Sentient spaces for wellbeing: An experiment with two responsive environments and one artifact that utilize biofeedback and body-scan meditation to observe the impact on stress and presence levels

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Abstract

In this article, I provide an overview of the creation and implementation of two sentient spaces and one artifact that were intentionally designed to help people connect more closely with their feelings and their bodies. I created two interactive environments, *Sensorium 1.0* and *Sensorium 1.2*, and one artifact, *Sensorium 1.3*, to observe the effects of biofeedback in an immersive environment on people's stress and presence levels. These *Sensoria* respond to an individual's biometrics in real time, using data collected by a wearable, and allow users to experience their emotions as lights and colors, offering an opportunity for introspection and a moment of presence to connect back to the body. *Sensorium 1.0* was experienced by 323 people, and participants noted informal observations such as losing their sense of time and wanting to engage with the experience longer, an effect that was reaffirmed with data from *Sensorium 1.2*. Surveys and physiological data were collected during the deployment of *Sensorium 1.2* and *Sensorium 1.3*. These data revealed that thirty out of forty participants who tried *Sensorium 1.2* felt less stressed after the experience, and twenty-three out of thirty-four participants who tried *Sensorium 1.3* felt more present after the experience. Physiological data demonstrated a significant decrease in heartrate at the exact same time for both *Sensorium 1.2* and *Sensorium 1.3*; however, there is not enough data to make an informed conclusion as to why this was the case. Overall, participants between the ages of twenty-five and thirty-six and who were from Africa and South America, and who work in the marketing industry, benefited the most from the experience. Additionally, the data shows that that females and males have different experiences using the *Sensoria*. Finally, when comparing the data between all three versions, there are a couple of similarities: *Sensoria* seem to have a very strong emotional impact, allowing people to gain more self-awareness, and most participants seemed to enjoy watching the visual representation of their own emotions. A significant number of people articulated their desire to have a *Sensorium* in their own homes.

Introduction

"The mind is a painter. It paints its own world".
– The Flower Garland Sutra

The concept of sentient spaces has expanded over the past decades to include managing a building's indoor ecology (Mahdavi 2006), responsive architecture such as *HygroScope: meteorosensitive morphology* and *Hylozoic Series: mobile forest*, responsive artifacts (Shepard, 2011, 110), responsive installations (Karandinou 2017) such as *Breathing wall II* by Behnaz Farahi, safety and security systems to detect suspicious and violent behavior (Shepard 2011, 35), smart homes, smart city attempts (Bozikovic 2022), and, most importantly, responsive environments and objects to improve wellbeing (Papadopoulou, et al. 2016, Paredes, et al. 2018, and Leslie et al. 2019).

This moment in history is unlike any other in terms of advancing sentient spaces for wellbeing, not simply because of the connectivity of embedded computers, sensors, and advancements in processing capability and HCI, but because we are transitioning to a post-pandemic world in which health, wellbeing, and mental health are arguably more in the foreground.

Technology and ubiquitous computing have now developed to the extent that physical spaces can be designed deliberately to interactively impact inhabitants. These new technologies can enable change in behaviors along with great emotional impact, thus transforming the role of the architect and their relationship with inhabitants of the spaces they design. To imagine the future use of sentient spaces for wellbeing, we need to approach architecture from a philosophical point of view, with the understanding that space is a social product (Lefebvre 1991), and that space can influence behaviors, emotions, perceptions, and health

(Pallasmaa 2012). Architects are in continuous and iterative discussions with their structures' inhabitants. Aalto's Paimio Sanatorium is a great example of this deep relationship (Woodman 2016). Baudrillard reframes the role of the inhabitant as an "active engineer of atmosphere" rather than an owner and/or user (Baudrillard, 1996). This new role can be observed in works such as *Amsterdam Realtime*, in which peoples' movements were projected on an animated map in real time, *Yellow Arrow*, where users annotated spaces with virtual messages, and in the research of Mick, Owen, and Mark, who outlined a method for planned interventions to enhance health and wellbeing (Mick et al. 2019). The ability to physically affect, annotate, and have ownership over public spaces is key to creating empowering spatial experiences that foster healing and connection.

If the pandemic has taught us anything, it demonstrated the importance of being connected, and the toll on the human spirit when that connection is lost. Connection is an integral part of our wellbeing and a peaceful society, and even of being human; Van Der Kolk says that almost all mental suffering is caused by the lack of satisfying relationships or difficulties in self-regulation (Van Der Kolk 2015). Unfortunately, during the pandemic, loneliness, which was already epidemic, has become worse and affected great numbers of people significantly (Weissbourd et al. 2021) as many of us had to isolate ourselves to our homes. What if our homes had the ability to understand what we were feeling and help us process those feelings? Could spaces help us become more relaxed? Or more self-aware? Van Der Kolk says that self-awareness is at the core of recovery, as it allows us more control over our emotions and physical sensations (Van Der Kolk 2015). Sentient spaces for wellbeing could utilize the powerful relationship between the mind and body to connect people with themselves and their surroundings. Van Der Kolk is not the only one who has done important work demonstrating the mind-body connection: Darwin (2015, cited in Van Der Kolk, 76) wrote about this connection and Jon Kabat-Zinn (Kabat-Zinn 2013) and Sara Lazar (Hölzel et al. 2011) have demonstrated that mindfulness-based interventions improve physical and mental health. Integrating biofeedback and meditation into the web of spatial interactions may have the potential to improve people's wellbeing.

I combined the concepts of responsive environments, the dynamic relationship between architecture and their inhabitants, loneliness, trauma, meditation, and body awareness and created an experiment with two interactive environments, *Sensorium 1.0* and *Sensorium 1.2*, and one artifact, *Sensorium 1.3*, to observe what effects biofeedback could induce in an immersive environment on people, and to investigate if sentient spaces and artifacts could help people improve their wellbeing.

Method

Sensorium 1.0

The first version, *Sensorium 1.0*, was created and exhibited for five consecutive days in 2019 as part of my capstone project at OCAD University (see Figures 1 and 2). *Sensorium 1.0* was an immersive wellness pod that responded to an individual's biometrics in real time using data collected by a pulse oximeter. It was an individual experience that lasted for four minutes.

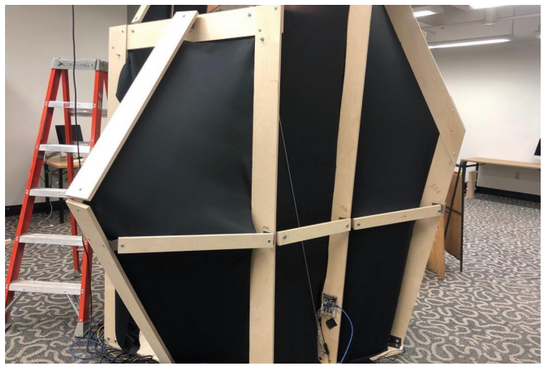

Figure 1: The outer shell of the pod made of plywood, metal, screws, bolts, nuts, peel and stick tiles and blackout fabric.

