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Digital Homeostasis: Tangible Computing as a Multi-Sensory Installation

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***Abstract*—**This paper explores computation as a process for design by examining how computers can become more than an operative strategy in a designer's toolkit. It documents this, building upon concepts of neuroscience and Antonio Damasio's Homeostasis Theory, which is the control of bodily states through feedback intended to keep conditions favorable for life. To do this, it follows a methodology through algorithmic drawing and discusses the outcomes of three multi-sensory design installations, which culminated from a course in an academic setting. It explains both the studio process that took place to create the installations and the computational process that was developed, related to the fields of algorithmic design and tangible computing. It discusses how designers can use computational range to achieve homeostasis related to sensory data in a multi-sensory installation. The outcomes show clearly how people and computers interact with different sensory modalities and affordances. They propose using computers as meta-physical stabilizers rather than tools.

***Keywords*—**Antonio Damasio, emotional feedback, algorithmic drawing, homeostasis, multi-sensory installation, neuroscience.

I. Introduction

THEORIES studied in design related to psychology, psychoanalysis, and phenomenology are scientifically proven through rigorous methodology, along with contemporary neuroscience studies. This paper examines the concept of homeostasis and considers how it might relate to design from the perspective of neurologist Antonio Damasio. Homeostasis is the regulation of body states through feedback aimed at maintaining conditions compatible with life [1]. In this paper, some questions are raised, such as: to what extent can design be seen as an extension of ourselves, acting as a psychic stabilizer?

The relevance of the body's homeostasis and emotional response in our brain is challenging to incorporate into the computational design despite becoming increasingly apparent in neuroscience; as a result, this paper allows a research topic. It discusses the role neuroscience and technology play in aiding the design process and making meaningful connections between the physical and digital worlds. In addition, it shows how designers can use digital feedback to enhance homeostasis and create projects with greater intelligence and performance. This is accomplished by using an algorithmic sketching process and discussing the results of multi-sensory design installations resulting from an academic course. The number of participants was 20, and the average age was 22 years, with a minimum age of 19 years and a maximum of 24 years old. The course was composed of undergraduate students with concentrations in product, strategic, fashion, and multimedia design. However, here just three selected projects will be showcased. The objective was to use Damasio's Homeostasis Theory [2] to inform the design to meet goals for well-being. The means developed toward this objective include proposing a concept for the multi-sensory installations based on feedback.

The course started with an analysis of case studies of multi-sensory installations, research of Damasio's Homeostasis Theory, and the development of the concept. After that, the students created algorithmic drawings that would change according to a specific data set. Next, decisions were made regarding the collection of data or the use of real-time data to link to context. The use of two senses, as a minimum, was required to be a multi-sensory installation: vision and sound. An audio narrative soundtrack was produced according to each concept and the homeostatic theme using music and mobile phones as recording devices. Finally, the projects used different software to construct the experience that varied from a partly physical and partly digital installation proposal, a VR, or an experience on the metaverse.

This paper demonstrates how the gap between software and sensorial processing can be bridged for homeostatic design. It allows real-time data flow between the digital and physical worlds, enabling us to evaluate human-computer interaction. The results demonstrate how people and computers interact with various sensory capabilities, suggesting that computers can be used as psychological regulators instead of only tools. Also, it reinforces the use of different software as an exploratory instrument for designers, enhancing human-computer interaction and mapping the digital process for the outcomes.

Ultimately, the results pointed us to a deeper understanding relative to feedback, balance, and emotions in design. They indicate a way to predict how factors of well-being can clarify and rationalize a more intuitive design process inspired by Damasio's Homeostasis Theory [3], [4].

II. Neuroscience and Antonio Damasio

Antonio Damasio's research has contributed to the understanding of the neurological foundation of feelings and emotions, as well as demonstrating the importance of affect in social cognition and decision-making. Besides all the research he has been developing, Damasio's Homeostasis Theory might be the most useful for design discourse. For him, homeostasis

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is a state in which human physiology is maintained within a range that allows survival and flourishing. It is mainly defined as a self-regulating process by which an organism can maintain internal stability while adjusting to changing internal and external conditions [5].

