytical and objective perspective, focusing on categorisation rather than emotional experience. This reduced emotional engagement with the plant and conflicted with the project's aim of fostering calmness and connection. The Co-Creation method was adapted in three ways:

- Emotional ranking replaced material descriptors, allowing participants to express affective responses instead of objective properties. This adaptation is based on affect-driven design research, which positions emotions as intentional design outcomes (Desmet, 2012).

- Participants were asked to score on a graph rather than categorical judgement, enabling relative comparison between interaction concepts rather than fixed classification to promote remaining in an experiential state rather than scientific or objective mindsets.

- Co-creation replaced evaluation, shifting the focus from assessing existing experiences to collaboratively imagining future human–plant interactions, consistent with generative co-design principles (Sanders & Stappers, 2008).

This adapted method resulted in emotionally richer and more meaningful insights, better aligned with the project's objective of reducing psychological arousal and supporting human–plant connection.

All co-creation sessions were conducted one-on-one with individual participants to support introspection, emotional awareness, and calm engagement, and to avoid social influence on subjective experience.

Appendix D: Analogy Evaluation Methodology

The analogies for the ideation phase were treated as design tools that supported the generation of ideas aimed at eliciting positive affect. To avoid superficial copying, the analogies were analysed using structure-mapping, focusing on the relational mechanisms that create connection and mapping these mechanisms onto the installation's interaction with plants. The analogies were interpreted through a Positive Design lens, focussing on pleasure, personal significance, and virtue, to ensure concepts supported not only curiosity, but also connection and empathy (M.A. Desmet & E. Pohlmeyer, 2013).

Each analogy was analysed to evaluate the participant role it implies, the relational mechanism through which connection is generated, and the affective outcome it tends to produce. This was then translated into concrete design moves across the three phased journey.

Appendix E: Biodata Measurements

CO_2 exchange (air around leaves)
Stem CO_2 using low-cost NDIR (e.g., COZIR-A) and fluorescence (e.g., LuminOx) sensors integrated into a customized chamber system controlled by an Arduino-based data logger (Helm et al., 2021). This can provide a clear metabolic signal, but the need for a chamber and controlled airflow introduces design trade-offs between measurement reliability and an open, non-intrusive visitor experience.

VOC emissions (air around leaves)
VOCs are one of the plant's communication networks with other organisms. This can be measured with MOx gas sensors (e.g., Figaro TGS 2602) or through more expensive and less transportable proton-transfer-reaction mass spectrometers (PTR-QMS). MOx sensors detect broad changes rather than distinct compounds, so the signal is best framed as a coarse indicator of chemical activity rather than precise data (Collier-Oxandale et al., 2019).

Sap flow (branch/stem)
Sap flow velocity can reflect plant transpiration and hydrological balance related to water transport and environmental conditions. It can be measured with temperature probes (e.g., Type T thermocouples) inserted into a stem following the heat ratio method (Cárdenas et al., 2019).