Figure 2: The interior of the pod during the real-time feedback of biometric data

Sensorium 1.0 collected heart rate variability data (HRV) through a pulse oximeter and allowed users to experience their HRV in real time. Simply put, HRV is the time interval between heartbeats, used by researchers as a marker of resilience and behavioral flexibility (Van Der Kolk 2015). Before the user entered the space, they received a quick verbal explanation of what was going to happen, then received noise cancelling headphones and the pulse oximeter. Once they entered the structure, they were guided through a body scan meditation superimposed with ambient sound for two minutes while the space was dark. Once the body scan meditation was over, the audio continued with ambient sound and the LED

lights turned on for the remaining two minutes of the experience. The user could then see their pulse as flashing lights and their emotional states (HRV) through different colors in real time. If they saw colors on the blue end of the color spectrum it meant that they were calm, and if they saw colors on the red end, it meant that they were either excited or stressed. The user could completely transform the space by listening to their bodies via the biofeedback.

The technical components of the project included a headphone, Arduinos, ethernet cables, analog LED strips, power supplies, power adapters, and an HRV monitor (Corsense). Over the five days of the public exhibition a total of 323 people tried this experience. Qualitative data collected during *Sensorium 1.0* will be discussed in the results section.

Sensorium 1.2

The second installation, *Sensorium 1.2*, was created and exhibited for three consecutive days in June 2022. In the majority, this version is the same as *Sensorium 1.0* with a few improvements. First of all, the structure was redesigned to improve the usability and portability of the experience (see Figures 3 and 4).

Figure 3: The geodesic dome built for *Sensorium 1.2* made with cardboard and over one hundred paper clips.

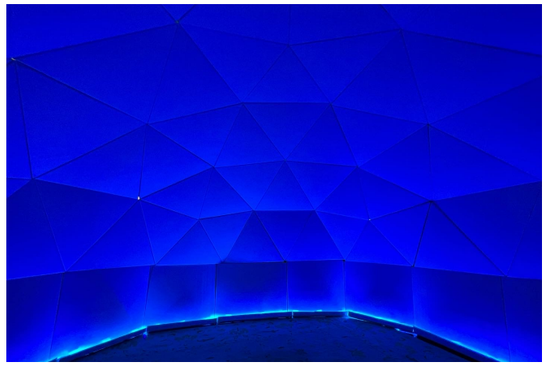

Figure 4: The interior of the geodesic dome with LED lights on.

Secondly, the ambient sound was reconfigured by a sound engineer with 80 Hz in one ear and 100Hz in the other, which creates binaural beats in the gamma frequency to allow the brain a state of attention and focus. Furthermore, I tried two durations, for two reasons: first, since there was only one pod, I had to make a strategic and efficient decision depending on the number of people waiting to try the experience; and second, to observe which duration was closer to ideal. Throughout the first two days of the exhibition, the individual experience lasted for 5:38 minutes, comprising two minutes of body scan meditation followed by 3:38 minutes of lights reflecting the biometric data. As a result of most subjects coming on the third day of the exhibition, the individual experience had to be reduced to four minutes just like the first version. Instead of informing subjects verbally about the experience prior to entry like in the first version, I showed them an informative video. Lastly, perhaps the most significant improvement, I collected surveys and physiological data in addition to qualitative data. Improvements still need to be made in the integration of data collection, which will be discussed in the recommendations section of this article. Experimentations were done with a different wearable to collect HRV for this version: a wearable sleeve called Komodo. This product allowed for more accurate data collection; however, poor connectivity issues hampered its use. Because the sleeve is more comfortable and less intrusive, work is ongoing to solve the connectivity issues for future versions of the *Sensoria*.

Due to the informal nature of this experiment, the subjects were not specifically recruited but were everyday people who simply came to experience the installation. All participants were aware that their data was being collected for research purposes and they have cooperated. A total number of forty-four subjects tried *Sensorium 1.2*; however, only forty data points were used for the survey results, since four of them were null values. The survey collected the following information: age, sex, occupation (industry), place of birth, and stress levels on a scale from one to five (one lowest, 5 five highest) before and after the experience. This information was collected to gain a general idea as to whether the experience had a positive or negative impact on subjects, to see which group might benefit the most and to forge a path for future, more structured and informed research. There were eighteen female and twenty-two male participants aged between twenty-two and sixty-eight. Almost half of the participants were from North America; however this was a highly international and varied demographic, as the rest were from South America, Europe, Africa, Middle East, Asia, and South Asia. Eight different categories of industries were identified and grouped: marketing, operations, finance, workforce, medical, engineering, creative, and others.

Physiological data such as HR (heartrate data) RR (time between each detected heartbeat measured from peak to peak) and RMSSD (successive differences between normal heartbeats, in other words heartrate variability) were also collected, although only for the last two minutes of the experience. The method of collecting this data lacked precision, not only because there is missing data for the first two minutes of the experience, but because the data points were logged in manually every twenty seconds for each person, which caused only thirty data points to be obtained instead of forty-four. Ways to improve this method will be discussed in the recommendations section of this article.

Sensorium 1.3

The third and last installation, *Sensorium 1.3*, was created and exhibited for a single day in October 2022. In the majority, the sequence of the experience is the same as the second one; however, *Sensorium 1.3* is a responsive artifact, a light, instead of a responsive environment (see Figures 5 and 6).

Figure 5: Origami lampshade for *Sensorium 1.3* made from high quality Japanese paper.

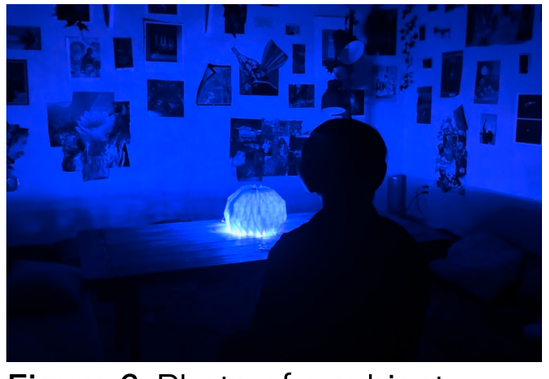

Figure 6: Photo of a subject experiencing *Sensorium 1.3*.

The choice to make this version an artifact had two aims: to discover whether the form of the experience would change its the impact, and to scope out the project's potential as a commercial product. Each individual experience lasted for 5:38 minutes, and subjects were instructed to read an informative paragraph about *Sensorium 1.3* beforehand.

