Augmented Spaces: Introducing a Technology-Supported Home Environment to Improve our Mental Health during "Work from Home" Isolation

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Abstract

During the COVID-19 pandemic many restrictions were implemented to prevent the spread of the disease. These restrictions included working from home (WFH) and self-isolation. However, this situation had a negative impact on our mental health, causing depression and anxiety in many employees around the world. In this context, we hypothesized that our home spaces could become a catalyst of positive emotions through the use of technology-supported home environments, which use cyber-physical systems to reduce mental health symptoms during the lockdown. We used a qualitative approach, through interviews and cultural probes, to understand the experience of people who were forced to work from home during the lockdown. Additionally, we used a design science approach to explore technology-supported solutions that could enhance our home spaces. The result is a system that mixes analog and digital elements to create interactive rooms, which have a positive impact on people's well-being.

1. Introduction

During the COVID-19 pandemic, several measures that restricted contact between people, such as quarantine, lockdown, isolation, and social distance were imposed in different countries to contain the virus outbreak. As a result, work was also turned into an online format, suddenly forcing most people to develop this activity in their homes. Working From Home (WFH) became a common practice, bringing new challenges and struggles for employees around the world. Although these measures were epidemiologically necessary, they caused people to experience more stress, confusion, and anger than usual [1]. They also lead to an increase of mental health issues, such as depression and panic attacks [2].

In this scenario, the influence that our home spaces have on our well-being became more relevant than ever. Studies have confirmed that the spaces where we live can influence our emotions [3, 4]. However, there is still a gap to be explored on how technology could be used to improve how we feel in our home environments, which is especially relevant in the context of the pandemic and isolation. For example, cyber-physical systems (CPS), which consist of intertwined computational software and physical components that can interact with humans [5] could represent an interesting alternative to address this issue. Thus, this paper aims to contribute to this topic with the following research question: "*How could we use technology to modify our home spaces and improve our mental health during WFH isolation?"* This question is addressed in an exploratory and a design science phase. The first part focuses, through qualitative research, on understanding how people perceive their mental state during WFH, and if their working spaces at home during the pandemic have had any influence on their well-being. The second part uses a design-science approach [6] to create a technology driven smart home system, as one possible solution that addresses the WFH challenges.

2. Literature Review

The aim of this research is at the intersection of three topics: Mental health issues due to isolation during WFH, the impact of space on our mental health, and technology as an opportunity to augment spaces. Therefore, the literature review explains the main points of each topic that have contributed to this research. We searched for sources by combining both, COVID-19-related keywords and general terms like "remote work" and "isolation".

2.1. Isolation and Mental Health During WFH

Isolation is defined by the Centers for Disease Control and Prevention (CDC) as a public health practice that separates sick people with a contagious disease from people who are not sick, to prevent exposure. In the context of the current pandemic and

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mandatory lockdown, it also meant for many people the prohibition to see their close relatives, go to work, or meet with friends, which, after a long period of time, harmed their wellbeing and mental health. Although the COVID-19 pandemic is currently still ongoing, some scientific studies have already been conducted on its psychological effects.

According to [1] it is possible to identify four factors that contribute to increase the levels of stress during the pandemic: duration of the quarantine, fear of getting infected or that a family member would get sick, frustration and boredom, inadequate basic supplies and information. Another study performed in Malaysia also identified other causes of negative psychological effects during the current pandemic: feelings of fatigue, loss of a family member, loss of a steady income, uncertainty, and the stigma of getting sick [7]. Additionally, a survey study performed in Italy provided quantitative data on the impact of a general lockdown on the mental health of a large population. It showed that out of 18,147 participants, 37.1% showed post-traumatic stress (PTS) symptoms, 17.3% reported severe depressive symptoms, 20.8% suffered anxiety symptoms, and 7.3% reported insomnia [2].