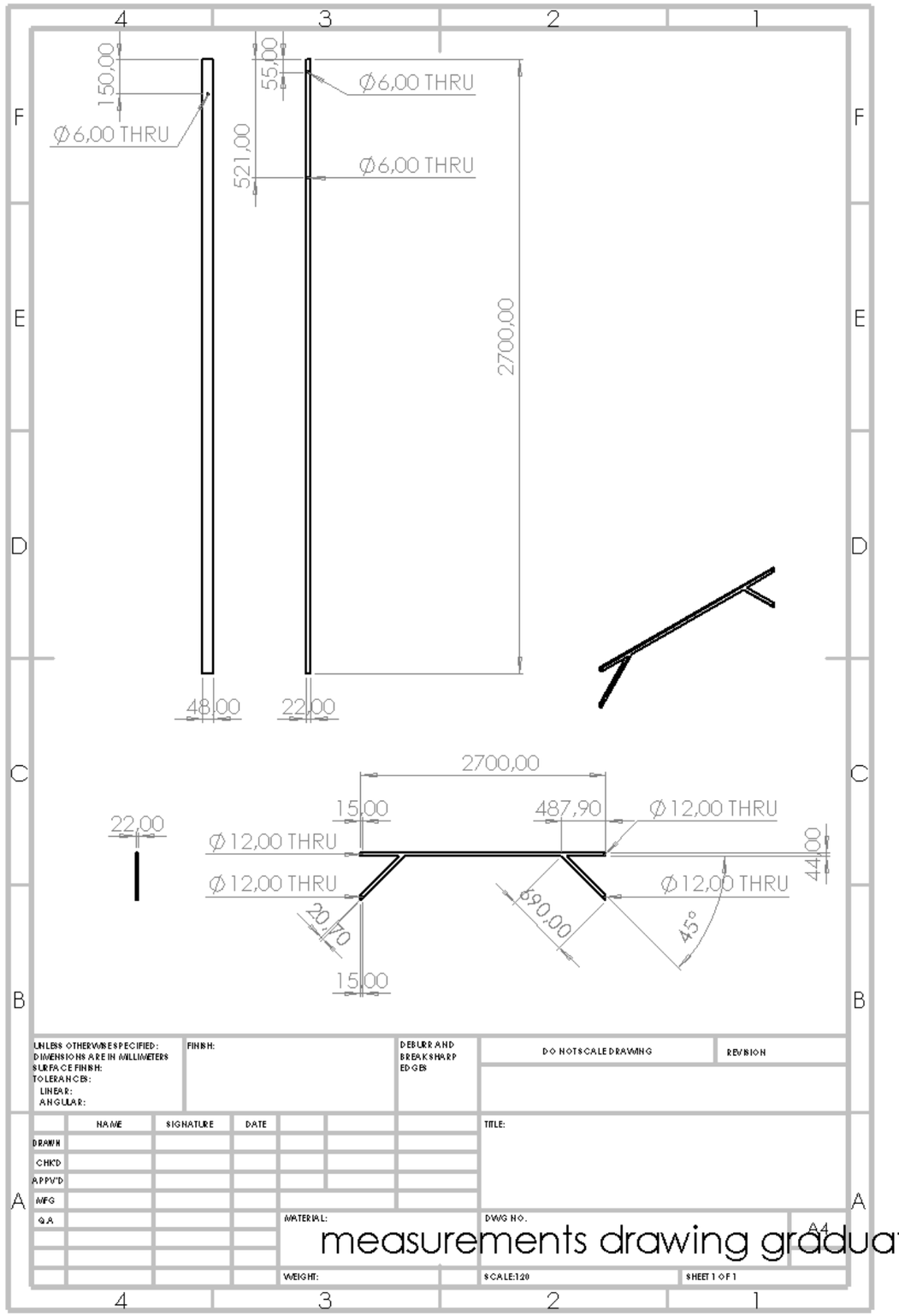
Soil conductance and soil moisture (root zone)
Soil conductance (EC) can be linked to nutrient availability and root-zone conditions, measurable via a DIY two-probe EC meter (AC excitation). Soil moisture reflects water content essential for hydration and nutrient transport, measurable via a capacitive sensor (with calibration) or a dielectric sensor. These root-zone measures are often robust and field-feasible, but they are indirect: they describe conditions affecting the plant rather than plant signalling itself, so they should be communicated as contextual drivers of plant state (Camdenl08, 2014).

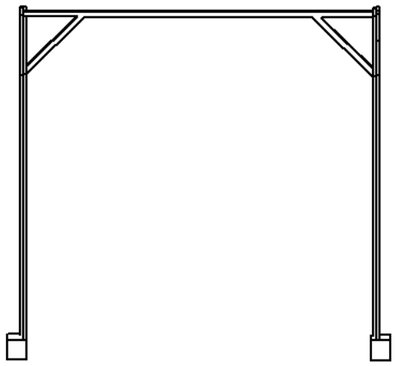
Leaf electrical potential (electrophysiology) (leaves, branches and stem)
Electrical potential signals can indicate stress and systemic signalling, including communication processes and circadian rhythms (Fromm & Lautner, 2007; Choi et al., 2016; Kozlova et al., 2025). In practice, this can be measured using electrodes combined with a microcontroller (e.g., Arduino) and a high-impedance amplifier (Volkov, 2006; Volkov, 2012; Kernbach, 2022). The main implication for design is that the signal can be treated as a dynamic responsiveness channel, but it demands careful handling of noise, grounding, and stable electrode placement (Volkov, 2006; Armada-Moreira et al., 2023).