Similar to *Sensorium 1.2*, due to the informal nature of this experiment, the subjects were not specifically recruited but were everyday people who simply came to experience the installation. All participants were aware that their data was being collected for research purposes. A total number of thirty-four subjects tried *Sensorium 1.3*, and all data points were used for the survey results. The survey collected the following information: age, sex, occupation (industry), place of birth and, differently from the *Sensorium 1.2* survey, presence levels on a scale from one to five (one lowest, five highest) before and after the experience. There were sixteen female and eighteen male participants aged between twenty-two and forty-two. This was a highly international and varied demographic, with participants from North America, South America, Europe, Africa, Middle East, Asia, and South Asia. Thirteen categories of industries were identified and grouped as wellness, finance, research and analytics, creative, engineering, computer science, logistics, workforce, marketing, operations, service, students, and others.

The same physiological data (HR, RR, and RMSSD) was collected this time, but only for the last 3:38 minutes of the experience. The method of collecting this data lacked precision, not only because there is missing data for the first two minutes of the experience, but because the data points were logged manually every twenty seconds for each person, which caused thirty-three data points to be obtained instead of thirty-four. Ways to improve this method will be discussed in the recommendations section of this article.

Results and Discussion

Sensorium 1.0

First of all, it seems that most people lose their sense of time — many people noted how quickly time passed, that even though they had been inside for four minutes, it only felt like one, or that they would want to spend at least half an hour inside. On the first day of the exhibition, for the first few people, the length of the experience was not dictated, which led to some people staying in for more than ten minutes at a time. It was clear that people enjoyed their time inside and wanted to spend more. Two subjects cried when they came out, and shared how powerful it was to see their being reflected on the walls of the space. As there was no protocol in place to prompt visitors more deeply, nor a psychologist or psychotherapist present to interpret peoples' emotional responses, it is not clear why they cried or whether crying was a positive or negative

experience. Out of 323 subjects, four were able to keep the room blue for the entire duration of the experience, and two subjects communicated how frustrated they felt because they were fixated on making the room blue while it continuously remained red. Fascinatingly, one hundred percent of participants made the room blue at least once while they were meditating. Through visual observation, it was noticeable that females experienced a wider range of colors.

Coming out of the experience, one subject shared the emotional impact *Sensorium 1.0* had on her:

> I am in my early thirties now, and when I heard your voice telling me not to judge any sensations that I was feeling, I realized that I have been constantly judging myself and my experiences my whole life. I do not want to live like that anymore. Thank you, thank you so much for making me realize that.

This verbal feedback shows that *Sensorium 1.0* left a strong emotional and positive impact on this person, and she was able to gain self-awareness about a mental pattern.

Sensorium 1.2

Overall, thirty out of forty subjects indicated they felt less stressed after trying *Sensorium 1.2* (see Figure 7). The difference is not significant, but shows that the experience helped people to relax. The most notable change occurred when one subject experienced a stress level of five (highest) before the experience, and the level had dropped to one (lowest) after the experience. Five subjects experienced no chance, and five subjects felt more stressed after the experience. Facing emotions or feeling physiological reactions can sometimes be stressful if people are not self-aware or do not feel safe to allow themselves to feel.

Participants between the ages of thirty-three and thirty-six showed the most difference in stress levels, followed by participants between the ages of twenty-six and thirty (see Figure 8). In terms of sex, overall, it is apparent that females were more stressed than males (see Figure 9). On average, females rated their stress levels before the experience at 2.61, while males were at 2.45; however, females also experienced a greater drop in their stress levels, dropping from 2.61 to 2, while males dropped from 2.45 to 2.2.

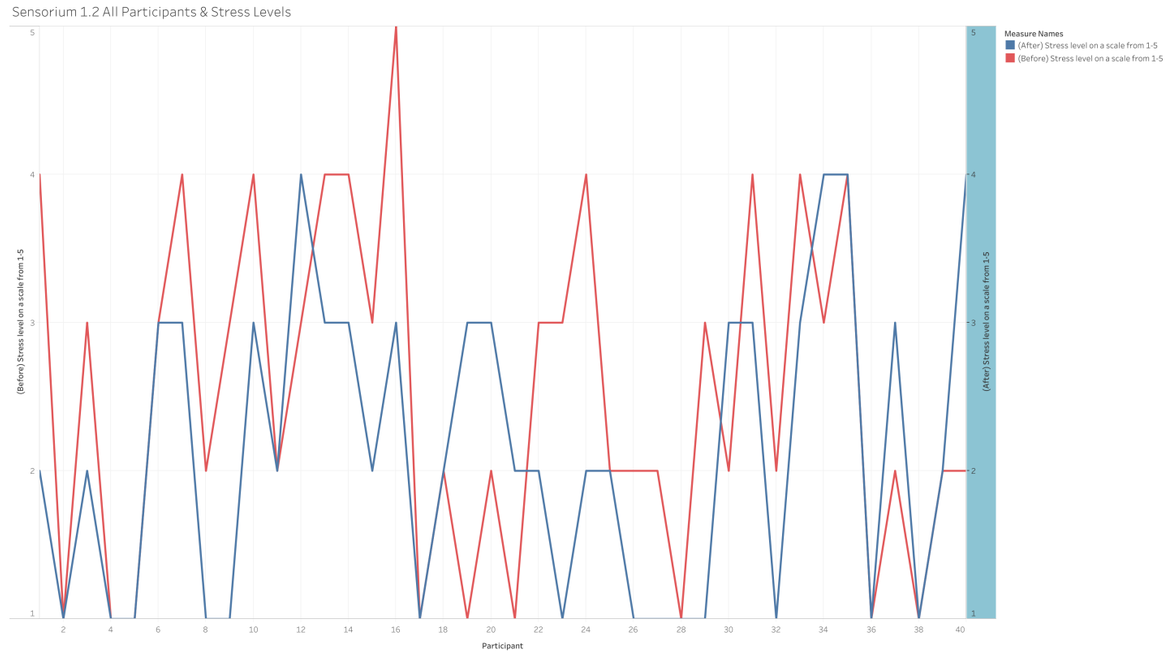

Figure 7: Line graph illustrating *Sensorium 1.2*. All participants' stress levels on a scale of 1 to 5 before (red) and after (blue) the experience.