In addition, our work life also changed with the new restrictions. The introduction of "remote work" or WFH forced people to stay inside their houses all day, instead of going to the office. Although [8] has shown that WFH during COVID-19 presented some benefits, such as avoiding traffic, time flexibility and reducing costs, it also exacerbated stress levels that harm our wellbeing and reduce productivity [9, 10]. Especially people who didn't have a dedicated workspace at home struggled with distractions and mental health [8]. The social isolation during the pandemic also led to a decrease in work satisfaction. A survey conducted with 265 employees confirmed that most employees perceived that their productivity had decreased during the pandemic, which made them feel unsatisfied and unmotivated [11]. These studies suggest that, not only has the pandemic harmed our wellbeing in general, but it has also brought new challenges to our daily activities, such as working.

2.2. Impact of Space on our Mental Health

Over the past years, there has been a growing interest in how spaces influence our emotions and mental health. According to [12], the sensory-motor systems in our brains are affected by the stimulation of our visual, auditory, vestibular, and olfactory neural networks, which can cause responses of approach or avoidance towards a space. Next, some of the most relevant findings for the purpose of this research will be explained:

1. Humans prefer a degree of complexity that is easy to process. This is because the visual system in our brain orders repeated patterns of forms and colors in architecture into groups that are easy to process, then these visual mechanisms associate a pleasure response to these patterns. It explains why symmetry is such an important part of aesthetics, as it contributes to a fluent process of a space [13].
2. Humans evolved to prefer landscapes that have visual and spatial characteristics that favor survival, such as open spaces with a clear view of the environment—such as a group of trees that can be used to hide from predators and find resources—because we associate them with safety and nourishment [14]. These characteristics can be translated to our current preferences of the built environment. A study on the effects of ceiling height and perceived enclosure of an interior space found that participants preferred open rooms with high ceilings, as they activate our temporal lobes associated with perceived visual motion [15].
3. Humans prefer biomorphic visual shapes, which include organic shapes and fractal geometry, as they create bigger stimuli in the brain and capture the attention of our visual system. According to [16], interior architecture with these organic and curvilinear patterns are perceived as more beautiful than rectilinear spaces.
4. Enclosed rooms with no windows generate fear and high levels of stress, because the amygdala, which is the part of the brain that coordinates responses to the environment, senses it as dangerous and produces a fearful response. This response is rapid and automatic and the user may not be completely aware of it at first. However, if the exposure to the enclosed spaces occurs for a long period of time, it may create a negative long-term impact on the mental health of a person [17].

2.3. Cyber-physical systems

Cyber-physical systems (CPS) is a term that refers to a system that allows the interaction between computational software and physical machines or objects [5]. For this research we considered CPS as the foundation for other technological systems that are more dependent on Internet connection, such as the "Internet of Things" [18]. The use of CPS continues to become more common in our daily life. Smart homes, which use connected devices to improve the quality of life or to connect people in residential spaces, demonstrate this clearly [19]. These systems are capable of automating a home of any type, providing energy management, security, well-being, and communication services. They are integrated through communication networks, wired

or wireless, and can be controlled from inside or outside the house [20]. The benefits of these technologies in our home spaces are varied. They can provide comfort by adjusting the light and acoustic conditions, or even collect data from the occupants to establish a pattern of the resident's routine. With the introduction of this technology, it is not hard to imagine a future where it could be common that our home spaces can automatically get adapted to our needs. This scenario could completely change our home experience and, hence, it presents an interesting opportunity for the field of Information Systems to explore further.

3. Methodology

A two-step process was used to address the research question. The first step consisted of a qualitative approach, through semi-structured interviews and cultural probes, to further understand the mental state of people during WFH and to gather visual information about the home spaces where they spent more time. We initiated the sample composition with young professionals from our personal network who were forced to work from home due to the pandemic restrictions in Latin-America (Peru, Mexico, and Colombia), as this was one of the regions where the mandatory lockdowns lasted longer. Hence, this target group was expected to provide us with more urgent insights regarding the occurring problems during the lockdown. After conducting 12 interviews, we noticed that no new insights emerged (i.e. the point of theoretical saturation [21]), so we decided to continue with the next phase. In general, the participants were between 25 and 35 years old, 25% of them identified with the male gender, and 75% with the female gender. 50% of the participants came from a background in architecture and 50 % from other professions, to compare their perception of space.