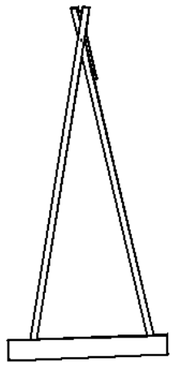
Appendix F: Selection of First Phase Concept

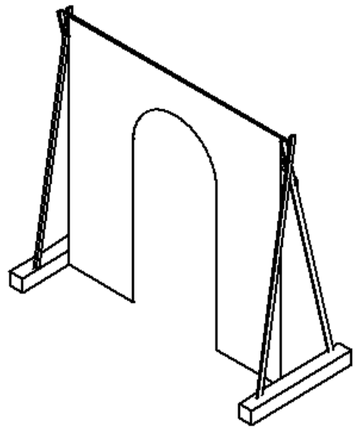
Design Parameter	Concept 1: Fabrics with audio	Concept 2: Wooden stepping stones	Concept 3: Audio and wood chip path
The plant with which the interaction occurs must be the focal point of the interaction.	8	7	6
The first phase should create a calm, receptive state that stimulates focus on the current experience of their sensory experience of the plant.	8	7	7
The first phase should have a low cognitive load	8	7	7
The first phase should have sensory conditions that support “slowing down” rather than stimulating fast interaction.	8	7	6
The experience must engage sensory modalities to create an embodied experience that grounds connection in experiential knowledge rather than cognition alone. By engaging the full sensory field, visitors experience plants as living beings rather than distant objects.	8	8	8
The installation must cultivate calm, relaxed, low-arousal positive emotional states rather than excitement or high stimulation, avoiding instant gratification. Gentle pacing and opportunities for stillness are essential, as this increases well- being and connection.	9	7	8
Encourage a meditative and calm state in phase 1 by minimising distractions and directing attention to sight, sound and/or scent, helping people stay emotionally engaged rather than overanalysing.	7	7	7
Guests should be guided into focussed attention on the plants in order to enable emotional resonance, create the perceptual intimacy necessary for relationship, and realise that every plant has its own agency and behaviours.	8	7	6
The First phase should highlight the scents, sights and/or sounds of nature to to guide guest’s attention to their senses that best enhance a feeling of calm.	8	8	8
Guest must be guided and stimulated to engage in the installation	9	6	4
Total	72	65	63

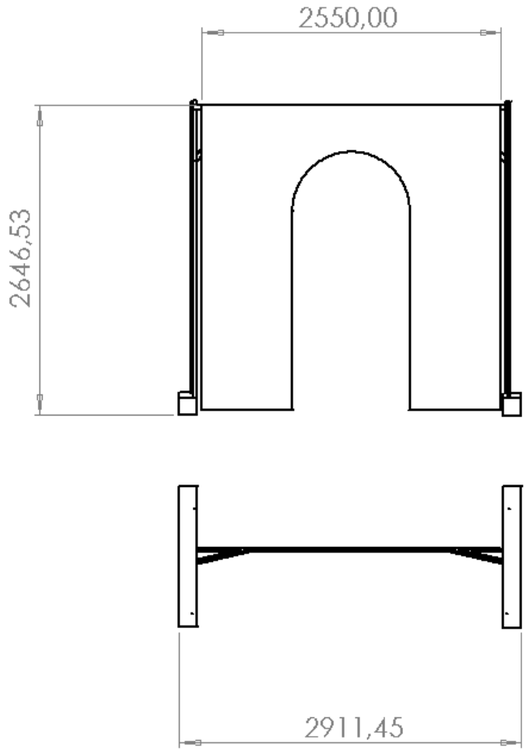
Appendix G: Technical drawing of strucutral elements







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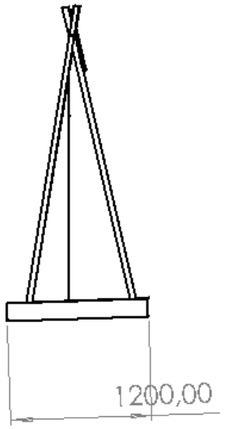
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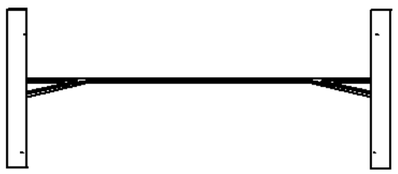