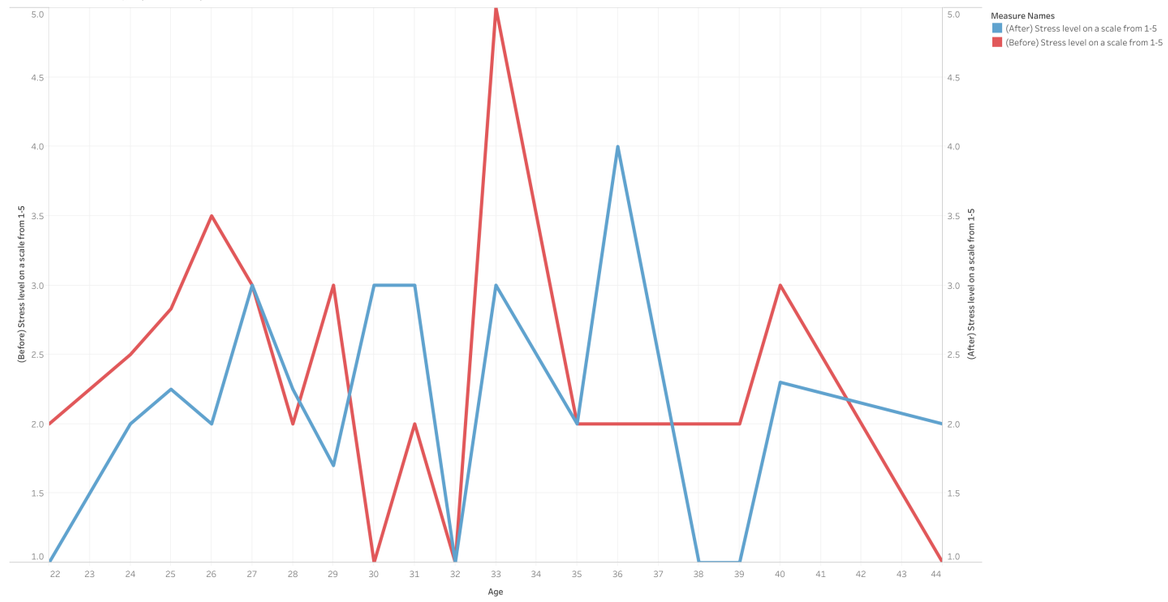

Figure 8: Line graph illustrating *Sensorium 1.2*. Age and stress levels on a scale of 1 to 5 before (red) and after (blue) the experience. (Participant aged 68 was excluded from the graph as it was a one-off extreme value.)

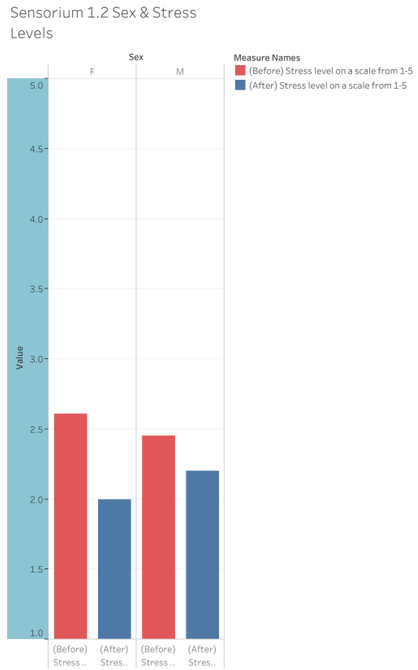

Figure 9: Bar chart demonstrating *Sensorium 1.2*. Sex and stress levels on a scale of 1 to 5 before (red) and after (blue) the experience.

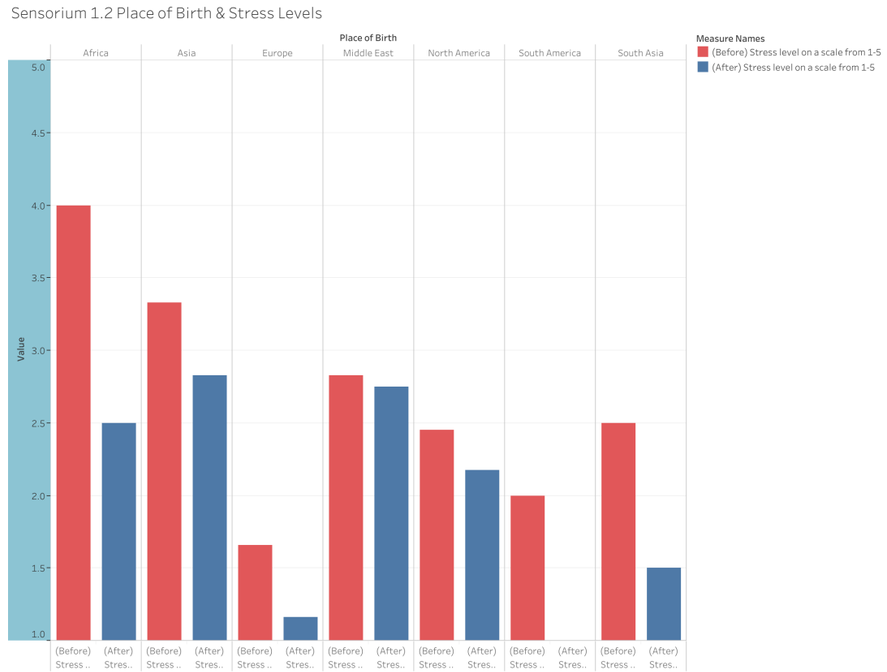

Figure 10: Bar chart illustrating *Sensorium 1.2*. Place of birth and stress levels on a scale of 1 to 5 before (red) and after (blue) the experience.

In regards to place of birth, the bar chart demonstrates that Africans were the most stressed going into the experience, followed by Asians (see Figure 10). While Africans had the highest stress levels, they also experienced a greater drop in their stress levels, followed by South Americans and then Europeans. The latter had significantly lower stress levels compared to participants from other continents. It is clear that cultural backgrounds definitely have an impact on how stressed people feel in their bodies.

Overall, subjects who work in the marketing industry experienced more stress on average than the workforce and the others category, which included a consultant, a scientist, and a human rights professional, who experienced the least (see Figure 11). Subjects who work in finance and operations benefitted the most from the experience. Interestingly, people who work in the medical industry, engineering, or workforce experienced higher stress levels after the experience. Perhaps people who are affiliated in hard sciences tried to make sense of what was happening inside, and as a result were not able to relax.

