Master's thesis in Interaction Design and Technologies

NEBULA

An Interactive Experience utilizing Biosignals for Creation in Virtual Reality to support Well-Being

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Abstract

Advancements in virtual reality(VR) technology offer the possibility of applying novel input methods that can result in more immersive VR experiences. This thesis investigates how people can use their biosignals, namely hand movements, breath, and heart rate, to create art within VR and evaluates how such activities can be conducive to well-being. It introduces Nebula: a VR creation experience, which was designed with a research through design approach, informed by artist interviews, playful hacking, and soma design. The process resulted in; (1) considerations for designing a VR experience where biosignals are used as input for creation and (2) identification of biosignal-driven activities in VR that are conducive to well-being. *Nebula* is conducive to hedonic well-being as users derive joy, satisfaction, and relaxation from creating and eudaimonic well-being as they learn about themselves through creating and new ways to express themselves. Nebula opens up a design space at the intersection of art, VR, and biofeedback. The results lay the ground for future research into this immense, virtually unlimited design space of using biosignals for art creation in VR.

Keywords: well-being, virtual reality, biofeedback, biosignals, art, soma design, somaesthetics, ux, HCI, research through design

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Birgir Baldursson & David Peterson, Gothenburg, June 2022

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1
Introduction

People have been creating arts for thousands of years [1]. A plausible reason to why is because the creation of arts can have several well-being benefits [2, 3, 4] and support sense-making activities [5]. Artworks are essentially an artist's expression, manifested in a medium of choice [6]. Technology can support art creation and, thus, as technology evolves, the possibility of new art mediums increases [7].
Virtual reality (VR) is a fast growing emerging technology [8] that has the potential to support human creativity and unleash new forms of human creations, such as being a new medium for art [9]. What is created within VR does not have to obey to the same laws that apply in the real world. Things in VR do not need to, for example, obey to gravity and material resources are not of scarcity.
One promise of VR is the feeling of immersion. Research also shows that new forms of input, other than from the hands and direction of the user's head, can additionally increase the user's sense of presence in virtual environments [10]. Companies like Teslasuit are developing products to allow the whole body to be part of the experience with wearable technology that both contains a wide range of sensors and various forms of outputs (such as haptics and electro-stimulation) [11]. This provides opportunities for enhanced immersion into VR, but we also see a potential for utilizing this new medium for creation in new ways, making use of measured biosignals as input. A biosignal is "any signal from living beings that can be continually measured and monitored" [12]. A wide range of biosignals can be utilized, but commonly used in commercial video gaming and game research are: Electromyography (EMG), Electroencephalography (EEG), Electrooculography (EOG), Electrodermal activity (EDA), Electrocardiography (ECG) [12]. Utilizing biosignals for creating means that artifacts created in VR can for example take shape based on the creators' heart-rate.
In this thesis work we explore a design space at the intersection of art creation, biosignals, and VR. Previous work show how art creation, reflection and contemplating on one's biosignals through biofeedback can support well-being [2, 3, 4, 13]. To our knowledge, no prior work has combined art creation and biofeedback within VR, which offers a potential for stronger immersion and higher artistic freedom.
We utilize a soma design approach, which is an approach that emphasizes designing for the soma; the body and the mind as a whole [14]. We include the soma principles to support our exploration through the design space, as reflections, sense-making, and well-being are at the core of soma design. We chose soma-design due to the immediate accessibility of designers and knowledgeable within this area to consult, one of them being our supervisor. The final delivery will be a design focused on somatic connection, combined with the design considerations for this space. To

support an exploratory process, we apply a Research through Design approach in a playful manner, being guided by material explorations between VR and Biosignals rather than driven by a specific design problem.
In this thesis we report on the whole process, present a final artefact: *Nebula*. Grounded on our design project and an evaluation conducted with 12 users, we attempt to answer two research questions poised on the design space between VR and Biosignals, and informed by art practice and soma design theory.

Research question 1:*"What should be considered when designing a VR experience where biosignals are used as input for creation, as informed by art practice?"*

Research question 2: *What creative biosignal-driven activities informed by somaesthetic appreciation in VR are conducive to well-being?*

1.1 Delimitations

The work of this master thesis was limited to 10 weeks. During the thesis work we aimed to explore a design space related to both well-being and arts – two vast topics with many different perspectives. It was outside of our scope to thoroughly research all the well-being perspectives and sensitise us towards the intricacies of arts. Therefore, a major delimitation of our project is that we merely scratch the surface of both topics which could mean the results have severe limitations both in terms of the theoretical approach to arts and to well-being.
Our design relies on a rather wide understanding of well-being. There are several aspects to this topic and achieving well-being could even be considered a "wicked problem" as the right solution for each person varies not only between people but also with time. Thus, our understanding of how to achieve well-being will be limited to the body of research, knowledge, and debate that exists in this space that we manage to review as well as personal preferences of other stakeholders in the project.
Our understanding of art and its inherent intricacies is also a limitation during this project. We are bound to our artists interviews, the theoretical foundation we have acquired during our literature review and our short experiences of creating art, as neither of us are art connoisseurs or artists. One clear manifestation of this limitation comes in the form of our possible inability to connect with the reasoning of artists and the tacit knowledge they possess on a deeper level.
The precision and quality of the sensors used in this project varies. This is due to limited budget and the exploratory nature of this project. We are sponsored by Volvo in this thesis work with a few high and low-grade sensors.
In many art practices, art can be created in a collaborative or at least shared experience. However, the time allocated for this thesis does not accommodate for handling the increase in technical complexity if this experience should allow for multi-person use. This means that the experience only allows one user at a time.

It would be interesting to look at the longitudinal effects of this experience. The time-frame does however not allow for this, thus the experience will be evaluate for single use only.

1.2 Stakeholders

Besides the authors Birgir Baldursson and David Peterson, these are the stakeholders in carrying out this thesis.

1.2.1 Chalmers University of Technology

Chalmers is the university at which we will be writing our thesis. We are required to meet Chalmers' academic requirements on a master thesis. Staffan Björk is the master thesis examiner at the Interaction Design and Technologies masters programme (IxD) and, Mafalda Samuelsson-Gamboa is our supervisor of the thesis.

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1.2.2 Volvo Car Group

Volvo is a mobility company with a strong emphasize on safety, personalization and sustainability. We approached their *Open Innovation Arena* which work a lot with extended reality (XR) in order to imagine possible futures for Volvo Cars and the way of working. The team at Volvo supported our idea of Virtual reality + Biosignals and have dedicated resources for the completion of this thesis.

Mentor: Aljoscha Ledwa
Email: aljoscha.ledwa@volvocars.com

1.2.3 Creators and other users

The target user is ultimately anyone interested in art, creation in VR and/or in enhanced body awareness and well-being.

1.2.4 Developers, experience designers and researchers

The resulting design considerations from this project is aimed towards virtual reality developers and designers with an intent to create immersive personal experiences. For examples entities considering well-being, personal development, self-discovery or training.
Furthermore, opening up and problematizing this design space creates new opportunities for knowledge accumulation for IxD, VR and biosignals.

2
Background

This chapter presents the project background, virtual reality, and biosignals. It is concluded with ethical issues of this project.

2.1 Project Background

This master thesis is conducted at the Open Innovation Arena (OIA) at Volvo Cars AB, an international company that develops and builds cars. Volvo emphasize safety, personalization and sustainability in their cars, which serves as a northstar in their innovation and development. OIA focuses on exploration of possible futures for Volvo Cars while designing, prototyping and evaluating different concepts beyond the current business. In recent years, Volvo has utilized virtual and augmented reality for product development and research. Now as this technology is moving away from being solemnly limited to capital intensive endeavours (due to its previously high cost), consumer facing solutions are emerging and the advent of this technology in the car is highly plausible. Moreover, as autonomous cars are progressing, more time and freedom is given to the driver and as new, advanced sensor-technology is integrated into the car, there is a big potential to increase the utilization of this technology for the benefit of the driver and passengers.
Additionally, with Volvo's emphasis on well-being and "omtanke" (a Swedish word, roughly translated to "considerateness"), there is a strong desire to help and do good. Thus, Volvo is exploring ways in which it can provide and support well-being practices to its users. This thesis project will therefore contribute to Volvo's innovation through researching, designing and evaluating how biosignals can be used for art-making in virtual reality, and what sense-making and well-being activities it can support.

2.2 Virtual reality

Virtual reality (VR) is a synthethic environment in which the user perceives to participate in and not merely be an observer of [15]. This synthetic, three-dimensional environment is created with the help of stereoscopic technology which renders one flat two-dimensional image per eye. The slight difference between the images creates an illusion of depth [16]. VR is a multi-sensory experience with head tracking, enriched with binaural, spatial sounds to further create realness to the illusion. It further has a possibility of hand and body tracking to further increase the immersion. VR is coupled with mental and physical fatigue due to the heavy headset and

high stimulus level. The technology is also known for inducing nausea due to moving objects, discrepancies in action and effect, and insufficient refresh rates of the lenses [15].

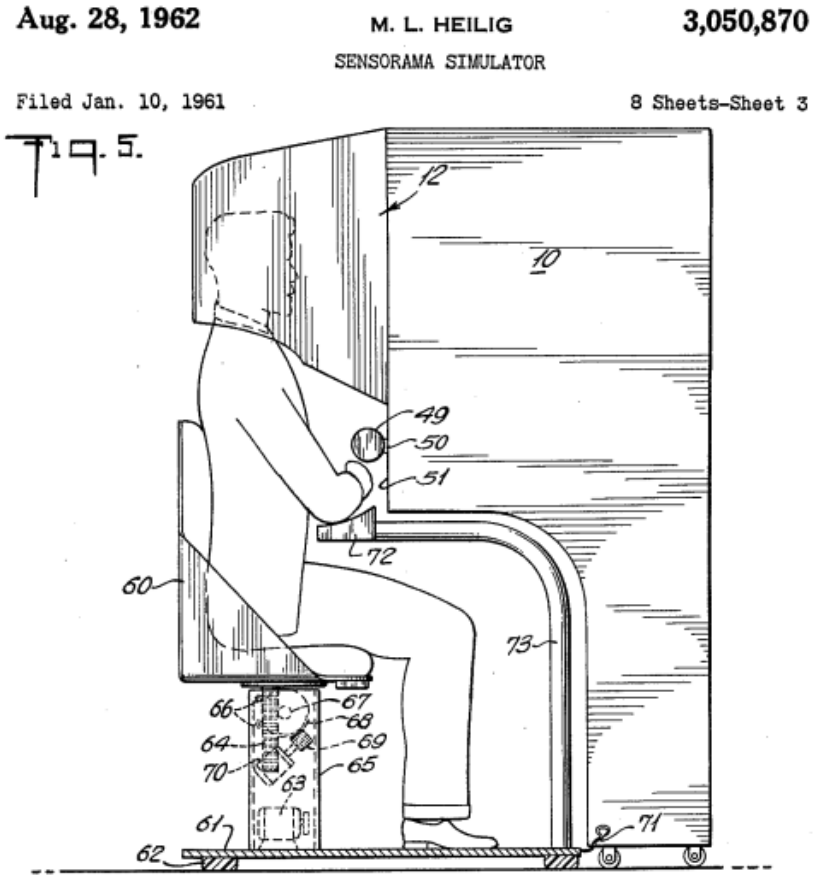


Figure 2.1: The earliest example of virtual reality, Sensorama. A patent and developed product by Heilig [17].

The first occurrence of virtual reality as mediated by technology is dated back to 1962 when Heilig patented the *Sensorama* [17]. The Sensorama was an immersive multi-sensory experience which incorporated sight, sound, smell and touch. In this early mechanical-device, a user could experience colored imagery in 3D with peripheral vision.

2.3 Biosignals

Naït-Ali explains biosignals as signals "recorded from the human body" [18]. It may refer to both electrical (e.g Electroenphalogram (EEG), Electrocardiagram (ECG) etc.) and non-electrical (e.g movements) signals [18]. Recording and reviewing these signals allows for a more comprehensive understanding of the human body.

2.3.1 Autonomic Nervous System

The autonomic nervous system is a component of the peripheral nervous system that regulates involuntary physiologic processes, including heart rate, blood pressure, respiration, digestion, and sexual arousal. It contains three anatomically distinct divisions: sympathetic, parasympathetic, and enteric [19].
The sympathetic nervous system (SNS) triggers increased attention and activity, a so-called "fight or flight" response [19]. This response is achieved by, for example, increasing the heart rate, blood pressure, respiration rate, and dilating the pupils.
The parasympathetic nervous system (PNS) counterbalances the SNS by inducing a state of "rest and digest" [19]. This state is achieved by lowering the heart rate and blood pressure, restarting digestion, and reducing respiration rate.
The enteric nervous system (ENS) is a "quasi-autonomous part of the nervous system" and acts independently of the SNS and PNS. Its primary function is regulating the digestive processes [20].

Prolonged exhales activates the parasympathetic nervous system A study made by Komori confirms that one can use breathing speed to activate either the sympathetic or the parasympathetic nervous system [21]. Furthermore, De Couck et al. goes on to explain how the ratio between inhale and exhale effects which part of the ANS is activated. Prolonging the exhale in relation to an inhale is conducive to an activation of the PNS.

2.3.2 ECG - Electrocardiograph

Electrocardiograph (ECG) is a graph with a signal representing the electric cardiac activity as it contracts to pump blood [23]. The electric signal is varying in its potential at different points of the body and by measuring with 10 electrodes, various insights can be drawn, such as; heart problems, blood flow, structural abnormalities, emotion recognition and biometric identification [24, 25, 26].

2.3.3 EEG - Electroencephalogram

Electroencephalogram (EEG) is a measurement of electrical activity in the cerebral cortex (or more precise a "summation of electrical potentials of neural cells") [27]. The neurons fire and oscillate within distinct frequencies bands, so called "brainwaves". These waves (alpha, beta, theta, gamma and delta) can be connected with certain mental states. No one brainwave is alone present at a single instance, but the ration between the brainwaves' prevalence is measured and conclusions regarding the mental state are drawn from these [27].

2.3.4 GSR - Galvanic Skin Response

Galvanic skin response (GSR), also refered to as electrodermal activity (EDA), measures the difference in voltage between two points on the surface of the skin. The skin's voltage is connected to arousal generated by the autonomic nervous system

which is triggered by “emotional or cognitive stressors”. The arousal generates skin perspiration (sweat) which changes the potential of the skin [28].

2.3.5 Respiration

The respiration process is the inhalation-exhalation process which exchanges the gas in the lungs. This gas exchange is necessary to fuel the body with oxygen which is required for multiple functions [28]. This process can be measured in multiple ways, although in this project a piezoelectric band will be used to measure the expansion and contraction of the thorax or abdomen [29]. Respiration is strongly connected to the sympathetic and parasympathetic nervous systems. In short, a high respiration frequency activates the SNS, causing a fight or flight response and a low frequency activates the PNS, causing a relaxed state [19].

2.3.6 Eye/Gaze tracking

Eye tracking can measure both pupil size, eye movement and eye position to understand focus and level of arousal. The eye movement and position gives information on what is being looked at or focused on. The pupil size increases with the arousal level [30]. In this report we will be using Varjo headsets which utilize camera images and "glints" (light reflections in the eye) to determine the eye direction [**VarjoTechnologies2022IndustrialHeadsets**].

2.3.7 Biofeedback

Biofeedback is the process of measuring biosignals and “feeding them back” to the user. There is no explicit mode of feedback, as it could range from concrete (e.g numbers, graphs etc.) to abstract (e.g colors, shapes or sounds). The biofeedback technique has the potential to help users with awareness and regulation of their physiological condition [31].

2.4 Ethical issues

Biosignals are an integral part of our project and, because how personal they are, they are the source of most of the ethical issues we suspect facing. In order to use biosignals for creation, we will both need to measure and store them to inform the creation. It is important that we are careful and considerate in regards to how we measure and store the biosignals and that participants are well informed about the process. Meaning, participants both need to know what we will be measuring and how we will use and store the data.
Furthermore, the act of creating with biosignals and reflecting on them might be very personal and emotionally upsetting. Strong emotions in front of strangers and in an unsafe environment might also be traumatising, which is a strong ethical issue. Additionally, during the evaluation of their experiences, they will be asked to recount their experience and what they believed caused it. If the matter is very private, it could make the user feel pressured. To account for this, it is necessary to create an

environment where users feel safe. Users should be informed about of the potential effects of the experience.
Using biosignals for creation is a form of biofeedback, and when incorporating biofeedback into designs to regulate anxiety it is important that the user has a sense of control [32]. Even though we are not designing for regulation of anxiety, we still need to have in mind that if users do not experience self-efficacy during the experience then the experience can be anxiety inducing and create negative feelings, which is an important ethical consideration that we need to be aware of.
We are also aware that measuring biosignals and utilizing them for creation within VR can evoke mixed feelings for our participants. Some, whom for example don't have good self esteem, might experience adverse thoughts during the creation because of that. Biosignals are also different between people and some, for example excess more perspiration than others, which affects the signal. During our prototyping workshops we need to be aware of that and account for it during our measurements and design without pointing it out explicitly to users.
Additionally, VR is a primary point of ethical concern, as it excludes the user from the immediate environment, disabling them from knowing what goes on around them. The user is highly exposed, and ensuring they feel safe and respected is crucial. Furthermore, VR commonly induces nausea and strains in the neck and eyes [15]. Therefore, we should create proper safety mechanisms to help the user if they feel bad.

3
Theory

This chapter presents the foundational theories upon which this thesis is written and planned. This chapter starts with the definition of art and artistic creation. We go on to present sense-making as it is closely related to art and artistic creativity. This is followed by two sections: well-being and soma design. There is work connecting art to well-being and soma design is a design approach supporting well-being through sense-making and body-centric experiences. Thereafter we address wicked problems as it relates to design problems in general, and research through design which is a design research approach we apply. Finally we introduce the fundamental theory of user experience, which permeate all work.

3.1 Art creation

As we want to design an experience where people can "create art" within VR, we will start of with giving a definition as to what is art and since that is a complicated philosophical question, we will also address definitions of craft and design, and through doing so, better more concretely explain art.

3.1.1 The definition of art

"What is art" is a philosophical question that many have attempted to answer by answering "what counts as art"[33] and even though the definitions differ they commonly agree that art has to be human-made [34]. There are also many theories about what is the purpose of art and even though there are various and evolving perspectives, the purpose is most often based on how creations should affect an audience [34]. That means that art, in its simplest form, is something created by people to have an effect on people. That is a very broad definition and could also encompass many other kind of creations. In the following section we will attempt to shine a little brighter light on what is art, but as that is an extremely difficult question that has been discussed in many waves through history, we will only scratch the surface of that topic and clarify which definition will be used as the foundation for this thesis.
No matter how art is defined, it is obvious that art needs to be created within a medium, something that serves the purpose of manifesting the creation. A way to classify different types of art, is to classify them by their medium: visual, auditory, verbal, and mixed [34]. Visual art is thus art that can be shared visually, auditory art shared by audio, verbal shared by language, and when they mix it is called

mixed arts. Some classical definitions of art characterize art based on a single property, namely representational, expressive, and formal [35]. There are theories and definition within each of these but essentially art as representation states that art should reflect the external world of the creator, art as expression states that art should reflect the inner state of the creator and the formalists theory relieves the creator from these duties [34].
The expression theory of art states that the function of the artist is to express emotions [36] . Collingswood is one whom has speculated about this theory of art and in his view, the creation of art is a means for artist to understand emotion, not merely translate them and thus artists do not fully grasp the emotion until after creating the artwork [33]. Following this theory, a difference between art and craft can be drawn that a craftsman should know in advance what shall be created and how to create it, an artist, on the other hand, does not know what she is creating until she has created it [34]. The artist and the craftsman might though be conducting the same activity and using the same medium for creation, but the purpose differs.
As stated before, some classical definitions of art are based on a single property, and thus they do not serve well to capture all aspects of arts. For example, the main criticism of the expression theory is how little it incorporates the imagination of the creator because the role of the artist is to express emotions [33]. In contrast, the formalist position towards art encompasses imagination much better since according to that theory, the main purpose of art is that it should be enjoyed and perceived, which liberates the creativity of the creator.
Based on the above, we believe the Britannica Online Encyclopedia defines art in a way that captures well various aspects of art, which is "modes of expression that use skill or imagination in the creation of aesthetic objects, environments, or experiences that can be shared with others." [6]

3.1.2 The definition of craft

Pöllänen described craft as "a distinctive knowledge that is intuitive and expressed through making and doing" [37]. Craft is defined by Shiner as to have the characteristics of body, medium, mastery and function [38]. An example of this is how the crafting of a wooden chair is incorporating the maker's body, the wood as a medium, mastery of the woodworking skill and the chair's function to unload the user's legs. Furthermore Shiner distinguishes craft as a "process and practice", not a "category of diciplines". We will further refer to it as a "process and practice". In terms of mastery, one necessitates practice to achieve mastery of a skill. Adamson defines craft as a general process of making, craftsmanship can therefore be considered as, in one sense, the act of developing this skill and using it to, with precision, create creations that are very much alike [39]. The ability to produce a creation in minute detail and handle the tools is an exhibition of true craftsmanship. This is again echoed by Anttila which stated that "Craft, as an activity, entails intuitive learning, which occurs in the craft process by evaluation and apprenticeship" [40].
A thorough review of texts from "92 textile craft makers aged 16 to 84" by Pöllänen states that the therapeutic effect in the process of crafting is naturally evident if one

is interested in it [37]. If craft has art-like qualities, then the therapeutic effects can be connected to when a person imbues love, personal histories and themselves into the craft product, thus, this process leads to strengthened identity, self-actualization and pure joy [41, 42]. The requirement of interest is grounded in the notion of a person not caring enough, thus not devoting themselves if they're not interested or motivated by either intrinsic or extrinsic motivation. It can then be argued that the lack of interest results in a weaker relationship with the creation and/or the process in itself.
Beyond these immediate effects, Tubbs and drake argues that the act of organizing material into a creation, is a great testimony to oneself that this organizing process can be achieved in one's own life as well [43].

3.1.3 The definition of design

According to the Merriam Webster dictionary, design is planning and making "something for a specific use or purpose", but design can also be the plans themselves, either manifested in one's mind or externalized somehow. [44]. Based on that, design differs from art and craft because designs can exists in a creators mind. Jones defined design as the "the initiation of change in man-made things" and according to him the objectives of design are more concerned with the design's benefits rather then the product itself [45]. Thus, Jones really emphasized that the change that the design should bring around should serve a specific purpose, ideally a beneficial one. Jones definition resonates well with the Merriam Webster dictionary that design is both planning and making.
In order to motive for design being its own discipline, Cross identified five aspects of designerly ways of knowing, to distinguish from scientific and artistic ways of knowing. The five aspects he identified are, (1) tackling ill-defined problems, (2) having a solution focused mode of problem solving, (3) thinking constructively, (4) use "codes" to translate abstract requirements into concrete objects, and (5) use these codes to "read" and "write" in object languages. [46]. Based on these designerly ways of knowing it can be concluded that design is not only about planning and making but also about problem solving, but that might be a too simplistic view. Cross states that designing is also about formulating a problem before generating solutions [46]. The problem understanding is thus vital for the design process, because as a problem solving process, designs can and should be evaluated on how well they solve specific problems that are often ill-defined. Based on the arguments above, design is a purpose driven way to creation. Simon articulated it well by stating that design is concerned with how things ought to be rather than how they are [47]. The purpose of design is thus to bring change in a direction that the designers designs for, which encompasses both planning and executing the change.

3.1.4 The relationship between art, craft and design

In the sections above we have discussed three forms of creations, namely craft, art, and design. We conclude, based on the arguments above, that design differs from art and craft in several ways. Design, is more so than art and crafts, interlinked with

problem solving and planning. The distinction is vague though because crafting a hand made mug, for example solves the problem of how to store and drink coffee. Additionally, if the mug where to include some aesthetic qualities, it could also be viewed as an art piece. Thus, art and crafts can also serve problem solving purposes. What differs though is that a design of a mug can be manifested in the design of the process of how to make a mug. Art and crafts on the other hand can only be manifested in the created objects themselves.

The discussion whether something is art or craft is a very old topic, as there's a strong link between art and craft. They can be considered to exist on a continuum as there are little differences between them, some even consider them to be non-existent [38]. When authors use the continuum metaphor, they argue that craft requires training of a skill but training oneself in expressing your emotions (art) is a skill, thus they are interlinked [48]. What differentiates art from craft is the lengths we go to, to make the ordinary extraordinary [49]. Adding a quirk, a new feature of some sort, adds creativity and new thinking to the creation. This new quirk can be an expression of self, which makes the creation unique and thus can be considered a piece of art. Although similarly, on the other side of the spectrum, it takes great practice and dedication to use tools so that every creation that one makes is similar to the other.

In common language the difference between arts and crafts is that "arts" is used for products and practices such as painting, sculpture, and printmaking meanwhile "crafts" to ceramics, weaving, and wood- and metalwork [50]. When analysing what counts as craft objects or art objects, Markowitz points out that craft objects usually have a practical or a utilitarian functions, while art objects such as paintings and sculptures do not [50], or they should have a value greater than the function [33]. Art objects, on the other hand, possesses aesthetic character which is often understood as the beauty of the artifact or the response it evokes when viewed, or as articulated by Danto, art should offer a possibility and necessity of interpretation [50]. Despite crafts utilitarian character it can meet the same aesthetic criterion of non-utilitarian arts because objects may well simultaneously be functional, beautiful, and evoke emotional responses [50]. An example of this would be art pieces that serve utilitarian functions, such as a Non-Fungible Token (NFT).

The difference between art and craft is thus blurry but as Markowitz points out that one reason for why people tend to interpret paintings rather than hand thrown mugs could be because the utilitarian functions of mugs and other craft artifacts are so obvious but the aesthetic function of paintings and art artefacts are not and thus requires mental activity [50].

The difference between art and craft gets even more blurry when craftspeople create commonly known craft objects but deliberately make them in an non-functional way, for example teapots with the lid glued on top [50] or when Marcel Duchamp's displayed common everyday objects as arts and called them ready-mades [51].

In conclusion, design differs from art in how its purpose is based on problem solving. Craft, on the other hand, has so many art-like qualities that distinguishing between art and craft within this project does not serve any purpose. We will thus be inspired by both art and craft within the project. The awareness of their similarities and differences will, however, support us in striving for a creation experience that is

more art-like than it is is craft like.

3.2 Artistic Creativity

Art and creativity are thoroughly interlinked and there are many theories of how they relate. Our work is grounded on Dahlstedt process-based spatial model of artistic creativity [7].
Dahlstedt introduces the notion of a “material space” which according to him is “the infinite space of inherent possibilities of the material”. Meaning, there are infinite possibilities of what can be created within each medium of creation (e.g. painting, music, or other). Tools, such as paintbrushes and music instruments, that creators use are thus both enabling and limiting factors to artistic expression. They are enabling in the sense that creators can use them to navigate the infinite material space, but limiting in the sense that they can only navigate “along the pathways offered by the tools”. However, when the tools evolve, the possibilities within that medium expand. The tools also affect how we think about the creative work, since our ideas and imagination are influenced by our knowledge of the tools and what has already been created with them.
Creativity is, in Dahlstedt’s model, essentially the act of exploring unknown space of possibilities. During the exploration, the creation is simultaneously represented in a “material representation” and a “conceptual representation”. A material representation is what the creator has manifested in the material space, such as painter’s strokes on the canvas, while the conceptual representation is manifested in the mind of the creator, in form of ideas and generative principles. The focus of the creator shifts between these two states during the creative process, and the mechanism to translate from one to the other are “implementation” and “reconceptualization”. Implementation is when the creators utilize tools to represent concepts in material, and re-conceptualization is when the creator interprets the material representation. According to Dahlstedt, "The discrepancies between the two[implementation and reconceptualization], and the imprecision of the translation in both directions fuels the creative exploration”. Thus, creativity is driven by the fact that nothing can be represented conceptually and materially in the same way, and the creative process is essentially the act of shifting between the two. In the example of the painter, the initial strokes on the canvas are not identical translations of the original conceptual representation the painter had in mind, and thus the painter re-conceptualizes an altered conceptual representation based on the newly formed material representation. This feedback process then continuous on through-out the creative process.

3.3 Sense-making

According to Dervin, sense-making does not distinguish between knowledge and information. Whatever sense someone makes of any information, at any given point in time and space, is knowledge. It is knowledge that is ”embedded in time and space”, and since reality changes across time and space, knowledge can change [53]. The study of sense-making thus refers to the study of how people make sense of their

experiences [52]. Russell et al., defined it more from the user's perspective stating that it as a process to answer task-specific questions, usually where the tasks are large, by encoding available information [54]. The fact that Russell et al. highlights "available" information underlines that people can make sense of information without having all the information, which aligns well with Dervin's notion that what people perceive is essentially what they know and also that sense-making usually refers to how people make sense of complex things where the information is vague [55]. Russell et al. also highlights that sense-making is a process to answer task-specific questions, and that aligns well with how sense-making is studied, which is how people make sense of certain tasks. In doing so, the researchers focus on the activities that people go through in order to make sense of the tasks [52]. Thus, sense-making can be viewed as an activity. For example, the sense-making activity of understanding your emotions.
In-depth one person interviews where people are asked to reconstruct how they perceived certain experiences is an essential theoretically-derived method to study sense-making. What people are asked to focus on while articulating their perceived experience varies depending on the research purpose but they are all focused on real experiences, not hypothetical situations [52]. That means that in order to research users sense-making, users have to be able to experience something first.

3.4 Well-being

The Oxford dictionary defines well-being as "the state of being comfortable, healthy, or happy" [56] which is a rather loosely vague definition. Gallup scientists have identified five essential elements of well-being that "transcend countries and cultures", and they are *career, social, financial, physical and community*. Which means that these factors correlate to ones perceived well-being [57]. In this thesis we will focus on well-being as related to the physical aspect of Gallup's definition, as this category also concerns mental well-being.
To better understand what constitutes well-being, it can be helpful to view well-being through two distinct philosophical definitions — namely, hedonic and eudaimonic well-being. The hedonic perspective views well-being as pleasure and happiness; meanwhile, the eudaimonic view encompasses self-actualization and meaningfulness as what constitutes well-being [58]. Although the two viewpoints oppose each other, we view them as supporting each other as well-being is a multifaceted phenomenon. In our project, we will refer to both theories.

3.4.1 Hedonic and Eudaimonic Well-being

The hedonic view of well-being is concerned with subjective happiness and pleasurable experiences. The hedonic theory is not about what activities bring people joy which is unique to each individual. It is rather about the subjective experience meanwhile doing whatever they do. In the hedonic view, improved well-being can thus be reached by doing more of what people deem pleasant and less of what they feel unpleasant [58].

In contrast to the hedonic view, the eudaimonic idea of well-being concerns people's actions and outcomes rather than their subjective experiences. According to eudaimonic theory, well-being is achieved by conducting activities that yield beneficial results. Whether the activities are satisfying is not the primary concern of eudaimonic philosophers, but rather whether the outcome of the action is good for people or not [58].

3.4.2 Well-being and Art Creation

Creating art and conducting in craft like activities has been shown to have many well-being benefits. Studies within non clinical samples have shown that:

- Colouring pre-drawn Mandala's for twenty minutes can reduce anxiety [59, 60] and improve mood [61].
- Colouring pre-drawn images for 30 minutes can both improve people's mood and relieve anxiety, especially with free choice of colours [62].
- Drawing free-form for 20 minutes with various choices of colours and pencils can improve people's mood [63].
- Manipulating clay for as little as five minutes can enhance people's mood [64].
- Creating art using collage materials, modeling clay and markers can lower people's cortisol levels, which is a stress indicator, regardless of previous art experience [5]. In the study participants reflected on the art-making session as "relaxing, enjoyable, helpful for learning about new aspects of self, freeing from constraints, an evolving process of initial struggle to later resolution, and about flow/losing themselves in the work."
- Creating visual art on a weekly basis for 10 weeks can strengthen psychological resilience (i.e. stress resistance) and increase self-awareness [65].

Gutman and Schindler also reviewed literature about neurological basis of common human activities and found evidence that activities that require constant engagement, such as arts and crafts, enhances health and well-being [66].

3.4.2.1 Art Therapy

Art therapy is when artistic methods are used to treat psychological disorders and enhance mental health [67]. As a psychotherapy technique, art therapy is conducted by professional art therapists. The art therapist encourage patients to create art to express their inner self and the skill level is not of concern. The techniques involve for example sculpting, finger painting, and drawing [67]

There are two main categories of art therapy. The first is based on the view that the creative process of creating art is therapeutic, and is often labelled "Art as Therapy". According to this view, making art is a way to express one self which can over time lead to personal fulfilment, emotional reparation, and recovery. The second category is based on art being able to serve as a communication tool and a conversation starter [68].

Stuckey and Nobel's literature review from 2010 explored the connection between art and health in a clinically ill population and found that visual arts is commonly used by to support patients in meaning making. Additionally, the studies they reviewed showed that visual art making, such as drawing, pottery, painting, textiles,

and other, had also support people in decreasing negative emotions and increasing positive ones, reduction in anxiety and stress, improved focus, and sense of self-worth [2]. Based on Leckley's literature review from 2011 on the effectiveness of creative activities on mental well-being, there is evidence to support that creative activities can have positive effect on mental well-being. For example, to promote relaxation, offer a means of self-expression, reduce blood pressure, boost immune system and reduce stress [3]. Jensen and Bonde's literature review from 2018, of the use of arts intervention for people with mental and physical health problems, concludes that there is growing evidence that engagement in art activities can reduce physical symptoms and improve mental health issues [4].

3.5 Soma Design

Soma design is a design approach grounded on the interdisciplinary field of somaesthetics, which is in turn grounded in pragmatist philosophy and phenomenology [14].
Shusterman coined the term somaesthetics by combining the words "soma" and "aesthetics" [69]. The Soma, according to him, "includes what is traditionally distinguished as mind and body" [70]. Soma is thus a term that opposes the division of mind and body, and in that view, the soma is both capable of actions that are commonly only associated to the mind or to the body. Aesthetics is, in his view, the ability to appreciate experiences, and as any ability it can be trained and enhanced – through what is called somaesthetic appreciation [14].
Soma Design, as described by Höök et al., is a design approach grounded on the somaesthetics theories of Shusterman. It is an approach that emphasizes designing for the soma, the body and mind as a whole, rather than only the mind as most current design approaches. The use of traditional design approaches have resulted in human-technology interfaces focused on language and symbol interaction styles but the soma design approach brings "an experiental, felt, aesthetic, movement-based interaction style". Höök argues that soma design methods are especially relevant to exploit possibilities of new interactive technologies that don't use a screen as a main communication point but instead interact via people's "movements, body postures, gestures, breathing, biodata, or facial expressions" to open up "a novel space of movement-based interactions" [14].