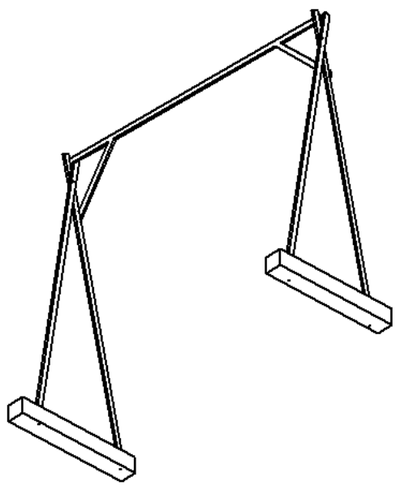

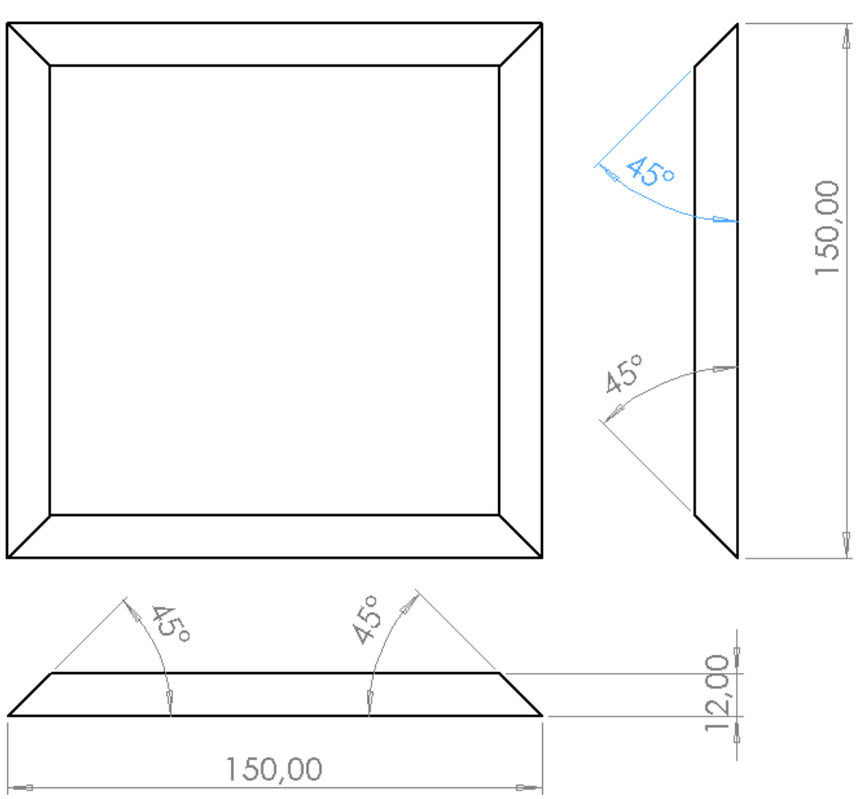
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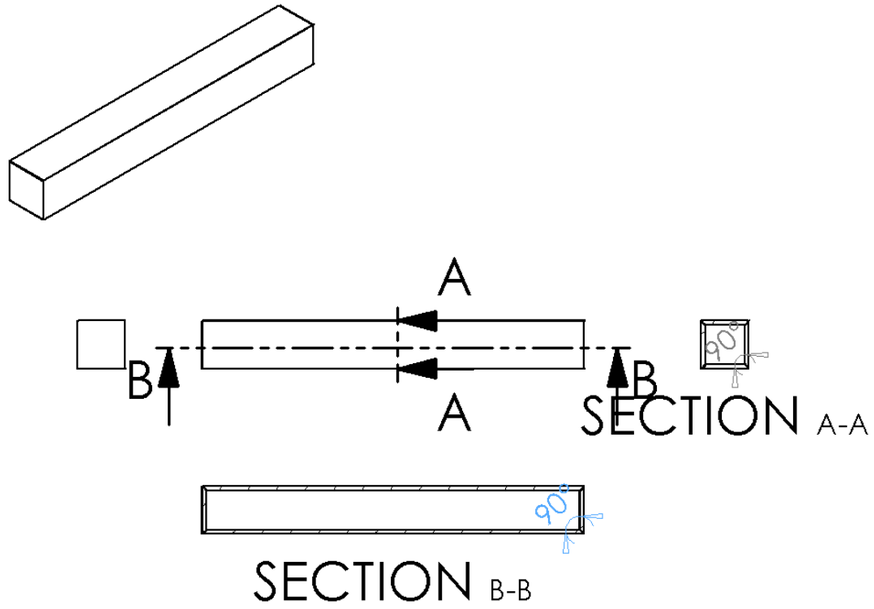
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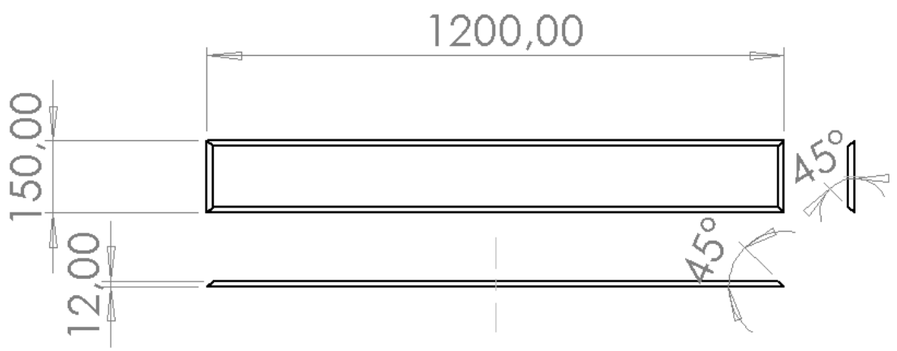
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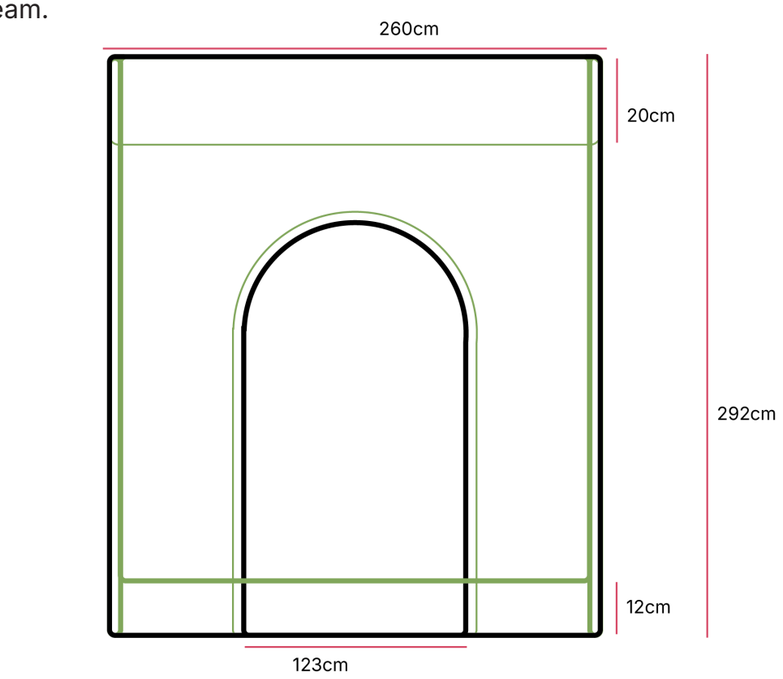