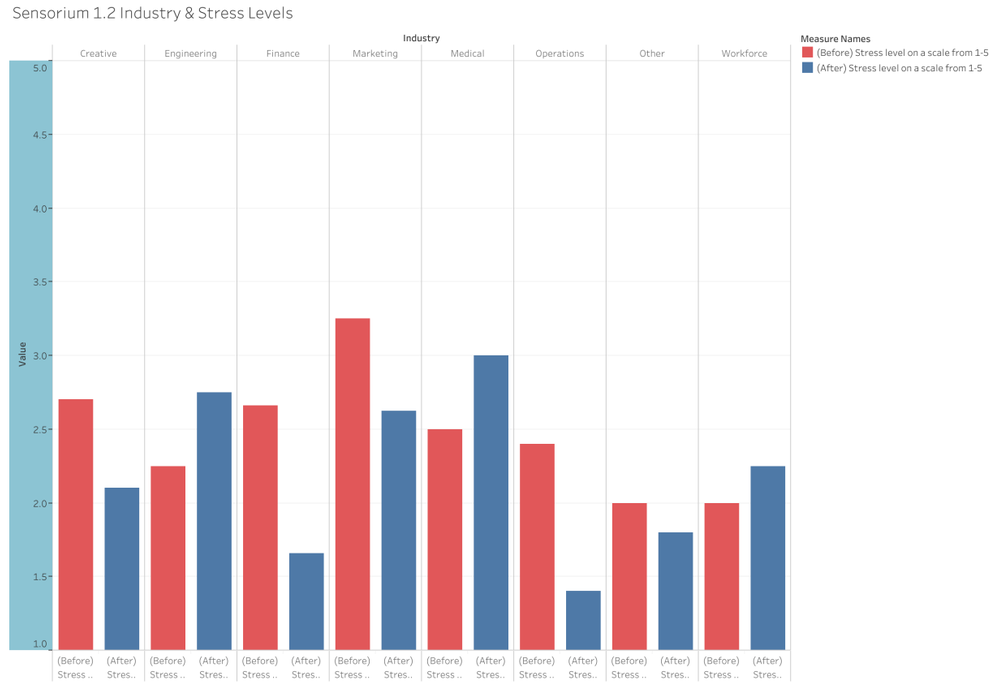

Figure 11: Bar chart illustrating *Sensorium 1.2*. Industry and stress levels on a scale of 1 to 5 before (red) and after (blue) the experience.

In order to understand and interpret the physiological data (see Figure 12), a medical professional who is a resident doctor was consulted and their interpretations incorporated into my analysis. Note that this data was collected only for the last two minutes of the experience, which was when the body-scan meditation ended, the audio continued with binaural beats in the gamma frequency (80 Hz in one ear and 100Hz in the other), and the LED lights started reflecting biofeedback. HR and RMSSD were observed to be lower at 2:25, 3:25, and 3:45, minutes which corresponds to when unexpected bell-like sounds appeared with a higher frequency. The most dramatic dip happened at 3:45, which is when the bell-like sounds appeared for the third time. These results may be an indication that the unexpected change in the sound had a calming and therapeutic effect on mood.

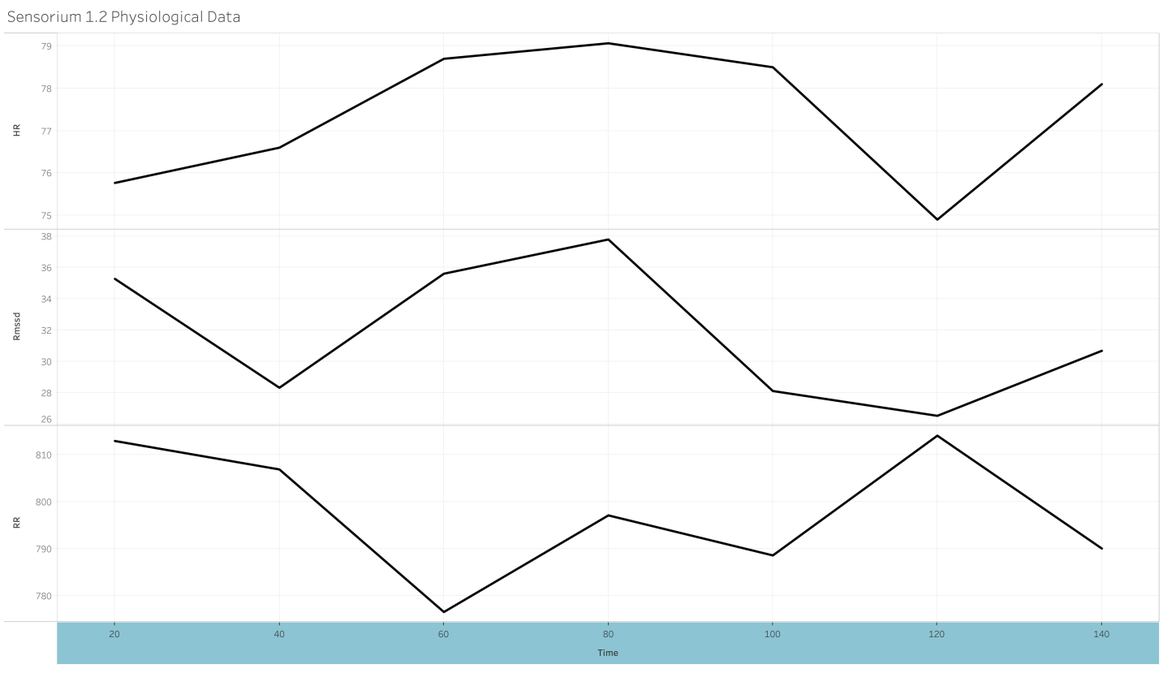

Figure 12: Three line graphs showing the physiological data (HR, RR, RMSSD) collected from *Sensorium 1.2*.

The verbal feedback received during the exhibition of *Sensorium 1.2* reaffirmed that visitors lost sense of time, just like with *Sensorium 1.0*. Even subjects who tried the longer experience communicated their desire to stay in the dome for longer periods, and noted that 5:38 minutes seemed like two. Two people even said that they would want to spend half a day inside the dome, and one of those two said that she would want to install a *Sensorium* in her home. This feedback is very significant, as it signals that people may want to integrate responsive environments like *Sensorium 1.2* into their living spaces. To test and measure these findings further in the future, a systematic experiment can be done where the length of the experience is not determined, and subjects are instructed to come out of the experience whenever they desire. One of the subjects who felt more stressed after the experience communicated that he felt anxious because he was not able to make the room blue; it was continually red, which made him more anxious. This echoes the feedback from *Sensorium 1.0*. It is possible that people who were frustrated with the experience approached it from a goal-oriented mindset and with self-criticism. This could be a signal that there may be a competitive side to people, and when they approach the experience with a goal-oriented mindset instead of presence, they do not enjoy the experience unless they feel like they win. During *Sensorium 1.2*, the connection failed for three participants, so the experience was mimicked manually by turning on the LED lights and imitating a heartbeat pattern while the colors progressed from red to blue. One of those participants' before and after values remained stable while the other two indicated that they felt less stressed. Perhaps the experience may have a similar impact even if biofeedback is not utilized; however, there is not enough data to make an informed conclusion and further research is needed.

Coming out of the *Sensorium 1.2* experience, one subject said:

> I think what is interesting about *Sensorium*, it forces you to ask yourself questions. It invokes introspection. I've focused on what I felt was taking me towards my blue, my blue being what I want my future to look like? Everybody's blue is different. The unfortunate thing about the red, all of a sudden you have to confront your reds. You can't really run and hide, like why am I red? You know exactly why you are red. The color is such a direct . . . there is honesty in colors, a truth. You kind of know what it means.

This verbal feedback indicates that there is a pleasure in witnessing one's own emotions. Moreover, since people wanted to stay in *Sensorium 1.0* and *Sensorium 1.2* longer, it seems that most participants enjoyed facing their own emotions and watching their visual representations.

The quotation above also reaffirms the feedback from *Sensorium 1.0*, that this experience helps people gain self-awareness.