The knowledge of physiological control has evolved from Hippocrates, Claude Bernard [6] to Walter Cannon [7]. The theory of the four humors (blood, phlegm, yellow bile, black bile) first appeared with the Hippocratic treatise called The Nature of Man, in which good health is defined as the balance and mixture of the humors, and their imbalance and separation are causes of disease [8]. Claude Bernard was a French physiologist who first described the idea of homeostasis, "milieu intérieur", analyzing that plants were capable of plenty of nonobvious, stealth movement [1]. Their network of underground roots grew toward the region with the most water and nutrients. Walter Cannon, an American physiologist, coined the word "homeostasis" and the application of control theory (feedback and feedforward regulation) to explain how a constant internal environment is achieved [9]. This evolution was essential to the homeostasis concept.

Nevertheless, these conceptions of homeostasis rarely suggest that there are two different ways to regulate internal milieu characteristics. The first is a non-conscious physiological regulation that happens automatically and without the organism's awareness or consent (traditional concept of homeostasis). For example: when the water balance is low, the kidneys slow down their operation to reduce diuresis and restore hydration [10]. However, in many living organisms, including humans, the classic concept of homeostasis presents an inadequate picture of reality because automatic controls also assist humans. However, humans and most other animals have an extra regulating system that involves feeling [11], [12]. Damasio's primary contribution to the Homeostasis Theory is feelings.

The second regulation of internal milieu conditions can be conscious and involve feelings of the most basic kind, also referred to as homeostatic feelings [13], which address essential life-controlling issues. Examples of that can be hunger, thirst, pleasure, desire, well-being, malaise, and pain. In terms of regulation, feelings are two-sided regulatory interfaces. The first is that feelings function as regulatory interfaces somewhat connected to regular physiological processes. These consist of the chemical and cellular processes that frequently enable the automatic regulation of internal body parameters. However, the other side of feelings is mental, providing organisms with something evolutionarily new: a direct and explicit experience. It enables the person with such experience to perceive the state of their organism—for example, the airway entering the lungs limitation when someone is submerged. Our organism responds quickly and automatically to get access to air, and the fact that this response is also seen as panic and air hunger is a benefit that ensures our attention is drawn to the organism's danger. So, the feeling experience has a content that refers to what the feeling describes, for example, difficulty breathing. Also, it has an intensity (weak or strong) and valence (positive or negative) that gives a pleasant aspect (joyful, energetic, relaxed) or unpleasant (disagreeable, painful, sick). The sum of these emotional dimensions is informative as it tells the individual whether the current state of the organism is usually conducive to sustained health or flourishing, for example, well-being, or whether it needs to be corrected in a quick summary style (hunger, malaise). Feelings, in other words, are regulatory interfaces that provide information and transform the individual into a potential regulator [11].

The fact that feelings are felt in the mind motivates the organism's owner to behave and encourages learning. Memory efficiency increases when a situation is present via mental states imbued with positive or negative valences, incentives or disincentives, and attractive or aversive conditions. Also, the conscious feeling of homeostatic regulation engages with complex affects, drives, motivations, and emotions shaped through evolution and individual sociocultural experiences. So, the responses to homeostatic feeling states are influenced by the basic homeostatic variable and many of the phenomena associated with affect processes [14] and cultural group tuning. Frequent engagement of such responses through time adds to the building of human preferences and, ultimately, what is known as rationality in individuals and cultural communities [11], [14]. So, it is crucial to comprehend homeostatic feelings and how they work because they potentially influence design. How we feel then starts to serve as homeostatic guides and, consequently, achieve well-being.

This paper proposes that design can be an example of such a regulating mechanism and that information about human homeostasis could be useful in studying this field. It raises some questions, such as: to what extent can digital environments be seen as an extension of ourselves, acting as psychic stabilizers? It examines how the existence of human homeostasis broadens our understanding of preferences and logical decision-making, as well as how designers can use feedback to produce more intelligent and effective projects. It pins emotions and feelings as basic forms of cognition. Also, it affirms their importance in well-being, especially because emotions and feelings have been undermined in neuroscience and design discourse for a long time.

Fig. 1 Student work, Fatima Alhalyan: a multi-sensory design installation as an immersive experience on the metaverse through Spatial

III. General Methodology

The 4-month course started with an analysis of case studies

of multi-sensory installations. For the course purpose, the use of two senses, as a minimum, was required to be a multi-sensory installation: vision and sound. This step was important to map the existing multi-sensory installations, track interesting design possibilities, and, at the same time, propose something different. The students started to develop the homeostatic concepts related to the exhibition. They had to think of the digital environment as a homeostatic mechanism and meta-physical stabilizer. For example, the digital environment could calm you down if you are anxious.