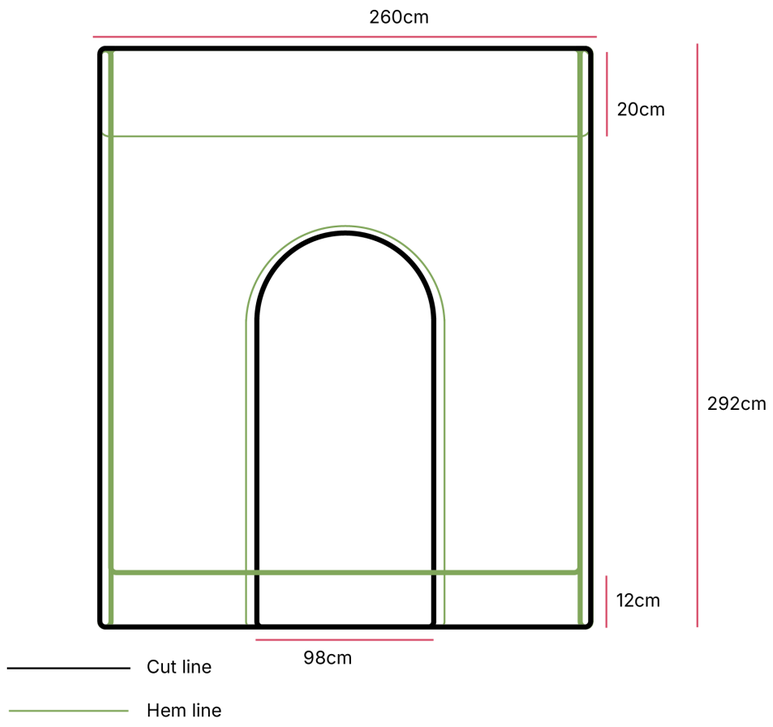
All fabric edges ahve a double hem of 6cm (3cm folded over twice). The bottom is 12cm that becomes a loop for the wooden rod at the bottom and is closed on both sides with the wooden rod inside. The top 20cm is wrapped around the traverse beam and then stapled (at many points to increase strength and reduce breakage) tot he traverse beam.