Sensorium 1.3

Overall, twenty-three out of thirty-four subjects felt more present after trying *Sensorium 1.3* (see Figure 13). The difference is not great but signals that the experience helped subjects to become more present in the moment. The most notable change occurred when two subjects experienced a presence level of two (lowest) before the experience and substantially peaked to five (highest) after the experience. Nine subjects showed no difference between the variables, and two subjects felt less present after trying the experience. Intriguingly, when subjects were asked about their level of presence during the experience, not even one person gave one as a value. Perhaps people associate absence with negativity and feel conscious of their answer. The logic behind switching the subjective variable from stress to presence was due to observations made in *Sensorium 1.2*. Stress is a word that is heavily attached to apperceptions, and it makes people consider their stress levels in general rather than how they feel in that particular moment. Since the aim of the experience, although it is never directly mentioned to any subjects, is to make people aware of what is happening in their own bodies in the present moment, asking about their presence levels seemed more fitting.

For *Sensorium 1.3*, on average, participants who were twenty-five, thirty, and thirty-six years old showed the most difference in presence levels, followed by participants who are twenty-seven and thirty-one (see Figure 14). The data of both *Sensorium 1.2* and Sensorium *1.3* show that the subjects between the age range of twenty-five to thirty-six benefited the most from the experience. In terms of sex, overall, there are no significant differences between the variables of females and males, although males showed slightly greater difference between their before and after values. For both sexes, the level of presence considerably increased after the experience (see Figure 15) which shows that *Sensorium 1.3* helped subjects to become more present. The observation that females and males have different experiences made in *Sensorium 1.0* is supported with data from versions *Sensorium 1.2* and *Sensorium 1.3*.

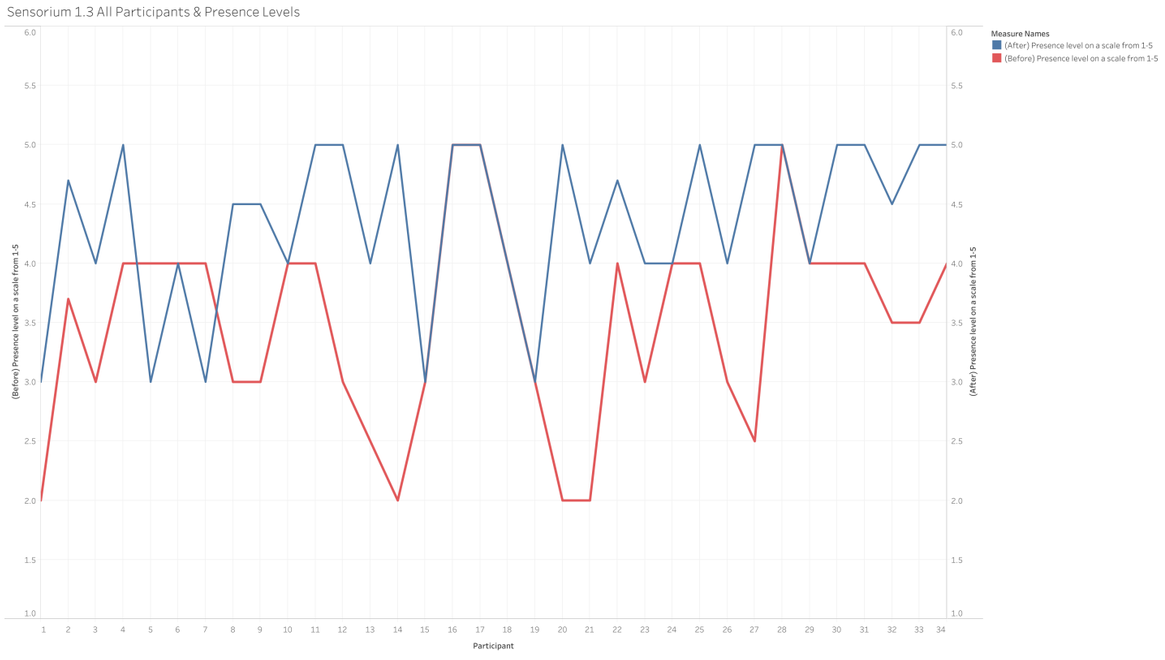

Figure 13: Line graph illustrating *Sensorium 1.3*. All participants' presence levels on a scale of 1 to 5 before (red) and after (blue) the experience.

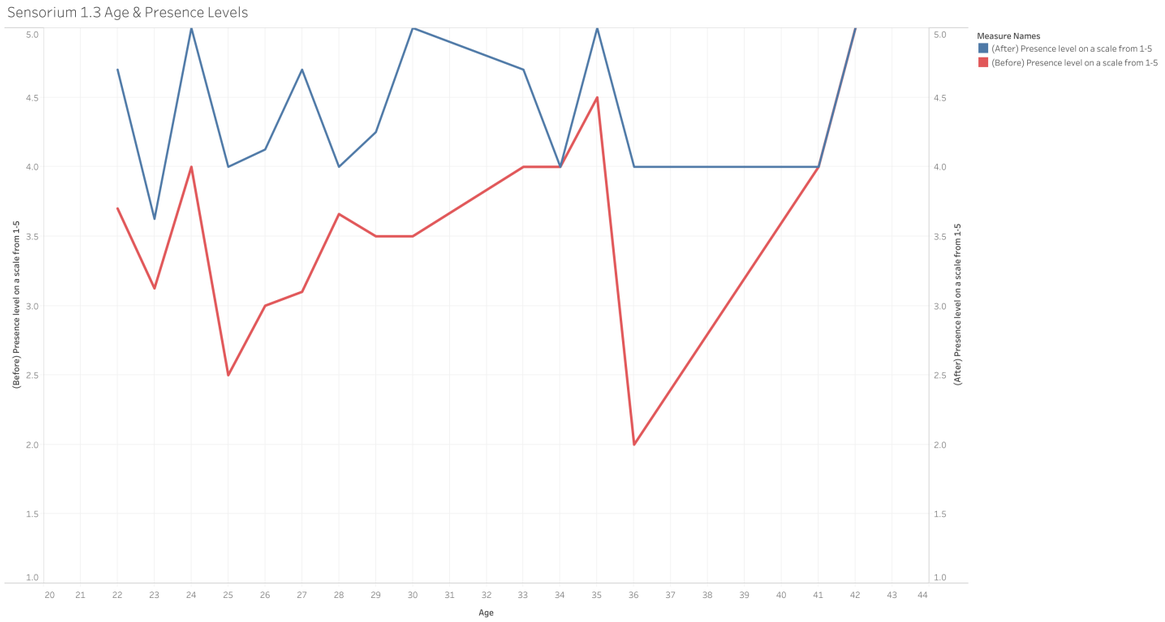

Figure 14: Line graph illustrating *Sensorium 1.3*. Age and presence levels on a scale of 1 to 5 before (red) and after (blue) the experience.