Subsequently, the students developed algorithmic drawings that would change according to a specific data set. The students were introduced to Processing, Rhinoceros, and Grasshopper. The critical aspect was that students with different backgrounds and course concentrations, such as product and strategic design, multimedia, and fashion, without previous skills in modeling tools, could create an algorithmic drawing that changed according to a set of pre-established parameters. Also, if any student had previous knowledge of other software or wanted to explore different ones, they could use it at any stage.

Next, decisions were made regarding the collection of data or the use of real-time data to link to a specific context. The students were instructed on collecting and displaying, using different methodologies from elaborating a filtered excel file with the date, creating a google form, and working with real-time data. An audio narrative soundtrack was created according to each concept and the homeostatic theme using music and mobile phones as recording devices which collected data from surroundings to show how logic could be applied to this contextual data and therefore be computed. The sound should accompany the transformation of the drawing and the data. Finally, the projects used software such as Adobe After Effects, Blender, or Unity to digitally construct the experience that varied from a partly physical and partly digital installation proposal, a VR, or an experience on the metaverse.

IV. Project Specific Methodologies and Results

A. Project 01 – Aura

Aura is a multi-sensory design installation created by Nivedita Noronha, partly physical and partly digital. This mixture has been increasingly important with technological advances. It offers an expanded mode of inquiry relative to various art potentials, dialogue, critique, and a profound sense of concept development. Also, it opens up questions such as: what happens when people are connected with deeper sensory experiences relative to space?

The physical part of the project was represented by an abstract tree that symbolizes the tree of life, and knowledge, connecting to heaven and the underworld. Numerous trees of life are described in culture, and fiction, frequently in relation to fertility or immortality—positive traits connected to thriving. So, the concept of the project is based on the magical flow of positive energy and sensory experiences that make people happy. The installation serves as a homeostatic regulator to balance our difficult times with COVID-19 and propose an experience that promotes happiness and joy. Hence, the installation visitors leave with a sense of positive well-being.

A survey was made to gather information and collect data through different social media, such as Instagram and WhatsApp, with approximately 30 participants of different ages. They had to choose among different sounds associated with the word happiness. Options were provided based on the student's personal experience of happiness, such as the sound of the ocean, coffee being brewed, and nature. People could either vote for the existing sounds or propose new ones for others to vote for. The top six sounds were chosen as part of the project: ocean waves (70% of the participants), nature (93%), long drives (57%), children (10%), cooking (100%), and coffee brewing (70%) organized in this order in Fig. 2.

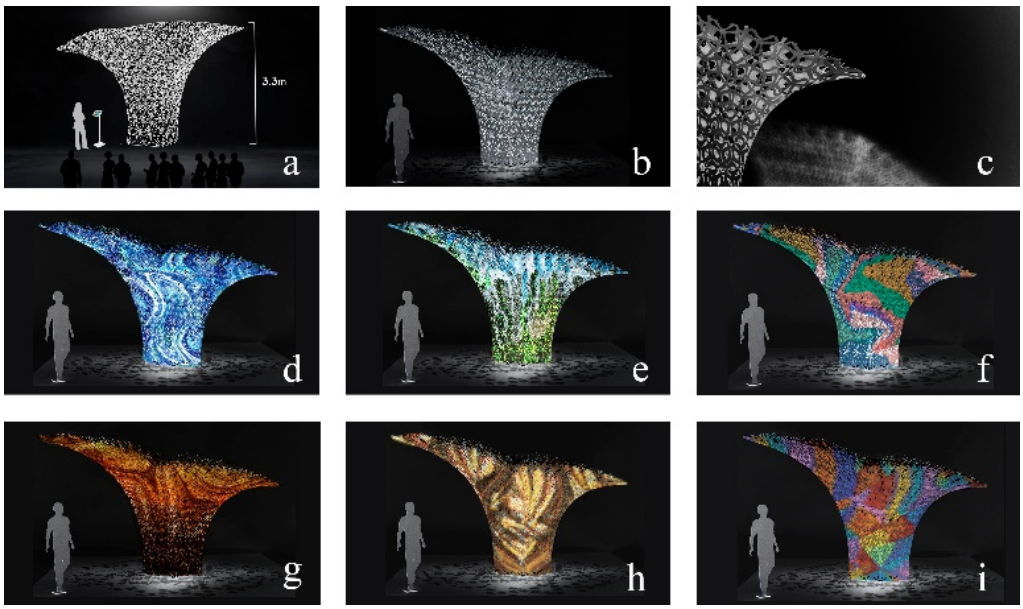

Fig. 2 Student work, Nivedita Noronha. (a) Project of the physical installation with an iPad, (b) Render of the physical installation, (c) Detail of the render, and (d), (e), (f), (g), (h), (i) Videos and sounds projected on the physical installation project