3.5.1 Somaesthetic Appreciation Design

Höök, has proposed several "strong concepts" within Soma design [14]. Strong concepts are abstracted design elements concerned with the dynamic gestalt of the designs, that can be applied through various use cases to generate different designs that carry the core idea of the concept [72]. "Somaeesthetic appreciation design" is one strong concept that Höök has formalized and its focus is on designing "applications where the interaction subtly supports users' attention inwards, towards their own body, enriching their sensitivity to, enjoyment and appreciation of their own somatics"[71]. There are four key qualities to somaesthetic appreciation design: "subtle guidance, making space, intimate correspondence and articulating experi-

ence."[71] and when they come together "users will find it easier to turn inward and experience their own somas." [14].

3.5.1.1 Subtle Guidance - directing attention inwards

The first somaesthetic appreciation design quality is about the subtleness of the stimuli that should guide users focus and attention inwards towards the soma. The stimuli needs to be noticeable in order to guide users but needs to be subtle enough so that users focus and attention does not shift outwards towards the stimuli.

Increased body awareness can both come from shifting the attention between different body parts and by practicing sustained attention in one area. The subtle guidance mechanism should thus support both. Finding the right balance of the subtleness of stimuli is challenging and thus a great care should taken towards the modality and source of the stimuli [71].

3.5.1.2 Making space - temporal, interactive and spatial places for reflection

The second quality is about designing for an experience that supports reflection making. Firstly, the design should "make space" for reflection by "slowing down the pace of life" and "actively disrupting everyday habitual routines". Secondly, the design should literally include a physical enclosed space where users feel safe and taken care of. Choosing materials carefully and being mindful towards not creating environments where people feel claustrophobic are two important factors to fulfill this quality [71].

3.5.1.3 Intimate Correspondence - feedback and interactions that follow the rhythm of the body

The third quality is about the feedback between the design's artifact and the user. The feedback should be immediate and synchronized with the "rhythms and flows of the body in a way that the interactive system is perceived more as an extension of the body than as a separate entity or communication counterpart". Thus the interaction should be implicit and the artifacts response has to correspond with the bodily experience of the users. Biofeedback is often utilized to design for this somaesthtetic appreciation quality. [71]

3.5.1.4 Articulating Experience

The fourth quality is about the articulation of felt bodily experiences. Experiences are subjective, but when articulated via language, visuals, clay, or externalized in any other way, they become shareable and comparable with other experiences. Reflection is needed to articulate; the more trained people are at such reflection, the more nuanced their articulations will become. [71]

3.6 Wicked Problems

Problems that are ill-defined and where no solution can be proven to be true or false can be called “wicked problems” [73]. Such problems can, however, be evaluated on their perceived quality, but the quality of the solutions of such problems are always dependable the problem formulation and Rittel and Webber states that the problem formulation process, of wicked problems, is the same process as the problem solving process [73]. That means, in order to understand a problem, one needs to attempt to solve it. Problems that designers engage with are often such “wicked problems”.

3.7 Research Through Design

Research through design RtD [74] is a research approach where design researchers engage in design practices, and evaluate their resulted artifacts for the purpose of knowledge sharing within the academic community [75]. According to Zimmerman, Forlizzi, and Evenson, RtD should be concerned with innovative design explorations that can bring a desirable change to current state of the world, and have a well rationalised and documented design process so others can build upon their work [75]. As RtD is concerned with “what might be” it is often used to address “wicked problems” where the solutions cannot be separated from their problem formulations. Thus, it is not an approach that acquires knowledge by validating hypothesis’s but should rather be “appreciated for its proliferation of new realities and its theory considered as annotation of the artefacts that are its fundamental achievements” [76]. As such, research through design artifacts can embody designs theories and either occupy a place within a previously defined design space or open up new design spaces [76].

3.8 User Experience

There are various definitions of what the term user experience (UX) means and what it should encompass. The international standard on ergonomics of human-system interactions, ISO 9241-210, definition states that a user experience is a “person’s perceptions and responses resulting from the use and/or anticipated use of a product, system or service” [77]. People are always encountering various experiences but according to this definition experiences that derive from certain products, systems or services can be referred to as the user experience of that particular product, system or service. According to the definition, an experience is also both what people perceive and how they respond, before, during and after use of a particular product, system, or service. Therefore, user experience encompasses everything from users “emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviors and accomplishments“ [77].
Since user experience is concerned with experiences before, during and after usage, Roto et al. proposed dividing user experiences based on which time span is in focus. The categories are “anticipated” which is the imagined experience, “momentary” which is the during interaction experience, “episodic” which is the reflective

experience after several usages and “cumulative“ which is the experience after extensive experiences [78]2. For this project we will utilize the ISO 9241-210 standard definition of user experience, with a focus on the anticipated and momentary user experience because users will only experience the prototype once.

3.8.1 Usability

Usability is, as defined by the international standard on ergonomics of human-system interactions, ISO 9241-210, “[the] extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” [77].
In comparison to the definition of user experience, usability is more narrowly defined and can be understood as one aspect of the user experience of the product [79]. Effective and efficient products which people are satisfied with using can certainly lead to a desirable user experience but that alone does not capture the whole user experience of the product. User experience is about peoples perception and responses before, during or after, but usability is about how specific users achieve specific goals within specific contexts and is thus the most related to the “during interaction” aspect of the products user experience.
Usability can be further broken down into six goals, that if followed and accommodated for appropriately should result in good usability [79]. The goals are the following:

1. Effective to use (effectiveness)
2. Efficient to use (efficiency)
3. Safe to use (safety)
4. Having good utility (utility)
5. Easy to learn (learnability)
6. Easy to remember how to use (memorability)

For this project we will use these usability goals as a guideline to ensure good usability.

3.8.2 Uncomfortable Interactions and Negative Experiences

When designing for user experiences, it can be beneficial to intentionally create uncomfortable interactions in the design to deepen the felt experience [80]. Benford et al. say that it is essential to manage the utilization of uncomfortable interactions ethically, and doing so is a helpful design approach when designing for entertainment, enlightenment, and sociality. These uncomfortable interactions can be both physical and mental. Benford et al. mention rollercoasters as an example of an uncomfortable physical interaction within entertainment where the intense accelerations on the rollercoaster are uncomfortable yet a vital element to the experience of thrill. Another example of Benford et al. is how mental discomfort through provocation in interactive arts can be conducive to enlightenment. Similarly, Fokkinga and Desmet argue for the advantages of designing for negative emotions to design rich experiences because the things we enjoy the most in our lives are neither simply positive nor negative [81]. Fokkinga and Desmet provide a three-step framework

for designing rich experiences. The framework has three components; a negative stimulus, subjective transformation, and a protective frame. The negative stimulus causes the negative emotion, which is conducive to the subjective transformation of the user's attitude and perception. These transformations are what give richness to experiences. The last component in the framework is the protective frame, which balances the negative emotions so the experience can be enjoyable. Fokkinga and Desmet provide four examples of protective frames. (1) The detachment frame, which can be created by having users interact with a representation of the negative stimulus. (2) The safety zone, which is created by designing a barrier between the user and the negative stimulus. (3) The control frame, which is created by designing how much control the user has over the negative stimulus. (4) The perspective frame, which is created by providing users with a perspective on the broader implications of the negative stimuli and how it relates to the user beneficially. Fokkinga and Desmet also list ten rich experience qualities and how they fit into the framework. One example is the "The challenging" quality. It is described as frustrating yet so engaging that people are determined to solve the task, and if they manage, they will experience a satisfaction. The negative stimulus in their example is in the form of an obstacle that is physical-, physiological-, social challenging, or skill-related. The resulting subjective transformations are demanding for the perception, and their attitude becomes more determined. The protective frame they then advise using for this quality is the control frame.

3.8.3 Ambiguity

Gaver, Beaver, and Benford explains how ambiguity "can be used to encourage close personal engagement with systems" [82]. Ambiguity applied correctly can make interactive designs both thought-provoking and engaging. It enables the use of low-precision sensors and inexact mappings by emphasizing the value of the personal interpretation of the output.

There are three categories of ambiguity that can be utilized in the design; (1) ambiguity of information focus on the artefacts itself, (2) ambiguity of context concerns the "sociocultural discourses that are used to interpret it", and (3) ambiguity of relationship describes the "interpretative and evaluative stance of the individual.".

Most commercial products with a utilitarian purpose stray away from ambiguity as it can cause confusion and lead the user away from achieving their purpose of using the product. **Gaver** goes, however, on to explain how ambiguity can be delightful, mysterious, and intriguing despite its risk of simultaneously being frustrating. Ambiguity can lead to personal affinities with technology as it similarly mirrors the ambiguous nature of the world, where most things have "multiple possible meanings". To design for information ambiguity, designers should "Use imprecise representations to emphasize uncertainty", which creates a mystique around the design and tempts users to make sense of it. Another example is to "Cast doubt on sources to provoke independent assessment", which can be achieved by using not completely certain mappings between sensors and outputs, causing the user to interpret and make sense of the system themselves, forming their own meaning. Ambiguity of context can support users to be more open-minded in their interpretations. This

can for instance be achieved by implicating “incompatible contexts to disrupt preconceptions.”. Ambiguity of relationship can help users question their attitudes in a way to adopt new beliefs and values. Pointing out things without explaining why or introducing side disturbing side effects are ways to achieve this.

4

Related Work

This chapter presents examples of work which have inspired the direction and shape of this project whilst having a strong connection to the Theory chapter. The examples, consisting of projects, consumer products and artists, are intersections of HCI, biosignal-driven art, virtual reality, Soma design and well-being.

4.1 The Breathing light and the Sarka

The Breathing light and the Sarka, figure 4.1, were both designed using a soma design approach and stimulated the identification of the *someasthetic appreciation design* strong concept [14, 72].

The Breathing light is a light stand which has fabric hanging down towards the floor. To interact with the product, users lie on the floor underneath the light stand where they are partly enclosed by the curtains hanging from the light stand, which creates a room for reflection. The light stand has a sensor that measures people's breathing rate and changes its brightness in correspondence with the users breathing. The product is designed to support users reflecting inwards and create a space for reflection [14].

Figure 4.1: The Breathing light which is controlled by the user's respiration and the Sarka, which encourages slow movement through giving audiatory directions and feedback based on the pressure of the user.

The Sarka is a pressure mat focused on movement. The experience is controlled via audio that encourages users to make small movements with certain body parts, and if users move accordingly and slowly, the soundscape will result in soothing sounds. On the other hand, if users move too quickly or vigorously the sound gets unpleasant.
Both products are good examples of how to design for somaesthetic appreciation. Both showcase examples of how the human body can have an intimate correspondence with a product, where the breathing light utilizes biofeedback and the Sarka utilizes movement feedback. Interestingly, Höök the designer of both products, notes that in their previous iterations of the Sarka said that they tried mapping movement to visualizations projected on the ceiling above users, but moved away from that solution because it drew too much attention outwards to the visualisation rather than inwards towards the soma. People were simply too mesmerized by the visualizations. The breathing light how ever managed to be subtle enough for users to reflect inwards but in that experience, however, users are encouraged to close their eyes. The light that still manages to travel through our eye-lids is a good stimuli for people to reflect inwards. Höök speculated that visual stimuli would be to strong for supporting inward reflection.
What is interesting here is that Höök, one of the main contributors to the soma design theories, has warned against using visualizations for somaesthetic appreciation designs, and yet we propose designing for somaesthetic appreciation within an VR experience which is mainly visual. She warns against visuals that are in correspondence to users biosignals because users attention are too drawn to them, and in turn

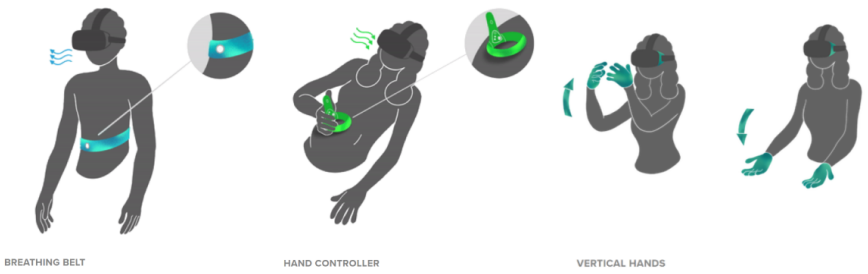


Figure 4.3: A user can signal their breath to the system by 3 different modes of input.

their attention is not subtly guided towards their soma.

4.2 DEEP

DEEP VR, figure 4.2, is an example of combining art, virtual reality, biosignals and well-being [13]. This VR experience was developed to help users improve their well-being by learning how to regulate their anxiety.

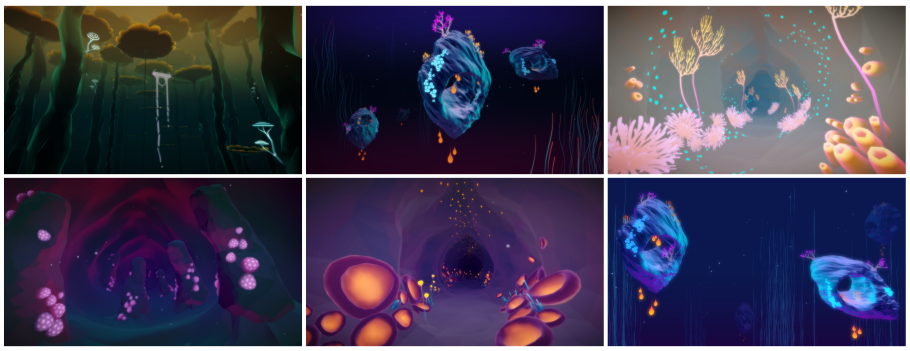


Figure 4.2: In the DEEP VR experience, a user moves through an underwater world by breathing slowly. The many objects in the immersive environment mimics the expansion and contraction of the user's breath.

In this interactive meditation experience, the user is situated "deep" down in the ocean and move through this underwater world by breathing slowly. The user's breath is sensed by the experience by using either a breathing belt around their abdomen, a hand controller on their stomach or by moving their hands up and down in motion with their breath. The movement in the virtual world is slow and the creatures, plants and patterns in the world mirrors the user's breath which helps with "reinforcing the link to your own body and mental state" [13].

We were very inspired by this immersive experience and the control being provided to the user. Our confidence for the potential of combining immersive experience with biosignals grew as this experience has 5 different papers evaluating and supporting its efficacy. There is however little to show for the progress of the user, more than one's own self-experienced improved control of anxiety regulation. As every experience starts from the beginning, there's nothing to show for all the previous breathing experiences. With time, the novelty of the experience decreases, as each experience has a clear start and progression, without possibility for more creative expressions than moving faster or slower.
From this work, we derive the strategies of making a clear connection between the used biosignal and the experience, of "making the experience beautiful" and of utilizing that more than one aspect of the experience can mimic one's biosignal to enhance the level of immersion.

4.3 Tiltbrush

Tiltbrush is a tool developed by Google which moves the act of painting into virtual reality [83]. Through the usage of hand controllers, the user is equipped with a color palette and a brush. The canvas is now however the thin air, which means that immersive creations with a spatiality beyond the flat 2D can be created. The laws of physics does not necessarily apply here, providing even more creative freedom to the artist.

4.3.1 Anna dream brush

Anna Zhilyaeva (artist name "Anna dream brush") seen on figure 4.4, provides a vast portfolio of example of how Tiltbrush can be used to create art in virtual reality. She examplifies the usage and potential of this new medium by also recreating classical artworks such as "Liberty Leading the People" by Eugène Delacroix [9, 84, 85].

Figure 4.4: Anna dream brush in action using Tiltbrush to paint the "Liberty Leading the People" in VR at the Louvre (Paris, France).

The work of Zhilyaeva is a great testimony of the level of immersion which art can achieve in virtual reality. The new medium provides freedom to explore creativity in new ways. For Zhilyaeva, painting classical works in 3D tasks her with imagining the before unseen in the artwork. In the same way, utilizing biosignals to create art in 3D could lead the user to imagine and interpret before unseen sides of themselves.

4.4 Mettāmatics

Mettāmatics is an interactive, biosignal-driven, artwork creation experience designed to support users to "explore connections between breathing, heart rate, emotion and attitude" [86]. The user is initially instructed to listen to an 8 minute long introduction which informs the user about breathing and heart rate variability (HRV) and how it relates to their body. During this introduction, their baseline HRV data is recorded and a 3D HRV spectrum is generated on a screen, which acts a starting point for their continued experience after the introduction. The user is instilled with a sense of agency through auditory feedback ("soft hissing sounds") which are triggered by reduction of heart rate, but also through seeing the HRV spectrum change in realtime and hearing their own pulse.

Figure 4.5: Mettāmatics biosignal-driven, artwork creation experience. Users are receiving both auditory and visual feedback on their heart rate.

Khut and Howard explains how the work supports the user in understanding and integrating their past, which forms new narratives of agency. We argue that this notion emphasize the importance of exploring if there's additional potential in developing the forms of expression.
Mettamatics has inspired us to emphasize time when designing an experience using biosignals to create art which supports sense-making. Adequate time should be given to support both observation, reflection and understanding, as biosignals vary in how apparent they seem to be to their users. Furthermore, Khut and Howard implemented an elaborate approach to onboard the user into the experience, which supported a "more engaged and embodied exploration of connections between qualities of attention and their physiological corelates".

4.5 Cardiomorphologies

Cardiomorphologies is an interactive artwork resulting from an action research project with the aim of designing a visualisation of breath and heart rate data [87]. The

purpose of this project was twofold; firstly, to create a "integrated physical and mental engagement with the work", and secondly to create a reflective state where users contemplate the connection between their physiological state and their thoughts.

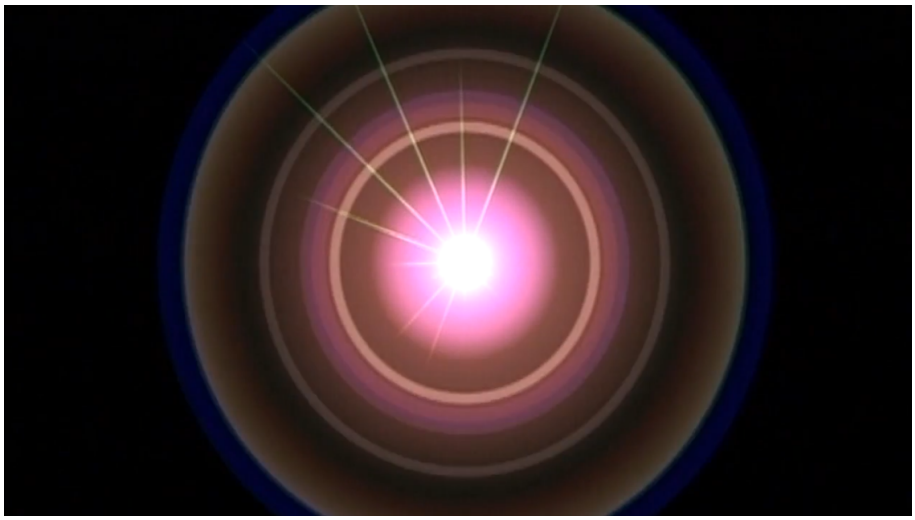


Figure 4.6: The moving visulisation seen in Cardiomorphologies, resulting from the user's heart and breath.

The setup consists of a reclining chair in a slightly darker room with speakers and a large screen in front of the user. Users are equipped with two sensors; one breath sensing band which measures the chest's expansion and contraction, and one heart beat sensor. The input of the user generates a colorful, abstract "audiovisual representation of the participant's breath and heart rate" (See Figure 4.6).
In this work, Muller et al. defines and evaluates the reflective state as; *explorative & curious* meaning that the experience sparks exploration, *enabling* meaning that the user is enabled a better sense of their own physiology and its connection to their mental state, *instructive* meaning that the user, as a result of the experience, feel that they can sense and control their own physiology, and finally *meaningful* which means that other experiences in the user's life might be informed by their new mind-body consideration. This definition is closely related to Somaesthetic theories, which focus on facilitating and enhancing the mind-body connection. In evaluating the design through this lens in a qualitative manner, Muller et al. made design choices which moved the artwork away from concrete representations of biosignals to more abstract and ambiguous, which proved to spark engagement and reflection. The researchers found that the added richness to their artwork supported the users in mind-body connection and in meaning making, which is in contrast to Somaesthetic theories which disregards external stimuli as it moves the user away from connecting with themselves. Furthermore, Muller et al. emphasize how "visualisations should offer the participants varied and creative possibilities" whilst not breaking the spell which simplicity casts on the user. They conclude the pepar by stating that future work should pay attention to fostering a curious and exploratory mindset in the user, rather than a deterministic, goal-achieving mindset.

5
Methodology

This chapter presents the methods, applied theories, and the approaches considered or used during the research and design process of this thesis.

5.1 Methods

This section describes the methods considered or used in the design work of this master thesis. These were selected as they were deemed appropriate for the approach, process and plan. They are presented in alphabetical order to support revisiting them when reading the the following chapters.

5.1.1 Affinity Diagram

Affinity diagram is a data analysis method for making sense of mixed and large amounts of information. The process evolves laying out all the gathered information in an accessible manner, such as with post-its on a wall, before synthesising the information through grouping, ranking and drawing connection between groups [88]

5.1.2 Annotated portfolios

Design knowledge can be communicated through annotated portfolios. Annotated portfolios consists of several design artifacts presented together within a medium of choice and include a short textual annotation. By showcasing the artifacts together their similarities can communicate a design style while their dissimilarities can give an idea of the scope of the design space [89].

5.1.3 Body Maps

Body maps can be used to evaluate somatic experiences. Body maps (as can be seen in figure 5.1) refer to blank outlines of the human body that users or designers themselves, during evaluation of their somatic experiences, can draw upon with various colours or other material of choice. Where on the body map people draw and with what material can serve as a manifestation of felt bodily experiences that are hard or cannot be articulated [90].

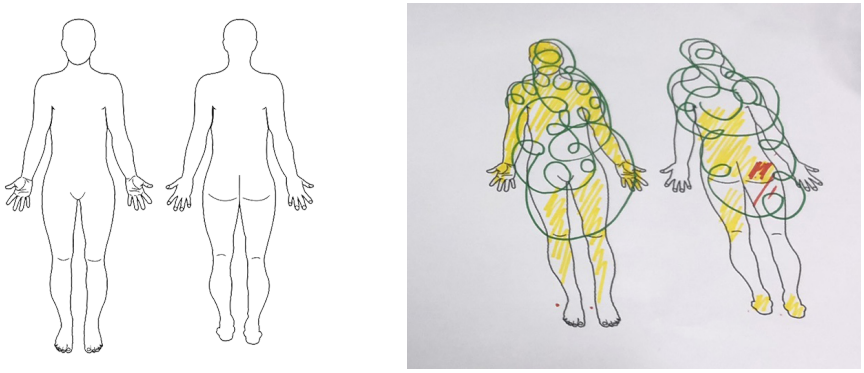


Figure 5.1: An empty body map (to the left) and one which is filled out (to the right).

5.1.4 Bodystorming

Bodystorming is both a method to gain empathy for users and an ideation method where ideas are generated through the movement of the body. Participants can for example act out actual user scenarios, with or without prototypes or props, while actively and spontaneously trying out different "imagined" solutions. Improvisation is encouraged within bodystorming sessions and just like brainstorms, it should be spontaneous [91].

5.1.5 Brainstorming

Brainstorming is an idea-generation method to which aids with producing a vast amount of ideas in a short amount of time by forming connections between otherwise separate ideas [79]. The right atmosphere for a brainstorm is created by having a non-judgmental attitude, anything goes, and through probing with "how might we..?" questions. In a brainstorming session, unrestrained ideas are encouraged as these might facilitate new thinking which could result in unconventional, unexpected solutions. A clear definition of the target problem is required to have a common aim for the solutions. Furthermore, some tools to quickly capture ideas, such as a whiteboard or post-its, are necessary to not loose progress nor momentum. As brainstorming is and should be highly intensive, a shorter duration for the session should be set (commonly not exceeding 60 minutes). Another argument for a short duration is the added urgency which keeps team members activated and increases the intensity [92].

5.1.6 Dot Voting

The Nielsen-Norman group describes dot voting as an efficient method for democratic decision-making [93]. This decision technique enables all participants to vote on their favorite feature, design, or whatever it is being voted on. Initially, the available options are presented, and it is decided how many votes each voter should have. Then participants get to vote in silence, and no talking is allowed, eliminating potential biasing and lobbyism. The voting is done either through dots (hence its

name) or using any other object which can represent a vote (such as a lego piece, coin etc). The votes are then counted, and the winner(s) presented.

5.1.7 Figjam board

The authors developed this method as a means to organize data and thoughts, and visualize concepts. A Figjam board is an extensive online web tool developed by Figma [94]. It allows multiple users to create and position text, shapes, arrows, and images. An ability to create visual hierarchies and structure information is enabled by zooming in and out of areas of the board and by working with almost any text size. A Figjam board removes the siloing of information which is often the case when working with separate documents. Furthermore, it provides an overview of information and the possibility to zoom in or place interesting information segments next to each other or interlink them with shapes, figures, and arrows.
A drawback with using a Figjam board is that text is not searchable. This makes working with text and locating specific segments when analyzing data cumbersome. In this thesis, one Figjam board was used (as can be seen in figure 5.2) which enabled the authors to quickly navigate between, and structure clusters of information as the project continued.

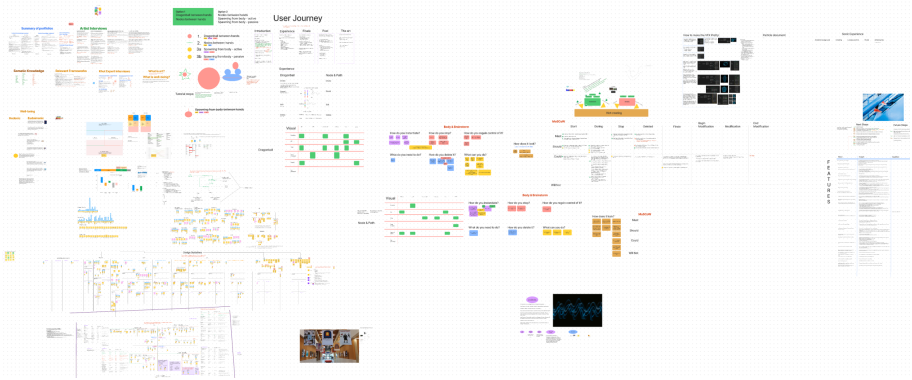


Figure 5.2: An overview of the Figjam board used in this thesis

5.1.8 Focus groups

A focus group is an interviewing method, where participants discuss in groups of three to ten people, led by a facilitator. The facilitator maintains order in the group and prompts discussion when necessary. The diversity and many perspectives in the group facilitates a wider range of issues, opportunities and thoughts which might not have been raised otherwise. Just like a semi-structured interview, a focus group has scripted questions but allows for the flexibility to dig deeper into interesting topics [79].

5.1.9 Formative Evaluations

Formative evaluations are conducted to inform the design process and improve the design iteratively before finalizing and possibly comparing it with other designs. A

formative evaluation entails testing a design (often a prototype) with potential users to find issues and strengths, which consecutively will result in changes implemented in the next iteration. Formative evaluations are suitable for the approach of iterative development, testing, evaluation, and improvement [95].

5.1.10 Heuristic Evaluation

A heuristic evaluation is an expert usability analysis of user interfaces and is recommended to use before conducting formal usability studies with real users [96]. Heuristic evaluations should be conducted by several evaluators whom all analyse the same user interface against a set of usability principles, the heuristics [97]

5.1.11 Interviews

Interviews is a versatile research method used to understand a person, a topic, or to evaluate anything specific. An interview should preferably be held in person to more easily perceive certain movements and expressions the interviewee could make [98]. Fontana and Frey explains that there are four main types of interviews; open-ended or unstructured, structured, semi-structured, and group interviews [99]. The open-ended interview structure allows the interviewee to go deeper into a subject and either part of the conversation may steer the direction. It is appropriate for gauging a user's impression on a new design for example. The structured approach use predetermined questions (the questions are equal for all participants) which is appropriate for getting feedback on a certain design feature [79]. Semi-structured interviews consist of both open and closed questions. With the guidance of scripted questions, the interviewer may also to probe for more relevant information. Furthermore, interviewers should try to build a connection with the interviewee in order to establish respect and trust which benefits the conversation [100].

5.1.12 MoSCoW analysis

The MoSCoW analysis is a method for analyzing features and prioritizing what should be developed [101]. Features are categorized into four categories based on the researchers assessments; Must have, Should have, Could have, and Will not have. "Must have" includes all features that are necessary for the product to be considered acceptable. The product is not deliverable if any of these features are not developed. Note that must-have features can be downgraded to lower categories. "Should have" are features considered highly value-adding to the product but are not critical for the product to be acceptable. "Could have" are "nice-to-haves" features, meaning that they are not highly value-adding but could provide some value. Lastly, "Will not have" are features that are unnecessary for this delivery. This does not mark them as non-valuable but could instead be delivered at a later time.

5.1.13 Ping-pong

Ping-pong is a sport were two to four players use small rackets to bounce a ball over a net on a table (see figure 5.3) [102]. In this thesis, this method is used for

ideation, reflection, and as an active break. The participants allow for pondering and debriefing between activities by casually playing the ball back and forth.The playful nature of ping-pong increases blood circulation and helps to refresh the participants' minds.

Figure 5.3: David and Birgir playing ping-pong at OIA, Volvo

5.1.14 Prototype

A prototype is an early and unfinished version of the design, intended to test certain characteristics. Through excluding certain functions, the design becomes easier to build and specific configurations, functions and features may be tested by designers, users and stakeholders. Prototypes vary in fidelity and are usually less complex in the early stages of a process (low-fidelity) and gradually increase in fidelity as design decisions are made. The fidelity and nature of the prototype ought to match which aspects of the design should be tested. Through building early prototypes in an iterative manner, limitations and opportunities that otherwise wouldn't have been discovered, may be found which could lead to reduced cost or improved design [79].

5.1.15 Observation

Observations are appropriate for understanding the context and in which manner a user is able to fulfill their tasks and goals. Observations are also valuable in acquiring knowledge which cannot be acquired through interviews or questionnaires, as users might not be aware of these facts themselves. An observation may be direct or indirect, meaning that an investigator could either watch the participant first handily or through recorded material [79].

5.1.16 Skewing

Skewing is a "structured ideation method" that changes an artifact's interaction-related properties [103]. Skewing supports designers in re-designing the interactions to find new, unthought-of design solutions. In brief, the designers picks one to five properties at a time and skews these. The ideation continues, now with the

properties changed, which supports the designers in coming up with novel ideas. An example would be to skew “efficient” to “inefficient”.

5.1.17 Somatic Connoisseurship

A somatic connoisseur is a person that is an expert in a skill that requires embodied or movement-based practices. Somatic connoisseurship is when the somatic connoisseur guides participants through the activities they are experts on [14]. Due to their expert knowledge, they can share with others what to attend to, how to move, and what to feel. In doing so, they facilitate participants' learning. As mentioned by Höök, Somatic connoisseurship usually involves the somatic connoisseur engaging in the practice with participants while leading them through the experience.

5.1.18 Storyboard

A storyboard is a sequence of sketches which present the intended interaction with a product, service or experience. Storyboards aid in communicating use-cases through presenting the progression of a scenario [79].

5.1.19 SWOT analysis

A SWOT analysis helps the team assess the internal and external factors influencing a project. The team gets an overview and a better situation understanding by listing the internal strength and weaknesses of a project and how they relate to the external market factors (opportunities and threats) [104]. Initially, a big sheet with four quadrants is prepared; strengths, weaknesses, opportunities, and threats. Beginning with the internal factors, the team writes down the project's strengths on post-its, one per post-it, in silence. When finished, the post-its are clustered, discussed, and duplicates removed but noted as they “could be particularly important” [104]. The process is repeated for the weaknesses, which could be lack of knowledge or dependence on other factors, for instance. Ultimately, the team now repeats the procedure but for the external factors, highlighting market opportunities and threats.
In this thesis, the definition of opportunities has been shifted from considering the market to considering opportunities that have been spotted for developing the prototypes.

5.1.20 Thematic analysis

Is a method to evaluate qualitative data in a systematic way. It is commonly used for semi-structured interviews where the interviewer might not have a clear idea towards how the interviewees will respond, and by using thematic analysis the researchers can inductively find patterns in what was said. The method contains six steps. First researchers should (1) familiarize themselves with the data, (2) assign preliminary codes to the data, (3) Search for patterns or themes in the codes across all interviews, (4) Review the themes, (5) Define and name themes, before (6) deliver the results [105].

5.1.21 User Journey Map

A user journey map is a visualization tool to map out the user's interaction with a product or service, detailing their thoughts, emotions and perceptions. The map helps with highlighting and evaluating key moments in the user journey, so that they can be considered and improved. Since users are different, drawing out their potential journeys in distinct contexts, flaws and oppotunities might arise. Through creating the user journey map, designers and organizations are assisted in shifting their mindset from a "system-centered view" to a bigger perspective [98].

5.1.22 Usability Testing

Usability testing is an evaluation method most often conducted in a controlled setting. During usability tests researchers observe users as they go through predefined tasks or scenarios and the goal is to identify potential usability process during the tasks. Usability errors can both be identified with objective measurements, such as by by measuring task completion time, or via subjective measurements, such as asking participants to think out loud during the session and interpret what they see. Additionally, questionnaires are also commonly administered following the sessions [98].

5.1.23 Wireframes

Wireframes can be considered low to medium-fidelity prototypes meant to convey the layout, feel and interaction possibilities of an interface. Without any aesthethics aspects such as color or graphics, the wireframe usually contains (but are not limited to) simple illustrations of buttons, titles, image placeholders, menus and texts [91].

5.2 Research Approach

The Design Councils's Double Diamond design process was utilized as a framework for planning the design process of this thesis [106]. The Double Diamond has four phases: *discover, define, develop and deliver*. The first two phases, *discover and define*, involve researching, understanding and defining the design challenge while the latter two phases, *develop and deliver*, are about exploring potential solutions, evaluate them and deliver the most desirable.

We applied a research through design approach within the double diamond framework and, therefore, created and evaluated various prototypes in order to seek answers to our research questions. The design space explored is situated on the intersection of art, artistic creativity, well-being, sense-making, biofeedback, and VR technology. To navigate the design space we utilized methods and theories from soma design, applied a playful hacking approach, and conducted expert interviews.

5.2.1 Soma Design

Soma design, as outlined in section 3.5, has four main design characteristics. The four main characteristics of soma design are: (1) *lived experience*, (2) *slowing down*, (3) *Iterative testing* and (4) *sociodigital materials* [14]. With *lived experiences* Höök is emphasizing the importance of first-person perspectives in soma design. Soma design designers must train their "aesthetic sensitivities" in order to design for somaesthetic experiences of others. The second characteristic, *slowing down*, relates to the first one as one way of training somaesthetic sensibility is to slow down movement. The whole soma design process is, however, also meant to be slow as it takes a long time to understand and articulate movement-based ideas [14]. The third characteristic, *iterative testing*, also relates to why the soma design process is slow as the design should be iterated on extensively. The fourth and last characteristic, *sociodigital materials* refers to how the soma design process relies strongly on "how properties can be shaped in [digital]materials to fit with our corporeal selves" which connects to the the first characteristic because soma designers need to be sensitive to how the material should change [14].