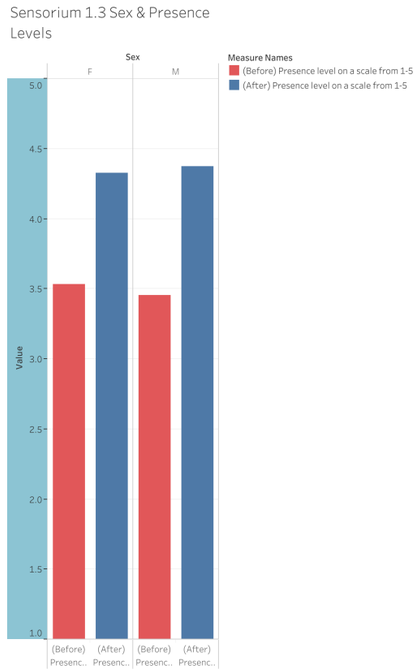

Figure 15: Bar chart demonstrating Sensorium 1.3. Sex and presence levels on a scale of 1 to 5 before (red) and after (blue) the experience.

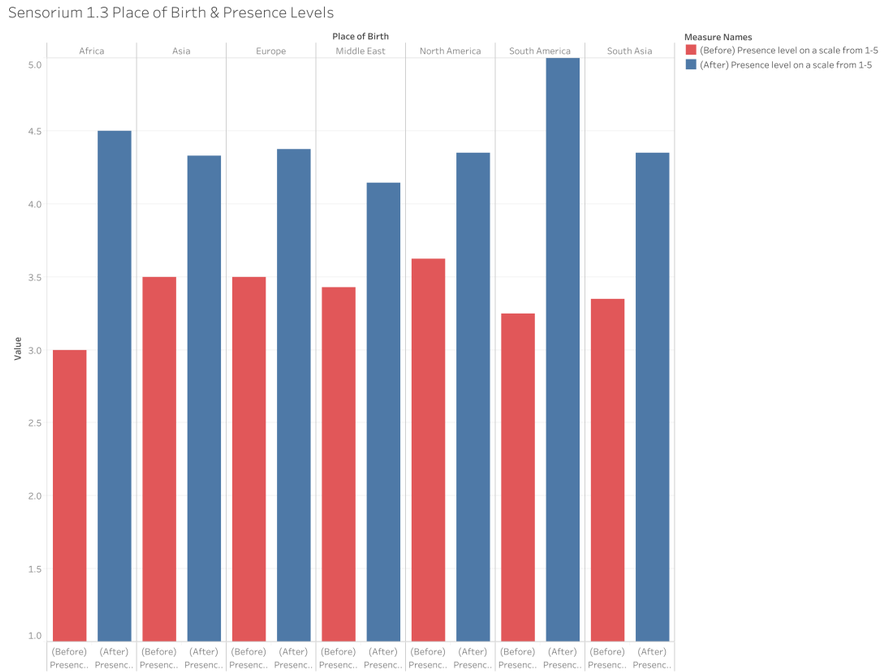

Figure 16: Bar chart illustrating *Sensorium 1.3*. Sex and presence levels on a scale of 1 to 5 before (red) and after (blue) the experience.

In terms of place of birth, the presence levels before the experience are all in the similar range of three to 3.6 for all regions (see Figure 16). South Americans experienced the most dramatic leap; their presence levels peaked to five from 3.25 on average, followed by Africans whose presence levels peaked to 4.5 from three, as opposed to Middle Easterns who had the lowest difference; their presence level increased to 4.1 from 3.4.

Overall, subjects who were students, and who worked in the marketing, creative, and computer science industries, felt less present before the experience compared to other subjects who worked in other industries (see Figure 17). The previous groups mentioned along with subjects who worked in finance and others category, which included two unemployed subjects and one who worked in charity, seemed to benefit the most from the experience, as the difference between values was greater. Interestingly, people who worked in the wellness industry, engineering, logistics, and service remained stable. Both the data of *Sensorium 1.2* and *Sensorium 1.3* show that the subjects from Africa and South America and those who work in marketing, benefited the most from the experience. This repetition may be a signal that there is a pattern here.

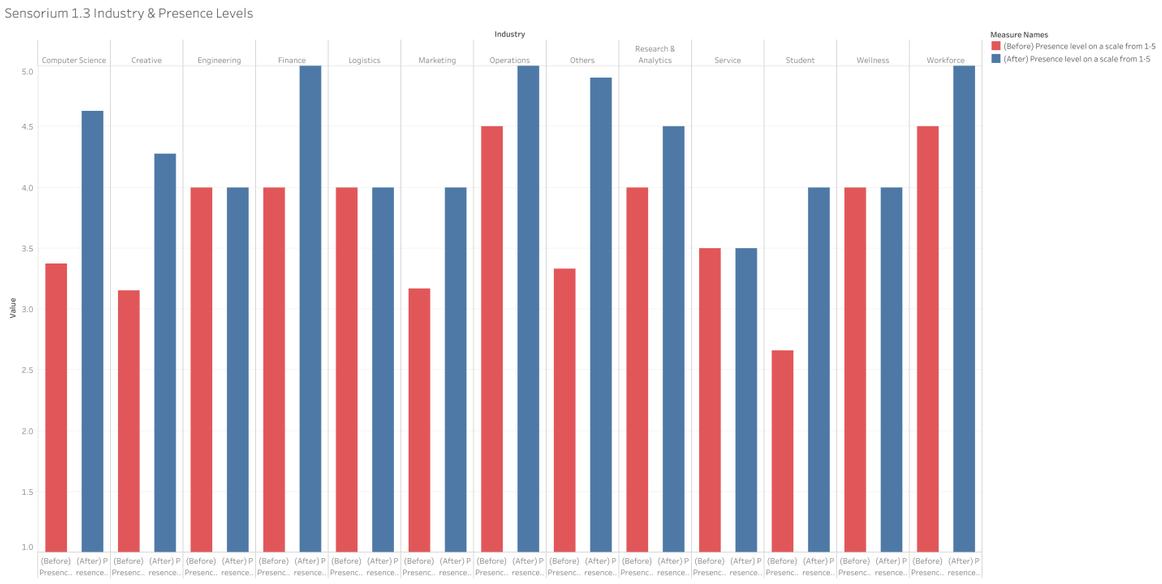

Figure 17: Bar chart illustrating *Sensorium 1.3*. Industry and presence levels on a scale of 1 to 5 before (red) and after (blue) the experience.