The interviews lasted between 45 to 60 minutes and consisted of three parts: The first one focused on the participants' general lockdown experience, the second part asked them to self-assess their mental state and emotions, and the third part included questions related to the space where they worked from home. Also, the Critical Incident Technique [22], which consists of asking a participant to remember an event in the past where a behavior generated a positive or negative outcome, was applied to identify relevant events. To analyze the data, the interviews were recorded and reheard, and specific quotes were transcribed and clustered. Both authors discussed the coding scheme as well as the results. After the interviews, the participants were asked to fill the cultural probes online template, which contained three parts and took them one week on average. The first part was a 3-day photo-documentation of their WFH spaces and a self-assessment of how they felt there. The second part consisted of creating a collage of images that made them feel happy, relaxed, and healthy, to visually identify what triggered positive emotions in them. The third task was to upload a picture of the place where they would have liked to be during the lockdown and how they would feel there. The data was analyzed by the first author of this paper, and the results were discussed among both authors.

The second step of the process was based on a design-science approach. With the insights gathered from the qualitative research and the literature review, a set of design principles were discussed by the authors. According to these criteria, small experiments were performed in a room to test different hypotheses and confirm which conditions of a space we could change to improve the mental health of its users. We invited one participant from the previous qualitative study to experience the developed interventions and to provide us with their feedback through an online questionnaire. These insights were corroborated through self-tests. After these experiments, a final prototype was designed and tested.

4. Results

4.1. Qualitative Research

4.1.1. Semi-Structured Interviews. The most relevant quotes from the participants were organized in a table and divided in three main topics (Table 1). The recurrent feelings and needs helped us to identify pain points to address, such as feeling anxious, frustrated and bored. Many participants reported feeling trapped and overwhelmed by being in the same space. Meanwhile, the coping mechanisms that the participants already performed were taken as opportunities for the design-science phase. For example, we discovered that some participants needed a change of the environment to relax, such as moving around the house, going to the roof, or a nearby park. The reason was that this simple action gave them a sense of freedom, especially after working from home for several hours. They also made changes inside their home environments, as most participants (10 out of 12) had to turn their bedrooms into their new home-offices. Their most urgent need was that these spaces were not appropriate for work. For this reason, many participants bought new furniture, such as chairs, desks, and lamps to work more comfortably. However, this also caused a second problem, as reported by one of them: "since the bedroom is now also an office, it is harder to rest there". Since the participants had to do many activities in the same home space, which remained unchanged, it increased their levels of stress and boredom.

Table 1. Selected quotes from interviews.