Appendix H: Final evaluation survey

Statement	BEFORE (Connection to Nature in General) Rating 1 (fully disagree) - 7 (fully agree)	AFTER (Connection to This Tree) Rating 1 (fully disagree) - 7 (fully agree)
I feel a sense of oneness with the natural world / this tree.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I feel connected to the natural world / this tree.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I feel a sense of kinship (friendship) with the natural world / this tree.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I feel like I belong to the Earth as much as the natural world / this tree does.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I feel that the natural world / this tree is not merely an object, but a presence.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I feel calm and relaxed.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I noticed many small details of my experience	1 2 3 4 5 6 7	1 2 3 4 5 6 7
My thoughts are clear and focused.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I noticed various sensations caused by my surroundings (e.g., heat, coolness, the wind on my face, scents, textures)	1 2 3 4 5 6 7	1 2 3 4 5 6 7
When I am in a park I notice individual plants, not just the forest as a whole. / I noticed this individual tree, not just the surroundings.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
When I take a walk outside, I notice the plants around me. / I noticed the specific details of this tree.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Being around plants makes me feel happy. / Interacting with this tree made me feel happy.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I enjoy caring for plants in an outdoor environment. / I enjoyed "caring" for (attending to) this tree.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I enjoy going outdoors because of all the plants in the environment. / I enjoyed this installation because of the tree.	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I am interesting in learning more about plants	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I am interested in plants	1 2 3 4 5 6 7	1 2 3 4 5 6 7
I think plants are useful to learn about. / I think this tree is useful to learn about.	1 2 3 4 5 6 7	1 2 3 4 5 6 7

In your experience, what caused the vibration and sound changes?

- The chair (mechanical program)
- The tree (biological signals)
- I don't know

To what extent did the following factors help you feel connected to the tree? (1 = Did not help at all, 7 = Helped immensely)

1. Slowing down/Calming in the arches:
2. Learning information about the tree's signals:
3. Feeling the "liveliness" (vibration/response) of the tree:
4. Having a lot of attention for the tree:
5. Focusing on my senses (smell/touch) before sitting:

How much did your attention for the plant increase (1= no attention for the plant), 7=full attention for the plant)?

How much did your information about the plant increase (1=no information gained, 7=much information gained)?

How alive/agent does the plant feel in comparison to before the installation (1=not alive at all, 7=very alive)?

How calm do you feel in comparison to before the installation (1=not calm at all, 7=very calm)?

Dear friends and family, thank you for supporting me in this project.

Dear reader, I hope you enjoyed reading this thesis as much as I enjoyed making it.