In order to understand and interpret the physiological data (See Figure 18), a medical professional who is a resident doctor was consulted and their observations incorporated into my analysis. Note that this data was collected only for the last two minutes of the experience which is when the body-scan meditation ends, the audio continues with binaural beats in the gamma frequency (80 Hz in one ear and 100Hz in the other), and the LED lights start reflecting biofeedback. The physiological data gathered from *Sensorium 1.3* demonstrates dramatic fluctuations almost every forty seconds. HR and RMSSD are observed to be lower at 3:05, 03:45, 04:05, and 5:25, which mostly correspond to binaural beats with low frequencies, with the exception of 03:45, which corresponds to the appearance of unexpected bell-like sounds with a higher frequency. At exactly 3:45, there was a significant decrease in heartrate for subjects in both *Sensorium 1.2* and *Sensorium 1.3*; however, there is not enough data to make an informed conclusion as to why this was the case. More research is needed to be able to conclude for the *Sensorium 1.3* artifact that it was the unexpected change in the sound that had a calming and therapeutic effect on mood as was noted for *Sensorium 1.2*, as some of the highest HR values correlates to those higher frequencies for *Sensorium 1.3*. This may be an indication that a minimum of 3:45 minutes is needed for the participant to receive benefits from the experience. It seems like the unexpected higher frequencies had a noticeable effect on people's heartrates during *Sensorium 1.2* (a space) while low frequencies had a noticeable effect on people's heartrates during *Sensorium 1.3* (an object). Perhaps this indicates that the same sound affects participants differently depending on the form of the experience.

The verbal feedback received during the exhibition of *Sensorium 1.3* demonstrates that the experience left a positive impact on the subjects, as many communicated that they felt much more present than before. Two subjects who tried both *Sensorium 1.2* and *Sensorium 1.3* communicated that the form of the lamp made it easier to focus and feel present as opposed to being in a space, and that they would prefer the lamp version of the experience as it felt much more intimate and personal. Almost half of the participants communicated that they would want a *Sensorium* lamp in their own homes.

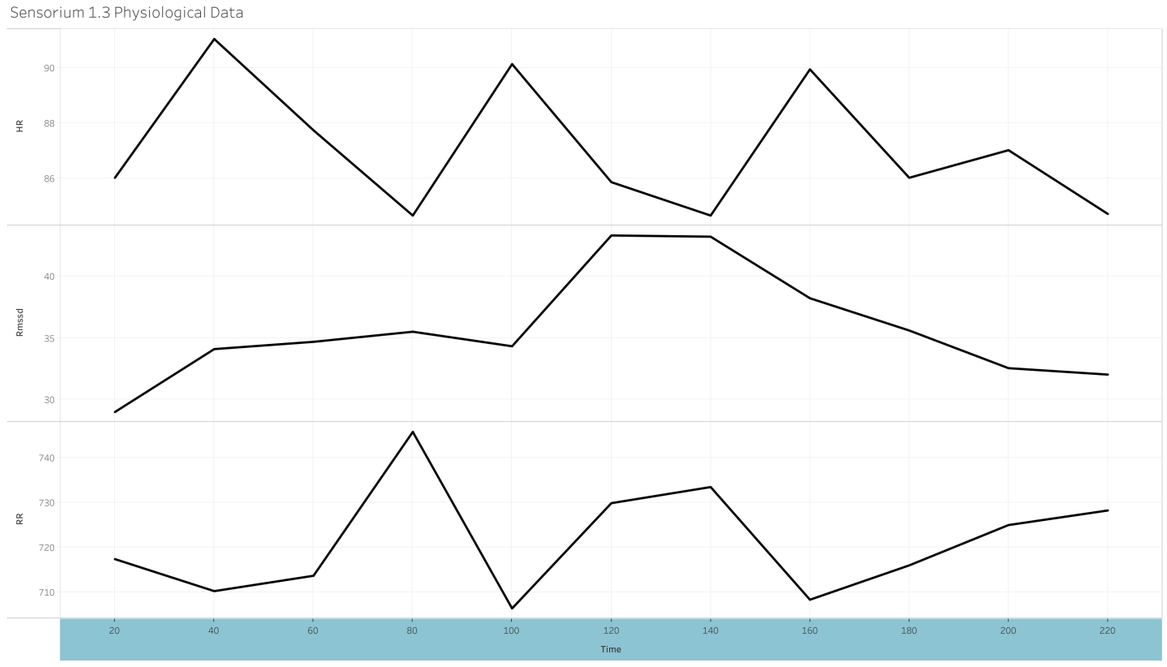

Figure 18: Three line graphs showing the physiological data (HR, RR, RMSSD) collected from *Sensorium 1.3*.

Coming out of the experience, one subject said:

> I have realized that I have so much anger inside me. My friends tell me I am okay, but I know deep down that there is so much anger. This experience made me face that, and I need to deal with it. Thank you so much.

This verbal feedback shows that *Sensorium 1.3* left a strong emotional and positive impact on this person, and she was able to gain self-awareness through watching her own emotions. This reaffirms the feedback from *Sensorium 1.0* and *Sensorium 1.2* and is perhaps an indication that the autonomy given to subjects in a highly personalized environment gives people a sense of safety and comfort where they are able to reduce stress levels and feel more present and more self-aware. Making intangibles such as emotions, moods, and biodata visible may make it easier for people to have ownership, awareness, and control over their own physiological responses.

Conclusion

The observations, verbal feedback, surveys, and physiological data show that *Sensoria* have a strong emotional impact on the participants and allow them to gain more self-awareness in regards to their feelings through offering a highly personalized and responsive environment. Most participants wanted to engage with *Sensoria* longer and lost their sense of time, which might be a signal that people have enjoyed watching the visual representation of their own emotions and a moment of introspection, so much so that some want *Sensoria* in their own homes. Asking the right research question is crucial to get accurate results. Choosing the right words to express and frame the experience can change how the experience is perceived. It is clear that changing the research question from stress to presence made a significant impact on the data. The average stress level before the experience was 2.5, and it dropped to 2.1 after the experience, which is only a 0.4 difference; whereas the average presence level before the experience was 3.4 and rose to 4.3 after the experience, which is 0.9, a greater difference between values.

The three iterations of the *Sensoria* provide a starting place for developing sentient spaces and artifacts that can help people connect more closely with their feelings and their bodies, and, by doing so, open new ways for them to connect with others.

Recommendations

Some of the similar results between the three versions of *Sensoria* indicate that there may be a pattern in this research. However, further research that is systematic and multidisciplinary is necessary to support the discussions and speculations made in this article. The presence of a medical professional will be instrumental in improving the methodology as well as integrating data collection into the software. This integration should eliminate the lack of precision and prevent the loss of data. It would also enable the recording of all the reflected colors alongside the physiological data, which would enrich the results. Being able to match the subjective (survey) data with the corresponding objective data (physiological data) would allow for the analysis to see if there are any similarities or differences between what each subject says and how their bodies really feel. Moreover, numbering the stress or presence scale from one to five did not seem natural or intuitive to most people. People naturally gave numbers like six, seven, and eight, which shows that a scale of one to ten might be better and more instinctual for people to rate their own experiences.

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