Participant	Recurrent feelings	Coping Mechanisms	Needs and wishes
1	"I feel trapped, the small space with 4 walls is overwhelming."	"Go to the roof, look at the sky"	"Want to be in the countryside or the rainforest, a natural area, free open space"
2	"My bedroom was before a place to rest, now it is a place to work and it's hard to rest here."	"I need a change of environment to relax." "Bought a new chair, had some furniture made"	"I want my space to be more minimalistic, too much stuff overwhelms me."
3	"In my bedroom I felt anxious, worrying about my work and the future"	"Traveling to a big house in the countryside, the vegetation and weather really improved my day."	"I would like to have an open living space in the garden with a pergola to sit outside and work"
4	"Mentally I feel more tired and anxious"	"I started to work from my bedroom, it has natural light & is big. Unlike the living room."	"Repaint the living room, it has a dark color and no window to the street."
5	"I feel warm and in silence, it's private, I isolate myself to work"	"Arranged furniture to make the space bigger, to not feel trapped."	"To sit in front of the sea and remember that there is something more other than being locked here."
6	"I get bored of working in the same place without interaction with others"	"Went to meet a friend at a big park near my house, I felt like a human again."	"Get out of the city, it is so big and noisy, there is no nature near or nice streets to walk."
7	"I am stressed because don't have enough space to move and do the things I like"	"Meditation: I imagined sitting on the grass, looking at the lake and the mountains. I felt calm."	"I would love to have a terrace where I can get direct sun"
8	"I felt anxiety about not having my own space"	"Organize things = sense of control, helped me to let go on all the anxiety"	"Would have liked to enjoy the summer in Germany"
9	"It was fine before but now that I am here all day I need more space"	"I conditioned the bedroom & decorated it to work, the room needs to motivate me"	"I would have liked to be in my house in Trujillo because it is bigger & has a garden"
10	"Anxious about not being able to do regular activities like meeting friends"	"I was having panic attacks. I turned off the lights in my bedroom and played some soft music. The DARKNESS helped me forget I was locked."	"I want to control better the light's intensity"
11	"ANXIOUS about not going out, but also too SCARED to go out"	"Intercalate between my bedroom and the dining room to not get bored."	"Have a private space to work, with natural light & plants"
12	"It's stressful to see the same things every day."	"I close my curtains, I like the darkness, it makes me feel safe and calm, isolating from the noise outside"	"Be at the beach alone, to feel calm,"

4.1.2. Cultural Probes. The purpose of this method was to collect visual data of the spaces where the interviewees worked from home during the lockdown, and to understand the relationship between the qualities of these spaces and their state of wellbeing. The following images show the digital template created with Miro Board and an exemplary result filled by one participant. Each section of the template was analyzed. The most relevant findings from the photo documentation were color-coded and clustered into similar topics. For the second part, the images were also organized according to common topics. For the last section, the images were clustered into four main groups: green spaces, open spaces by the sea, small towns, and others.

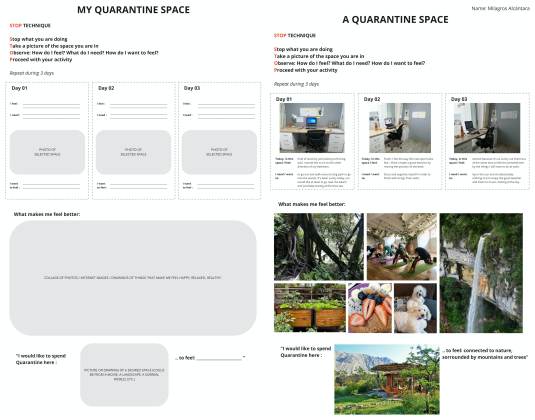

Fig 1. Cultural probes; left: digital template, right: filled example from one participant

By having a visual documentation of the spaces that the participants mentioned during the interviews, we were able to analyze how the evolution of these spaces affected their mental state. For example, we realized that organization, a nice view, and appropriate furniture had a positive impact on how they felt while working in these spaces. Light was also an important element. Participants who spent time in well-lit spaces expressed more positive emotions such as excitement and relaxation, and they had a more positive mindset. It was also important to control the intensity of the light, especially during the afternoon and night. For example, the light needed to be dimmed enough to allow relaxation in a room during the night. Having the same type and intensity of light every day increased the participant's sense of feeling bored and stressed. The control of light was for many an unconscious choice, one participant even reported how he intuitively turned the lights off in his room to calm himself during a panic attack, the darkness in the room helped him to forget that he was trapped in four walls.

Interestingly, although they were not asked to, many participants made changes in their work environments during the research. For example: changing the position of their furniture to make the space bigger or have a better view. One participant even decided to change the entire decoration of her space after filling the cultural probes, as she realized how badly she was being influenced by the environment. The perception of the size of the room was also important. Participants with a space perceived as "too small" felt uncomfortable and had feelings of anxiety, boredom, and stress. Moreover, it was easier for the participants to fall into negative emotions when they were in an unlit, unorganized, small, cluttered space. Finally, through the collection of visual images of the collages and "ideal quarantine place" we were able to confirm that there was a common desire to be surrounded by nature in open spaces, such as forests, parks, and the beach.