5.2.2 Playful Hacking

In Playful hacking, one is concerned with playing with technology connected to the design space of the current research. By doing so, one opens up for the possibility of generating new, unexpected insights or ideas for the actual research. Playful hacking is not a method, as it is not structured nor does always have an outcome, but rather an approach within Research through Design. It should be regarded as a mindset, which according to Goddard and Cercos, has the value of enhancing one's creativity, collaboration and motivation for research [107]. Goddard and Cercos provides a "manifesto" in which the values of playful hacking are imbued; *Minimal Viable Product, Hacking as Play, Making Mode of Thinking, End in Itself, Loose Structure. Minimal Viable Product* means that it should be quick, preferably achievable in one hour and never more than four. The focus should be on testing a hypothesis. *Hacking as Play* means that one should refrain from current research problems in the hacking, so that the hack is characterized by play and not work. *Making Mode of Thinking* means to do more and think less, not to concern oneself with a 'what-if' mentality. *End in Itself* means that the playful hacking is the only purpose, not any potential outcome. And lastly, *Loose Structure* means to be only as structured as necessary for momentum of a "scholarly discursiveness".

6
Planning and Execution

Here we present how we planned our design process. We list the phases, subcategories, time-plan and visualize it in a Gantt chart. We then elaborate how the planned process changed during the project and introduce our executed design process which we structure next chapters based on.

6.1 Preparation (week 1-5)

- Review and exploration of available technology
- Literature review - Definition of Creation
- Literature review - VR & Biosignals
- Literature review - Sense, Soma and Wellbeing
- Definition of Methods & Process
- Creation of planning report & timeline

6.2 Exploration (week 2-10)

- Track 1a: Expert interviews
- Track 1b: Playful Hacking
- Somaesthethic appreciation development
- Conclude & Analyze tracks
- Ideation

6.3 First prototype Sprint (week 11-12)

- Prototype design & build + evaluation preparation
- Prototype evaluation & data analysis

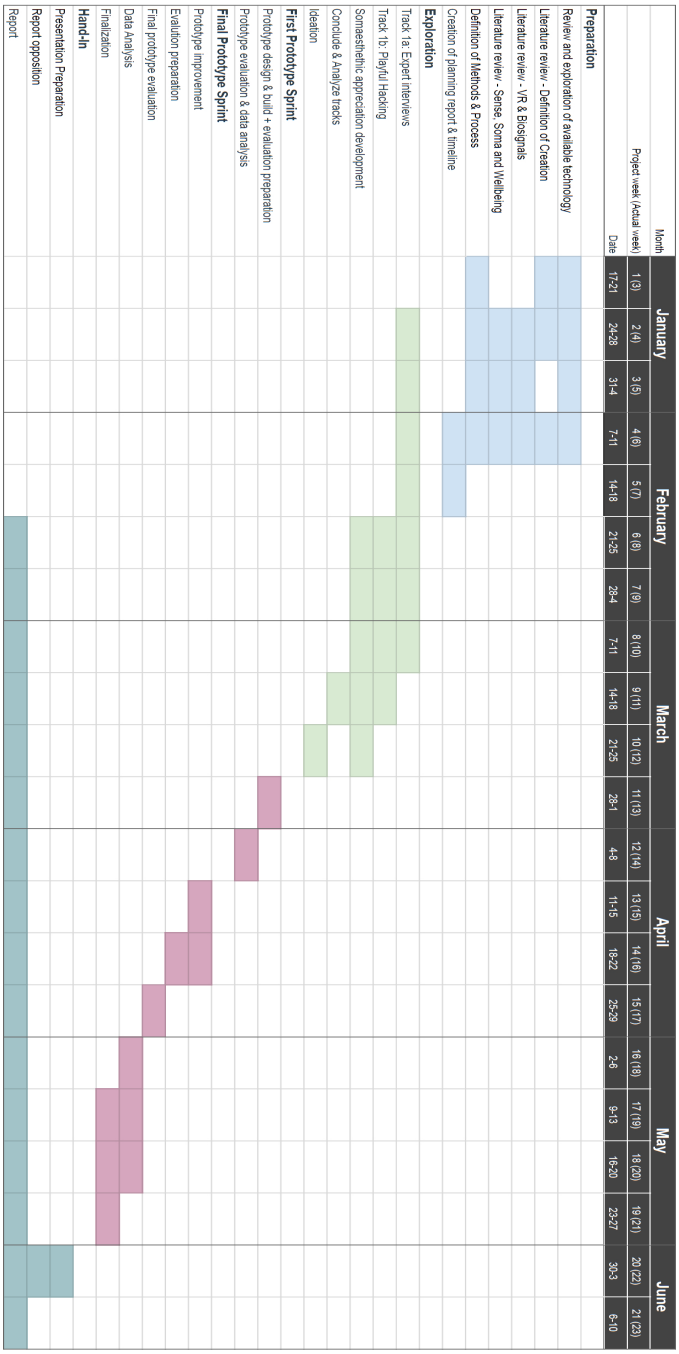
6.4 Final prototype Sprint (week 13-19)

- Prototype improvement
- Evaluation preparation
- Final prototype evaluation
- Data Analysis
- Finalization

6.5 Hand-in (week 20-21)

- Presentation Preparation
- Report opposition
- Report

6.6 Gantt Chart



6.7 Execution

We mostly followed the planned process. The main deviation was that we only made one prototype instead of creating two versions of the prototype, which we planned to evaluate at two distinct evaluation phases. However, we constantly iterated on the prototype between formative evaluation sessions and thus continuously improved it before the final evaluation. The executed design process is visualized on figure 6.1. As can be seen, we emphasized understanding at the beginning of the process before synthesizing our learnings. The learnings supported our ideation phase and defining of the idea we developed and evaluated.

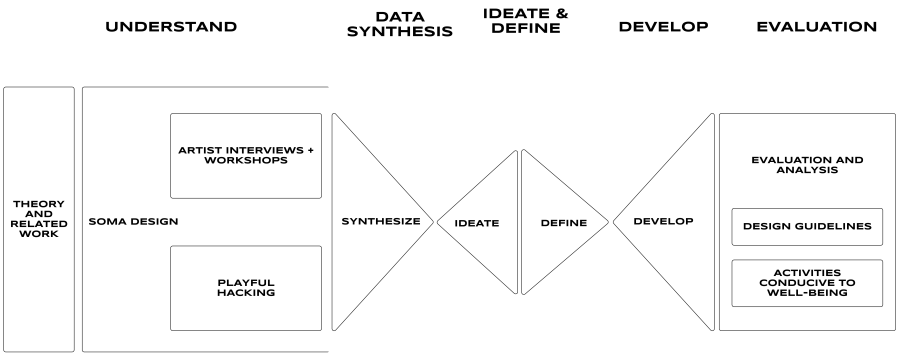


Figure 6.1: Visualisation of the executed design process.

7
Understand

In this chapter we report on what we did within the discover phase of the project and report on the main findings from our research and explorations. The discovery phase was split into two separate tracks, one for expert interviews and information gathering through somatic connoisseurship and another for playful hacking where we built our understanding of the design space through explorations. We incorporated soma design methods and guidelines into both tracks and therefore we report on that separately as well.

7.1 Soma design

Throughout this project, we were inspired by Soma Design, see section 3.5. One the main design characteristics of Soma Design is, as mentioned in section 5.2.1, the emphasize on designers "lived experience" [14]. Meaning the designers first first-person perspective is important when applying Soma Design methods. Designers must thus cultivate their "aesthetic sensitivites" and be sensitive to their own soma, before designing for somaesthetic experiences of others. That may take years of practice. However, we only had a few months for this project. Therefore, we refer to our design as Soma inspired rather than a Soma Design.

Throughout the project, we tried to sensitize our somaesthetic appreciation by including soma design methods and exercises into our processes, and engaging directly with the material both through first-hand experiments with art and also through our playful approach to the materials used. By doing so, we cultivated our somaesthetic appreciation continuously.

7.1.1 Soma Design and Expert (Creator) Interviews

We report extensively on the expert interviews we conducted later in the report (see section 7.2). Of importance here is that the two creators, a painter and a ceramic crafter, hosted a first-person impression session for us following their interview. During the sessions, we created art and craft under their guidance. To articulate our impressions, we wrapped up both sessions by filling out body maps together with the creators. We asked them to elaborate on their body maps so we could better understand the most prominent sensations during their creation sessions.

7.1.2 Soma Design and Playful Hacking

We report extensively on our playful hacking sessions later in the report (see section 7.3). Here, we relate how we weaved soma design into our playful hacking. After each playful hack, we evaluated the created artifact with a first-person evaluation, inspired by the Soma Design emphasis on the importance of the designers' first-person perspective. We utilized body maps for these evaluations, which helped drive discussions about what were our most prominent sensations. We thus, filled in numerous body maps throughout the project and deepened our understanding of the somatic experiences we were designing for. By combining Soma Design methods with the Playful Hacking approach we were able to test prototypes that we created quickly and make informative decisions based on our felt experiences. We could also feel how it became more natural, during the course of the project, to understand and articulate felt experiences, which is indicative of us having sensitised our somaesthetic appreciation.

7.2 Expert interviews

We reached out to expert creators to enhance both our theoretical and first-person understanding of art creation. We conducted five interviews with individuals with different creative skills and experiences. One was George Khut, an interactive artist and researcher from Australia who is engaged with aesthetics and biofeedback, and is the designer of the Mettāmatics mentioned in section 4.4 and Cardiomorphologies mentioned in 4.5. Our work is heavily inspired by and can be thought of as an extension of Khut's work. Therefore, the interview with him aimed at getting his view on interactive arts and actionable insights to use during the design process. The other creators we talked with have been creating extensively in their personal and professional lives for years. The creators we interviewed have the following specialities:

- Motion designer from France
- Ceramic crafter from Sweden
- Geometric artist from United States
- Acrylic art painter from Sweden

This set of creators was chosen to include someone that create digitally and physically, abstract and concrete as well as moving and still creations. Although we had decided to be mainly informed by art creation practices, interviewing a designer and a crafter suited our process and developed our understanding of how artifacts are created. Our aim was also to be informed by art, not merely to copy a previous practice. Additionally, even though the motion designer and ceramic crafter do not label their creations as pieces of art, others might. What is considered art is not agreed upon, and being open to different interpretation serves our purpose. We view them as somatic connoisseurs because of their extensive experiences and how skillful they are in their respective creation practices [14]. The interviews were thus conducted in a semi-structured manner. We did not brief them about our design before the interviews, we only informed them that we wanted to know about their creation practice. During the interviews we focused on understanding their practice

and what they do, think, feel, and pay attention to during their sessions. Secondly, if and/or how they connect feelings and emotions to their practice. We met the painter and the ceramic crafter in their own studio. That allowed us to have a short somatic connoisseur workshop in connection to the interviews, where we experienced their practice first-hand, created art, and craft under their guidance.
We recorded and analyzed the five interviews. We report separately on the interview with George Khut through a critical analysis. The other four were analysed through thematic analysis. With the thematic analysis, we began by listening to the recordings and corrected the supporting transcriptions from the AI transcription software. Next, we coded sections of each interview, before extracting the codes to a Figjam board. We also added insights from the somatic connoisseurships with the creators on the Figjam board and therefore our thematic analysis is also based on learnings from those sessions. On the board we did 2-3 iterations of reorganizing them into themes by affinity. The final version included nine themes, and we report on all of them in section 7.2.2. Lastly, we describe the first-person perspectives on the workshops.

7.2.1 Biosignal driven interactive art artist expert George Khut

To set the context of the interview and get actionable feedback from George Khut, we began with briefly sharing that we were aiming to design a VR creation experience, where biosignals are used as inputs. The interview was conducted in a semi-structured manner, as we had many questions to ask in case of running out of follow up questions on the feedback and comments from Khut. The interview was highly insightful, and five themes of interest emerged: (1) How to get people ready to experience, (2) Agency and layers, (3) the Art visuals, (4) Measuring biosignals, and (5) Sound and Environment in VR.

Introducing the experience In many of his artworks, people can "explore qualities of being and qualities of attention, and how [people] can sense those shifts in the physiological qualities, and feel and explore the connections with mental qualities as well." The framing of the experience is essential to consider. He emphasizes engaging with people's motivations and curiosity before grounding the experience on physiological sensing in the body. Therefore, he often begins each session with a body scan exercise to enhance people's sensitivity to their own bodies, getting them into an interoceptive state [1]. In his experience, it also increases people's sensitivity to the artwork because then they connect it to their immediate experience of themselves.

Agency and layers In George Khut's view, interactive arts are driven by the curiosity and playfulness of the people experiencing the artwork. As an artist, he needs to offer some sense of connection to the artwork to evoke those feelings. Agency is the key to that, and he usually layers the experience and introduces it

[1] Interoception is the perception of sensations from inside the body [108]

slowly to people, one layer at a time. For example, the first layer could be seeing something that corresponds to their heart rate before he would encourage them to alter their heart rate with their breath. He also emphasizes providing space for reflections in between layers, as it is vital to support the feeling of agency. For agency, it is important that users understand, through the design, that their heart rate is changing.

The Art Visuals On the art's visuals, Khut emphasized seeking ways to soften the quality of attention to make it more global rather than focused. If the visual is something that requires concentration, it arouses the sympathetic nervous system which activates people's flight or fight response. Global attention, where people are not trying to focus on a specific point in space is, on the contrary, likely to soften the attention and arouse the parasympathetic nervous system which supports relaxation (2.3.1). Secondly, he recommends utilizing contrast in the visuals to support noticing differences in bodily states.

Measuring biosignals It is almost impossible to eliminate noise artifacts from movement when measuring biosignals. Thus, Khut recommended designing affordances and constraints into our design to make it intuitively clear which movements are desirable or not.

Sound and Environment in VR Khut advised us to take special care about the sound and environment when sharing our thoughts about a virtual reality experiences. He said that sound is vital for interactive artwork to focus on the body, mainly because people cannot stop listening. He, therefore, advised applying some ambient sound to the experience to create a sense of space. Additionally, for enhanced immersion, actions must have acoustic consequences. Environments affect our different qualities of attention and states of emotion, and hence, he recommended considering what qualities of the environment we wanted.

7.2.2 Thematic analysis of the creator interviews

Nine themes of interest emerged from our thematic analysis of the expert interviews, mentioned in section 7.2, and subsequent somatic connoisseurships with two of the creators as described in section 7.2.3. These themes inform the understanding and definition of creation used in the subsequent research questions. We frame these results as themes to be considered when tackling creative practice in interactive systems. The themes should also be viewed in the light that we only interviewed four creators; thus, the findings represent the themes that can be drawn from the specific practices of those creators. The specialties of the creators interviewed are, as mentioned in section 7.2, a motion designer, a ceramic crafter, a geometric artist, and an acrylic art painter.

Actions Before Thinking None of the creators we talked to create from a completely blank slate. The ceramic crafter starts by centering a block of clay in the middle. The painter poured the painting on the canvas before reflecting on what

to make. The designer learned from tutorials and made his own version. Lastly, the geometric artist manifests sudden insights of how to visualize interesting equations which appear to him in his work as a math and a geometry researcher. Our first-person impression of the somatic connoisseurship session with the painter also highly influenced this theme. During the session, we created art by breaking the coal on the paper before realizing we were doing so. Thus it felt like the threshold to creating was very low because there was no initial struggle in conceptualizing what to create. Meaning we created art with actions before thoughts. This theme was of interest to us because it raised the questions: "What could be our method of not having a blank slate?" and what initial ritualistic actions can we design into the experience of creating art.

Immediate visual and/or tactile gratification Receiving immediate visual and/or tactile gratification was another theme that emerged. The geometric artist said that he could, for example, change a few lines of code, compile and see immediate visual results. The ceramic crafter was constantly feeling the clay and letting it navigate her process, which she said was satisfying:

> *"When you get that kind of stability in your body, and your hands and everything knows what to do. You can really focus on just feeling and that opens up another just satisfying part of it. Then I almost do not have to think about it. I just feel like oh, now I need to push here. No, I have to here."*

This theme indicates that the creation experience we design should be responsive, and the responsiveness could be pleasurable.

Exploring the boundaries of knowledge, skill, and material derives learning and well-being. The artists push the boundary of what is possible to do within their medium, and that is how they learn and improve. They refer to exploring as playing around, having fun, and acting on their curiosity. The geometric artist explained it as follows:

> *"There is the sort of initial like, Hey, I have an idea. Oh, that is exciting. Let me let me play around with that. And then [...] I play around, try different things, and this or that, or come on, you know, I initially think I am going to do it from this perspective, and actually better if I shift to this perspective, or change the timing, or, you know, a million different things."*

As the creators push the boundaries of what is possible, sometimes their experiments do not go as planned. They learn from failing, and failing does not necessarily have to be contradictory to well-being, as the ceramic crafter explained:

> *"I have made really beautiful things that I have then messed up somehow, but it has not taken away that feeling of happiness and excitement that you get from just like I did that, even if it actually does not turn out to be anything in the end."*

This theme relates well to themes "proud of accomplishing something challenging", "manifesting your ideas with precision requires practice and skill" and "frustration is part of the process". Artists are proud when they have managed something chal-

lenging through explorations, but not managing can lead to frustration. However, whether they manage or not, they are honing their skill and adding to their knowledge.

Lost and Enlightened in Flow A theme we saw was the absence of analytical thinking. Artists follow their excitement, a small voice or feelings in their bodies in how to begin or move forward. Insights, inspiration, and excitement thus guide the process. The painter explained it as follows:

> *"When I and my will step aside, and I do not know what I would like, then there is often a small voice erupting, wow, what is this? which is not mine. That [the voice], becomes art."*

In following this gift of energy, artists can become so absorbed and invigorated that they lose connection with time, body, and space. In this absorbed state of flow, distractions diminish, but a heightened sense of awareness occurs. Sensations that add to the experience emphasize while others fade, or as the ceramic crafter said:

> *"I always forget like, time and place and eating and everything. [I] Just like feel completely blank. And then I can still feel it. I feel it in my hands afterwards."*

Meaning that if one uses their hands to create, their sensations in the hand increase, while maybe they do not sense their leg falling asleep due to improper posture.
This theme connects to the "manifesting your ideas with precision requires practice and skill" theme because if abilities to create hinder artists, they will not experience the state of flow.

Creation as a Step-wise Activity We noticed a theme in the creation process about how creating is a step-based activity.Meaning that actions need to performed in the right order. Most of the creators have the basic form and structure in place before adding details to the creations. As in the case of the geometric artist, he sketches in black and white and only adds color to his creations last in the process. There were also specific steps in the creation process of the other mediums. For acrylic painting, it necessary for the material to rest in between sessions. For motion design, it is important to first design the elements that are supposed to be moving. And lastly, there are a lot of specific steps within the ceramic crafting process, she for example said that glazing was the most creative part of the creation process, and that was the last step before firing the creation in the kiln.
This theme was interesting because it implied having multiple and varying steps in the creation process.

Temporal changes and considerations within art creation There are temporal considerations inherent to the creation process. The artists differ in their relation to it. Some respect it and find beauty in allowing the creation to take the time it needs, while others limit themselves to only creating for a set amount of time, and the creation will only be what it becomes within that time frame. The inherent temporal considerations in the creation process also vary between mediums. It is more rigid for painting and ceramic than digital mediums because the material needs time to dry and rest between creation sessions. There are also specific points

of time within ceramic crafting where the creator needs to work fast and others where the creator needs to work slow. As the ceramic crafter explained, working slow is a necessity to shape creations into large creations:

> *"If you are throwing, basically what you are doing is working slowly to create the shape. And if you work slowly enough, you can turn this into a big thing that can stand, which is awesome. Like it is fantastic."*

In contrast, she said that it is essential to work fast when glazing the creations:

> *You have to be very focused. You have to be very exact. You have to work quite fast when you are doing it. If you screw up, you cannot really fix it unless you want to take away everything again and start over. So it can be quite stressful.*

Designing slowness, pauses and, rhythms into the creation process could be valuable.

Calmness and elation follow intense creation sessions The creators describe a calming feeling of relief and relaxation when intense creation sessions are over. The ceramic crafter referred to it as her head can be "just empty" after creation sessions, similar to when she does yoga. The geometric artist conveyed comparable feelings and elaborated on the happiness that is also connected to it.

> *"It is not just relief. There is also some kind of elation in the sense of like, look like, this is cool. Like, that makes me happy."*

This theme relates well to the theme of "Lost and Enlightened in Flow" because participants here elaborate on how it feels like coming out of such experiences.

Discovering the genius within Artists speak about how art can help them understand themselves better and how it can be self-fulfilling to create. The geometric artist, for example, discovered through creating art with code that he had a creative side. He said that he was never good at using his hands to create paintings and drawings and added that he had recently realized that:

> *"It was not so much because I was, you know, just did not have an artistic brain. But more like, I did not have the ability to get my brain to tell my hands what to do."*

The abstract painter also said a painting is finished "when it no longer calls on" him to do a little bit more and when he has made sense of it and has understood it. Implying his art creation process is a constant sense-making process and agency of created things is an important factor in art creation. It also raised the question for us of how can we replicate this in an interactive system.

This theme connects to the "Lost and Enlightened in Flow" theme as these states are both gratifying, and the release of control allows for new, unexpected thoughts, ideas, and inspirations to occur.

Art process and artwork derived well-being Artists speak about their creation experience as something gratifying and uplifting. Artists "look forward to create art" and feel "peace and happiness" when creating, and the abstract painter said, " I am in my life when I paint." The creators derive pride from creating something they deem challenging as one participant said, "effort derives well-being."

Sharing their work is an example of how artwork derive well-being. It can be seen as an extrinsic appreciation and something more profound. One artist enjoyed listening to how others interpreted and made sense of his work, while another said that satisfaction comes from sharing ideas through his creations. Which relates well to art definitions that state that art is created to be shared [6].
Following this theme, it is not just the process that is rewarding, but also the artwork. The reflection on themselves through the artwork, which connects with the "Discovering the genius within" theme, tells stories about their sadness, happiness, history, and genius. The notion of self-discovery and strengthening of self-worth was of interest to us for the project. This insight thus suggested highlighting the reflection aspect of the experience and generating a way to capture the reflection of identity in the art piece.
The theme also raised two questions for us. Firstly, whether and how we allow people to share their creations. Secondly, we noticed that artists have many artworks they do not deem share-worthy. This means that artists have agency over which creations they share with others and which do not. So the question is whether and how we can provide our users with that agency.

Frustration is a natural part of the process The experience of creating art is a rich experience between frustration and stress when things do not work out and intense satisfaction when things do.
The motion designer said, for example, that it is "very frustrating to have an idea. In my world. [...] but you cannot express it." The geometric artist also expressed experiencing frustration when he is trying to create a specific visualization but is not able to, and for him, it can also lead to the feeling of failure

> *"It can be frustrating. It is like, I am just, I cannot find the right way to think about this, right? And like, that's sort of like, I am failing at this or something."*

The ceramic crafter also said that opening the kiln to see the outcome is the most exciting part of her creation process, which can result in negative feelings if the outcome is not desirable as she said:

> *"If it goes badly and everything just messes up, you get miserable like you get so much trouble. You feel like, why am I doing this? This is the worst thing ever. I hate that. I hate myself. So it is an extreme."*

Interestingly, the only creator we talked to that currently did not experience frustration in his creation process was the abstract painter. He, however, remembers having had negative feelings as part of his creation process but has managed to overcome them as he said:

> *"My big problem was that I thought that I would create, so I had a lot of performance anxiety in everything I did. I went to art school to learn to create. Then I understood that I was in the process of learning to not stand in the way of that which wanted to be created within me."*

This theme was informative for us because if we were to try to find the balance between manageable and challenging tasks, as implied by the theme "Lost and Enlightened in Flow," it would likely lead to frustration and stress for some, which is ok.

7.2.3 Somatic Connoisseurships with the expert creators

These workshops were conducted following our interviews, each lasting an hour. Here we report on our first-person impressions.

7.2.3.1 First-person Impressions of Crafting Ceramics

The Ceramic crafter began the workshop by preparing the material and setting up her workstation, meanwhile telling us what she was doing and why. She then sat down by the wheel and started throwing the clay, and we stood by and observed her actions. She told us the main actions needed, such as keeping the left-hand firm and still, gently shaping the clay with the right hand, and the necessity to feel with both hands when to add water. Afterward, she prepared clay on the wheel for us to throw the clay first-hand. While creating, she guided us in what to attend to, what to feel and how to move. For example, she highlighted the importance of sensing how to shape the clay with our hands instead of relying on our sight. This sensing of the clay is something that we were drawn to, and we both felt high gratification in the tactile stimulation of molding the smooth clay. As also highlighted by the ceramic crafter, there is something very satisfying with touching the clay and just having our hands immersed in the creation. The messiness of the activity also reminded us about being kids when we could play and express ourselves without worrying about our clothes getting dirty. Thus, having the apron on and being in a particular studio where it was acceptable for clay to splatter everywhere was very liberating. We were also drawn to the wheel's cyclical motion, which was enticing and brought us a sense of calm after observing it for a while. Lastly, we felt the strain on our bodies after creating for a while, and it is evident that it was much more challenging to throw clay at the wheel than it looked like observing doing it. However, we felt something interesting about the contrast of being so firm in our bodies while working with such delicate material. The contrast made us simultaneously feel empowered and highly cautious. Interestingly, the first feeling that emerged for us when reflecting on the practice was that we felt it was fun. However, through further analysis, we identified the feelings of focus, satisfaction, calmness, cautiousness, empowerment, and more, which created the overall experience. We wrapped up the session with all of us filling out bodymaps, and we asked the craft creator to draw the map based on her most prominent sensations during a typical creation experience. Figure 7.1 shows the workshop set-up and figure 7.2shows her body map.

Figure 7.1: Image from the first-person impression with the ceramic crafter.

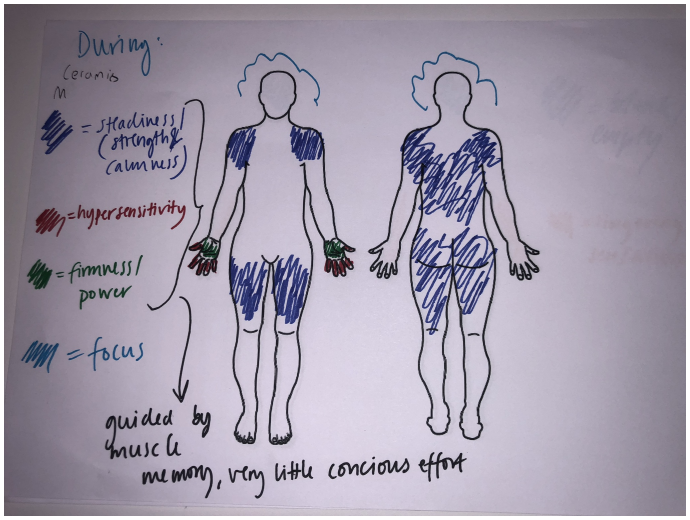


Figure 7.2: Bodymap created by the ceramic crafter.

7.2.3.2 First-person Impressions of Creating Art

The creation workshop began with the painter preparing the material. He laid a piece of coal on a sheet of paper, and before informing us why, he asked us to break the coal with our knuckles and spread it on the paper. We did that for a few seconds, and then he instructed us to pause and provided us with a small adjustable paper frame. He informed us that we had begun creating the artwork, and the next step was to frame and interpret it. We moved the frame on each other's artworks and interpreted what we saw, for example, animals, volcanos, and human faces. The framing exercise was stimulating, and we got surprisingly excited about finding meaning in the randomness of our coal creations. It was satisfying to make sense of

it and rewarding to show one another our findings. The major takeaway from the session was how he made us feel like we had created art, with him simply instructing us to perform some reasonably ambiguous and unplanned actions. We were unaware that we were creating art until after we had created it. Doing so lowers the threshold for creating and is indicative of how much art appreciation is in the eye of the viewer. We wrapped up the session with all of us filling out bodymaps, and we asked the painter to draw the map based on his most prominent sensations during a typical creation experience. Figure 7.3 shows the workshop set-up and figure 7.4 his body map.

Figure 7.3: Image from the first-person impression with the painter.

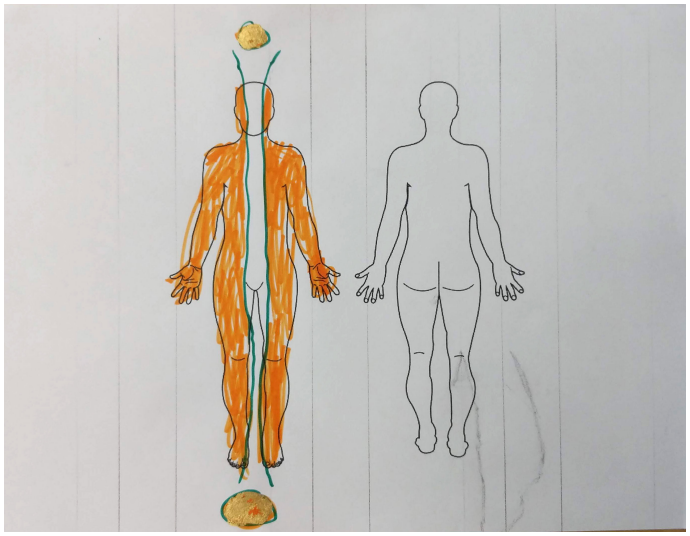


Figure 7.4: The painter's bodymap after the first-person impression session.

7.3 Playful Hacking

The playful hacking approach was utilized to build our technical understandings and abilities related to the project. That means experimenting with VR technology and biosignal measurements in an unstructured way. Additionally, in order to practice our soma appreciation and understand the possible practical implications of the resulting playful hacking prototypes, we articulated our experiences with the support of soma design methods.
To offer an overview of our use of playful hacking [107], we present the activities we engaged with and the prototypes generated, see figure 7.5 for an overview.

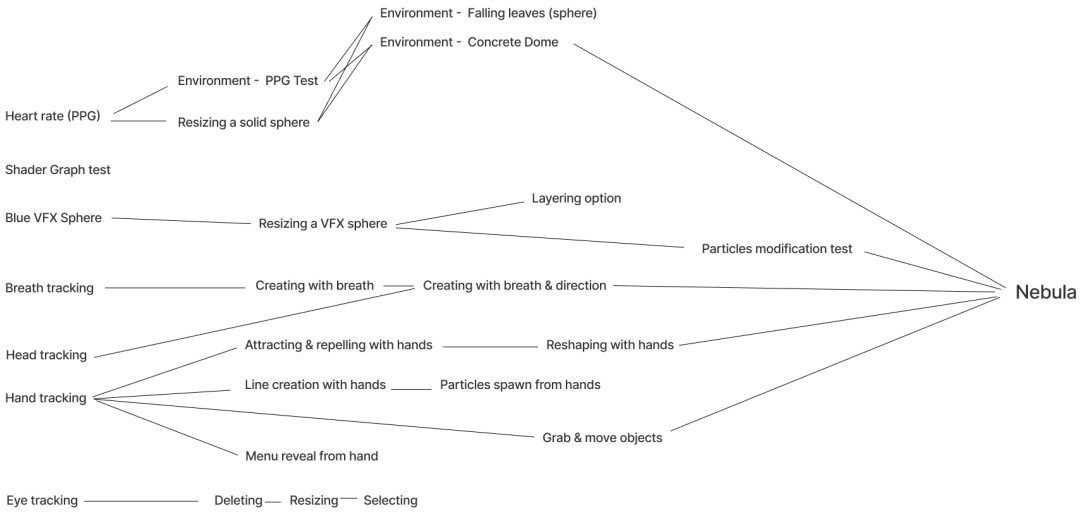


Figure 7.5: An overview of all the playful hacks we did, how they are connected and how they guided us forward.

7.3.1 The VR Environment

With VR comes the opportunity to tweak the environment into whichever is most suitable for the design. We wanted to create a grounding environment with minimal stimulus that was calming and would make space reflections as informed by the somaesthetic appreciation quality "making space". However, it should not lead the user to create something specific but merely instill creativity.
From having connected our heart rate to the computer, we wanted to explore how it could potentially be visualized. Therefore, we created a prototype where our heart rate changed the brightness of a VR environment made up of only one gradient color (as seen in figure 7.6). To alter our heart rate, we experimented with shallow, rapid, and deep, slow breathing. This test gave us a slight understanding of how perceivable our heart rate would be if translated into environmental brightness. From this test, we learned that we were drawn to decreasing our heart rate as we had mapped it to reduced brightness. The reduced brightness was enjoyable because it strained our eyes less and perhaps because the restful darkness related to the parasympathetic response of an exhale. We also first-handily could experience that exhaling decreases

our heart rate while inhaling increases it. Albeit fascinating, we concluded that it was relatively intense and straining to have the environment's brightness repeatedly shift.

Figure 7.6: David, one of the authors, testing how it feels having the brightness of the VR environment be changed through his heart rate.

We tested a platform in an infinite space with a horizon, one inside a giant sphere of falling leaves, and finally a concrete dome with a platform inside and an open sky. The infinite space made us feel cold and an eerie feeling, while a wholly closed space induced claustrophobic feelings. The sphere of leaves felt small despite its vast size, and we concluded the reason for this to be insufficient and incorrect lightning which failed to produce a sense of depth.

The concrete dome was our final attempt at the environment. This dome had an enclosed design that closely resembled the "making space" quality described in section 3.5.1.2. Its beige concrete texture provided a warm, grounded feeling, while its lack of corners led to a sense of infinity. As the dome was open, it allowed for the opportunity to select a sky. The open sky also reduced the feeling of claustrophobia, another aspect of the "making space" quality. Through testing morning, evening, and night skies, we preferred a star-filled night sky as it created the feeling of awe and endless opportunity, a feeling shared by many as we look upon a star-filled night sky. We felt this resonated with the quality's mention of "actively disrupting everyday habitual routines". We also learned that its darkness added to the design as it allowed to dim the light inside the dome further, which increased the visibility of the generated creations.

7.3.2 Measuring biosignals while moving

A hack we found necessary was to experience how much movement would affect the biosignal measurements (i.e noise artifacts). Understanding how much movement was acceptable would inform our future idea generation. We tested the measurements by walking around in circles while breathing and moving our arms up and down, while the other observed the measurements.

Pulse and movement Moving our arms vertically with the PPG sensor attached to the index finger completely distorted the measurements. Even slight movement interrupted the measurement. We, therefore, changed the equipment to attach to the earlobe with a clip instead of to the finger using a band. With the ear clip, we could move, look and wave our arms freely without any noise artifacts. Albeit slightly more intrusive to attach and uncomfortable to have under the headphones, we concluded that having the sensor attached to the ear would be beneficial for us.