When a visitor arrives at the installation, a question appears on an iPad in front of the physical tree: What sounds make you happy? And the previous six sound options are displayed on the screen. Depending on the visitors' choice, a sound and a corresponding video with the chosen theme are projected on the three, and the multi-sensory experience begins. The installation is customized according to each person that visits it, leading to a more personal experience that contributes to a deeper connection between the visitor and the art installation. The project's concept is a gratification of the little things in life that sometimes are taken for granted and sharing the positive experiences with more people, hoping to make them feel better.

The student used SolidWorks and Adobe After Effects to model the installation and Adobe Premiere Pro to edit the sounds. Aura explores concepts relative to digital design and material interaction in the field of art and constructed environments. It supplements new tools and advanced technologies that allow us to experiment in extremely informed ways relative to the perception of the physical context. This heightened mode of inquiry proposes a new way of looking at the process of designing full-scale projects by interacting with materials in a unique sensorial way [15].

Fig. 3 Student work, Nivedita Noronha. Render of the physical installation

B. Project 02 - Blinking Eye

Blinking Eye is a multi-sensory design installation created by Nayef Albastaki as a VR experience using Oculus Quest 2. The concept of the project is the amount of visual information and how it affects one's homeostasis. The VR is composed of three rooms and a hall. When a visitor accesses the hall, a question appears: Are you calm or excited? Depending on how the visitor feels, the exhibition pairs itself and is shown according to the sequence. If the answer was calm, the rooms start from 1-3, increasing visual and auditory information. On the contrary, if the visitor answers excited, the rooms are displayed backward, decreasing the amount of information. This "pairing" is important to align what the visitors are feeling with the digital information [16] and, from there, take another direction. It makes a person identify more with a situation, align psychologically, and lead to another position. The way visitors experience the exhibition depends on their feelings.

Blinking Eye was made using 3D modeling tools for VR, such as Tilt Brush and Gravity Sketch. It allows real-time data flow between the digital and physical worlds and enables us to evaluate human-computer interaction. The soundtrack was made using different mixed sounds, the final video was done in VR, and the video and sound editing was done using iMovie. Later, the multi-sensory design installation was passed to Spatial as an immersive experience on the metaverse.

Fig. 4 Student work, Nayef Albastaki experimenting with the VR set and the three rooms with different states of stimulation

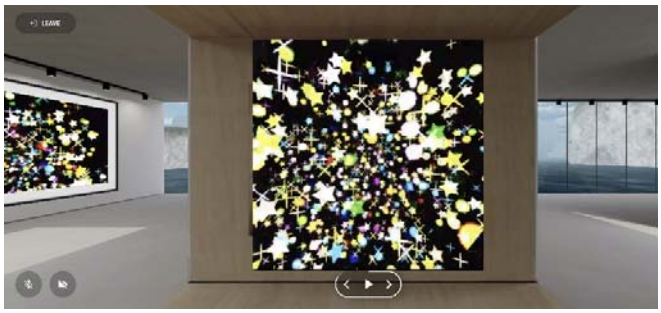

Fig. 5 Student work, Nayef Albastaki in VR and later an immersive experience on the metaverse through Spatial

C. Project 03 – Network Trees

Network Trees is a multi-sensory design installation created by Fatima Alhalyan as an immersive experience on the metaverse through Spatial [17]. The metaverse is an era of evolution in how we live, and it is a shift in dealing with daily tasks such as meetings and other interaction methods. It is a shared virtual environment, leading to different social, educational, and industrial elements.

The concept of the project started with the acknowledgment that our modern environment is saturated with technology, and all aspects of our life are inundated with social media, apps, and communications efforts. The media we use is often so seamless we forget how pervasive it is. Network Trees focuses on the most direct aspect of our digital life - ringtones - as they accompany, guide, and chase us through our day. The project is based on the number of ringtones and how it affects one's homeostasis. According to the amount of information, it increases and decreases anxiety, among other emotions and feelings.