To summarize, the qualitative research resulted in a wide range of possible aspects to intervene. We identified patterns by clustering reappearing data on the interviews and cultural probes, based on which we identified pain points and opportunities. For example, turning coping mechanisms (Table 1) into a starting point to brainstorm ideas and develop different concepts on the design science phase.

4.2. Design-Science Research

After gathering and discussing the main insights from the qualitative research and the literature review, the following list of design criteria was developed. It defines the core principles for our design intervention:

- Environmental interventions, visible without a smartphone or VR headset.
- Change the atmosphere of a room throughout the day to avoid monotony and feeling trapped.
- Use of light (especially blue light) to change the atmosphere and create relaxation,
- Use of patterns that evoke nature, such as trees and waves, as they trigger a pleasure response on the brain.
- Use natural sounds to create more immersion.
- Design furniture that makes the space flexible enough for different activities, for example, to allow both, work and relaxation.

Based on these criteria, we performed a series of experiments to test if we could change the interior of a room by using sensorial elements, such as light and sound. The first experiments consisted of changing the intensity and color of light inside an enclosed room. We learned that altering the intensity alone was insufficient to improve a person's wellbeing, but when we changed the color of the light, it could transform how a person

perceived a room. For example, the use of blue light (Fig. 2, top left) evoked a feeling of calmness and depth which was consistent with the literature research that stated that blue light can lower high blood pressure and it is used in light therapy to regulate our circadian rhythm (sleep/wake cycle). Also, the color is associated with water, which most of the participants found relaxing as well. Nevertheless, when the intensity of the colored-light was too bright, it caused the opposite effect. Hence, it wouldn't be comfortable to have this type of light for many hours. It was appropriate for passive activities, such as meditating and resting, but not practical for more active tasks that require a different type of light, such as studying or working.

Fig 2. Experiments inside an enclosed room.

The next experiments consisted of using light projections inside a room (video mapping). We used a mini LED projector of a native resolution of 320x240 pixels and a supported resolution of 1920x1080 pixels to project videos with different patterns, colors, geometries in the same room and tested its effects. The insights from the previous research showed that nature evoked feelings of calmness, hence, we chose videos with natural patterns and organic shapes, such as tree shadows, clouds, and rain. We confirmed that the projections were more efficient to create an immersive experience in an interior space because they allowed controlling a wider range of light qualities: intensity, color, patterns, and motion. Also, we added natural sounds, such as birds, rain, and waves, which showed to be beneficial and increased the level of relaxation in the room. Overall, we found that when mixing the right visuals and sounds, the atmosphere of a regular room can be transformed into a more relaxing space.

For the last experiments, we combined the findings of the previous experiences in a piece of furniture, as a first low-fidelity prototype. We fabricated a wooden beam and installed a stripe of Smart LED Lights inside of it, that could be controlled with an app, a mini projector with a USB with images of nature, and a wi-fi speaker, to recreate the conditions of the previous experiments (Fig. 2 bottom right). Also, since an insight from the interviews showed that most participants worked from their bedrooms and needed, but struggled, to separate the functions of the room, we tested if separating the "work area" from the "sleep area" with a physical, yet light, element could help them to improve their wellbeing while working and resting in the same space. This low-fidelity prototype gave us a better idea of how a simple piece of furniture with digital elements could improve a person's wellbeing during the lockdown. It was successful in creating a sub-space with a relaxed atmosphere, created by the projections of nature and natural sounds, which was useful to take a break during a stressful working day.