Breathing and movement The movement would create noise artifacts as the PZT sensor is created to pick up on expansion and contraction of the abdominal area. We learned that the measurements would be reliable when breathing fast and excessively while moving. We hypothesized this had to do with the movement noise artifacts diminishing compared to the abdominal movement. However, the noise artifacts would be prevalent when moving and breathing slowly. See figure 7.7 for a comparison of typical breathing values and breathing values cluttered with noise artifacts). We concluded that encouraging users, through the design, to be static while measuring the breathing would be to our advantage.

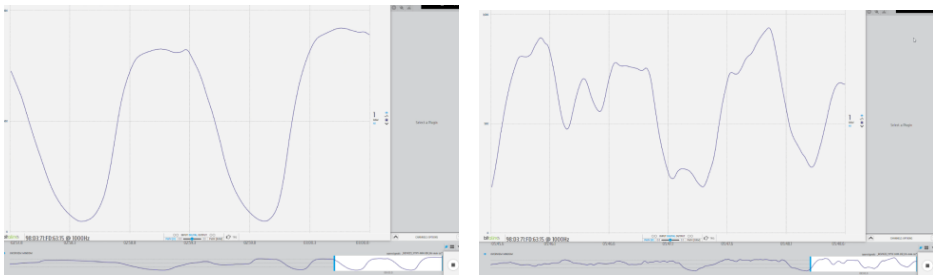


Figure 7.7: Comparison of normal breath values (to the left) and breath values cluttered with movement noise artifacts (to the right).

7.3.3 Generated art with Visual Effects Graph

In order to generate visual creations inside of VR, we tested a tool within Unity called Visual Effects Graph (VFX graph). This tool simplifies the creation of visual effects through a relatively simple node drag-and-drop workflow. Additionally, we found several guides online which taught and demonstrated how to achieve different particle systems (here referred to as creations). Below, we list the hacks performed in finding material for art creation in VR.

7.3.3.1 Sphere

Inspired by the ambiguity as explained by Gaver, Beaver, and Benford, and in section 3.8.3, we set out to find an object with a form which did not resemble anything we had seen before [82]. We stumbled upon a guide for a sphere-like creation during our search. Evaluating this sphere from a first-person perspective, we realised how tantalizing the complex creations were and how alive and organic the systems appeared to be.

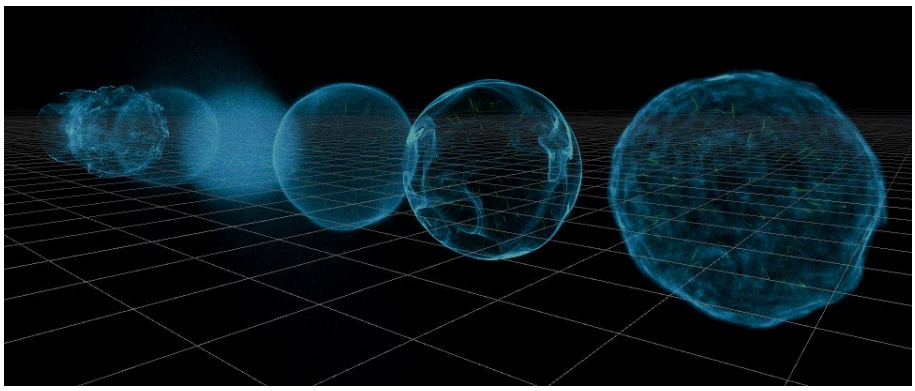


Figure 7.8: Series of blobs from our tests with different parameters.

By exploring the nodes and parameters in the VFX graph, we learned how the creations' turbulence, speed, and size affected us differently. We felt stress, curiosity, awe, and calm by tweaking these parameters. For instance, the perceived randomness of the particles added to the feeling of awe as we tried to make sense of how the particles at times conformed into streams to later dissolve (see figure 7.8.

7.3.3.2 Attracting and repelling force

This hack built upon previously enabling hand tracking in the prototype. Having watched plenty of Star Wars growing up, we thought it would be interesting to see how it would feel to be able to interact with the creation from afar, using attracting or repelling forces, seemingly, from our hands. We set up a test where we could modify a sphere creation (developed in section 7.3.3.1) by placing one hand anywhere around it and activating an attractive force by pressing a keyboard button. Before applying the force, the particles constituting the creation were always moving semi-randomly yet in unison, conforming to a sphere. When applying the force, the particles would continue this behavior, although now with a simultaneous gravitational pull toward the hand. The particles would also increase in the speed toward the hand. The effect felt slightly empowering and a bit magical. While moving the hand around the creation with the effect turned on, it did not convey the sense of being able to attract and deform the creation.

Out of curiosity but also to see if we could increase how effective this force could be, we changed the force from attracting to repelling. Now the hand would instead what we would say "blow the particles away from us". This change did increase the perceivable effect on the creation and thus also how empowering and magical it felt.

Conclusion This effect was indeed cool and could provide a new dimension to the art creation experience we were designing. We saw potential challenges with implementing this technique as an on/off force would probably have to be designed and implemented, as well as a way to indicate how much force should be applied. Furthermore, adding this effect to the generated creation and having it persist on its own, without hands, was expected to be quite challenging.

The extracted qualities from this hack were: empowering, magical

7.3.3.3 Particles spawned by breath

The sphere in section 7.3.3.1 gave us an idea of adding particles to it using our breath. The sphere would then become a visualization of our breath (see figure 7.9). This meant that a strong exhale would generate particles that would spawn from the user's mouth and travel to the sphere in front of the user, where they would join the other particles. This, we thought, would fit very well with the notion that prolonged exhales are conducive to a relaxed state (see section 2.3.1) because it might encourage user to prolong their exhale to create more particles with each breath. While testing this we initially realized that it was uncomfortable having the particles spawn, seemingly from the face (the mouth), due to the high amount of particles and their brightness. We thus moved the stream of particles down to seemingly come from the our torso. That we found to match better with our initial idea of visualizing our breath, and having the particles spawning from our bodies created a sense of agency.

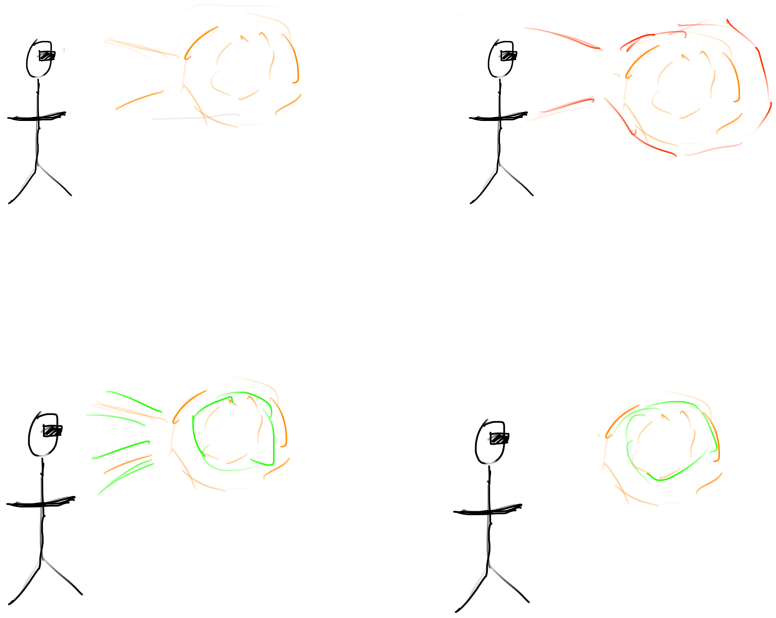


Figure 7.9: An initial sketch for how particles would be spawned by breath.

We also conducted a second test inspired by the same idea of visualizing our breath. To further strengthen a slow exhale, we conceptualized that only small particles spawned by a slow breath would form into spheres, but others would instantiate and slowly vanish. To evaluate the idea, we implemented it so that every breath would form into a separate sphere. While testing, we created many separate spheres, which felt quite confusing and cluttered. We thus never implemented the latter part, of particles disappearing when instantiated with slow breaths, because we did not deem it worthy of further pursuit.

7.3.3.4 Body Storming

We realized that we had not explored many input methods for creation. We mainly played around with the idea of using the breath to create. In order to support us in exploring new ways of input, we conducted a body storming session. We started the session by listing all the possible biosignals we could utilize in our design, then stood up and enacted possible scenarios for each input method. We concluded the session by sketching several scenarios, which we then broke down further to explore parts of the ideas. A glimpse of this session can be seen in the figure 7.10. After this session we discussed which scenarios to explore further. We evaluated the perceived difficulty of implementation and how much potential for creativity each idea had. Based on that, the following ideas were chosen:

- Electric ray creation with hands
- Particles spawned by movement
- Deleting, resizing, and selecting with gaze

Figure 7.10: Glimpse of the bodystorming session used to generate new ideas.

7.3.3.4.1 Electric ray creation with hands This idea was a result of our body storming session. It is a concept where the user can create a ray of particles between the hands. We implemented it so users had to sustain their sight on the left hand for a few seconds, which set the starting point for the ray of particles. The endpoint for the ray was then set by correspondingly focusing the sight on the right hand for a few seconds. The ray of particles was then immediately generated between the two points. The continuous movement and fluctuation of the ray, similar to an electric ray (hence its name), was perceived by us as enjoyable, even though the start- and endpoints remained constant. We did not find the thin electric arc interesting, but we argued that the creation technique could be valuable for precise creation. The qualities we extracted from this hack were: empowering, magical, intuitive, and novel.

7.3.3.4.2 Particles spawned by movement Particles Spawned by Movements This idea was also a result of our body storming session, and build on the Electric ray creation with hands. We modified when and how the particles would spawn; instead of happening in steps, the code triggered the particles to spawn continuously from the hands. This change made the creation experience fun, unrestricted, and energizing. As the particles never stopped spawning, we felt compelled to continue moving. This phenomenon was also somewhat stressful as there was no moment to pause and reflect. Therefore, a conclusion was that we would have to ideate a way to start and end the stream of particles coming from our hands. Another aspect of this technique was that we deemed the creativity and imagination needed to draw particles that resembled something interesting to be relatively high. In other words, it felt challenging. Additionally, the technique felt like Tilt Brush and like painting but in 3D, not novel nor very exciting. Ultimately, this technique did not support us in reflecting inwards towards our soma. The qualities we extracted from this hack were: creative, unrestricted, and challenging.

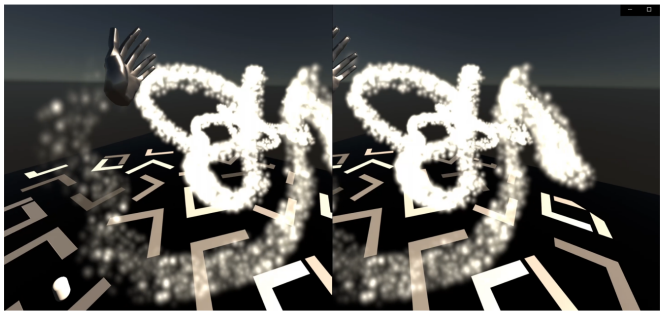


Figure 7.11: Particles spawning from hands.

7.3.3.4.3 Deleting, resizing, and selecting with gaze This idea was yet another result of our body storming session and inspired by how powerful, precise and unused our eyes are as input into systems, we started thinking of ways to use our gaze for art creation. We thought of our eyes as a way to reduce the need for ours hands, thus the initial features we created where selecting, resizing and deleting.
Leveraging the Varjo VR headset's proprietary eye-tracking system and Unity plugin, we could reasonably quickly set up a test environment with the Sphere VFX from paragraph 7.3.3.1 as the subject for our modification tests.
Initially, we set up a test to delete spheres using our gaze. We wrote the code so that one touch with the gaze on a sphere would delete it. Twelve spheres were positioned in arbitrary locations surrounding the person at a 360-degree angle. Deleting spheres by merely looking at them felt powerful but also frightening. Suddenly, we had to be careful where we placed our gaze and make an effort not to look at spheres we did not want to delete.
In the second test, we placed a sphere between two relatively small cubes. By looking at the left cube, the sphere would decrease in size and vice versa. This technique felt safer and more calm in relation to the delete technique. By placing the modification action on the two cubes, we enabled observation and inspection of the sphere without fear of modifying or deleting it. This technique felt easy, but it did not provide a connection to the art. Instead, we felt disconnected from the sphere as our actions were not directly connected to it. We gathered that a more organic approach for increasing or decreasing any parameter would have to be ideated to feel connected to the art artifact without being afraid of where we placed our gaze.
Ultimately we coded a "select" technique building on the "hit" (delete) and "resize" technique. We argued that this selection technique would be good if a user had multiple saved creations and wanted to reengage with a creation to continue modifying it. The "select" technique was coded to increase the sphere size after a brief moment of gazing at a sphere. Its increase in size would continue until reaching a certain threshold. The sphere would then shrink back to its original size but change

color, indicating that it had been selected. The technique felt easy, powerful, and valuable.
The qualities we extracted from this hack were: powerful, scary, easy, valuable

7.3.4 Sound

Following the expert interview with George Khut (see section 7.2.1, we looked into the soundscape of the design. He recommended hooking up the biosignals to the sound so the sound would change based on the measured biosignals. We envisioned two ways to accomplish that. The first option was to have an ambient sound that could be altered based on biosignal measurement. Meanwhile, the second option was to have an ambient sound stable through the experience but instead connect additional sound to every creation action that the user would do during the creation.

7.3.4.1 Ambient sound

For the ambient sound, a metastudy by Witte et al. explain that music with lower beats per minute (bpm) (typically between 60-90) has a calming effect, but music with higher bpm makes listeners alert [109]. Therefore, we decided that using music in the lower bpm ranges would be a good starting point. In order to experience various high-quality sounds, we bought a license for Artlist.com. We used this music library to download royalty-free sound clips and music to incorporate into our design.
As with the environment, we wanted to create ambiguity in the sound experiment, inspired by the Making Space quality of Somaesthetic appreciation Design, see 3.5.1.2.Therefore, we did not want any natural sounds that could provoke memories of the forest, animals, or similar. We also avoided sounds with vocals and too many instruments for the same reason. We found seven appropriate sounds, which we decided to test.
Using Unity's propriety music player and audio effects, we set up a test inside the concrete dome environment we previously had built (see section 7.3.1). We then listened to these sounds inside the environment with five different sphere particle effects to observe. One at a time, we listened through the sounds and took time observing our Soma, stating what we felt, and finally attributing an abstract score between 0 and 10 to the sound before progressing to the next. After both of us had tried this, we had a clear winner for the ambiance sound called "Breath Within" by Onyx Music, which we both rated highest. See section 12.1.3.2.1 for more information.

7.3.4.2 Sound Parameters

With the ambient sound set, we explored alternatives for layering the sound experience with distinct sounds for each creation. These sounds would become distinct through connecting sound effects and parameter changes to the user's biosignals. The parameters inside Unity we found most applicable for this purpose were make-upgain, low- and high pass filters, flange, and distortion. We conducted a test listening to a sound clip and modifying said parameters. We noted how they made

us feel and how the parameter changes could be utilized to induce or convey certain emotional states.

7.3.4.3 Creation sound

We, eventually, did not develop a connection between biosignals and alterations of the sound due to prioritization. Instead, we decided to fade out the current ambiance sound when entering creation mode and instead fade in another sound, which we refer to as the creation sound. The creation sound was selected using the same considerations as for the first ambiance sound: less than 60bpm, it should spark ambiguity and preferably not include any vocals and instruments. This selection process was less thorough as a "good enough" sound was initially selected as a placeholder. It was not until later in the project that we spent time selecting a better sound. In the end, we selected a creation sound called "Peter Rabbit" by Jon Gegelman as it was peaceful, playful and had a BPM of 81, in the high of the low bpm ranges which makes listeners more alert [109]. See section 12.1.3.2.2 for more information.

7.3.4.4 Spatial sound

Spatial sound means that the sound can be perceived as having both distance and position of origin in the room. Only a few hours were dedicated to exploring this technique as our tests concluded that more elaborate design work was needed for this, which required time we did not have. We tested adding a specific sound to a creation, which was exciting and made it seem more alive. An issue was that the sounds would stack on each other when adding more creations, which made the environment more stressful, a quality not sought after.

7.3.5 Additionally explored biosignals

Our implemented tests in this thesis include heart rate (PPG), eye-tracking (Varjo technology), hand tracking (Leap motion technology, inside Varjo headset), and breath tracking. However, these are not the only biosignals we explored during the playful hacking phase. We also explored GSR, ECG, and full-body motion tracking. These tests are explained briefly in this section and why these biosignals were not further pursued.

GSR - Galvanic skin response We tested GSR (Galvanic skin response, explained in section 2.3.4) using a GSR sensor connected to a Bitalino from Plux Biosignals. As we followed the guide provided online and different setups preparing with skin cleaner and applying contact paste, we never got it to work. We decided to discontinue testing with this biosignal due to the combination of many failed tests and how difficult we imagined it is to perceive GSR.

ECG - Electrocardiograph The ECG (Electrocardiograph, explained in section 2.3.2) was intended to be measured by wearing a Teslasuit. The Teslasuit is a vest and pants measuring body movement, ECG, and producing haptic feedback [11].

We spent two weeks of trials and conversating through email with the Teslasuit team in England. The API is, in our view, poorly documented, and the code was challenging to understand. Although as we managed to extract the biosignals, we stumbled upon an issue with the ECG measurements; they were often faulty. On inhale and hold (expanding the abdominal area), the measurement would work, but upon exhale, we would get erroneous signals (see figure 7.12). The Teslasuit team then explained that ECG measurements were mainly intended for measuring users lying down, which was not a constraint that we were willing to guide our project. We had no other device for measuring ECG; we thus decided to end this track.

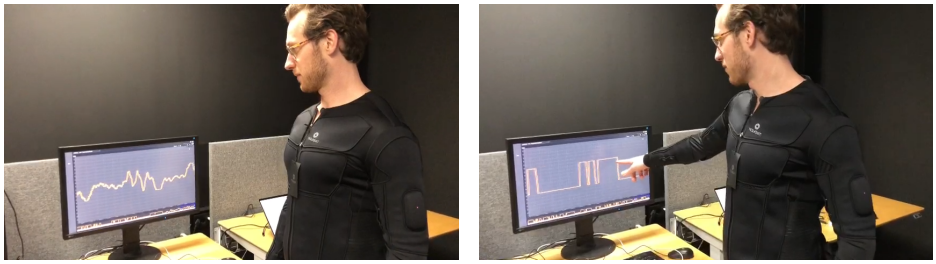


Figure 7.12: David testing out the Teslasuit and ECG measurements, first image depicts good readings and the second depicts erroneous.

Full-body motion tracking As previously mentioned, the TeslaSuit also measures full-body motion. Although since we could not use this suit for ECG measurement, it made less sense to use it for motion measurement only. At this point, we already knew we could use the Leap Motion technology inside the Varjo VR-3 headset for hand tracking. Additionally, we wanted to be as non-intrusive as possible in measuring the biosignals, meaning the less equipment the user had to equip, the better. Due to these reasons, we did not proceed with full-body motion tracking

8

Data Synthesis

After the discover phase, we gathered and synthesized all of the collected data thus far in the project. That is, information and insights accumulated from the playful hacking, expert interviews, and relevant frameworks and definitions from the Theory chapter.

We visualized our learnings on a Figjam board as seen in figure 8.1.

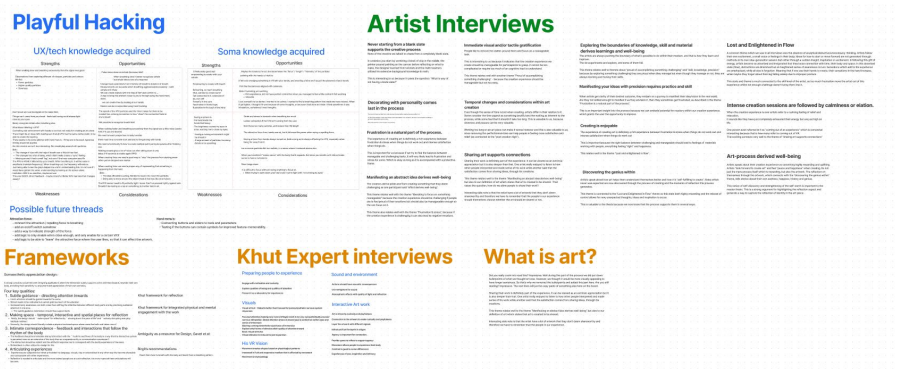


Figure 8.1: A visual overview of the Figjam board with all the collected data.

We divided the insights from the Playful Hacking phase into acquired (1) user experience and technology knowledge and (2) somaesthetic knowledge. Next, we displayed the themes that emerged from the thematic analysis of the expert interviews and the main take-aways from the George Khut expert interview. On the board, we also placed summaries of Khut's frameworks for (1) Reflection and (2) Integrated physical and mental engagement with the work, as well as Kristina's Höök framework for somaesthetic appreciation design and Gaver's framework for how ambiguity can be used as a resource for design. Finally, we gathered some art definition sentences.

Reviewing the board of all the gathered information, we realized that our themes from the thematic analysis of the expert interviews were too abstract. Meaning they were not very specific to art creation practices. We also realized that Höök's, Khut's, and Gaver's frameworks are presented via qualities. Thus we decided to review the thematic analysis themes again and extract qualities from them. In doing so, we synthesized our learnings from the expert interviews into actionable insights beneficial for our ideation phase. We eventually also extracted qualities from our Playful hacking learnings and the art definitions, figure 8.2, shows and overview of the qualities.

Figure 8.2: A visual overview of the Figjam board with all the qualities.

9

Ideation and Define

This chapter explains how we ideated, chose, and defined the design for the final phase of high fidelity prototype iterations. Initially, we gathered all collected data, insights, and qualities to use for a brainstorming session. The ideas with similarities or little difference were initially grouped to reduce the number of ideas to vote on. We then utilized dot voting to synthesize all of our ideas from the ideation phase into three that had the most potency to support our project. Out of those three ideas, we choose one to continue developing and elaborate on. To inform our development, we reviewed our previously acquired insights. A bodystorm session followed this to align our thinking and figure out the details of the idea. We ultimately documented our elaborated idea with a preliminary user journey map, storyboard, and a MoSCoW.

9.1 Ideation

The ideation was supported by the qualities we had collected from several sources, the artist interviews, an expert interview with George Khut, technical and first-person knowledge from playful hacking, and the relevant frameworks and definitions listed above. All the data and insights were summarized on a Figjam board and projected on a big screen in the room to be readily available for referencing and inspiration. We gathered all the qualities from the project in a spreadsheet and did several rounds of extracting, at random, one quality from each source, six qualities in total. For each round, we ideated how those qualities combined look and sound, how they behave, and what biosignal actions they could support. Generated ideas were noted on post-its and placed on the whiteboard with the current six qualities, shown on figure 9.1. When we felt the flow of ideas stagnating, we skewed 1-3 of the qualities. This meant we skewed their meaning, so the quality “empowering” would become “weakening” for instance. After each round, we photographed the whiteboard, removed the post-its, and erased the qualities. In total, we did four rounds of extracting random qualities and skewing some of them.

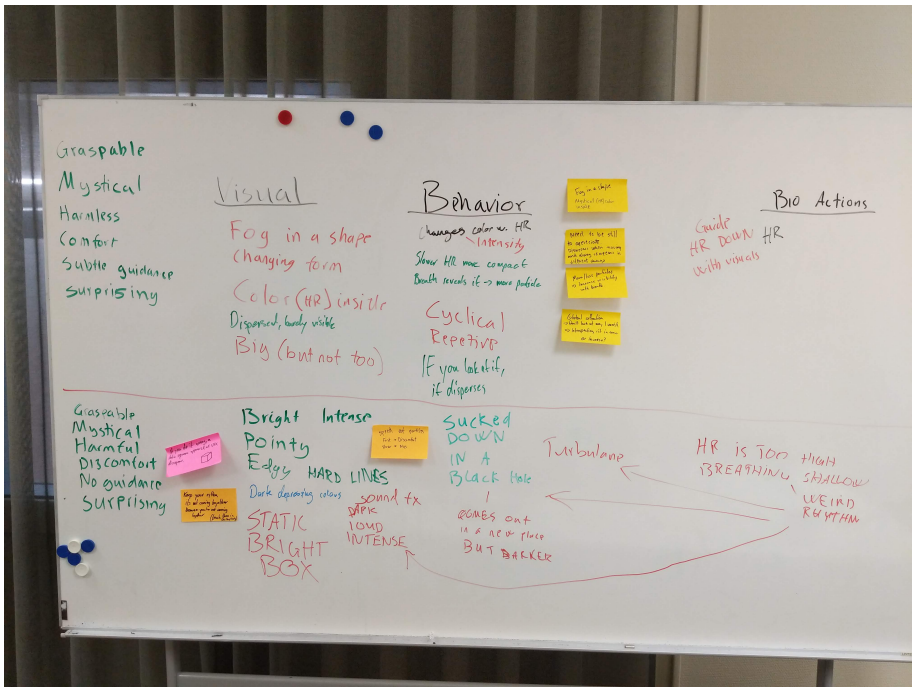


Figure 9.1: The whiteboard used to support the ideation session.

9.2 Dot Voting

The resulting ideas from the playful hacking and ideation phase were placed on a table (see figure 9.2), and each of us had five votes. After voting, we discussed and elaborated on what qualities we liked within the ideas that we voted for. Through discussions, we gradually discarded ideas, supported by the knowledge we acquired in the previous phase of the project. Some ideas were, for example, discarded due to technical feasibility and others due to their weakness in supporting our goal. For instance, one idea was to have a bonfire in the middle of the space, generating small random shapes floating upwards. If a user catches them, they are saved and can be modified, if not, they eventually disappear. This idea resonates with easy, playful, creative, interactive, versatile, and magical qualities. We discarded the idea because of the technical feasibility; we had not tried anything similar during the playful hacking. It also had a risk of it not being as good in practice as in theory.

Figure 9.2: The main ideas from the ideation phase.

9.3 Reviewing collected data and bodystorming

Before elaborating on the idea we felt was the most conducive to supporting our goals, we revisited our data analysis insights. We resurfaced the themes from the thematic analysis, the somaesthetic appreciation design framework, the advice from George Khut, and the insights from our playful hacking. Afterward, we conducted a bodystorming session (see figure 9.3) where we acted out the idea. The purpose was to expose flaws in the user flow, embed value-adding activities and qualities, and align our thinking. The questions we focused on answering during the session where:

- How do you instantiate?
- How do you stop?
- How do you regain control of it?
- What do you need to do?
- What can you do?
- How do you delete it?
- How does it look

The results from the bodystorming session were various insights but some of the majors ones were; have a certain sound for when the creation has been instantiated, moving the hands too quickly will delete it, the creation is saved if the user and hands are still for a few moments and the user can resume modifying the creation through placing their hands in or around it.

Figure 9.3: David, the co-author, performing a bodystorm to try out the generated idea.

9.4 User Journey Mapping

”Getting users ready to experience is half of the work´´, George Khut. Based on the advice of George Khut, we knew that it would be critical to the design's success to think about the user journey, from before start to after finish, as early as possible. We were not only designing a prototype in which people can create art; we were creating a complete user journey. Therefore, before elaborating on our idea further, we mapped out a preliminary user journey map where we focused on how users should be introduced to the experience and how we end the experience (see figure 9.4).

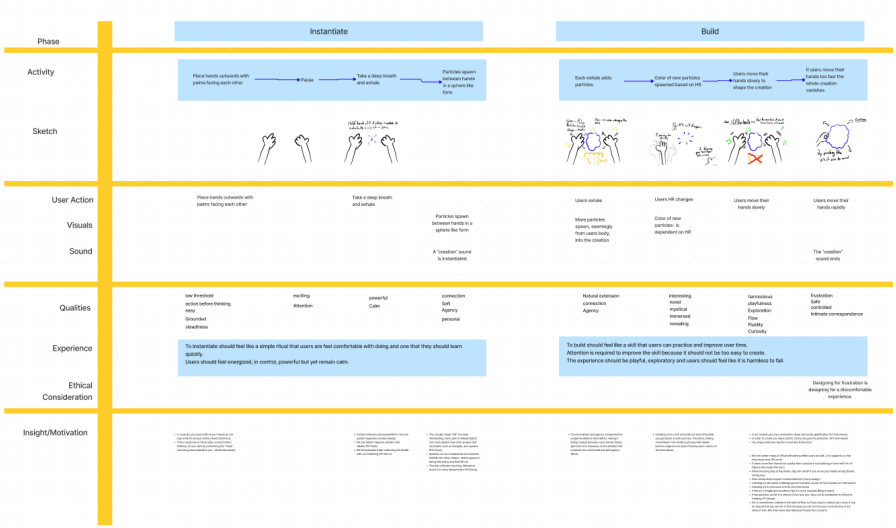


Figure 9.4: The resulting user journey in Figjam from the ideation phase

9.5 Storyboard

We sketched a storyboard of the imagined user flow from the bodystorming session to manifest and align our current thinking. The storyboard would also serve the purpose of presenting our idea to others.

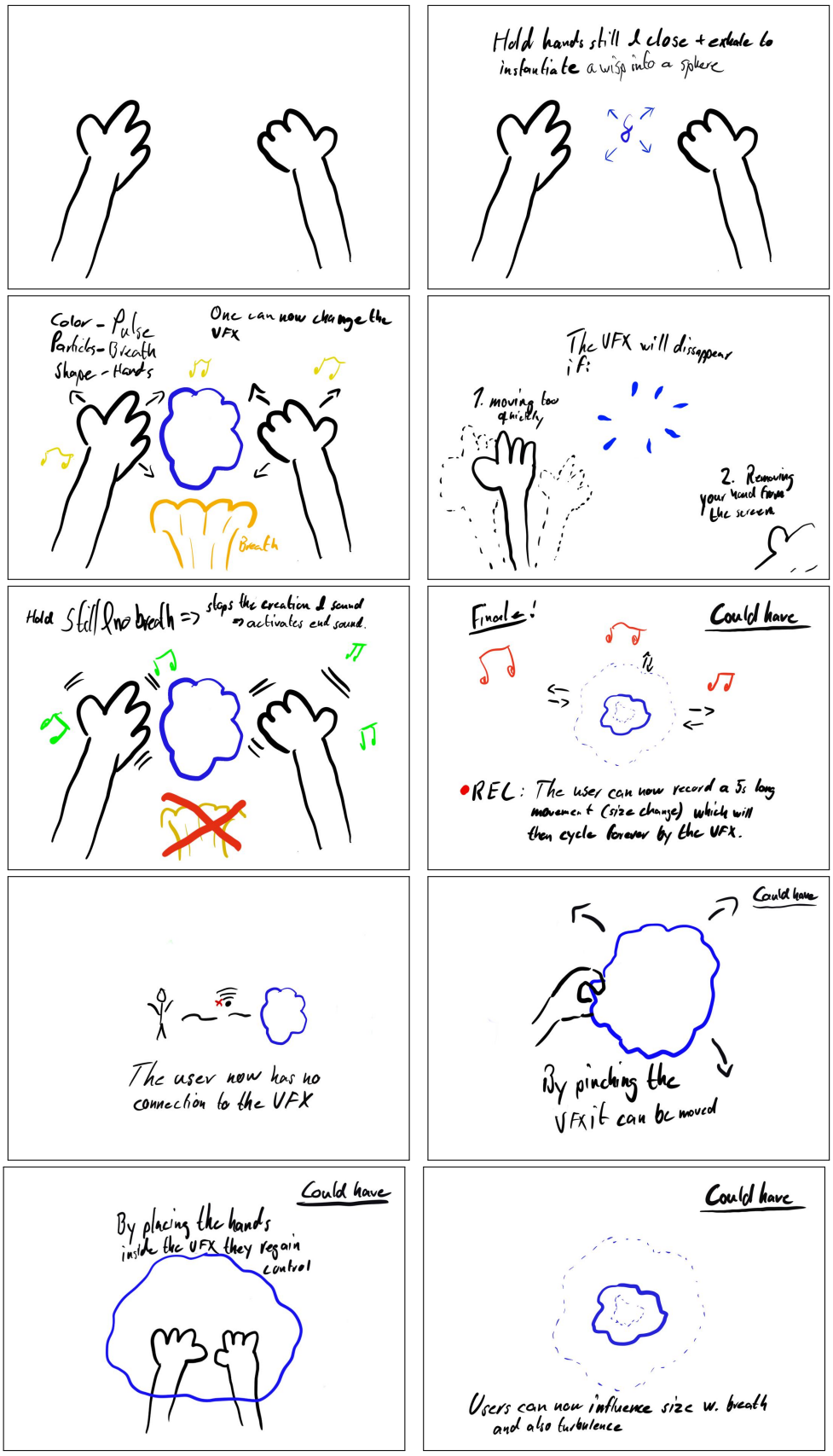


Figure 9.5: A sketched storyboard of the resulting idea from the ideation phase.

9.6 Moscow

To structure our work going forward, we placed all of the feature ideas into a Moscow diagram (see figure 9.6). The Must's were the essentials that we deemed necessary needed to develop, the Should's were features that we thought would be valuable yet not essential, and the Could's were features we deemed as intriguing to have but not essential at this stage. We started without any Will not's but reasoned that as the project progressed, we would move features to this section.

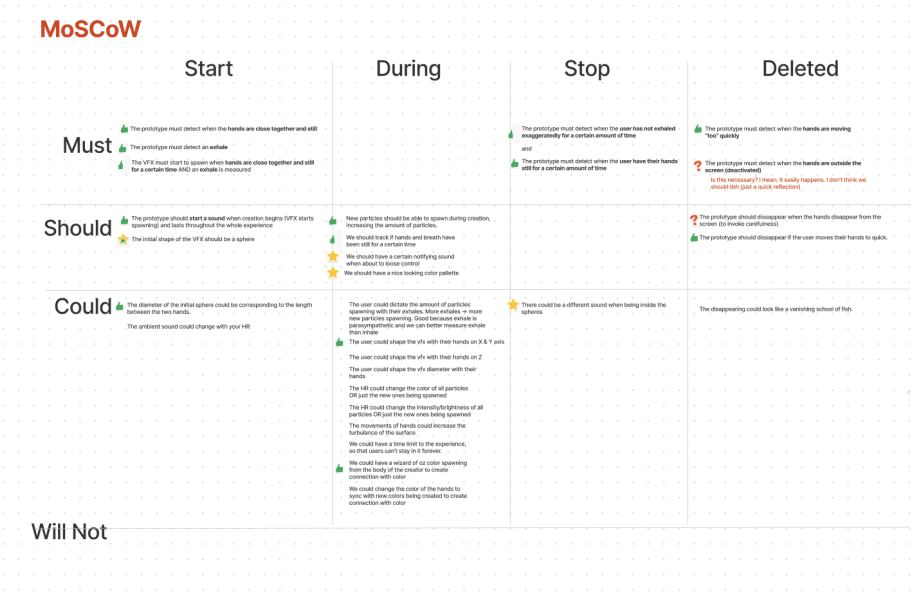


Figure 9.6: A view of the MoSCoW which was utilized for prioritizing development of features in the thesis

This Moscow overview of the required features aided us in prioritization and dividing the work among us. We marked the finished features with a green thumbs-up and a half of this icon when in progress. Structuring the features in this way also helped us align our minds on how to structure the development, what should be developed first, and what follows. Furthermore, an unexpected outcome was insights into how certain features should be developed together to generate "milestones" for testing the prototype. Following the development pace and the roadmap, we could also relax into the understanding that we will not be able to develop all features (such as modifying a creation after saving), which was OK because then we could prioritize Should's and Could's instead.