The audio notifications were collected from various apps and sources for two weeks throughout the student's day. In total, 606 notifications were received: WhatsApp (208), Snapchat (158), Discord (103), Twitter (97), and Skype (40). Merging them with music on GarageBand, they were mixed to gradually build

and grow into several exponential layers of conflicting sound, increasingly highlighting our everyday chaos of communication expectations as it descends into an overwhelming cacophony toward the end. The initial drawing – 3D synthetic trees – was created on Blender. Sound visualizers such as Vythm and Luminant Music were used to create a series of varied patterns revolving around rendered natural environments, an almost kaleidoscope-like structure, contrasting with the gradual auditory overload. On the one hand, the installation expresses a hope to return to our parents' and grandparents' generation, who grew up without the extensive electronic expectations or notifications culture we have today. On the other hand, the synthetic graphics of the tree visuals combined with the sensory distortion alludes to the fact that the synthetic reality we have created is here to stay, and there is no going back.

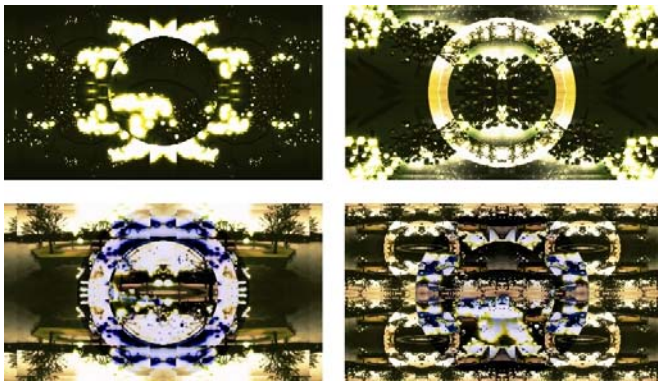

Fig. 6 Student work, Fatima Alhalyan: video frames of different moments with increasing levels of ringtones

V. Conclusion

This paper documents the process of three multi-sensory design installations created during a course in an academic setting to induce a sensory experience and asks questions about designing using Damasio's Homeostasis Theory [12] to impact our experience in both mixed and digital environments.

The importance of body homeostasis and emotional reactivity in our brain is becoming progressively apparent in neuroscience. Still, it is difficult to include in computational design, so this work presents a potential as a research line of inquiry. The purpose was to engage people with multi-sensory experiences that force humans to re-perceive our physical and digital worlds. It addresses the effects of multi-sensory design installations and follows a process using algorithmic drawing. It discusses both the studio and computational methods used to produce the installations, both of which are relevant to algorithmic design and tangible computing. It started by employing typical algorithm design, thinking of the digital and the physical potentials, and incorporating different software to offer pragmatic insight into how this can contribute to the built environment that privileges design and outcome. The outcomes of the multi-sensory design installations show clearly how people and computers interact with different sensory modalities and affordances. They advocate the employment of computers as metaphysical stabilizers rather than as simple instruments. They also reinforce using different software as an exploratory instrument for designers, enhancing human-computer interaction and mapping the digital process for the final outcomes. The outcomes imply that stronger sensorial experiences can be used to increase awareness perceptibility through research and design and create new design conversations.

The installations show that it is possible to think about a design whereby both sympathetic and parasympathetic systems are present (those that stimulate us vs. those that relax us), helping us thrive in the world as organisms by preserving our biological and emotional equilibrium. They place this work within a larger field of design theory aligned with neuroscientist Antonio Damasio's Homeostasis Theory as a dynamic, optimal form of self-regulation that ensures survival.

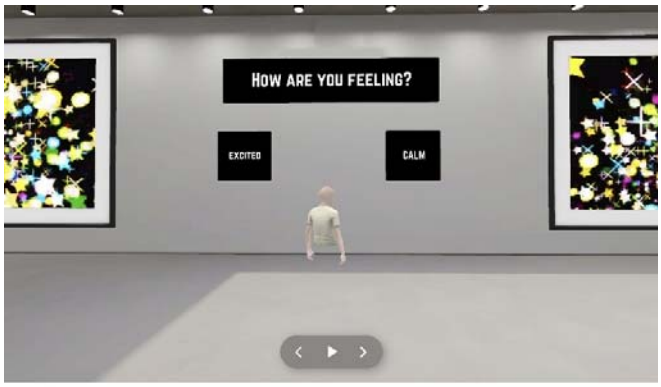

Fig. 7 Student work, Nayef Albastaki in VR and subsequently an immersive experience on the metaverse through Spatial

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