4.2.1. Augmented Spaces System. With the learning from these experiments, we designed a cyber-physical system of digital and analog elements that can be controlled through a software to change the atmosphere of a room during lockdown, reducing the sensation of being trapped and, hence, improve the mental health of its users. During the research phase, it was identified that, due to the lockdown, people usually spend a lot of time inside a specific room while working from home. Most times this place is the bedroom, which now also functions as an office or even a space for other activities (studying, exercising). Hence, there is a need to constantly change the atmosphere of this room to fit the activity that is being developed and to avoid boredom and frustration.

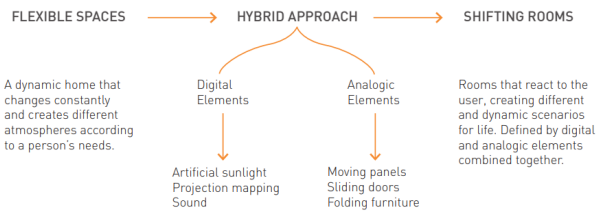

Fig. 3. Design concept.

After the experiments, we learned that although light is a very important element to transform an atmosphere, its effect can be empowered when combined with other elements. So, the concept of the design intervention was a cyber-physical system that can be integrated into a home's interior design. By using a hybrid approach, physical elements such as furniture and panels can be combined together with smart devices and sensors that

activate specific types of light and sound to create immersive shifting atmospheres (Fig. 3).

The next step was to further define the elements to be used and how they will be combined. We curated a matrix of elements outlining the most relevant elements for creating a shift in a space (Fig. 4). The selection criteria for including these elements were feasibility and impact. Therefore, the selected elements are the ones that may have the biggest impact on the user's daily routine, and at the same time, they are not too complicated to install and control.

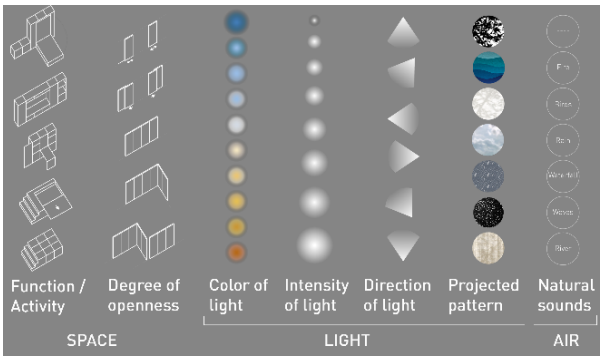

Fig. 4. Matrix of elements.

The element matrix consists of three categories: space, light, and air. The space category changes the spatial configuration of a room by using folding furniture and sliding panels that adjust according to the activity and the degree of openness desired. The configuration of the lighting conditions in the room can be set by adjusting the intensity, color, and direction. Also, this category includes projections of patterns onto the surfaces of the room. Finally, for the air category, only sound is being considered, as it is the simplest element to implement, which also has a significant influence on our emotions. The matrix can be used by the software to mix different components and change a room to address the needs of different users. For example, adjust the light and furniture to calm a headache while working. Also, it is the base of the Augmented Spaces System: a smart home system that shifts the atmosphere of a room when the user interacts with its furniture, which is programmed by a software to activate digital responses. We defined the principles of this system:

- Natural interaction: the panels and furniture are activated by daily actions, which tell the room the activity that will be performed next.
- Digital response: Light, projections, and sound are integrated into the physical space by a software to create different scenarios.
- The scenarios are designed to help the user to relax during WFH and isolation.
- The system is modular and flexible enough to be easily installed in any room with Wi-Fi and electricity.
- Internet of Things (IoT): The furniture and devices are connected by the internet and the users can also adjust them through the app.

The system is a hybrid of smart devices and furniture, which act synchronously creating a technology-supported environment that improves our mental health. To show how the Augmented Spaces System can work in a person's daily routine, we created a storyboard with rendered scenarios with the 3D software SketchUp Pro and the rendering engine VRAY 4 (Fig. 5). They show how a person triggers different atmospheres by interacting with the room, which improves the physical conditions of their spaces while working from home. These settings could have been previously programmed by the user to be activated when they move a certain piece of furniture at a certain time.