10

Develop

In this chapter we elaborate on how we implemented the most promising idea from the previous phase. We had built up a lot of technical know-how from playful hacking, which was beneficial to produce a working prototype quickly. The Moscow diagram was helpful for prioritization, and here we report on the most important aspects that we implemented before conducting formative evaluations. The prototype evolved a lot throughout the formative evaluations and thus we also mention the main findings and iterations during that phase.

10.1 Utilized Threads from the Playful Hacking

The playful hacking was not directly intended to contribute to the final prototype but rather to explore the space and understand the possible opportunities of the design material. In the end, we did however get to utilize most of our acquired knowledge from the playful hacking. The encircled hacks in figure 10.1 are the threads from the playful hacking utilized in *Nebula*.

Figure 10.1: The threads from the playful hacking which we utilized in the *Nebula*.

10.2 Color

We had previously decided that color should map to the user's heart rate. We conceptualized it so that the color of new particles would map to a heart rate value at the instantiation time. The colors of the particles inside the creation would not

Figure 10.2: The heart rate zones used in the experience with corresponding colors.

change, but the color of new particles emerging could be different if the heart rate was different. The temporal aspects of heart rate fluctuations during the creation experience are thus stored within the creation. This means the artwork is rather mono-color if a user's heart rate is stable during creation. If a user's heart rate fluctuates, the resulting artwork is subsequently represented by having multiple colors. We argued that these shifts in color could provide depth by provoking thoughts and supporting the user in reflecting on their heart rate, and subsequently their soma.

We implemented the color and heart rate connection in *Nebula* by calculating the average heart rate from the last five measurements. We used the average heart rate of the last five measurements instead of just one due to the technical limitations of the measuring device. We noticed that some heart rate measurements fluctuated significantly due to poor measurements and an at times unreliable algorithm, but using the average heart rate, we could somewhat counter those inaccurate measurements. We assigned a color based on what heart rate zone the calculated number falls within. *Nebula* has fourteen heart rate zones, as shown in figure 10.2 and each corresponds to a unique color. The colors were picked using a color wheel, attempting to pick colors that looked good in VR. The number of particles, their brightness, and their movement made it hard to distinguish similar colors from each other. We, therefore, tried to pick distinct colors which contrasted each other. As shown in figure 10.2, we tried to separate similar colors as much as possible so that users would experience color changes when their heart rate changed. The 14 zones resulted from dividing the heart rate span of 60-171 into granular sections, which would produce varying colors for participants.

As we were designing for users to create art, we did not design the colors to represent anything. It was important to us that the color palette was harmonious, and users should establish the meaning-making of colors (rather than us). It was critical, though, that users could distinguish between colors to reflect on whether and when their heart rate would change. The resulting colors used in *Nebula* were thus chosen with a focus on contrast and shown in figure 10.2. It is important to note that

the colors look quite different in VR because of luminance and other additional features. Thus, we conducted extensive testing with the VR headset to compare the contrasting colors. An example of such a test is seen in figure 10.3.

10.3 Introduction to the Experience

One of the most urgent initial aspect, aside from creating a working prototype, was elaborating on how to introduce users to the experience. We thus drafted a script, informed by Khut's recommendation of beginning with a body scan to ground people (section 7.2.1) and emphasis on layering the experience to provide Agency (section 7.2.1). The introduction begins with a four-minute-long body scan where the user is instructed to close their eyes and focus on different parts of the body, sensations and thoughts. It is supposed to help them to become more aware of themselves and create a judgement free mindset (see appendix A to read the whole body-scan). Following the body scan, the user is introduced to what is possible within the *Nebula* experience. To provide agency, we structured the information so users have to follow the instructions and essentially create their first art creations under the guidance of the voice narration. The actions available to users to create are introduced and enabled one at a time in a tutorial-like manner, with room for reflection in between. During the first formative evaluations, we read out the script to participants in real-time meanwhile they had the VR headset on and followed the instructions.

10.4 Formative Evaluations and Iterative Development

We began conducting formative evaluations with Volvo employees when we had a working prototype. The evaluation set-up was simple: we just invited people directly to our workstation to test the prototype. People had a few square meters to move around, and we tried to keep the small office area quiet when testing. We had, in total, eight participants and also tested the experience extensively ourselves. Each formative evaluation session with participants lasted about one hour. The sessions began with us informing participants about what they would do during the session and asking them to sign a consent form. Afterward, participants filled out a body map before equipping them with the biosignal measurement devices, VR headset, and audio headphones. What happened next varied between tests because we constantly iterated on the prototype between evaluations. However, participants would essentially listen to the introduction narration before having the opportunity to create freely. After the VR experience, participants filled out a second body map and shared their thoughts with us during a 20-minute interview. The interviews were initially semi-structured, but we then began asking participants only three questions and followed up with appropriate probes. In the first question, we asked them to tell us about their body maps, the second how they would describe their experience, and lastly, if they had any suggestions for improvements. During the interviews, one of us asked questions while the other took notes.

Figure 10.3: The resulting user journey in Figjam from the ideation phase.

We iterated on the prototype and the overall user journey during the formative evaluations. After each interview, we reviewed our notes and arranged the findings into a modified SWOT analysis on a Figma board. We grouped insights under “Strengths”, “Weaknesses”, and “Opportunities”, and skipped the “Threat” category as we saw no benefit in it. Next, we reformulated the learnings from the SWOT analysis into actions we could take to address each insight. We then arranged these actions on the Moscow board. The actions we placed as “Must” were the ones we deemed essential to address before evaluating with another participant. On the contrary, the actions we set as “Could” were of low priority to us, and that category grew quite large during our formative evaluations. Figure 10.4 shows and overview of the structure on Figjam.

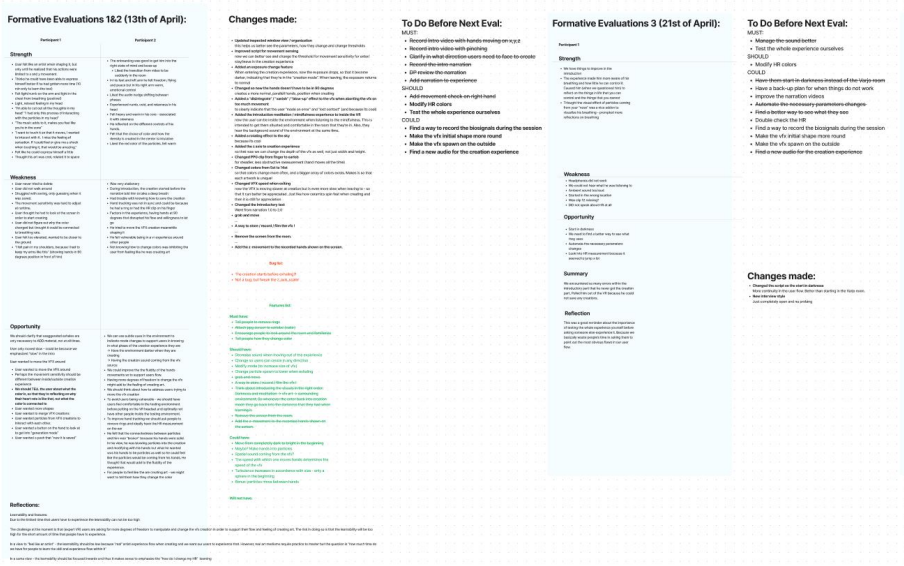


Figure 10.4: An overview of the formative evaluations structure on Figjam.

In the following paragraphs, we briefly report on each formative evaluation session and some of the main findings we derived from each participant.

Participant 1 In the first version of the introduction narration, we did not inform the participants that the color of the particles was connected to their heart rate. We assumed it would be more impactful and inward reflective for them to discover it themselves. However, the first evaluation it resulted in reflections on what technical aspects of the design could be affecting the color of the particles. Our main takeaway from the first test was thus that we should inform participants that the particle’s color connects to their heart rate to support reflection.
We did not implement any changes between participants 1 and 2.

Participant 2 The second participant is an expert VR user and has been working at the forefront of the technology for years. He had difficulties in knowing how to save the creation. Thus, he recommended that we could use subtle cues in the environment to indicate mode changes to support users in understanding what phase of the creation experience they are in. An example he gave was that we could make

the environment dark when people are creating to indicate that mode. That could then be contrasted with a lighter environment when users are not creating. He additionally advised us to have the overall environment darker so the creations themselves would shine brighter. Another helpful insight he had was that we should take care of the environment surrounding the user with the VR headset because people tend to feel very vulnerable inside VR.
We implemented all of the recommendations from participant 2 listed above and added to the introduction information that the user's heart rate connects to the color of particles. We also acknowledged after conducting two tests that we needed a better way to control the experience. There was a high workload on the one moderating the experience. Many steps in the introduction were not automated, and observing and calibrating threshold parameters before and during the experience was challenging. We, therefore, developed an updated inspection window where we could monitor the main thresholds and adjust them in real-time, as seen in figure 10.5. Additionally, we automated many steps in the introduction by recording the narration text and breaking it into audio clips to play to participants.

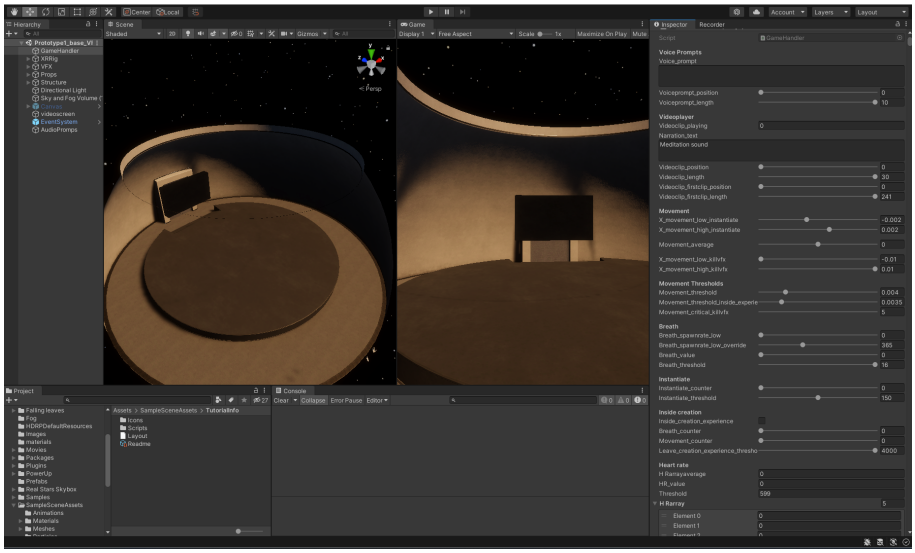


Figure 10.5: The control panel where we could monitor and adjust thresholds.

Participant 3 We had attempted to automate many steps in the introduction process before evaluating with participant 3. We discovered many flaws in the automated narration during this evaluation, mainly apparent errors we could have identified ourselves, such as having the user start at the wrong position in the VR environment, and the sound being too high. The primary learning from this evaluation was that we should be cautious in rushing testing with participants and evaluate new implementations ourselves before user evaluations.

Participants 4 We encountered some issues during the test with participant 4 because we forgot to calibrate the measurement devices properly. We, therefore, developed a preparation checklist to go through before each test. The checklist is in appendix B.

Participants 5 Participant 5 experienced difficulties saving and deleting creations and expressed that she found the instructions confusing. Until this point, we had deliberately not used the word "save" in the introduction text because we did not think it aligned well with creating art. We had, however, heard participants repeatedly use that wording when referring to the action. When participant 5 experienced the prototype, how to save creations was introduced and explained in the following way:

> *"If your hands remain steady and you do not take any belly breaths, you can hear the sound change after a while and the room you are situated within gets lit up. Try it when you feel ready."*

and followed with:

> *"When that happens, you can freely move your hands again, and as you can see, your artwork is there to be appreciated."*

After this test, we decided to use the word "save," and explain the action more thoroughly. The final version of this part of the narration became:

> *"If you keep your hands and head steady for long enough you save the creation. You can see the creation's movement slow down when it has been saved."*

which was followed with:

> *"Now you have saved the creation and you can freely move again. Your creation is stored within this safe space you are situated."*

First person evaluations During this project phase we repeatedly tested the prototype between iterations. We most often tested isolated parts or features within the experience, but at several occasions we tested the whole experience with a first-person perspective from start to finish. One of those occasions was after participant 5's test and before participant 6. Our primary learning from doing so at this point was that the introduction was very linear, but there were still actions that users could perform that we could not foresee and control within a linear narration. We, therefore, at this stage, developed narration clips we could utilize in a non-linear way and play to participants during the introduction. For example, suppose participants were not taking deep enough belly breaths to instantiate creations. In that case, we could play a short audio file saying, "Remember to exhale completely by pulling your belly button inwards."

Participant 6 Participant 6 is an expert VR user and has been working at the forefront of the technology for years. He pointed out that the breathing band we were utilizing might not accommodate users with more sizeable abdominal circumference. He also mentioned how it could be troublesome having the heart rate measurement cables hanging from the ear in front of the user because they might accidentally pull on the cable. We accommodated these concerns by ordering an extension for the breathing band and always had, from this point onward, the wires hanging behind the user. When reflecting on the overall experience, he said he had understood that heart rate dictated the color, but he had no connection to it. Following that insight, we added a section to the introduction where the narration guides users through breathing exercises: one session where a user breathes rapidly and another where

they breathe slowly. The narration then explains to the user that this is how they can increase and decrease their heart rate and thus change colors.

Participant 7 During the evaluation with participant 7, we discovered a technical error in the system that we had not observed before. The participant took a deep breath and exhaled, which instantiated particles spawning from the participant's body towards the creation. At the same time, the participant moved her hand rapidly, making the creation vanish. The result of these two actions happening simultaneously' was that the particles spawning from the body continued spawning endlessly because they had no target, as seen in figure 10.6. At this point, we decided that instead of revising the whole code to accommodate this use case, it would be better to deal with the problem more quickly but less thoroughly. We thus implemented a special override button that would delete the exhale stream in case this happened again.

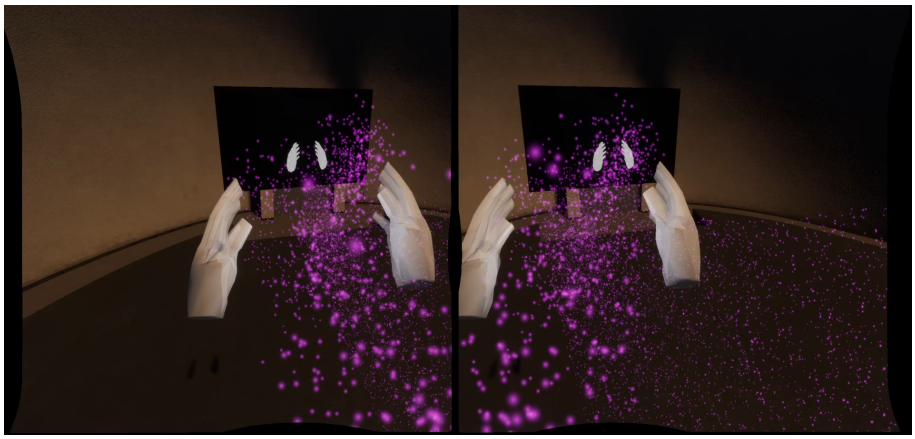


Figure 10.6: Particles spawning from the user's body to a creation that has already been deleted.

Participant 8 We observed no new insights of concern during the evaluation with participants 8. The interview with him and previous participants provided promising information that we were on the right track with our design. In his interview, it was evident that he had not fully understood how to control all parameters of the creation experience. For example, he said he was unsure how to manipulate the colors. Yet he felt like the experience was highly intriguing. When the experience was over, he had a big smile on his face and said, "This is really cool. I want to continue creating." He later elaborated on feeling empowered during the experience, "Felt like being a god. Being in a universe, creating like a god." We felt promising that even though he had not managed to grasp and reflect on everything within the experience, he still found it so powerful and rewarding. We were aiming for an experience where people felt like creating art, and thus some system learnability should be expected, but it could not be too much, so it would override the pleasure of creating. That is the balance we felt we were striking at this point, or as he stated:

> *"It felt super nice. It takes a while to you get it. It did not feel like you learn it quickly."*

Before the final evaluation, we sent all the narration text in the introduction to a voice artist. Thus, the final version of *Nebula* is narrated by a smooth and calming female voice.

11

Evaluate

In this chapter we describe our process of evaluating the *Nebula*. We recruited 12 participants and each session lasted 60 minutes where they got to individually try out the experience and retell their experience during a unstructured interview.

11.1 Participants and Environment

We recruited 12 participants using university slack channels, LinkedIn, Lindholmen internal channels, and word of mouth. All participants had some connection to either Lindholmen Science park, Chalmers University of Technology, or Volvo. (6m/5f/1 did not answer , Age: 22 to 56). The majority of participants (41.7%) had minimal experience with VR; 25% had no experience using VR; 16.7% had used it from time to time, while another 16.7% had used it often. The total duration of the study did not exceed 60min. No compensation was given, but participants were gifted with a 10s video recording of their artwork if they managed to create one (and if the system did not crash when finishing the experience).

The test was conducted at the Visual Arena at Lindholmen Science Park. The Visual Arena's studio is a room of roughly 20x30m with a ceiling height of 7m, see figure 11.1. This room is typically used for video presentations or recordings where the subject needs space for movement.

The experience was set up in a 4m x 4m space in the center of the room. A set of two Lighthouse Base Stations were installed in each corner on tripods. Outside this space, we placed the desk with the control panel to run and moderate the experience.

Figure 11.1: The studio in the visual arena.

11.2 Procedure

To subscribe to the evaluation, participants were asked to fill in a questionnaire and book a time. In the questionnaire the users answered the following questions; (1). What describes your employment status the best? (2) What's your previous experience with virtual reality? (3) What's your age? (4) To which gender identity do you most identify?. These questions were asked to give us an understanding of the group of participants, which perhaps could influence the outcome of the evaluation and thus the results. The participants could then book a 1 hour time slot between 8 and 17. Upon entering the room, the participant was welcomed to sit by a small round table and presented with the consent form. After providing informed consent, the participant was instructed to calmly take a few breaths and fill out a bodymap with their most prevalent feelings and sensations at the moment. The participant was left alone during this exercise. The participant was then positioned inside the interaction space and presented with the biosignal measuring equipment. Provided with a brief explanation about the equipment worked and how it should be fitted, the participant was then asked whether we could help them with the fitting or if they wanted to do it themselves. To gather biosignals, a Piezo-Electric Respiration (PZT) sensor band was placed around the torso of the participant, and a small heart-rate Photoplethysmography (PPG) sensor was clipped to their ear. These devices were connected to a micro-computer, attached to the participant's clothes or the respiration band itself. The Varjo VR headset was then fitted together with a pair of headphones. The experience was then started after a biosignal and sound check. As the experience began, a camera on a tripod recorded the participant from the outside, and a screen recording was started.

During the experience, one moderator was in control of the participant's experience in VR by observing on the screen what the users were doing and moving through the instruction phase accordingly and providing additional supportive voice prompts. The other moderator observed and assisted the participant in the physical space by moving the cable to the VR headset so that they would not trip over it, and simultaneously acting as a safety net if the participant should lose their balance. Figure 11.2 shows the described set-up.

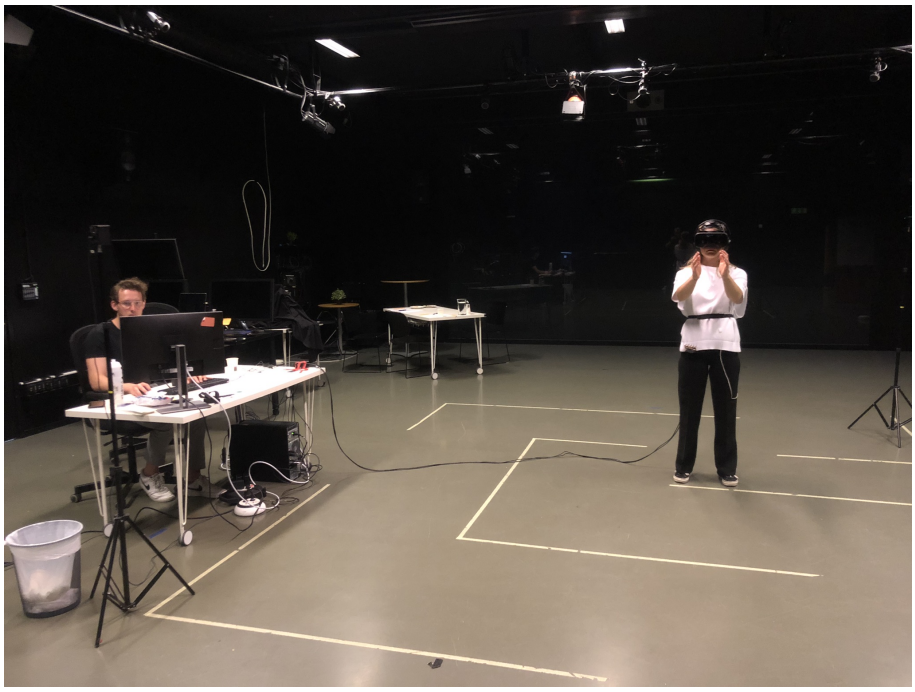


Figure 11.2: The setup of the experience including moderator, space for moving and the participant.

After participants had tried *Nebula*, their immediate, unprompted verbalizations of the experience were recorded with a voice recorder. The participant was then instructed to return to the first table, fill out a post-experience bodymap and bring both of their bodymaps to a table on the opposite side of the room where an interview followed. In the interviews, recorded with a voice recorder, participants were asked to begin with explaining their body maps, prior to asking:

> "If you were to tell a friend about what you did in this experience here today, what would you say to that friend?"

We then probed on the activities mentioned by participants with the aim to map their mentioned actions with the resulting feelings. We structured the interviews this way to support our second research question, which is about what creative biosignal-driven activities are conducive to well-being.

11.3 Data Analysis

At this stage of the project, we had to find strategies to tackle the thematic analysis of the extensive data. We thus chose three participant interviews to focus on and analyze in detail. We carefully selected participants with varying experiences who had articulated themselves well. We then reviewed the remaining nine interviews after doing so, and the analysis of the other nine interviews was through the lens of finding insights to support our previously concluded results through the first three interviews. Furthermore any new insight from the remaining interviews was also reported. Below, we report on how we evaluated the data for each research question.

11.3.1 Research Question 1

> *"What should be considered when designing a VR experience where biosignals are used as input for creation, as informed by art practice?"*

Initially, we extracted actions, feelings and qualities from the three participant interviews into a set of post-its and text (further referred to as "sets") the Figjam board. We then grouped these sets into themes and named the themes. During this process, we also changed the theme names and moved sets that did not fit in any longer. The theme names were then copied to a new location without their sets of post-its. A new process of finding affinity between the themes names began. We used position and arrows to indicate connection, order, and hierarchy. This process supported us in discussing the findings and aligning their meaning and inherent connections. The result was the initial design considerations, which did not include VR and Biosignals. A similar process began again, but now including our notes from the playful hacking, the literature, and the expert interviews to find design considerations for VR and biosignals, in this context. The new sets of this review's post-its were moved into either a VR or Biosignal category and then grouped into themes within each category. The themes then generated the new design considerations. An overview of the results on Figjam can be seen on figure 11.3.

Figure 11.3: Overview of the data for Research Question 1 in Figjam.

11.3.2 Research Question 2

> *"What creative biosignal-driven activities informed by somaesthetic appreciation in VR are conducive to well-being?"*

The same sets of post-its from the analysis for research question 1 were used in the analysis for research question 2.

First, we split the sets in each design consideration into the four someaesthetic appreciation design qualities; making space, intimate correspondence, subtle guidance, and articulating experiences.

Then we combined all sets from the design considerations into one large 2x2 grid with each someaesthetic appreciation design quality. The sets in each quadrant were split and sorted into either hedonic, eudaimonic, or only connected to the somaesthetic guidelines. This separation was done to gain an overview and insight into the well-being aspects of the data at hand. We then reviewed every quadrant and listed what actions, feelings, and quotes were in them. An overview of the results on Figjam can be seen on figure 11.4.

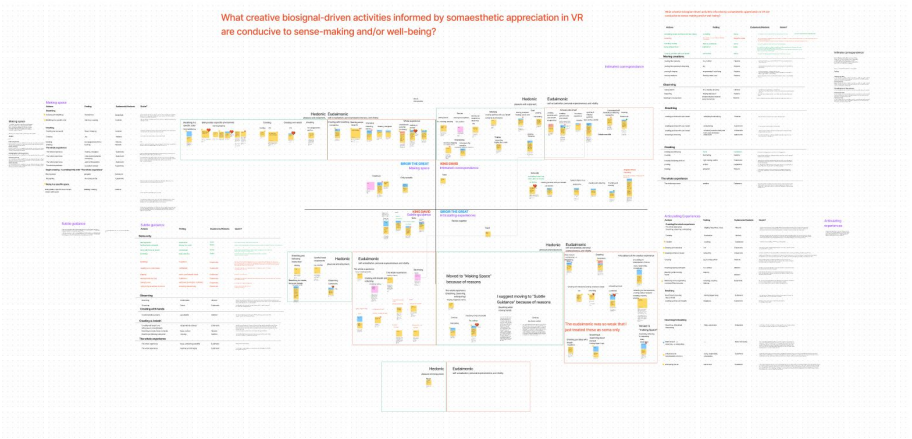


Figure 11.4: Overview of the data for Research Question 2 in Figjam.

12
Results

In this chapter we describe the resulting design, Nebula, and the quantitative data from the evaluation. Finally, we answer the two research questions stated in the introduction.

12.1 *Nebula*

In this section, we describe our design artefact, *Nebula*. We start by giving a short descriptive summary, followed by the technical set-up required. We offer details on how the environment and sound were designed and a description of each phase of the experience. We conclude the section with reporting on the descriptive quantitative data measured during the evaluations.

12.1.1 Summary

Nebula is an experience where a user can create art in virtual reality using their pulse, breath, and hand/body movements. Initially, a user is equipped with the technology and given brief instructions about what to expect when putting on the headset. The experience begins inside darkness in VR with a 4-minute narrated body scan to sensitize the user to their soma. The user is then instructed to open their eyes and follow narrated and visualized instructions on generating and shaping creations consisting of moving particles. After completing the introduction, the user is free to create and explore independently. The narration gently acknowledges when there is only one minute remaining and then turns down the light when the time is up. Before removing the VR headset, the user is invited to reflect upon and interpret their artwork in darkness, within a final observation phase where they can only view their creation. The experience ends when the user decides to take off their headphones.

12.1.2 Technical set-up

Nebula is run using a computer, a virtual reality headset with scanners, and an on-ear noise cancellation headset for audio. The biosignals are recorded and transmitted using a microcomputer which records breath using a piezo-electric respiration sensor and an earlobe ppg sensor to measure the pulse (see figure 12.1).

Figure 12.1: The complete setup of *Nebula* during the evaluation

12.1.2.1 Computer

Nebula is run on a x64-based PC with a Windows 11 Pro OS. This computer has a Intel(R) Core(TM) i9-10900 CPU @ 3.70GHz and 64gb of RAM. The graphics card is a NVIDIA Quadro RTX6000.

12.1.2.2 Virtual Reality headset

The Varjo VR-3 is the virtual reality headset used. This VR headset has a human-eye resolution of 70 pixels per degree and a 115° field of view. The Ultraleap Gemini V5 technology is integrated into this headset, enabling hand tracking. It has a refresh rate of 90 Hz and weighs 944g (including the headband of 386g). The headset is connected to the computer via two USB-C cables and its position in the room is calculated using two scanners mounted on tripods facing each other [110].

12.1.2.3 Sound equipment

The headset used is a Bose Noise Cancelling Headphones 700. The Bose 700 has excellent noise cancellation and emphasizes the ears' comfort.

12.1.2.4 Biosignal measurement equipment

The biosignals are recorded and transmitted using a BITalino (r)evolution Core BT from Plux Wireless Biosignals. This is a micro-computer (nr.2 in figure b 12.2) with real-time data streaming capabilities (sampling rate of 1, 10, 100 or 1000Hz) using an Atmel ATMega328p chipset.

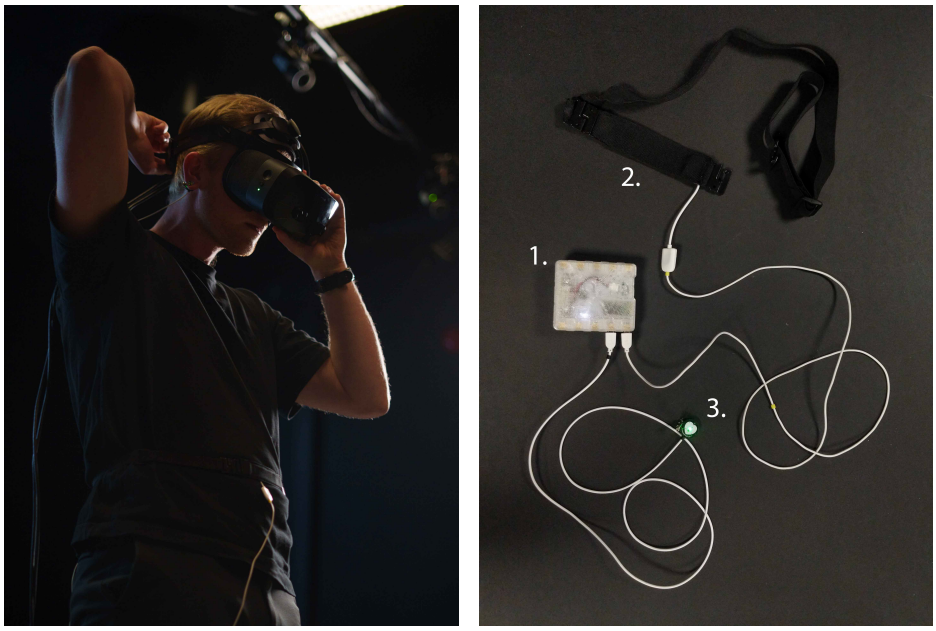


Figure 12.2: To the left: Birgir, the co-author, trying out the biosignal measurement devices. The ppg and pzg sensor and the bitalino are hanging from the belt on his back (visible on the image to the right)

Pulse The pulse is measured with a sensor for photoplethysmography (PPG) from Plux Wireless Biosignals (nr.2 in figure 12.2. The sensor is of a reflective type (emitter and detector on the same side), emits green light with a wavelength of about 520nm, and has a diameter of 1.6cm.

Respiration The breath is measured with a piezo-electric Respiration (PZT) sensor from Plux Wireless Biosignals (nr.3 in figure 12.2). The belt has a range of 1.50V, is adjustable, and placed around the user's abdomen, on top of their belly button. It can be equipped with an extension for users with a larger abdominal circumference.

12.1.3 Environment and Sound

This section describes the environment and sound in *Nebula*.

12.1.3.1 Environment

The user is virtually situated inside a round concrete dome with an open, star-filled sky (see figure 12.3). The room is still, as nothing in the environment is moving except for the night sky, which is rotating with an almost unnoticeable angular speed. A light with a warm temperature illuminates the concrete and produces shadows, adding to the room's sense of depth. The room's brightness is similar to an early evening, not bright, not dark. While creating, the user may utilize the entirety of a slightly elevated platform with a small stairway leading to a door blocked by a snug-fitted boulder.

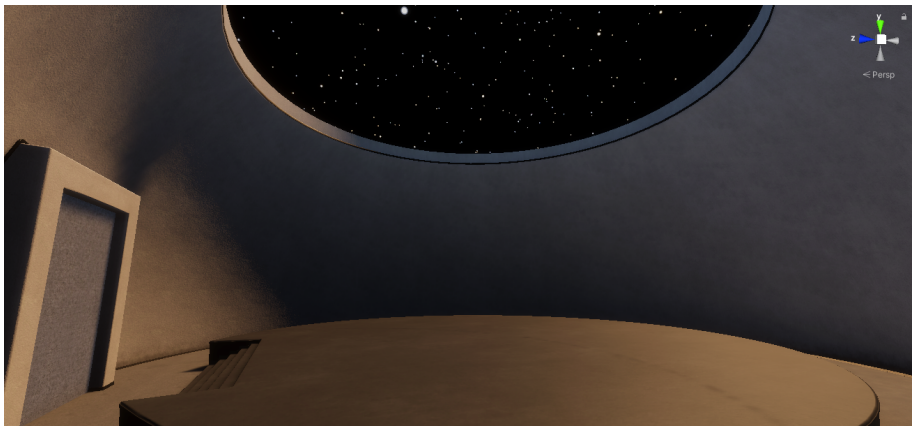


Figure 12.3: The concrete dome in which the user experiences *Nebula* [An overview from the dome, ideally including the door]

12.1.3.2 Sound

The sounds in *Nebula* have common denominators of ambiguity. Both sounds are also instrumental, relatively slow, and peaceful.

12.1.3.2.1 Observation and Rearrangement sound "Breath within" by Onyx music is a peaceful and mystical ambient sound with a BPM of 54 [111]. It is played on loop throughout the whole experience, except when the "creation sound" is being played. We consider it somewhat dark in its tone, which fits the dark environment of the dome but also has light tones, which, according to us, instills a sense of awe and slow motion. Instruments used in this sound are synth, keys, and pads. Listen to the sound here: Link to Breath Within by Onyx Music

12.1.3.2.2 Creation sound "Peter Rabbit" by Jon Gegelman is an uplifting and peaceful sound with a BPM of 81 [112]. We find it somewhat dramatic in its tone like "Breath Within", which fits the creation mode but also had light tones which we perceived to instill a sense of playfulness. Instruments used in this sound are piano, strings, synth, and pads. Listen to the sound here: Link to "Peter Rabbit" by Jon Gegelman

12.1.4 Introduction to *Nebula*

Initially, when the user has been connected with the biosensors, they are shown by the moderators how to do belly breaths and are informed that doing belly breaths will be part of the experience. This is important to calibrate the measurements and ensure that the user knows how to perform belly breaths. Afterward, the user is equipped with the VR headset and audio headphones before beginning the experience.