4.2.2. Smart Panels. To materialize this system and test it, we prototyped a single piece of furniture that any person could install in their rooms to improve their wellbeing while WFH: "Smart panels." These panels can change the spatial configuration of any room to allow simultaneous activities, such as working and resting, and at the same time, have a smart digital system that changes the environmental conditions of a room to respond to a user's needs. The Smart Panels consist of a translucent partition system and a wooden beam, which contains contact sensors and smart devices that control the conditions of the room: smart LED lights, sound system, and mini projectors. The panels are programmed by a software to activate the smart devices and project different scenarios, when the sensors detect that the panels are opened or closed by the user. For example, the projector could be turned on when the panels are opened halfway to start working. Or a dim warm light turns on when the user closes the panels to rest during a break.

A physical prototype (Fig. 6) was made of MDF (Medium Density Fiberboard) to test the furniture in a real-world environment. For the partitions, a wave pattern was drawn with the software AutoCAD, then, the MDF board was cut on a laser cutter machine based on this trace, and a sheet of semi-transparent Japanese paper was placed behind it. Based on our research results, an organic shape and natural materials were chosen to evoke a feeling of nature and calmness. The beam was produced also with an MDF board and the smart devices were installed inside of it.

Fig. 5. Rendered scenarios.

Finally, it was installed on the ceiling with a drill and the partitions were hung from a rail under the beam. The result was an almost fully functional prototype, which was installed in a room with different light settings and projections. We tested its impact by inviting one participant from the qualitative research and asking him to share his impressions. This initial test allowed us to confirm that the combinations of the different smart devices and the furniture were able to change the atmosphere of the room. Also, we corroborated that the light projections with organic patterns, such as waves and shadows of trees, were effective to help people to relax, and that the natural sounds from the speakers generated immersion in a relaxed environment. Overall, the prototype was successful in changing the physical conditions of the room and creating a subspace, separating the area of the bed from the working area. A simple artifact like this one could signify an improvement in a person's wellbeing while WFH during the lockdown.

Fig. 6. Prototype

Fig. 7. AR App

By creating different scenarios during the day, we could eliminate feelings of boredom and frustration, while helping people to relax and stay motivated. Finally, an app was designed to adjust and program the smart devices and their digital responses in the room (Fig.7). The app uses augmented reality (AR) to interact with the room. Users can visualize their room with AR and point towards the furniture that they want to adjust. At the bottom, there is a slider menu that contains cards with the different functions that can be app controlled.

5. Discussion

Cyber–physical systems, in the form of smart home devices, is a developing technology, which still has many unexplored benefits. In the context of the coronavirus pandemic, where a large part of the population was forced to work from home and saw their mental health affected, we became aware of the influence of our home spaces in our wellbeing. Hence, the research question of this paper: *"How could we use technology to modify our home spaces and improve our mental health during WFH isolation?"* was formulated as an aim to explore possible solutions with a technological approach in the home environment.

During our research, we found that the biggest pain in most of the participants was feeling trapped in the same room, which was not always adequate to WFH. Interestingly, they adopted many coping mechanisms as a way to solve this problem, which were mostly unconscious and included changing their environment physically or with sensorial elements. These findings and the results of the literature review, which confirmed that certain types of spaces and visual patterns may trigger responses of pleasure or avoidance in our brains, were the starting point of our design intervention. In summary, we learned that to improve the wellbeing of people who WFH, we need spaces that are dynamic enough to stimulate our brains and trigger positive responses throughout the day. In this challenge, technology-supported environments were an interesting opportunity to explore. After a series of experiments, we designed a smart home system that mixes furniture with smart devices that control certain types of light, sound,

and projections with IoT and sensor networks. This approach proved that current technology can offer promising possibilities to improve our home experience by altering sensorial elements that affect our subjective wellbeing and create an "augmented" home, capable of changing its atmosphere to create a better work environment during the pandemic.