12.1.4.1 Body Scanning

When the experience begins, the user is, virtually, in the concrete dome. The lighting in the dome is almost completely dark, and thus the user can barely see anything, see figure 12.4.

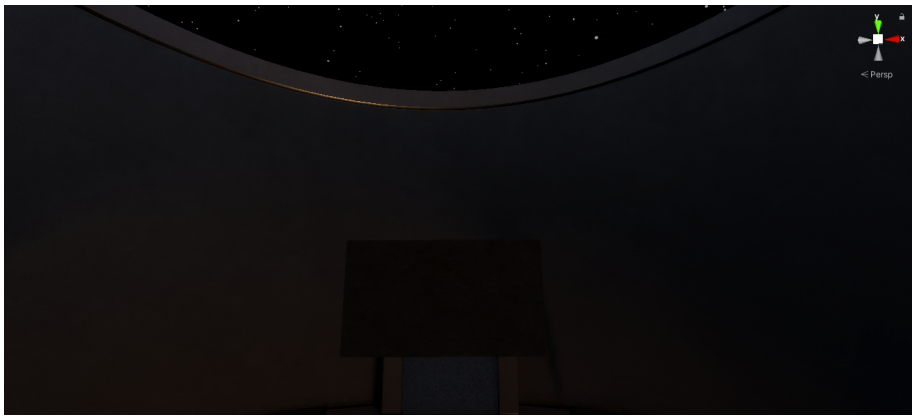


Figure 12.4: The initial visual the user sees.

There is, though, a narration voice that gently asks the user to close their eyes and follow along with a four-minute body scan. The body scan and the whole narration text can be found in Appendix A.

12.1.4.2 Instructions and Sensitising

After the body scan, the narration asks the user to open their eyes and bring their hands forward.

Creating The user needs to align their hands like those shown on a screen in front of them (see figure 12.5) before pausing for a moment and taking a deep breath. On the exhale, a creation is instantiated, and material, in the form of particles, seemingly flows from the user's body, and shapes into a sphere between their hands, as seen in figure 12.5.

Figure 12.5: The user aligns their hands like those shown on the screen before the initial creation shapes between their hands on exhale.

Heart rate and color When the user takes deep belly breaths, more material adds to the creation on exhale as a flow of particles from the user's body. The

new material's color can vary and the narration informs the user that the colors connect to their heart rate – and that they can affect the colors of particles by lowering or increasing their heart rate. Next, the narration guides the user through a breathing exercise where the user inhales and exhales rapidly for 10 seconds. The user is informed that they can increase their heart rate by breathing rapidly. The narration then similarly guides the user through an exercise where the user breaths slowly to lower the heart rate. There is a pause after both breathing exercises for the user to reflect on how the breathing patterns influence their heart rate, as seen in the color of particles. Figure 12.6 shows examples of different colors emerging.

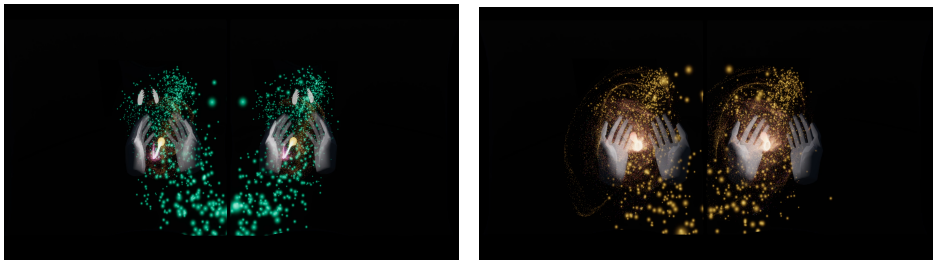


Figure 12.6: The color of the emerging material is dependent on user's heart rate.

Shaping Following the breathing exercises, the narration informs the user that they can shape the creation by gently moving their hands. The hands displayed on the screen show users how they can move their left hand "to the side and back again," and the right hand "up and down, and forward and back". The creation follows the user's hand movements accordingly, as seen in figure 12.7.

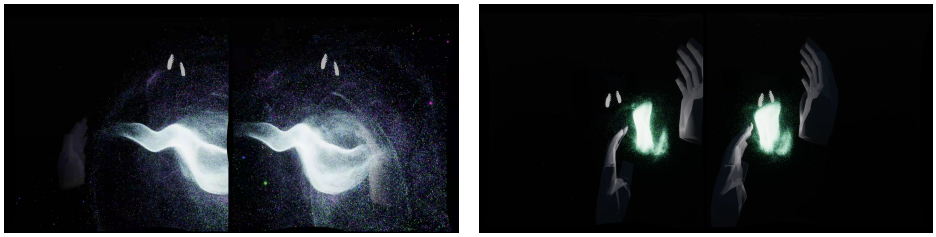


Figure 12.7: The users shapes the creation with their hands.

Deleting At this point, the narration encourages the user to move their hands faster. The creation vanishes when the user does so, as seen in figure 12.8. The narration then explains that the creation vanishes when they move their hands too fast.

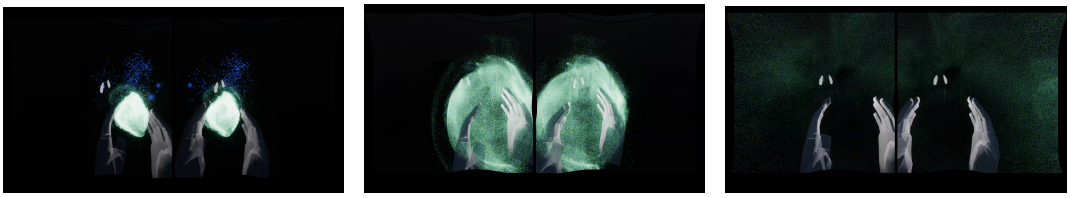


Figure 12.8: The user deletes the creation when moving their hands too fast.

Saving The narration now encourages the user to generate a new creation, but this time instead of moving the hands fast, the user should keep the hands steady. When the user does that, the creation saves, and users can freely move their hands again. Figure 12.9 shows an example of saved creations floating in the concrete dome.

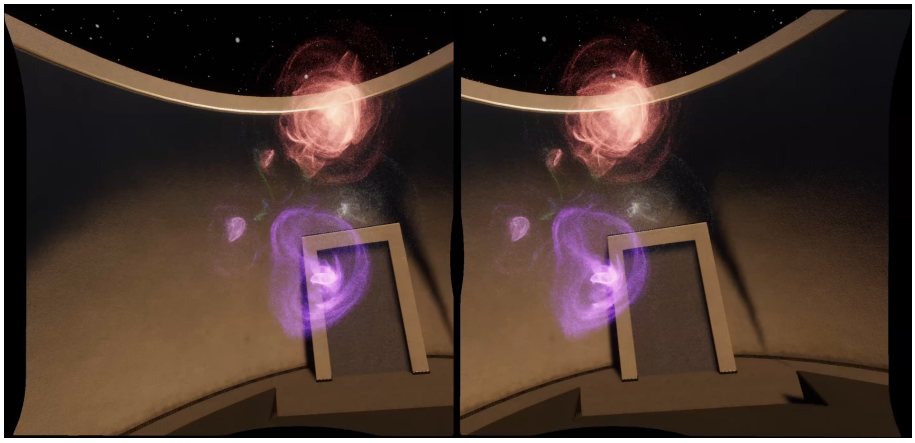


Figure 12.9: Multiple saved creations floating in the concrete dome.

Exploring the dome Until this point of the introduction, the dome's light environment is very dark. When the user saves the creation, the concrete dome lights up, and the user can explore the concrete dome and walk around.

In *Nebula*, from this point onwards, the dome's light environment darkens when the user generates a creation. The dome's environment then gets brighter again when the user is not creating. The difference can be seen in figure 12.10.

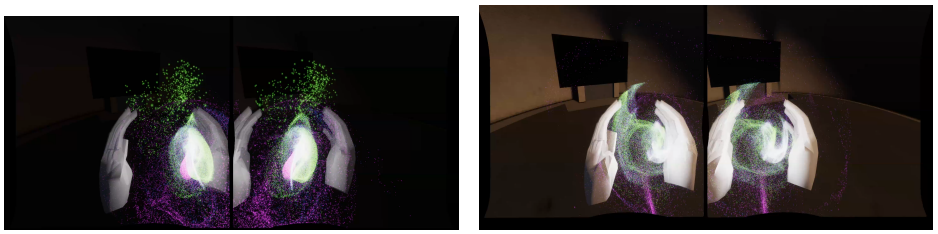


Figure 12.10: The dome's environment is dark when the user is creating, but lighter when the user is not.

Moving The user can also move saved creations. The narration explains, and the screen displays how the user needs to pinch the center of the creation to move it and place it somewhere else by releasing the grip, as seen in figure 12.11.

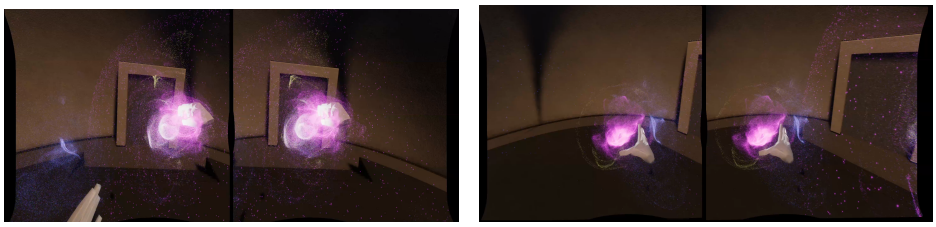


Figure 12.11: The user moves the saved creation by pinching the center of the creation and releasing the grip.

The freedom to create in a safe and personal way The screen is now removed from the dome, and the narration informs the user that whenever they want to generate new creations, they need to position their body in the direction of the door in the dome. Lastly, the narration informs the user that they can now create freely.

12.1.5 Creation mode

We refer to "Creation mode" when users actively create artworks. As touched upon in the introduction, see 12.1.4, the concrete dome is darker when users are creating. However, here we will elaborate on what other factors change during the creation mode and how users enter and leave the creation mode.

12.1.5.1 Entering Creation Mode

In order to enter creation mode, the user needs to hold their hands and head still for a moment. After that, the user can enter creation mode by taking a deep belly breath. On the exhale, particles flow seemingly from the user's body and shape into a sphere between the user's hands. Simultaneously, the ambience sound changes to the creation sound 12.1.3.2.2, and the dome's lighting dims.

12.1.5.2 During Creation Mode

Whenever the user takes a deep belly breath to add particles to the creation, particles with a particular color corresponding to the current heart rate flow, seemingly, from the user's body. At the same time, new particles form in the same color in the middle of the creation. The particles that flow from the user's body vanish when they reach the creation. However, the ones that form in the center of the creation move to the surface and are stored there.

12.1.5.3 Leaving Creation Mode

The user can leave the creation mode by either deleting or saving the creation, as explained in section 12.1.4, and the user stays in creation mode as long as they slowly move their hands. The system has a threshold detector for when the hands and the head move too fast or the user is still enough. If the system detects too fast movement, the creation disperse and is deleted, the creation sound fades out, and the environment lights up. However, if the system detects stillness, the environment's

lighting gradually lights up, and the creation sound slowly fades out. Thus, the user has a chance to move the hands again to continue creating before saving. When the creation is saved, the environment is fully lit up, the creation sound is replaced by the observation and rearrangement sound, and the creation particles move slower.

12.1.6 Final observation

When there is only one minute remaining of the experience, the narration gently acknowledges that the experience will end in one minute. This gives the user ample time to make their last changes, additions, or re-arrangements to their artwork before they would have to stop. After one minute, the brightness is reduced (see figure 12.12), and the narration explains how the time is up. However, the narration also invites the user to take some time to observe their artwork before they exit the experience. During this final observation, the user's abilities to create and move the creations are withdrawn. As the light has been turned down, the artwork and its movements is now better visible and shine more brightly. The user now has the possibility to reflect on and interpret their artwork. The experience ends when the user removes their headphones and the moderators assist in removing the technology.

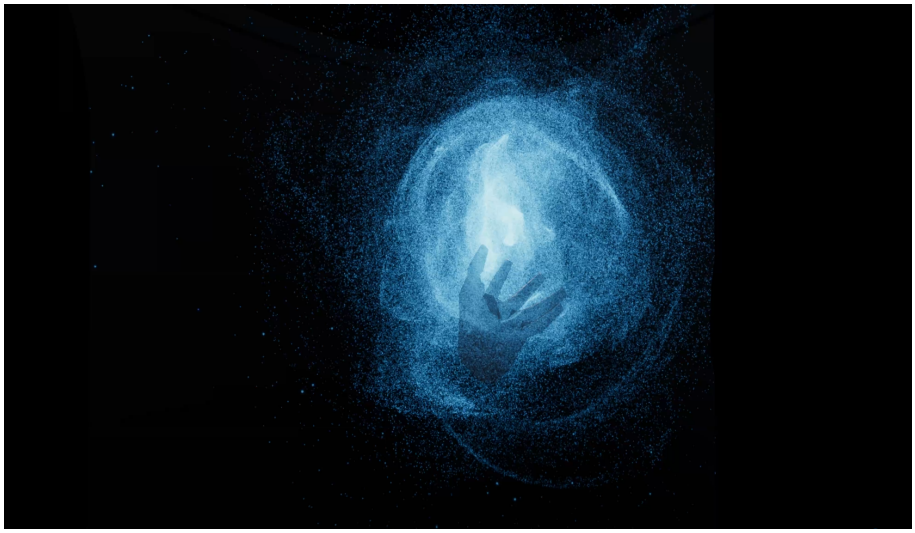


Figure 12.12: An example of what it could look like with the lights turned down during a user's final observation

12.1.7 Quantitative data

Here we report on the how much time the participants spent, on average, in the different phases of the experience, how their heart rate changed between the phases, and, the actions they took during the whole experience.
This quantitative data only includes 11 participants as data from one participant was lost due to technical issues. During the first 6 sessions of the evaluation, there were issues with the biosignal measurement equipment losing connection, resulting in gaps in the measurements and less data points. The data should be reviewed through the lens of lower precision as the gathering and reviewing of quantitative

data to prove something statistically was not of our concern. This data is mainly presented to describe the experience more thoroughly and give indications to how the experience unfolded for the participants.

12.1.7.1 Experience timeline

On average, participants spent 24 minutes and 49s (standard deviation (SD) = 3 min 20s) in the experience (see figure 12.13), measured from when the experience began until when they took off the headphones. The reason for this difference in time is due to technical issues, the set-up time sometimes required more time, and it happened that we had to restart the system. This caused the "Before experience" time to increase. The body scan was always 4 minutes, but the instruction and sensitizing averaged 7min 17s (SD = 2min 40s). The difference in the instruction time is due to some participants needing more time to perform the actions instructed, because the narration did not continue to the next step until the participant had managed to perform the instructed technique. We observed, for example how participants sometimes struggled with understanding how and where to pinch the creation to move it and also how still they needed to be to save. Resulting in a longer instruction time for those participants. The length of the Free Creation phase averaged 6min 43s (SD = 1min 20s). The deviation is due to the 60 min evaluation length cap we had and the time required to set up the biosignals. As we required 25min for the evaluation after the experience, we, unfortunately, at times, had to decrease the participant's allotted time in the Free Creation phase. Lastly, the participant's average time in observation mode was 56s (SD = 25s).

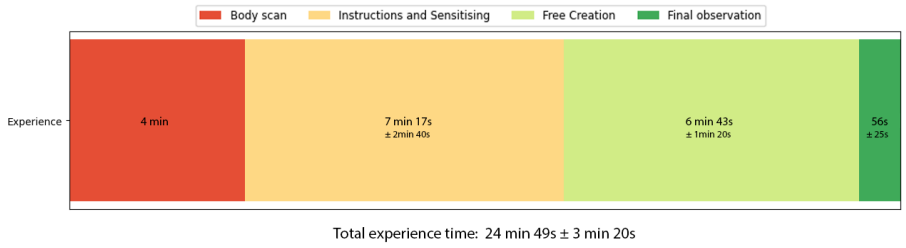


Figure 12.13: A timeline of the experience with the average time of each phase, total time includes biosignal set-up and connection.

12.1.7.2 Participants' heart rate during the experience

The heart rate span differs between humans; some have a higher average, and some have a lower. Therefore we decided to look at how participant's heart rate changed in relation to their average heart rate throughout the whole experience, not the average of all participants (see figure 12.14). Furthermore, the heart rate is influenced by many factors, meaning that both negative and positive experiences can change the heart rate. This is highlighted by Benford et al. example mentioned in section 3.8.2. There it is explained how rollercoasters have intense accelerations which raises the riders heart rate but the experience can both be a positive experience of thrill and excitement yet also a negative experience of stress and fear. This phenomenon

should be considered when reviewing the following data.

Before the experience started, participants generally had a lower heart rate than their average for the total experience, -2.8% (SD = 5.7%, see figure 12.14. During the initial phase of the experience, the body scan, the general trend was a slight increase in heart rate compared to the previous phase, -2.1% (SD = 5.1%), but the heart rate was still lower than their average. As the participants went through the instructions, the common experience was an above-average heart rate, averaging at 2.6% (SD = 3.3%). In the next phase, when the users were free to create independently, the trend was a decrease in heart rate with an average of 0.2% (SD = 2.2%), still averaging slightly above the average heart rate for the experience. It is noticeable how the standard deviation decreases as the experience unfolds.

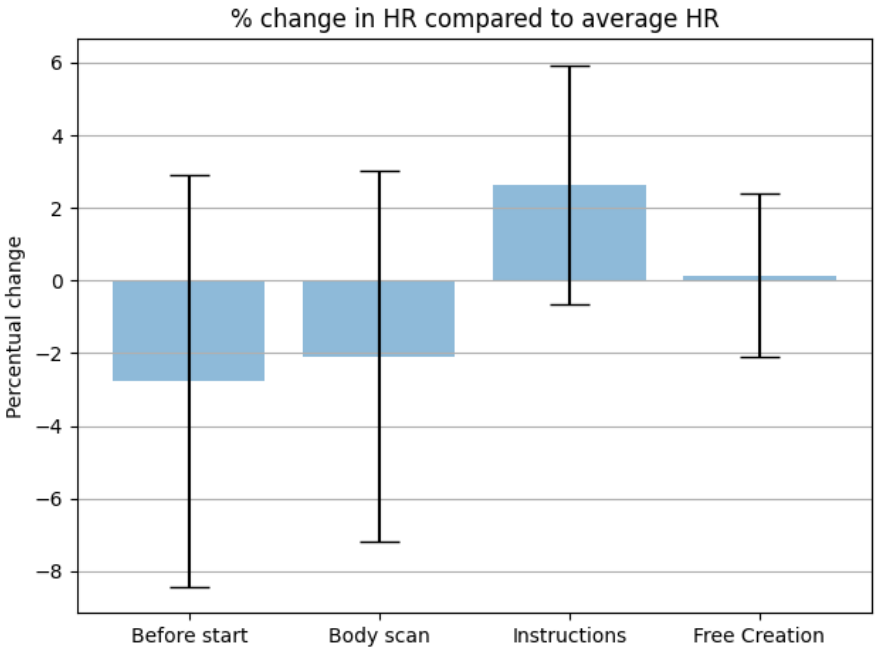


Figure 12.14: A visualisation of how the users' heart rate changed in % during the different phases in relation to their own average heart rate throughout the experience

12.1.7.3 Participants' actions during the experience

As can be seen in figure 12.15, a participant instantiated on average 13 (SD = 4) creations. This does include the creations during the instruction phase, which were a minimum of three but slightly more for the participants who did not follow the instructions exactly. After instantiating, there was a tendency to delete (avg = 7, SD = 5) rather than save (avg = 6, SD = 3). However, we observed a higher count of seemingly accidental aborts than accidental saves (which also can be spotted in the recordings of the participants' experience).

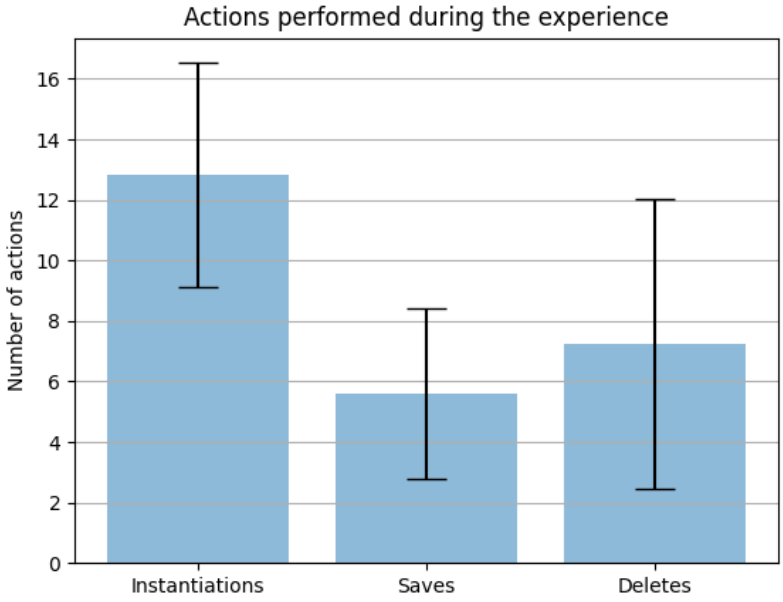


Figure 12.15: A graph depicting the count of instantiation, save and delete actions performed by participants during the experience

12.2 Research Question 1 - Design considerations

Our first research question is:

> *"What should be considered when designing a VR experience where biosignals are used as input for creation, as informed by art practice?"*

To address the question, we explain each category of considerations as visualized in 12.16. Each consideration category contains examples from the evaluation and insights from our work: they are generated through the analysis of first-person interactions, observations, and evaluations with users. These insights are expressed as design considerations, and are non-exhaustive, and serve the purpose of guiding the design process of other interaction designers endeavoring further work in the combination of VR and biosignals as inspired and informed by art practice. First, we explain why one should make it welcoming but challenging. Then we describe why it is important to make it meaningful. Ultimately, we review the considerations for utilizing the potential of VR and the importance of being mindful with the biosignals.

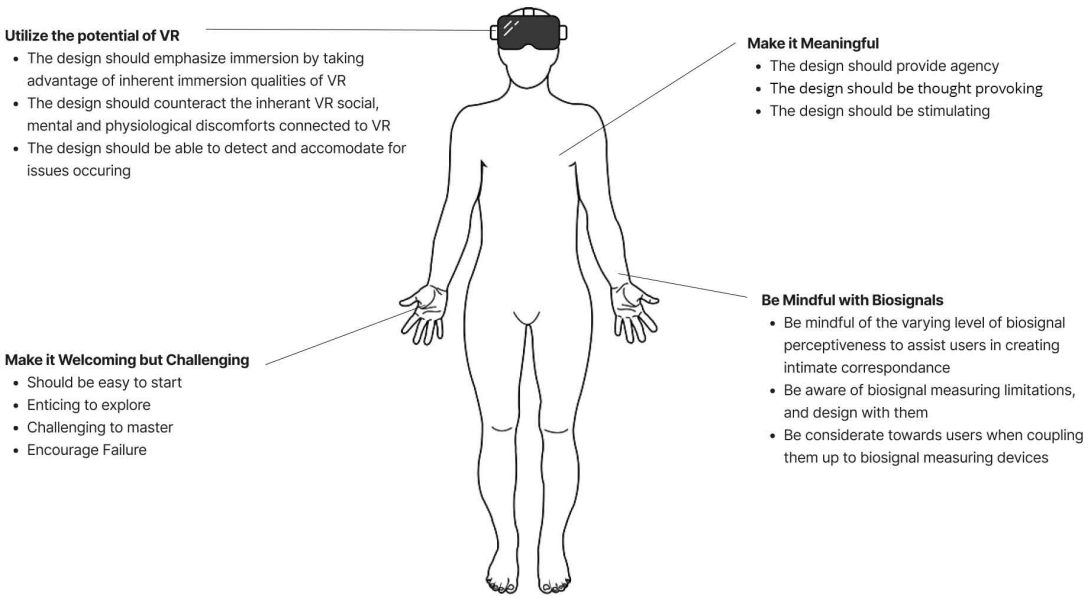


Figure 12.16: The design considerations for designing a VR experience where biosignals are used as input for creation, as informed by art practice

12.2.1 Make it Welcoming but Challenging

The experience should be welcoming but challenging. Meaning that it should be easy to start, enticing to continue, challenging to master, and encourage failure (see figure 12.17).

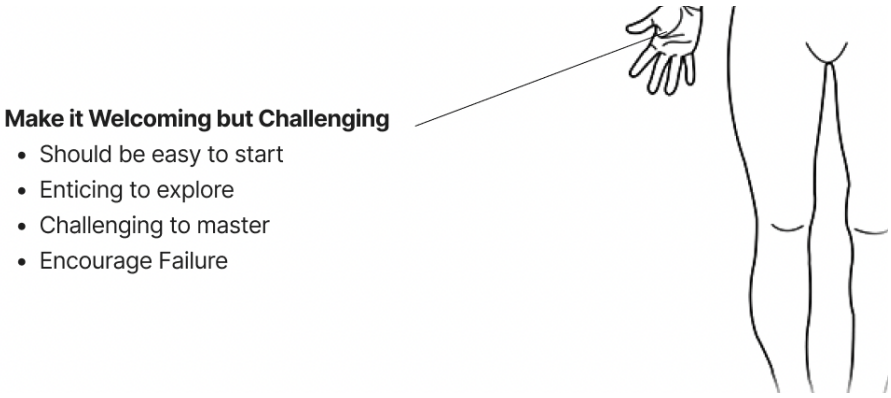


Figure 12.17: Visual overview of the welcoming but challenging design considerations

12.2.1.1 Should be easy to start

We learned through our artist interviews, in section 7.2.2, that artists rarely start creating from a blank slate. For example, the painter we talked to began his art creation process by pouring paint on the canvas, and only after that did he reflect on what to make out of it. Additionally, the motion designer often watches creation tutorials and replicates before tweaking them to his liking. The qualities we

drew from that were "draft", "low threshold," and "action before thinking." In this project, we lowered the creation threshold by coupling the creation activities to the biosignals we most easily can control, namely hands and breathing.
In *Nebula* experience, users begin with an introduction, where they actively create with the guidance of a voice narration and a supporting video screen. Going through the introduction narration lowers the creation threshold and assists users' in familiarising themselves with the main features. Inspired by the quality of "action before thinking", users create their first creation without being explicitly told they are about to create. The narration simply asks users to perform the actions: placing their hands forward, staying still and pausing for a moment, and then taking a deep breath. After doing so, users can observe the artwork between their hands and are informed that they just performed the actions needed to create the artwork. Also, building upon the "action before thinking" quality, users always begin creating by performing these ritualistic actions that result in immediate creations between their hands. These actions also "lower the threshold for creating" by limiting the amount of thinking needed to create. Users, for example, do not to start by choosing a color as they cannot explicitly choose the color. The color is a result of their actions. A participant summarized the beginning of the experience as follows,

> *"Lots of people feel like 'I cannot write, I cannot draw. I cannot sing. I cannot do a lot of things'. But getting into this, you do not have any judgment. So this is, I do not know... I can just as well try. So maybe that is part of the liberation and fun stuff. It is very easy to make."*

We also aimed for the narration voice to be supportive and calming. One participant in the evaluation said that the narration voice itself was "very calming and soothing," which we believe adds to the easiness of starting to create.

12.2.1.2 Enticing to explore

The experience should be explorable to drive people's curiosity and playfulness.
This is informed by our interview with George Khut (see section 7.2.1 and our expert interviews with creators (see section 7.2). Khut said that curiosity and playfulness is what drives interactive arts and when talking to artists, we observed that they are constantly exploring the boundaries of knowledge, skill, and the material they work with. They refer to exploring as playing around with the material and derive pleasure and satisfaction from honing their knowledge and skill through acting on their curiosity. If the design is playful and users are intrigued to explore, it will be enticing to continue.
When designing the *Nebula*, we emphasized implementing various ways for users to express themselves, such as being able to constantly add material during the creation phase, shape, and move the creations around. We believe that having different ways to express and interact adds to the playfulness end evokes curiosity because the creations will be unique. Both factors that should entice users to explore. In the introductory narration, we inform users about the main actions possible in *Nebula*. We carefully structured the information, so we first ask users to perform a particular action without informing them what the consequences of the action will be. This is informed by Gaver, Beaver, and Benford and how they have shown ambiguity to be beneficial when design engaging experiences [82]. User's can thus observe the

consequence of the action before the narration vaguely explains what happened and begins introducing the next action. We believe structuring the information like this aided the curiosity of the users. Users are, for example, asked to slowly start moving their hands before we inform them about that is how they shape the creation. A participant described it as,

> *"So you just like slowly try and figure out... what happens when you move your right hand, what happens when you move your left hand and see what kind of things you can do with shaping the little sparkles in some way."*

Having the instructions vague, for example, only telling users to move their hands and interpret how their hands shape the creation, is also beneficial to stimulate exploration. We saw several participants trying to shape creations that they had already saved, an interaction that we, the designers, believe is intuitive but not one we had time to implement nor had taught them.

Another example of how *Nebula* is explorable is that users do not necessarily know what color will emerge next during the creation. That keeps it interesting as explained by one participant in our evaluation:

> *"It was cool with the explorative aspect of not really knowing what material you will generate, you know that you will generate something but you don't know really exactly what it would look like. And that's really interesting. And I think it was like quite nice, satisfying fun, like making something that looks beautiful and nice."*

An example of a playful action that participants referred to was the "pinch-to-move." One participant said that moving the pieces was very satisfying, and he:

> *"[I] felt empowered. I felt like some kind of God, or like in a Marvel universe."*

Another figured out how to move art creations by exploring:

> *"And I was not sure it is like... how hard I pinch them? Like some, I would just like very gently take like, barely touch my fingers together. And others I would be like, you are gonna move and I would just really try and grab it and like, throw it and see where it would end up."*

A participant that was particularly enticed to continue creating had plenty of ideas she wanted to try out next time she got the chance. She, for example, wanted to try to stack the creations, make a house out of them, try to go into them, and drink them before concluding with the words: "Things like that. Just fun".

12.2.1.3 Challenging to master

We learned that frustration was part of the process from the interviews in section 7.2.2 with artists. The artists expressed being frustrated when unable to create what they envisioned and when something did not work out as they thought it should. On the contrary, being so focused on the art creation process can also result in experiencing a state of flow, and the artists said they often completely lose track of time and place. These insights reflect how art creation is a skill that can be improved through practice and repetition. It it also resonates well with Fokkinga and Desmet framework, in section 3.8.2, about designing for rich experiences [81]. The "challenging" quality listed there is a negative emotion of frustration that is

conducive to focus and a positive emotion of satisfaction. In *Nebula*, we introduced several actions and parameters for users to explore and learn during the creation and one example of how we made it challenging was by having it sensitive to the user's movement and breath. Thus, in the view of the Fokkinga and Desmet framework, the negative stimuli in the experience is the artwork itself.
The challenging creation experience was, as expected, focus-inducing for participants:

> *"I had to be very, very still and very careful. And that if my hands were not exactly in the right position, and if I was not really focusing on breathing directly in between them, then I would not generate something."*

Focusing on the creation had different results for participants. As this participant describes, some were very frustrated and expressed self-doubts,

> *"I tried to save it. And it was so unclear. I was unsure, like, did I miss how I saved it? Or did I misunderstand that? I was totally confused, because I felt like I held my arms forward, saving it for like 10-15 seconds. And then I would let go and it still exploded around me. So that created a lot of frustration."*

Other participants described similar experiences where they felt like they had failed, and some even got angry,

> *'I lost a couple of things they disappeared for me. And that created the sense of irritation that I did not want it to disappear. It was not intentional. I never deleted anything intentionally. It was unintentional. It felt bad. I just got angry."'*

On the contrary, participants also expressed being in a flow-like state. One was so immersed in the experience that he lost "track of time and space for a little while," and another said he forgot about the design team being in the room. Some participants did not attempt to create anything in particular and thus did not experience failure. Meanwhile, others who intentionally set out to create something particular managed. For example, this participant who wanted to produce the color purple,

> *"I wanted more. But how can I get more? Well, it is through my body. Just breathe that way. And it will come. And then in the beginning, I started to get a little bit of green. That is because I hustled and wanted to get that purple, but I was not thinking I was just doing it. Yeah. And then when I started to listen a bit more. It happened correctly. Yeah. All right, get the purple."*

12.2.1.4 Encourage Failure

Being harmless to fail in the experience is a vital protective frame, as defined by Fokkinga and Desmet, to counter the possible uncomfortable feelings that derive from the design being challenging to master [81]. Even though users experience uncomfortable emotions while practicing how to create, they should always be able to try again without any other harmful consequences built into the system. This is informed by the "Control protective frame", as defined in 3.8.2), where user's are always in control of the stimuli. This also aligns well with what we learned from taking to artists, they can always start again with new material, and their failures strengthen their knowledge instead of being detrimental to their next creation 7.2.2.

Additionally, what is a failure should be up to the users' interpretation. Just like artworks are subjective to interpretation.
We implemented this into *Nebula* by allowing users to generate as many creations as desired. Being able to create constantly was relieving; as this participant explains,

> *"You can stay in the failure of having lost something, or you pick up the pace and make a new one... Picking up the pace. That felt quite good. I had a chance."*

Most participants experienced the creations vanishing as a failure, although how harmless it actually was, was interpreted differently between participants. One participant described how the vanishing felt like chasing butterflies as a kid, "very soft disappearing, which was nice." Another participant interpreted the creation as a precious life form that "you are going to kill if you do not pay enough attention to it," which made her anxious.

12.2.2 Make it Meaningful

The experience should be meaningful by providing agency, provoking reflections, and stimulation (see figure 12.18).

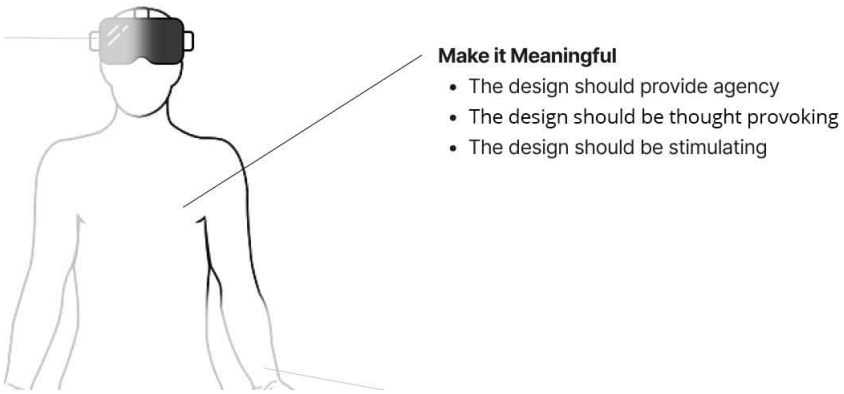


Figure 12.18: Visual overview of the make it meaningful design considerations

12.2.2.1 The design should provide agency

Agency is a topic mentioned by both creators, in section 7.2.2 and our interview with interactive arts expert George Khut in section 7.2.1.
When relating to biosignals, Khut informed us how the agency is essential for connecting to the artwork and evoking curiosity and playfulness. These feelings support users in learning about their state and their reactions in a less judgemental way. He explained that layering the experience and giving space for reflection creates agency.
Creating art is also a skill that artists are constantly honing, as illustrated by the "Exploring the boundaries of knowledge, skill, and material derives learning and well-being" theme in the thematic analysis (see section 7.2.2) and by Dahlstedt [7]. When artists improve their creation skills, they improve how they use their tools for creation within their respective art mediums. Therefore, when designing a new art creation medium, users should have room to improve their creation skills through practice; the agency is essential for that.

In *Nebula* we layered the experience in the introduction by gradually introducing possible actions to the user, one at a time. The user begins in a dark environment, and their first instruction is to bring their hands forward and look at them, the first connection between themselves and the experience. Subsequently, the user exhales into the space between their hands, generating particles and forming an initial creation. The narration then explains how exhaling generates new particles to strengthen the connection. This creates an action-consequence loop but also a lingering sense of agency as the generated particles remained in the artwork in front of the user. The participants highlighted this feeling of agency, here described as:

> *"my pulse and breath was translated into some kind of vision that also could be shaped and moved by me and the vision or the creation was organically like, space like creations that was cool and beautiful."*

Another participant also felt this connection between themselves and the artwork:

> *"It's my body, who can create that by breathing in a specific way. So I would say I found a connection between my hands, body, and brain."*

When breathing to create, we designed it so the new particles would seemingly come from the user's body. By doing so, we aimed to create a connection between the user's body and the artwork. It was appreciated by most participants, as the previous examples suggest. However, one participant, who interpreted it as coming from her nose, said:

> *"sort of colorful sparkles start shooting out, it seems like it is coming from your body, like from your nose, right in front of you."*

She felt that it was disturbing and discomforting. Nevertheless, the agency seemed clear to her, and she experienced as inward attention-inducing as she said,

> *"I am really confronted by the consequence of my breathing, creating this thing that comes out, and I can see it."*

We also attempted to instill agency through the breathing exercises in the introduction, where users are instructed to breathe fast and slow to explore the connection between breathing and heart rate. It is not until afterward that the narration probed the user whether they had noticed the difference in the color of new particles. The narration then explains how the users can change their heart rate by changing their breathing rate, resulting in different colors. Silence follows this explanation to make space for reflection and rumination on this phenomenon. As explained in section 12.2.1.2, similar actions follow by an explanation and time for reflection occurred throughout the introduction to the experience.
Lastly, one participant said that she found a connection between her body and brain by breathing in a certain way to create a specific color. She said it felt wonderful and was a good reminder of how the head and body are connected.

12.2.2.2 The design should be thought provoking

According to Danto's definition of art, art should offer a possibility, and a necessity of interpretation [50]. Art's beauty can be understood as the response it evokes when viewed. Artists speak about their creation experience as something enriching and uplifting. Their self-reflection through the artwork tells stories about their sadness, happiness, history, and genius. This notion of self-discovery and strengthening of self-worth is a theme found within our artist interviews and a strong argument for

highlighting the reflection aspect and generating a way to capture the reflection of identity in the art piece. One artist we spoke to, in section 7.2.2, said that his art is interpreted very differently by people from different cultures. Essentially, everyone can find symbols in his artwork that relate to their culture.
We implemented this, informed by two bodies of literature. Firstly, literature that remarks the lengths people go to to make the ordinary extraordinary is what differentiate art from craft [49]. These extraordinary quirks materialize the state of the artist. Secondly, we were also informed by how ambiguity of information can support reflections and engagement [82]. Therefore, when designing the *Nebula*, we emphasized that each creation that users would create should be unique and ambiguous. Having different creations where no one looks exact supports reflection through comparison. It is also in line with definitions of what art is. Hence, if people feel like they are creating art, reflections will follow because reflections are an essential part of the creative artistic process [7].
In *Nebula*, users can articulate themselves by adding particles of different colors, shaping the creation, and moving it to layer or build with other creations. Participants in our evaluation were amazed by how they could express themselves and how empowered they felt. One participant described herself as a "purple person" and when she managed to produce purple particles repeatedly, she got calm and described the creation as "a reflection of my inner self." A fantastic experience, she also said, which, in her words, made her speechless. The possibility to move creations made participants feel like they could "create their own world" and be "myself a bit and create in a different way". Another user shaped and had the intention to create "three different emotional clouds, each for a respective feeling". Some did not articulate as much on the creations,

> *"the shapes does not actually tell you anything more than the colors. The shapes do not say that much. So I think it is more of a distraction."*

. While others felt sad and felt like they had failed when unable to create a wider range of colors and express themselves fully.
Participants also reflected on how to control their creations and their biosignals and bodily state, and some contemplated the meaning between their artwork and their biosignals. One participant said, for example,

> *"you are not quite aware of how your pulse is changing. Like you are thinking, what is the difference between blue and purple, for example."*

Another participant interpreted her lack of colors to mean that her breathing was boring,

> *"It is very monochrome. And maybe that is boring. And is my breathing boring, because it is all the same color."*

12.2.2.3 The design should be stimulating

Our expert creator interviews (in section 7.2.2) taught us that visual and tactile stimuli are significant for continued interest in art creation. One artist explained how "I leave it [the piece of art] in the room, and I pick it up and continue again whenever it calls on me". The importance of stimuli resonates well with the philosophy of art being something created by people to affect people, as explained by Hospers in section 3.1.1. Furthermore, if the art does not affect the artist, it is reasonable to

think it will not affect others. The resulting experience of the art being stimulating varies between creators, as we also learned from our interviews. In general, creators find meaning and create a connection with their work, but in distinct ways. One might enjoy the process of learning, and the artwork is a result of their newly acquired skill. Another artist might enjoy the aroused feelings while exploring and expressing their inner self. A third might highlight the sensations in their hands and body when sculpting their creation. The resulting art becomes a testimony of their moment. However, importantly, the art needs to stimulate the artist.

When designing for virtual reality, there is vast potential in providing stimuli to users through visual, auditory, tactile, olfactory, and potentially taste. In *Nebula* we focused on designing the visual stimuli but also provided an auditory experience. We implemented visual stimulation by having it continuously moving, somewhat unexpected in its appearance, and by it having several minor compelling quirks such as high-quality particles. A participant described it as:

> *"when you watch a, a fire or like a stream, like that continuous movement is quite fascinating. It's something you know, that you can rest your eyes on. And it's comfortable because it's slow, and it's things happen, but it's not like disturbing."*

Another participant mentioned how it was "fun to just watch it morph around". Some participants even resonated with the movement of the particles, instilling a sense of desire and understanding what they were lacking:

> *"I felt more drawn to like, oh, I want to be more like that. I want to be more fluid and relaxed"*

The visual stimuli are a component of artists' continued effort. Our evaluation proved how effective this can be:

> *"there was this kind of like tadpole-shaped form that would emerge. And it was very, very small and very densely packed dots all together and had this really beautiful sort of like ombre effect, going from purple to yellow. And that was where I was like, Oh, that's a cute thing. I was really excited. I think I made one of them twice. And both times, I'm like, Yes, this is like this is really, this is getting fun. Now, this is like really, really good."*

The stimuli was also gratifying in a personal way, for example as one participant described the sheer joy of creating:

> *"When I see my children when they are creating stuff in Tilt Brush. And I see their joy. And I, I felt that"*

The same participant later expressed how he felt as if the experience was good for his health, as he walked in with tension headache and left without,

> *"I was indulging in the experience. I felt like, this is good. This is good for my health. I feel better"*

Another participant articulated how she was amazed by her connection with the art. She explains how she felt like it understood her and how they communicated:

> *"I think it could be something when it comes to senses and connection... It's like having a dog. You know. It has another language, but it understands you through senses and through motions"*

Interestingly, the lack of tactile stimuli was also seemingly stimulating for one person:

> *"I could not feel it. I was just seeing it. I am trying to hold something that's there but not there. And I did not feel anything. And not any warmth or coldness or anything physical."*

She said it made her feel like her hands were floating, which was simultaneously a weird and a cool experience. The same participant felt like the whole experience was recharging and creative inducing,

> *"like my creative mind started to wake up... it feels like more lamps or lights are starting to turn on."*

12.2.3 Utilize the potential of VR

The experience should utilize the potential of VR. Meaning that it should emphasize immersion by taking advantage of the inherent immersion qualities of VR. It should also counteract the inherent social, mental, and physiological discomforts connected to VR. Furthermore, the design should be able to detect and accommodate for VR issues and user misunderstandings (see figure 12.19 for a visual overview).

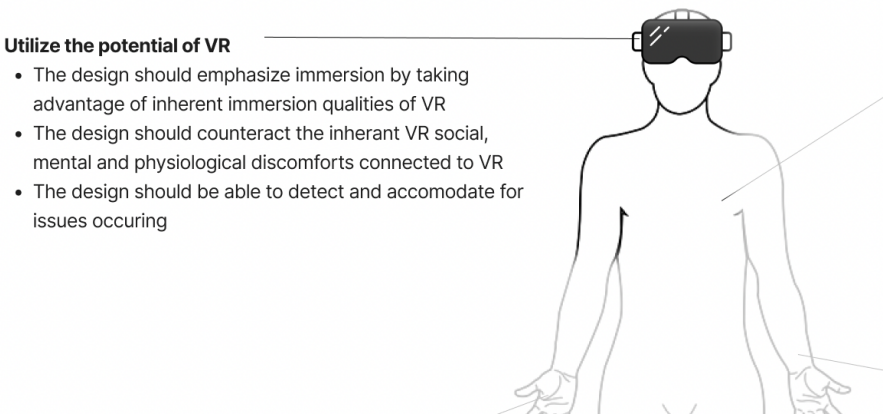


Figure 12.19: Visual overview of the utilize the potential of VR design considerations

12.2.3.1 The design should emphasize immersion by taking advantage of inherent immersion qualities of VR

The artists, in section 7.2.2, described how they forgot their surroundings, lost track of time, and achieved an intense focus. They described the joy of being in the now and fully immersed in the task at hand. From these interviews we also learned that the experience should create immediate visual and/or tactile gratification. The artists derived immediate pleasure and immersion from touching the clay or slightly changing the code, which in turn changes the art. The sound and environment are also two strong components in immersing the user into the experience. In section 7.2.1, Khut explains how the user always is exposed to the sound and environment , and it should therefor be paid attention to. Actions should have acoustic consequences for increased immersion. He also explains how the environment affects our attention and emotional state, thus it is a big component in emphasizing immersion.

The inherent, immersive nature of VR is exceptional for inducing said states, and a VR experience designer should utilize the potential of the medium (as explained is section 2.2). The common physical laws do not apply in VR, and as such, designers should defy what is expected to create a mystical experience which provokes new thinking. In *Nebula*, the design of the space aids in teleporting the user to a new mystical space, or as one participant said, away from their "everyday thoughts". An abstract environment which emphasizes infinite possibilities through a round dome with no edges and an open, star filled sky. One participant described the experience as "a break from reality" and "it was also like an open sky. It was cool and calming enlightenment". Another participant described it as a room in their own head:

> *"it feels like you're in, in one of your rooms in your own head, like it gives very, this is your own space to create things. So that's when you don't when you don't have like, yeah, it feels like the judgments from others and yourself is quite far away"*

In *Nebula*, gravity does not apply to the artwork and it remains floating in the air when saved. Also, the particles in the artwork reduce their speed when the user leaves creation mode to indicate leaving creation-mode and to afford a passive mentality, characteristics of observation and rumination. We think combinations of elements like these have an actual effect. One participant explained:

> *'I felt very passive. What I mean by passive I think, I felt like I was kind of absorbed in a very observant of state, like I was really observing myself and what like to experience my body and I think the sense of wonder was really, like present"*

Furthermore, the combination of the surroundings, the sound and the novel interactions was interpreted as mystical:

> *"I would say that I went into some kind of like universe spacious setting to create particles by breathing and like shaping it with my hands or like at least trying trying it out... a very mystical experience, I would say."*

The acts of creating, shaping and moving was also considered as surreal experiences for participants, one participant described:

> *"at some point I felt like some kind of God you know, or like in a Marvel universe when they were like shaping. That was like super exciting to feel that, oh, I have power, you know, power of making it bigger or smaller. So it was satisfying."*

In *Nebula*, there is an ambient sound played in the background throughout the experience. Whenever a user starts creating, a distinct creation sound starts playing and when the user is about to exit creation mode, that sound gradually decreases. The environment's brightness increases and decreases between creating and observing, to support user's focus. When creating, the decreased light emphasizes the shining nature of the artwork between the user's hands, assisting the user in focusing. A participant explained how focused they were on the creation and the creation only:

> *"And then when there's a lot of sparkles that are in front of you, they're all sort of moving and so going around. And it can be a little bit confusing, but just focus on your hands so that you don't get overwhelmed by all of the colors around that are moving around you"*

12.2.3.2 The design should counteract the inherent social, mental and, physiological discomforts connected to VR

The design should counteract the inherent VR social, mental, and physiological discomforts (see section 2.2). Among these are the feeling of being observed by people outside the VR and the anxiety of colliding with physical objects in the room, as we learned during our formative testing (see section 10.4) while testing in a confined area with other people around. Physiological discomforts such as mental or eye fatigue and nausea should also be considered.
With VR being such an immersive experience, it also comes with several pitfalls in making it a good experience. In our formative evaluations, participants remarked that it felt somewhat uncomfortable being inside VR when surrounded by other people, as the person was incapable of knowing if others were observing them or not. We thus recommend creating a safe environment where the user can enjoy the experience and express themselves freely without the concern of observers. Creating a safe space is also recommended by Khut in section 7.2.1, who is well versed with interactive biosignal-driven art in open spaces. This safe space should also constitute sufficient space for the user not to feel restricted or intimidated to injure themselves or others. We conducted our evaluations in a large, private room with abundant space for movement and gestures.
Additionally, physical discomfort such as nausea and loss of balance are common in VR but can become an even bigger issue if the artwork or environment moves considerably. We thus designed our environment to be rigid, but even though, some users felt nauseous:

> *"I felt like incredibly seasick and very, very nauseous. And I do this little sort of picture of this person in a tornado [points to the body map]. And that's very much how I felt my my sense of balance, especially my side profile, I felt like I was really swaying back and forth a lot during the experience. And it felt really hard to get a sense of where my center of gravity was. And orientation was was really hard in terms of where my body was in relation to the space. And where my center of gravity was being distributed throughout the space."*

We, therefore, strongly encourage attempting to counteract these discomforts through design, yet it is important to always be vigilant to these discomforts appearing. At the beginning of our interviews with participants, we for example, offered cookies, treats and water which was appreciated:

> *"Having sugar was a good decision on your part, because I was like, Oh, my God, I need to like, eat something sugary right now. Because I feel really nauseous. So that that I really appreciated "*

12.2.3.3 The design should be able to detect and accommodate for issues occurring

We acknowledge that the designer's virtue is eliminating issues and misunderstandings through design, as addressed by the Usability testing method in section 5.1.22 and by Hanington and Martin [98]. However, we want to highlight with this design considerations that things do not always go according to plan, and you cannot

foresee every potential use case. Therefore, it is vital that the design is flexible and adaptive to handle unforeseen issues.

One issue that can occur is not moderating the experience sufficiently, as we learned in our formative evaluation phase (see section 10.4). This can happen because biosignal-driven VR art creation experiences include a lot of equipment and software. Ensuring everything is on, connected, and calibrated is vital to the experience. We, thus, developed and recommend using a pre, during, and after experience checklist to not forget important steps for keeping the equipment working. Our pre-experience checklist included tasks such as "is the biosignal device on and charged?" and "is the computer volume at 65?". Our during experience checklist included all steps necessary to get the experience started, such as "attach biosignal measuring equipment", "check breath value and tailor to user's movement" and "position the user-facing in the right direction". The after experience checklist was mainly hygiene tasks: "clean headset" and "record, save and send creation to user". The cognitive load is also high for a moderator of an experience that is not fully automated or in the development phase. The high load is due to the vast amount of data produced inside the experience by the experience itself, the user, and the biosignals. We therefore recommend building an adequate operations panel with a good overview. It should be easy to know where the participants are in the experience, how well the system responds to the incoming biosignals and if there are any issues.

Other issues that can occur are users not understanding the given instructions, system errors, and unexpected user behavior. For those issues, the design needs to be flexible and adaptive to accommodate that beneficially. The *Nebula* is a narrated experience where instruction clips follow each other linearly. However, when issues occurred, we utilized the same narration voice to guide participants or to explain that there was a slight glitch. We recorded these supplementary narration clips separately, based on the most persistent user issues during the formative evaluation. We could access them through button shortcuts on the keyboard. One participant explained how she received helpful instructions when confused:

> *"I remember her saying that you need to keep your hands still, and I'm like, Okay! I'm going to keep them still, I'm not going to move, and then I'm going to create this little particle cloud and it will be safe."*

12.2.4 Be Mindful with Biosignals

The experience should be mindful of the varying level of biosignal perceptiveness to assist users in creating intimate correspondence, as informed by the somaesthetic appreciation design qualities (see section 3.5) we used for guidance. Designers should also be aware of biosignal measuring limitations and design with them. Finally, designers should be considerate towards users when coupling them up to biosignal measuring devices (see figure 12.20 for a visual overview).

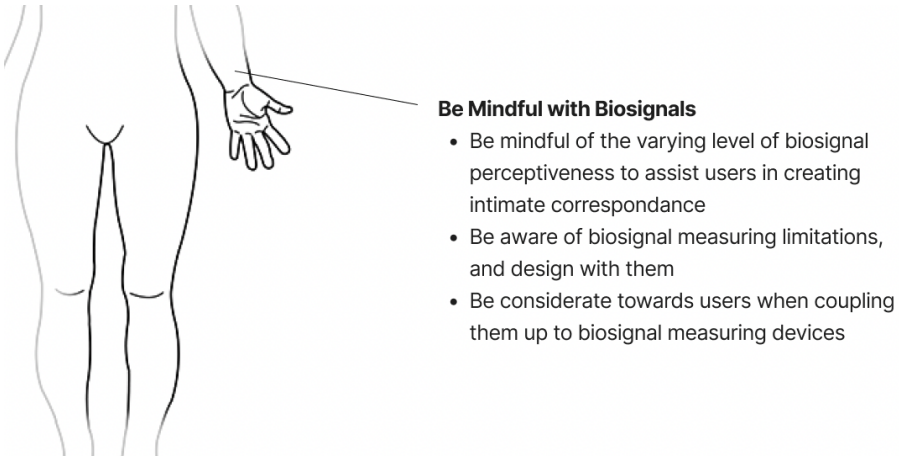


Figure 12.20: Visual overview of the be mindful with biosignals design considerations

12.2.4.1 Be mindful of the varying level of biosignal perceptiveness to assist users in creating intimate correspondence

From playful hacking we learned that the harder to recognize (less perceptible) biosignals such as heart rate and GSR should not be mapped to something in the design that is less detectable. Instead use the design to make biosignals which are more challenging to perceive more prevalent. This will help users to create a more intimate correspondence with themselves. In *Nebula*, we created an immediate but gentle connection between user and their heart rate. When creating and adding material, each deep exhale generated particles with a color corresponding to their current heart rate. This was a way to visualize and make the heart rate more perceivable in a non-stressful nor distracting manner. Despite not being able to achieve the colors that he wanted, this participant related understanding their colors to their "emotional state stress levels";

> *"I guess there's a reward in there, as in being able to control my emotional state stress levels. I can, like see this as a, as a receipt that I've in some way had the capabilities to control myself. Like, this is a receipt that I've managed to I can control my feelings in a way maybe I would say like that, I think"*

12.2.4.2 Be aware of biosignal measuring limitations and design with them

As with any technology, biosignal measurements have their limitations and flaws. As George Khut pointed out to us in section 7.2.1, one limitation is noise artifacts. He advised us to design affordances and constraints into our system so that it would be intuitive for users which movement are desirable and which are not. We recommend doing so, but designers should also make an effort to use the biosignal measurements' limitations to their advantage. In *Nebula*, we did so by aligning the measurement's limitations with our design goals. For example, the breath rate values were noisy when users were on the move, so we designed stillness into the experience as a

necessity. Users have to be still to create. That means users can only create when they are still, and when they are still, the breathing measurements are more precise. This means that it is not possible to create when the measurements are noisy. Another example is our measuring device could better detect exhale signals than inhale signals. Therefore, we only utilized the exhale value to signal a breath. That aligned well with our design's goal because exhales are parasympathetically arousing, meaning they activate the part of the nervous system responsible for our resting functions. (see section 2.3.1).

12.2.4.3 Be considerate towards users when using biosignal measuring devices

We are all unique when it comes to boundaries for personal space and how tight the biosignal measurement equipment can be equipped. Acknowledging this and taking measurements to respect our differences will make sure that no unnecessary discomfort is inflicted upon the user. In *Nebula* we used an earclip for the PPG sensor and a belt fitted around the abdomen. When coupling our participants with the equipment, we first explained what it was and how it worked, followed by an instruction of how to put it on, but demonstrated on ourselves. The demonstration was followed by a gentle ask if they would like to put it on themselves or if we could help them. By asking this question we acknowledged their personal space and provided the participant with the option to maintain distance to us. Most participants preferred us assisting them, but giving them the option is considerate. We believe that eventually, designers should aim for not needing to be there to assist users because giving them total control of how to experience the design would be the most considerate. To achieve that the measuring devices and the set-up need to be quite sturdy, but examples show that it is possible. In the Mettāmatics experience, shown in section 4.4, is such an example. There, users themselves put on a pair of headphones, follow instructions and attach the biosignal-measuring device on themselves.

12.3 Research Question 2 - Activities and Well-being

Our second research question is:

> *"What creative biosignal-driven activities informed by somaesthetic appreciation in VR are conducive to well-being?"*

To address the question, we will first answer how the somaesthetic appreciation design qualities inform the design of *Nebula* and report on participants' experiences as they relate to the qualities. Then we will accentuate the activities in *Nebula* that are conducive to well-being based on participants' experiences.

12.3.1 The Somaesthetic appreciation design qualities

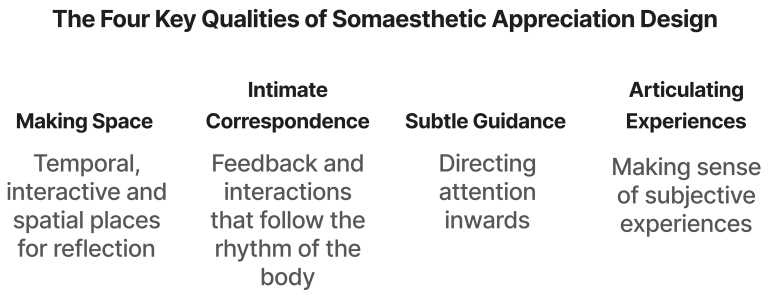


Figure 12.21: The four key qualities of Somaesthetic appreciation design

There are four main qualities of Somaesthetic appreciation design. They are, as seen in figure 12.21 “Making Space”, Intimate Correspondence,” “Subtle Guidance,” and “Articulating Experiences.” All inform *Nebula*’s design, and here we report on how the participant’s experienced them.

12.3.1.1 Making Space

Making space for reflection is one of the somaesthetic appreciation design qualities. Making space implies that the design should "make" space for reflection by "slowing down the pace of life" and "actively disrupting every day habitual routines." Making space also conveys that the design should include a physical enclosed space where users feel safe and cared for [71].
During the evaluation, we were mindful of making the participants feel safe in the physical environment before putting the VR headset on. We evaluated within a reasonably large room so users would feel comfortable moving around and closed the doors so participants could be sure that no one except us would observe them while having the VR headset on. We designed the VR environment with the same considerations and aimed for it to feel safe, rigid, not too stimulating, yet ambiguous, and open enough to provide room for reflections. The resulting design became the circular concrete dome with an open starlit sky. A participant described the environment as follows:

> *“It was kind of surreal feeling because I felt like I was there. And it was also like an open sky. It was a cool and calming environment.”*

Another participant pointed out how the VR environment was conducive to mindfulness and contrasted it to other similar experiences where he has found it challenging

to stop paying attention to the surrounding environment.

> *"When I have tried meditation before, then you just need to close your eyes and think of a place, more or less. I really need to focus on that part. And that part is given to you. Straight away. Because I at times, I did not even think about that you guys were in the room. That is like a big step. [...] It is hard to like not think about the stuff around you. And so it was fun to experience that in a more easier or more intuitive way."*

Participants also had many diverse reflections on the experience itself. Many referred to it as being space-like, as described by a participant as:

> *"I did create stuff like stars. Milky Way or small Milky Way's between my solar systems, or more Milky Way's. Zillions of small planets between my hands. And I was controlling or changing them with my breath."*

Another participant felt like being in the movie Avatar:

> *"I kept thinking about the movie Avatar. Because it was the same, like sparkling colors. And I guess you have seen it. But when they are under this big tree with sparkling colors. It felt like I was there. And it was fascinating to just be, yeah, part of something."*

A third participant then had a more personal interpretation as she felt she had created "a reflection of her inner self."

Therefore, we conclude that creating a safe environment for reflections within VR while taking care of the user's needs in the physical world is an excellent approach to fulfilling the Somaesthetic Appreciation Design quality: "Making Space". This shows great promise for the expansion of soma design towards virtual reality.

12.3.1.2 Intimate Correspondence

This somaesthetic appreciation design quality concerns the user's connection with the created artifact. Such as how well the feedback from the artifact map to user actions. The artifact should be synchronized with the user and perceived as an extension of the body rather than a separate entity or communication counterpart. In *Nebula*, the artifact is not just an artifact that users passively interact with, instead the users actively create within the experience. Users can generate a creation by taking a deep belly breath, perceive their heart rate through the color of new particles emerging during each belly breath and shape the creation with their hand movements. Furthermore, users can move their creations with their hands. We designed *Nebula* to be responsive, which adds to the feeling of the experience as an extension of themselves.

Participants felt and commented on their intimate correspondence with the created artifacts. One participant explained how it felt like her "pulse and breath was translated into some kind of vision." Similarly, another participant commented on how *Nebula* felt as an extension of himself:

> *"it felt like it was me who created the particles, as they came from me on my exhale"*

The experience did, however, not resonate with every participant. One participant reflected on how the particles from her exhale emanated from an unexpected position

which she described as "disturbing", and she resultingly felt more disconnected from her body:

> *"[It felt] really disconnected from my body. I was really confused about where they were coming from, because I was not expecting them to come out of here. [...] It really felt like it was coming right out of my nose. And that kind of disturbed me. And I'm not sure why but it just felt for me very discomforting that they were shooting out of there"*

The difficulty of connecting body parts to their virtual counterparts in the VR environment is a design challenge for intimate correspondence.

12.3.1.3 Subtle Guidance

Subtle guidance concerns guiding users to focus their attention inwards towards their soma using subtle yet noticeable stimuli. Subtle guidance supports increased body awareness through subtle guiding the user's attention between different body parts and practicing sustained attention in one area. According to Höök et al., the stimuli that guide the user's attention must be subtle enough so that the user's attention does not shift outwards toward the stimuli [71]. For *Nebula*, we interpreted this quality differently. That is because, within *Nebula*, users are creating art, and the art artifact guides the user's attention during the interaction. The art artifact thus guides users' attention inwards like other somaesthetic appreciation design strong concepts, but importantly, the user's attention is also outwards towards the art artifact. We acknowledged this during the design of the experience, and studies indicating that the art creation process is conducive to well-being [2, 3, 4] support our deviation from the standard interpretation of this quality. So whether the user's attention is inwards towards the soma or outwards toward the art artifact, *Nebula* should be well-being conducive.

Here, a participant stated how he enjoyed having the attention outside himself and relaxed because of that:

> *"This, for me, is very much helping me put the attention outside myself. And it is here you see, so you will like so your breathing at the same time you are modeling with your hands. So my attention is not trying me to breathe and relax. Relaxing is a result of what I am doing. So by creating, I get relaxed."*

Slowness is, in soma design, a key element in sensitising users toward their own soma, as mentioned in section 5.2.1. The slowness and added sensitivity also assisted in both exploration and creation:

> *"So just like slowly try and figure out, Okay, what's the, what does it have what happens when you move your right hand, what happens when you move your left hand, and see what kind of things you can do with shaping the little sparkles in some way."*

In *Nebula*, we instilled slowness with having the creation activity sensitive to movement. If users moved their hands or head too fast before saving the creation, the creation would vanish. Users thus had to learn how fast they could move their hands to continue creating because as soon as their hands were stationary, they started saving the creation. This interaction caused much frustration in the experience. We categorize most of the frustration as part of a eudaimonic well-being journey

because the frustration is primarily due to the user's learning a new skill. A skill that can potentially support their well-being in the long run, namely the skill of being capable of creating art within *Nebula*. An example of that is this participant here that said he felt frustrated because,

> *"in several times I lost the material. I must have done something that reacted too fast, I believe. And then I lost.".*

There were also additional design elements within the design that some users had difficulties understanding how to manage and were a source of negative feelings. Participants wanted, for example, to shape and create with certain colors but failed in doing so:

> *"I didn't get though is how to change the colors that annoyed me a little bit. I didn't get it to work."*

Studying *Nebula* in a more longitudinal manner would help us understand to what extent the subtle guidance needs to be considered and balanced with negative emotions.

12.3.1.4 Articulating Experiences

In most Somaesthetic appreciation design, the quality of articulating experiences is interpreted as allowing users to articulate their felt bodily experiences after interacting with the design. Bodily experiences are subjective, but designers attempt to provide users the means to communicate what they feel. A typical method is using body maps, where the users draw attention to the parts of their body that they feel are or were the most prominent prominent during the exercise (see section 5.1.3). When evaluating the experience, we began and concluded each session by asking each participant to fill out a body map. After, we invited them to share with us what they had drawn. Participants shared rich, and various felt bodily experiences. As an example, one participant felt like her lungs were occupying space in her abdomen:

> *"Yeah, and then here I had like a space that was kind of. It cannot be the lungs, but it feels like the lungs were like down here. [points to her abdomen] Like a big container with oxygen."*

Another participant described her experience as if her "heart went up to the brain." She related it to happiness and said:

> *"It feels good. It feels like sometimes it is in the stomach. You feel something. [...] I was having a little bit of yeah, it was curious. But then I felt like I was so focused. So everything was in the brain, felt like that. So the emotions, I mean, I think you, even if it is the brain who gives you the emotion. For me, it feels like the heart is the source to the good feelings. And it felt like well, the breathing everything like this was the center, and now I am creating so now it is so the heart is also in."*

We also view the "articulating experiences" quality in a broader scope than other soma designs. That is because, in *Nebula*, users are actively creating an art artifact that stores temporal bodily elements from its creation in the form of colored particles and overall shape. This artifact can be stored and shared with others; thus, it can serve, on its own, as a means of articulating an experience. That is in contrast to most other designers grounded on somaesthetics where users do not create artifacts.

Users can only share their felt bodily experiences with others, and only if they manage to articulate them. We, therefore, believe the experience goes further in providing users the availability to articulate their felt bodily experiences because the articulation is inherent in the art creation. Due to that inherent articulation quality of creation experiences, we extrapolate the "articulating experiences" quality to encompass users' articulations of the created artwork. We did not prompt users to reflect on the created artefacts themselves, but we find value in multiplying the possible articulations of felt experience afforded by virtual reality and biosensors.

12.3.2 Activities Conducive to Well-being

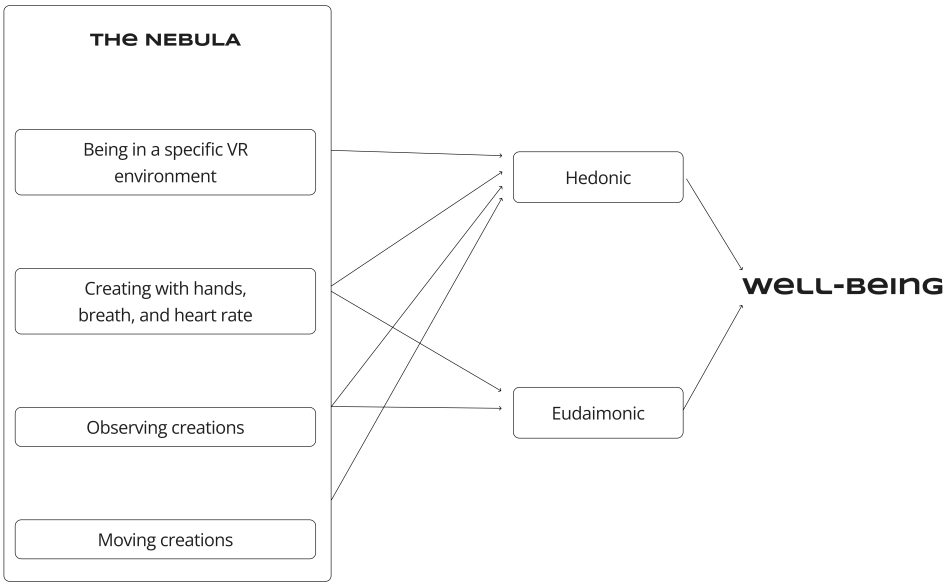


Figure 12.22: A visual overview of the activities conduce to well-being

Nebula comprises a determined set of creative biosignal-driven activities the user can conduct. This section breaks down the steps by singling out the activities, and we convey how each activity is conducive to either hedonic and/or eudaimonic well-being, as seen in figure 12.22. However, these activities are chained, and the user must perform them one after the other. Therefore, we summarize this section with examples of how the composition of the identified activities, performed together within the Nebula experience, are conducive to well-being.

12.3.2.1 Transporting to a calming VR environment

Figure 12.23: Outside view of a user exploring the *Nebula* environment

Figure 12.23 shows an user experiencing *Nebula*, and as informed by Making Space, the activity of transporting to a calming VR environment, a specific space can be conducive to hedonic well-being.

Hedonic well-being Being transported to a calming VR environment was said to be surreal and pleasant:

> *"It was a kind of surreal feeling because I felt like I was there. And it was also like an open sky. It was a cool and calming environment."*

Another experienced a pleasant break from reality and said:

> *"I really felt like I was completely somewhere else. And that kind of illusion felt very pleasant, because I think it worked well with the attitude or the brain fog that I had when I walked in. So it kind of helped me to escape from that."*

12.3.2.2 Creating with breath

Figure 12.24: An outside view of a user creating with their breath

Breathing to create particles in colors depending on the user's heart rate, as the user is doing on figure 12.24, disrupts habitual daily routines and provides users a space for reflections, as informed by Making Space. The interaction is also an example of an Intimate Correspondence and can be conducive to both hedonic and eudaimonic well-being.

Hedonic Well-being The activity and resulting reflection can be calming, as explained by a participant that continued breathing, in the same way, to continue creating purple particles:

> *"My favorite color is purple. So when I got that color, I continued to breathe in the same way to create more of them. That made me calmer. [...] in the end, it felt like it was shaped like a face. So maybe a reflection of my inner self. [...] I am a little bit speechless."*

The pleasure of visualising the breath was stated by many. One referred to it as:

> *"When you see that you can spit fire like a dragon, it was very satisfying."*

Participants also derived both visual and mental pleasure from creating:

> *I could create in different ways [in the experience] than I do usually. I was more present because what I created was just what I saw and felt, there was nothing physically being created.*

Eudaimonic Well-being The activity and resulting reflections can also be conducive to eudaimonic well-being. One participant interpreted the experience as a

game where one tries to collect colors to see what their breathing looks like:

> *"It sort of felt like a competition in some way. You are to pass a checkpoint and try and collect as many colors as you can to sort of be able to see, okay, what does your breathing actually look like?"*

Participants connected with their soma through breathing and creating in an intimate correspondence:

> *"[I] shaped a connection between body and brain by being capable to create with the body through breathing in a specific way".*

Participants reported being better able to perceive biosignals which otherwise often are less easy difficult to perceive:

> *"you don't know how your heart rate is changing and you start to reflect on what the different colors mean to your heart rate".*

12.3.2.3 Creating with hands, breath, and heart rate

Figure 12.25: An user creating with hands, breath, and heart rate

Creating art with hand movements, breath, and heart rate, as the user is doing on figure 12.25, disrupts habitual daily routines and provides users a space for reflections, as informed by Making Space, guides the user's attention, as informed by Subtle Guidance, and supports personal interpretations, as informed by Articulating experiences. The activity can be conducive the hedonic and eudaimonic well-being.

Hedonic Well-being Participants expressed joy and excitement due to having created art within *Nebula* experience. As one participant said:

> *"Was kind of swept away. It was really, you know, exciting to be in that in there. It was really cool to be able to add all these fantastic shapes, and I forgot how tired I was"*

Participants also highlighted how being able to create without judgment was essential for them to enjoy the creation experience. One participant described it as:

> *"Here, you do not have to perform. [...] It was just for me. Yeah. Just for myself. Just the joy of creating, it was just beautiful."*

Participants found the guidance of being more mindful about their hand movements joyful.

> *"But it's not that easy. I have to be more careful. Which was good. Because that first part when I actually was careful. I enjoy that the most, I believe."*

The breathing guidance from the narration was also found to be relaxing without being demanding.

> *"The breathing, trying to do as the voice said, was in the end relaxing. without actually forcing me to relax or to breathe? I wanted to, to do it you know?"*

Eudaimonic Well-being A participant found the breathing saddening, as she failed to achieve something she desired. The guidance assisted her in reflecting on her body and why she failed.

> *"There was one time I got like this bluey purple. And I was like, Oh, yes, I got like three different colors!! But I was sort of felt a little bit sad that I wasn't able to see, like a greater range of colors. And I'm like, Yeah, okay, that makes sense. Because I haven't been able to do and interact with, like, the full range of breathing patterns that I would normally get to."*

Interestingly, the creation did not only follow the participant, but participants also changed due to the creation. One participant felt drawn to be more fluid and relaxed like the particles but she could not because she "had the responsibility to create the life form". Therefore, she was strong, rigid, and with hands still. Like a parental figure. We consider this to be eudaimonic in the sense of bringing forth and actualizing sides of self.

One participant reflected on the experience and contrasted it to painting with pencils. She said that when painting her "brain and the hand do not do the same thing" but, "here it felt like I could just shape and it was much more easy to just create with the hands not a pen or something that does not do what I wanted to do". For her, the creation was thus enabling, or as she said, "It was really nice to do something I did not know that I could do before."

Another participant reflected on the experience as he was creating with his emotions and tried to create different "emotional clouds." He intended to create "one calm cloud, one mid-level cloud, and one hectic cloud". Unfortunately, he did not manage to save these creations within the timeframe allotted for the experience. He, however, saw a eudaimonic well-being benefit in doing so if he had managed:

> *"I guess there is a reward in there, as in being able to control my emotional state stress levels. I can, like, see this as a receipt that I have in some way had the capabilities to control myself. Like, this is a receipt that I have managed to. I can control my feelings."*

A third participant then said he had a contrasting experience. At first, he was creating and enjoying the pure joy of creating. However, in the latter half, he attempted to create specific things, which resulted in him feeling frustrated when he did not achieve them. He thus concluded that to feel well and relaxed through creations; he must "create with honesty."

12.3.2.4 Moving Creations

Figure 12.26: An user moving the artwork.

The activity of moving the creations in and Intimate Correspondence with one's hands, as the user is doing on figure 12.26, can be conducive to hedonic well-being.

Hedonic Well-being Several participants derived joy and satisfaction from moving their creations and used similar phrases to describe this;

> *"Moving the pieces was very satisfying. I felt empowered. I felt like some kind of God, or like in a Marvel universe. I have power, you know, power of making it bigger or smaller. So it was satisfying"*

The empowered feeling, which arguably can be considered eudaimonic, was considered by us to be hedonic as we could not link it to any further growth of participants' persona.

12.3.2.5 Observing Creations

Figure 12.27: An user observing the created artwork.

Observing the creations in an Intimate correspondence Subtly Guides users' attention and supports them in Articulating experiences. The activity, as seen in figure 12.27 can be conducive to hedonic and eudaimonic well-being.

Hedonic Well-being Moving the creations while simultaneously observing them aided pleasure, as one participant said: "I really enjoyed the part where you can sort of move them around and they can watch it from different angles". Observing the creations, one's own hands, and the response in the body from breathing was also a hedonic well-being conducive factor for other participants, that expressed feelings of joy, relaxation, warm feelings, and feeling empowered. As described by one participant:

> *"To see my hands was super important [. . .] It was just fun. The presence of the hands, that it was not actually remote controls was also kind of relaxing or amusing".*

Many reflected on the connection between themselves and the creation, and one resonated with how the creation was mimicking their bodily sensation:

> *"I would describe it as tingling [the relaxing feeling] ... I was I felt a bit like the images or the visualizations looked. Also, maybe a bit warm. Yeah!".*

Observing is also connected to the audio elements of the experience. Listening to the body scan in the intro while standing was described as enhancing the bodily

connection but also empowering: "When I connected more to my body, I felt I could stand here forever. That was interesting".
The creation was also subtly guiding participants' attention towards it, in a comfortable, fascinating and slow manner:

> *"I think it relates a lot to the feeling to like when you watch a fire or like a stream, like that continuous movement is quite fascinating. It's something you know, that you can rest your eyes on. And it's comfortable, because it's slow, and things happen, but it's not like disturbing."*

Eudaimonic Well-being The creation guided participants' to reflect on their current and desired state:

> *"And unlike, I felt very, not distracted. But I felt more drawn to like, oh, I want to be more like that. I want to be more fluid and relaxed."*

One participant felt like the artwork was, as she described it, "like having a dog," or something capable of understanding her through senses and motions and has another language that is not verbal. She said that the artwork could thus really enhance her connection with it.
Another participant interpreted the artwork as a "precious life form" for which she was responsible. She said that being responsible for them felt scary and made her anxious. We argue that such a strong feeling of responsibility can induce eudaimonic well-being when she manages to take care of the "precious life form" accordingly. However, as with other eudaimonic well-being-inducing elements, the journey to well-being can include momentary negative feelings.

12.3.2.6 The Nebula Experience

Figure 12.28: An user experiencing *Nebula*

The *Nebula* experience is informed by all of the four Somaesthetic appreciation design qualities; Making Space, Intimate Correspondence, Subtle Guidance and Articulating Experiences. Figure 12.28 shows a user during the activity, which can be conducive to eudaimonic well-being, as supported by the following examples.

Eudaimonic well-being Participants made space to experience *Nebula*, as informed by Making Space, said they felt introspective, energized, curious, and liberated. A motivating reflection that one participant had when realizing he could generate as many creations as he desired was:

> *"You can stay in the failure of having lost something or you pick up the pace and make a new one. Picking up the pace. That felt quite good. I had a chance."*

Another participant felt more creative and energized. She described it as the feeling of slowly waking up, being more colorful, and, "just feels like floating." A third participant said he had much on his mind and felt very occupied before experiencing *Nebula*, but during the experience, he felt very slow and introspective. He described it as:

> *"I felt like I was kind of absorbed in a very observant state. Like I was really observing myself and what it is like to experience my body."*

After the experience, he felt less occupied in his mind and like he had more space to perceive his surroundings:

> *"I could just zone out for a little bit and kind of escaped that [the things on his mind]. That is why I feel like my mental space broadened where I could take in a little bit more from the environment."*

As informed by Intimate Correspondence, the combination of observing, breathing, creating, and moving opened up sides of the participants which they enjoyed:

> *"And in my head, I didn't feel any warmth. It was more colorful. It felt more like my creative mind started to wake up. And it felt a little bit like lamps. [before the experience] I didn't have any lights on. [...] Right now it feels like more lamps or lights are starting to turn on".*

Participants mentioned how they felt inclined to try more actions, as informed by Subtle Guidance. The experience was thus conducive to exploration and challenging oneself.

> *"It sort of inspires you and intrigues you to try more and you start thinking like, oh, maybe this and that, that I could try this."*

Another participant explained how he was guided to focus on one thing only and how it felt as he could take advantage of his whole headspace:

> *"feels I mean, like, focus on one thing, instead of having like multiple thoughts at the same time, like flying away in different directions. I feel like I had like one or two centered thoughts or I guess like since I was focusing on this so that was like to go to almost my whole headspace I guess"*

13
Discussion

This chapter initially discusses the answers to the two research questions. We then go on to highlight the similarities and differences of *Nebula* in relation to similar work. Subsequently, we review our design process, the technical aspects of the project, and how we managed the generated technical knowledge. Finally, we discuss the ethical concerns of this project and potential future work.

13.1 Research Question 1

We set out to understand and answer the following research question:

> *"What should be considered when designing a VR experience where biosignals are used as input for creation, as informed by art practice?"*

During this thesis, we have realized that VR is an excellent but vast space for art creation. It exhibits near (if not) endless opportunity for creativity which instills the question. We have but explored one possible direction in this thesis, and many others are left open for further investigation. Creating a VR experience in itself is a demanding activity requiring considering for example, visuals, audio, movement, space, user experience, usability, and more. Adding biosignals to this mix makes it even more complex. Thus, it should be considered when reviewing our design considerations that these were informed by the small ray of light that we shone on this material. Our results showed interesting directions that can be applied to further define this specific combination of technologies, but are open to be reworked and further iterated by others.

We were fortunate to speak and collaborate with talented artists. We have found that creating art is a profound, rich experience that is highly personal and a skill that can be enjoyed instantly but can take a lifetime to master. We were inspired by merely four artists, an incredibly narrow angle to build design considerations on as it is just the beginning of what art practice is. Engaging with the knowledge of artists is a worthwhile endeavour as future work, and it can be made even richer by involving art practitioners in further phases of the development of interactive experiences. In this thesis, we involved their knowledge as first input, but have not evaluated with them.

13.2 Research Question 2

For our second research question, we explored:

> *"What creative biosignal-driven activities informed by somaesthetic appreciation in VR are conducive to well-being?"*

In *Nebula*, we have designed available activities for users to be creative with their biosignals. Users can breathe to instantiate creations and exhale deeply to add material with color dictated by their heart rate. Users can also use their hands to shape the creations and either save or delete them. If a user saves a creation, they have the availability of moving them and rearranging them to their liking. It can be questioned whether all of the activities above are biosignal-driven. For example, shaping and moving the creation can be argued to be a biosignal driven activity because moving hands requires muscle tension. Muscle tension is a bodily signal that can be measured, and thus it is a biosignal. With that logic, though, using a controller in VR is also biosignal-driven because people use their fingers to press the button. Therefore, we argue instead that all activities are biosignal-driven because they all depend on the first one, which is to instantiate a creation with breath where the color depends on the user's heart rate at the instantiation time. Thus every interaction with the creation that follows its instantiation is arguably biosignal-driven because the measured breath and heart rate values are stored in the creation.

The second discussion point we want to bring forward regarding the second research question is how and to what extent we were informed by somaesthetic appreciation design. We argue how the four somaesthetic appreciation design qualities informed the activities in the Result section 12.3. We also explain how we interpreted the "subtle guidance" and "articulating experiences" qualities in a broader scope than typical somaesthetic appreciation designs. The "subtle guidance" quality is about guiding the user's attention inwards to their soma. However, we interpreted it to also mean that the user's attention could be drawn to the art artifact since art creation is also conducive to well-being. Our interpretation of the "subtle guidance" quality is broader and can seem contradictory because guiding the attention inwards is the opposite of guiding the attention outwards. Höök also recommends against using visuals for somaesthetic appreciation designs precisely for this reason [14]. In her experience, visuals draw too much of the user's attention towards the visual. We, however, believe that it was necessary to re-interpret the quality to design a creative experience because, as defined by Dahlstedt, the creative process is a feedback loop between shifting attention between the material- and conceptual representation [7]. The material representation is the idea manifested in the material world, while the conceptual representation is the idea as the creator interprets it. Thus it makes sense for a creative experience that the stimuli guide the user's attention both inwards and outwards. Regarding the "articulating experiences" quality, we stated that the created art artifact could also serve as a means of articulation on its own because of the inherent articulation quality of creations. However, this part of the results lacks comments from participants regarding how they interpreted this articulation potential of the creations. As previously stated, we used body maps during the interviews to bring forward discussions about participants' felt bodily experiences. We could also have asked participants to interpret their creations and how they relate them to their felt experiences. We suggest as future work the evaluation of these creations as a means of articulation. We hypothesise that different expressions

of biosignals may be worth a closer look in sense-making activities, which can be incorporated as evaluation methods for soma design.

13.3 *Nebula* in the context of related work

We believe that *Nebula* is unique in that it combines the topics of art creation, biosignals, and VR. The relevant work we have been inspired by and put forward in section 4 all touch upon one or more of the topics mentioned above, but none combines them. The Breathing Light and the Sarka utilize biofeedback and thus are examples of using biosignals as an input for design. The game DEEP similarly utilizes biofeedback as an input and combines it with VR. In the game, players need to breathe to move around the game environment; thus, nothing is created with the user's breaths. The Tiltbrush is then a tool for art creations in VR, but the input is through a controller, not biosignals. Lastly, George Khut's Mettamatics and Cardiomorphologies are biosignal-driven interactive artworks that do not utilize the VR medium.

13.4 Design Process

Our overarching design approach was utilizing the method of Research through design. The method supported our project very well because of its exploratory nature and because we were not aiming to solve an existing problem. We were just interested in this particular design space that we wanted to explore. The other frameworks, methods, and approaches we weaved into our design process also supported the exploratory approach we aimed for.

Playful Hacking At the start of the project, we had limited technology knowledge within the field of VR and biosignals. Thus, the playful hacking was beneficial since we could improve our technological capabilities in parallel and create small prototypes to test. However, how we utilized the approach deviates slightly from how it is defined in its manifest by Goddard and Cercos (see section 5.2.2). According to Goddard and Cercos, hacks should refrain from current research and should not take longer than four hours to implement. Our approach was more strategic since all our hacks were related to our current research, and many took more than four hours to implement. We believe that that is coherent with using the approach as the primary method of exploring and learning about the design space.

Soma Design The soma design approaches and frameworks supported our project well. As explained in the Results section 12.3, we were informed by the somaesthetic appreciation design qualities, but we also utilized other soma design approaches. Soma Design emphasizes the first-person perspective of the designer because when designing for somatic experiences, a designer needs to be sensitive towards the design. We, as designers, strongly agree with this notion and believe that it also applies to other interactive designs because the designer can never be removed from the human. A designer cannot be viewed as a purely objective entity because their

lived experiences influence every designer's decision. Therefore, we embraced the first-perspective approach for our project and utilized it to cultivate our somatic experiences. The first-perspective approach was especially beneficial within the playful hacking phase of the project since it allowed us to test prototypes quickly but, more importantly, make design decisions. At first, it felt weird making decisions only based on what we, the designers, felt because it goes against much of what we have learned about user-centered design. However, we trusted the process and kept exploring, driven by the excitement of what seemed endless possibilities to test and try out. Eventually, the method became more natural to us, and our discussions about different felt experiences became more elaborate throughout the project. We also realized that the material and concept we were working with were subjective, broad and could have been better defined. Thus, involving users when setting the project's direction would not necessarily have been advantageous. The user's perspective was, however, highly valuable at the later stages, when we had set the direction and aim of the project.
In our formative and final evaluations, we also asked participants to fill out body maps based on the most prominent feelings and sensations. A few had seen them before, but many had not. What was of interest to us was how everyone, no matter how skeptical they seemed at first, managed to utilize the method to communicate something to us that we believe would have been very difficult to communicate with words. Utilizing body maps was thus a surprisingly good method for us during design and evaluation.

Qualities for Design A valuable learning from the project is how beneficial it can be to utilize qualities for design. Before the ideation phase, mid-way through the project, we had gathered a lot of information and insights from various sources. We extracted the qualities of all the data and utilized them for our ideation. In doing so, we abstracted the data, allowing for re-interpretations that sparked new ideas. At the same time, the new ideas still contained the critical qualities of the initially gathered data we were informing our design. This learning and how much we appreciated utilizing the somaesthetic appreciation design qualities for our design supported our intention to deliver design considerations in the form of qualities like we did for research question 1.

13.5 Technical aspects and generated knowledge

Currently, *Nebula* is experienced using not-so-accessible technology. The technology is both expensive and somewhat complicated to equip and calibrate. As a result, it is unfortunately not likely to expect a widespread use and evaluation of *Nebula* in this composition.
As for future work in this area, we spent a vast amount of time exploring and discovering opportunities with the technology. These opportunities allowed us to experience and extended our somatic sensitivity in a novel way, which benefited our project. We were proficient in documenting the felt and experienced sensations from the explorations, but the technical documentation and generated knowledge

remain in our heads. This is very unfortunate as we saw many possibilities with the developed prototypes, and it was hard even for us to reopen VR prototypes to try to re-utilize them. In hindsight, it could have been beneficial to outline a proper methodology for documenting the generated technical knowledge. A good structure would have made the generated knowledge accessible and apt for further development.

13.6 Ethics

Despite the positive comments from many participants and perceived benefits, it is debatable whether the actual value of this experience and investing a considerably large amount of resources into developing it is ethically defendable. The list of ethical considerations can be made long, but here we list the design's physiological, mental, and moral aspects.

13.6.1 Physiological considerations

Screens in their many shapes and sizes are becoming increasingly common. Many of us expose ourselves to screens mindlessly as we use our phones, computers, TVs, or other equipment. Just because this is a norm in many societies does not mean that this is a positive norm. As we set out to develop for VR, we were enchanted by its possibilities and how it could enable our work. Unfortunately, we did not discuss the unethical nature of attempting to compel users to continuous and repeated close exposure of their eyes to two luminous screens. We do not know about the long-term effects of exposing the eyes in such a way, although ignorance is no excuse as we observed strain in our eyes after having the VR headset on for sustained periods lasting as short as half an hour. Furthermore, we found the extensive use of VR exhaustive to our necks as the significant load is exerted in front of the head, not on top of it.
The design is also heavily based on breathing in a way beyond the ordinary due to technical limitations with the PZT-band. Breathing is not harmful, but its impact on the user and the user's context when breathing should be considered. It strikes us now that we never implemented a proper safety mechanism for users who could fall into an unhealthy breathing pattern and spiral out of control, effectively fainting and perhaps injuring themselves from a fall.

13.6.2 Mental considerations

Not being experts on biosignals or algorithms, we did the best we could with the time at hand to extract and fine-tune the biosignals. It is evident that all algorithms can be improved to increase their precision, but the question remains whether it was ethically correct even to use the algorithm from the start. The effect of erroneous heart rate measurements leads to an incorrect and potential change of colors, which could induce incorrect reflections and perceptions of the bodily state. Furthermore, what will the user's reflections be if they have issues with the measuring equipment, but the blame is on the technology, not them? As we observed plenty of feelings of

failure during our evaluation, we deem it highly likely that we could be burdening the user with unnecessary feelings of failure in some occasions.

13.6.3 Moral considerations

The mobility and accessibility to biosignal measurement equipment is a recent advancement that exposes new understandings into the depth of our physiology and mentality, or as defined in this project, the Soma. Self-knowledge is arguably always beneficial but is it morally right and a good thing for people to create like this and expose their art to others? Similarly, the adverse effects of portraying our lives on social media were not highlighted until the damage was already done. Another moral consideration is that Nebula can currently only be experienced by quite able people. It is not very inclusive and that is a major drawback to the design and was a limitation due to the limited time we had. Furthermore, the experience is dependant on users understanding our instructions on how to take belly breaths as well as comprehending the whole the narration. This is a weakness and the design should perhaps be modified to allow for multiple ways of learning the techniques required.

13.7 Future work

During the project, we accumulated an extensive list of possible next steps in designing *Nebula* that we have grouped under "could's" on the Moscow diagram. To name a few, "coulds" that we as designers are especially interested in are:

- Work on the audio so the audio changes in unison with biosignals changes, as we believe it would add to the immersion of the experience and provide a strong technique for personal articulation.
- Implement more degrees of freedom for users to create more unique creations, such as by adding a step in the creation process where users could add specific movements to their creations.
- Implement the possibility for users to create in all directions so they do not always have to face the same way when creating.

However, if we were to continue with this project, there are five main areas that we would want to research and explore further.

- As this project has been conducted in collaboration with Volvo Cars, we would want to explore how the *Nebula* could be integrated into future Volvo products. In conjunction with Volvo employers we could also explore how the quantitative biosignal data could be utilized to predict well-being.
- Conduct a longitudinal study to evaluate the "episodic" and "cumulative" user experience [78], because knowing how the experience of the *Nebula* changes after more than one use is essential for continued work. Especially since we are designing for well-being, for example if the *Nebula* is only conducive to well-being when users try it the first time, we would either need to accept that limitation or change its design.
- Explore how the *Nebula* could be made into a shared experience because currently, we only support one user at a time. It would be interesting to see what

happens when two (or more) users are interacting with each other's biosignals and attempt (or not) to synchronize or coordinate their states. That research could be a valuable addition to current research within Human Centred Design about co-experiences and something we would be excited about exploring.

- Make the *Nebula* more accessible. The current setup requires much expensive technology and relatively complicated biosignal measurement devices. For further work, it would be of high value to try and implement the experience into cheaper and more accessible devices.
- Lastly, as also mentioned in section 13.2, we want to explore further how the creations can serve as a means of articulating felt bodily experiences.

14
Conclusion

This thesis explored the intersection of VR technology, biosignals as input, and art creation practices. Furthermore, we aimed to understand how this novel design space is conducive to well-being. Others have researched and designed the combination of two listed components, but we have found no examples of the combination of all three. The thesis is thus of value as it opens up an unexplored design space that consists of components that are all highly relevant in today's society. The growing demand and potential use cases for VR technologies are imminent, and with it comes the need for more immersive experiences, as that is the promise of VR. Biosignals as inputs are thus of value to VR. Lastly, humans have been creating art for centuries and will continue until extinct. However, art creation is ever-evolving, and creating art within VR is already appealing. Designing for well-being is also a worthwhile virtue for designers, and us addressing it from a novel perspective serves the design community as a whole as it riches its shared knowledge.
We applied a research through design approach to explore the design space and utilized soma design theories and methods as guidance throughout our process. During the design, we employed Playful hacking as an approach to learning and examining the design material and interviews with expert creators to inform us about the somatic intricacies of creating art. The resulting outcome was *Nebula*, an interactive VR prototype where users can create art using their hand movements, breath, and heart rate.
During development we conducted formative evaluations with eight participants and numerous first-person evaluations. We then evaluated *Nebula* with twelve participants during 1-hour-long sessions where a user had the chance to try the prototype for around 20 minutes before elaborating on their felt experience. The evaluation and our overall findings from the research through design cultivated design considerations for the design space, which addresses our first research question:

> *"What should be considered when designing a VR experience where biosignals are used as input for creation, as informed by art practice?"*

We cluster the thirteen considerations into into four groups:

- The design should be welcoming but challenging
  - Should be easy to start
  - Enticing to explore
  - Challenging to master
  - Encourage failure
- The design should be meaningful

  - The design should provide agency
  - The design should be thought provoking
  - The design should be stimulating
- Utilize the potential of VR
  - The design should emphasize immersion by taking advantage of inherent immersion qualities of VR
  - The design should counteract the inherent social, mental and, physiological discomforts connected to VR
  - The design should be able to detect and accommodate for issues occurring
- Be mindful with biosignals
  - Be mindful of the varying level of biosignal perceptiveness to assist users in creating intimate correspondence
  - Be aware of biosignal measuring limitations and design with them
  - Be considerate towards users when using biosignal measuring devices

The second research question was:

> *"What creative biosignal-driven activities informed by somaesthetic appreciation in VR are conducive to well-being?"*

To address the question, we report on how the somaesthetic appreciation design qualities informed the design of *Nebula* and how participants experienced it. Our evaluations indicate that *Nebula* satisfies the "Making Space" quality better than most somaesthetic appreciation design strong concepts, meets the "Intimate Correspondence" quality, pleases yet requires a broader interpretation of the "Subtle Guidance" quality, and lastly, opens up the possibility of fulfilling the "Articulating Experiences" in a new way. Lastly, to address how *Nebula* is conducive to well-being, we single out what creative biosignal-driven activities are conducive to well-being. The activities are; "Being in a specific VR environment," "Creating with breath," "Creating with hands, breath, and heart rate," "Moving Creations," and "Observing creations." Our findings indicated that most of the activities within the context of the unified experience are conducive to both hedonic and eudaimonic well-being.
We realize that we only scratched the surface within the VR, art and biosignal space. Other designers have a lot to gain in terms of developing on the level of immersion, the agency, and the potential for expression. The reader should also be aware that we broaden a major somasthetic appreciation design quality which states that users should be guided inwards. In contrast, we guide them outwards towards the generated artwork, to be guided inwards as a result. Unfortunately, we did not have a proper methodology for documenting the acquired technical knowledge. Thus there are insights and wisdom which are not transferable. This might be admissible, since developing this experience should perhaps not be pursued, because we recognize the ethical issues with a project like this. Potentially, it is not physiologically, mentally, nor morally ethical to develop an experience like this.
Should anyone, however, decide to continue our work, we recommend making *Nebula* more accessible, primarily in a physiological aspect. Secondly, we recommend longitudinal studies to understand the episodic and cumulative user experience. Further-

more, this experience could relatively easily be converted into a shared experience to study the effects of users interacting with each other's biosignals. Finally, future researchers are recommended to explore further how the creations can serve as a means of articulating felt bodily experiences.

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A

Appendix Narration Script

Meditation transcript:

Clip 0 - black screen:

To begin just let yourself get into a comfortable position. Whatever that looks like for you

When your body feels ready, you may gently close your eyes.

With your eyes closed, take a moment to tune inwards.

First simply noticing your body. Tuning in to the weight of gravity. The points of contact between you and the surface on which you are resting.

What else do you notice? What is it like for you to be in your body right now? As you observe this, you simply accept and allow whatever it is you notice.

Harboring no judgment. Just being mindful. Noticing what is and letting it be.

Continue to do this now with your breath as well as your body. If you haven't already, begin to tune into the sensations of breathing.

What do you notice? Just observe, accept and allow. No judgment. Just let everything be how it is and remain mindful of your breath and your body.

Now try to move your attention to your heart rate. Is it fast? Is it slow? Can't you feel it? Whatever it is, it is okay. Seek the sensation of you.

Keeping your eyes closed, you allow your awareness to expand to include the space around your body.

It is as if you can sense the air around you, the objects around you and you just allow them to be as you simply are. There's nothing to do. There's nothing to judge.

If your mind wanders, that's okay. Don't judge it. Just return your focus to what is. Being connected to your breath, your body, and your sense of presence in the world around you.

You let everything simply be, [pause] including yourself.

The Introductory Narration 5.0

Clip 0 - Meditation [Finished at 03.48] - Change at 03.55

Clip 1 - black screen: Before you start creating, we want to introduce you to the art medium.

Clip 2 - black screen: Open your eyes and bring your hands forward so you can see them both.

Clip 3 - instruction1: Please align them like those shown on the screen in front of you. The palms should face each other. [Pause for a moment] Keep them still and pause for a moment. [finished at 15s, change at 17s]

Clip 4 - instruction1: Now take a deep belly breath and exhale completely by pulling your belly button inwards while you exhale.

Clip 5 - Instruction 1: You have now taken the first step in generating the creation between your hands.

Clip 6- Instruction 1: Take another deep belly breath and exhale completely.

Clip 7 - Instruction 1: Every time you inhale deeply and exhale completely, you add material to the creation. You control how much material you add by taking deep belly breaths and exhaling completely.

Clip 8 black screen [3s wait] Maybe you have noticed how the colors change? The colors are connected to you.

Clip 9 black screen: You can control the color of the added material (pause), by lowering or increasing your heart rate. The colors correspond to your current heart rate

Clip 10 black screenLet's see what happens with the color when you inhale and exhale rapidly. Follow along and remember to use belly breaths:

3s pause

Clip 11 black screen Inhale strongly (1s), Exhale strongly (1s). Inhale (1s), Exhale (1s). Inhale (1s), Exhale (1s). Inhale (1s), Exhale (1s). Inhale (1s), Exhale (1s).
[Do this for 10s, 5 inhales, 5 exhales] [Here each “Inhaly strongly / exhale strongly” need to be maximum 1s to fit the tempo.]

3s pause

Clip 12 black screen Did you notice how the colors changed with your breathing? [Pause] You achieved that by raising your heart rate with your breath.

5s pause

Clip 13 black screen Now let's breathe slowly. Follow along and remember to use belly breaths:

3s pause

Clip 14 black screen Slow inhale (4s), Slow exhale (4s). [Do this for 32s, 4 inhales, 4 exhales]
3s pause
Clip 15 black screen Did you notice how the colors changed with your breathing? Your heart rate slowed down as your breathing slowed down.
5s pause

Clip 16 - Instruction 2: Now please try to gently move your hands like the ones shown on the screen. Your left hand slowly moves to the side and back again, and your right hand goes up and down, and forward and back. [Pause for a moment] This is how you shape the creation. [Finished at 26s, watch them and change at 33]

Clip 17 - Instruction 2 (sped up?): Now try to move your hands faster. [Finished at 4s] [long pause] Can you move them faster? [long pause] Can you move them even faster?

Clip 18 - Instruction 1: The creation vanishes when your hands move too fast. That is okay, though, because you can generate as many as you desire. As explained before, you can generate new creations by aligning your hands in front of you, keep them steady while pausing for a moment, and then take a deep belly breath where you exhale completely.

Clip 19 - Instruction 1: [SKIP IF USER CREATED] Please try to create a new one, just like you did before

Clip 20 Instruction 1: - If you keep your hands and head steady for long enough you save the creation. You can see the creation's movement slow down when it has been saved. [Finished at 13s]

Clip 21 - Black screen: No sound

Clip 22 - black screen: Now you have saved the creation and you can freely move again. Your creation is stored within this safe space you are situated. Please walk around and explore the room.

Clip 23 - Instruction 1: In order to generate a new creation, you need to position your body in the direction of the screen and your hands and head need to be still. When creating, you continue as long as you gently move your hands. Too fast movement will make the creation vanish. Holding your hands and head still will save the creation. [Pause, give them a breather] Please generate a new creation and either save it or make it disappear.

Clip 24 - Instruction video 3: Before we give you time to create on your own there is one more thing you should be familiar with. You can move every creation you have saved by pinching your thumb and index finger at the center of the creation as shown on the screen in front of you. While holding your hands like that you can move the creation around and position it somewhere else by simply releasing the pinching grip. [Finished at 28s]

Clip 25 - Black screen: We will now give you time to create on your own. Remember to position your body so it faces the door whenever you generate a new creation. Create what you want for as long as you desire. [Pause] You are the artist.

Experience ending:

- Hey there.. This is a notice to let you know that in one minute, the experience will come to an end.
- The experience is now ending. Thank you for creating. Before you remove the headset, please take a moment to observe what you have created.

New Creation:

- Please generate a new creation

Clip 17 Save and delete reminders:

- Please save or eliminate the creation
- Save the creation by holding your hands and head still or eliminate it by moving your hands fast

Reminder about features

- Remember to face the door when generating a new creation
- You need to hold your hands and head steady when generating a new creation
- You can add material to the creation by taking deep belly breaths and exhaling completely
- You shape the creation by moving your hands slowly
- You save the creation by holding your hands and head steady
- You eliminate the creation by moving your hands fast
- Remember to exhale completely by pulling your belly button inwards.
- You need to gently move your hands to continue creating

Encouragements

- Well done, please keep going
- Please try again
- Give it a try
- Try moving your hands a little bit more up and further away from you

Crash Control

- Everything is fine, the system just lagged a little. Please continue as before
- Unfortunately we need to restart the experience due to slight technical difficulties on our end. It will just be a moment
- Thank you for your patience, it will not take much longer

B

Appendix - The Checklist for each session

The Checklist

Pre-test:

- [ ] Is the headset clean?
- [ ] Is the headset on?
- [ ] Check so that hands work in VR (turn on experience and then turn off)
- [ ] Make sure that “test mode” is not on.
- [ ] Is the biosignal device on and charged?
- [ ] Are the headphones on, connected and charged?
- [ ] Is the computer volume at 65?
    - [ ] Videoscreen video player at 0.6?
- [ ] Have you opened up a notes document?
- [ ] Have you opened up “keyboard shortcut” document?

During test:

- [ ] Remove earrings and rings
- [ ] Attach biosignals
- [ ] Teach them breathing
- [ ] Connect biosignals
- [ ] Move the XR rig to the center of the dome
- [ ] Check breathing. Potentially make adjustment to sensitivity (breathing_spawnrate_low)
- [ ] Check so that it is the correct headset
- [ ] Put on the headset
- [ ] Check so pulse is working with headphones on
    - [ ] Ask user to move their head around
- [ ] Position the user facing the right direction
- [ ] Tell them that they will now be in the darkness, don’t worry.
- [ ] Start! (press S)
- [ ] Change videos with I, O, P

- [ ] **4 min in:** turn on Varjo recording

After experience:

- [ ] record their creation with unity
- [ ] Change name of biosignal document (in masterthesis/assets) to the corresponding participant number. Move and upload it for backup
- [ ] Upload the creation recording for backup
- [ ] Name participant documents and store.
- [ ] Put out new consent form and bodymaps