However, this leads to a further question: Are we ready to introduce this technology in a space as intimate as our homes? Smart home systems can have great benefits for its user, but, according to this research, it needs a good interaction design to work. We argue that users need to feel that the interaction with their homes is still familiar, and to have a sense of control over their intimate spaces. For this reason, one of the principles of the design project was to activate the smart devices with common mechanical actions, which users normally perform during their routine, for example, opening the panels in the morning. In this way, the new atmospheres become a background that empowers their daily activities. As digital technology becomes more and more essential in our lives, it is not difficult to imagine that in the near future they could blend in with our homes. And if this is the case, as designers, we should consider this technology when we rethink the future of our home environments.

This pandemic has created an awareness of the importance of our daily spaces and their future challenges. Just like ourselves, they will need to adapt and become more flexible. Since the necessary technology is already available, we could predict more spaces such as homes and offices to interact with users and adjust to their needs, shortly. As the fusion of analog and computational components in the architecture around us is not only feasible but highly probable in the future, it is expected that more cyber- physical systems will be developed. The digital world is already a prominent part of our lives and will continue to expand further. At the same time, many buildings already include smart technologies to facilitate and track the management of resources. So, why couldn't we use it to track and aid something as important as our personal wellbeing? This could be a great opportunity for designers and architects, to achieve new ways to experience space, and maybe even create a new home aesthetic in the future.

The relevance of this paper goes beyond the context of the pandemic. First, in a post-COVID world it would still be important to address mental health issues, such as stress and burnout, in the workplace. The time we spend inside office spaces would also influence our wellbeing. Thus, this research could be expanded into finding technologically driven solutions to improve the impact of workspaces on the mental health of employees. Secondly, we expect that the learnings from our qualitative research might inspire other designers and researchers to develop more innovative solutions for the identified needs during WFH that could not be addressed in this paper. Finally, we expect to contribute to the field of cyber-physical systems and technology-supported environments, by providing an example its benefits. Innovations in spatial augmented reality and smart homes are emerging areas with potential uses to be explored. Hence, we expect that this paper could start the discussion on how we could benefit from it and change our home experience in the future.

5.1. Limitations

It is important to mention that we had some limitations during the research process. The sample of people who participated in the interviews and cultural probes were mostly young professionals from Latin America, as it was a target group that we wanted to focus first and to which we had easier access. In the future we would like to expand the sample of participants to people from other age groups and countries. Additionally, we established that 50% of the sample would be people with a background in architecture, which was also part of our network. However, this decision may have created an imbalance in our results. Thus, we will expand our research sample in the future to include more people that do not come from a design background. Finally, we had some limitations testing the interventions and prototype because of pandemic restrictions. Nevertheless, we argue that with only one participant it is still possible to gain qualitative insights into the effects of our interventions. Future research will have to corroborate these insights also with other participants.

5.2. Future Work

The Augmented Spaces System presented in this paper is only one of the multiple ways in which we could use technology to support and augment everyday spaces. The smart technology involved is widely available (smart lights, sensors, projectors), and it could be taken further with the inclusion of an AI software that learns the needs of a person's routine and automatically adjusts the conditions of their spaces for them. In this sense, to include machine learning in the system would create automatic responses and enable the room to know what the user needs beforehand. This could potentially be helpful in preventing panic attacks or reducing stress levels before the users even develop symptoms, which would be a great way to improve our mental health inside our home spaces.

6. Conclusion

This paper presents a design system that illustrates how we could use technology to create spaces that improve our mental health during WFH, in the context of the COVID-19 pandemic. To achieve this, we conducted first a literature review about the impact of isolation on our mental health, especially during WFH, and how space can be used to influence our well-being psychological and neurologically. Secondly, we conducted qualitative research, with interviews and cultural probes, to understand the main pain points and challenges of people who worked from home during the pandemic. Finally, we used the results from the literature review and the insights from the qualitative research to create a set of criteria, which was used to develop a technology-supported spatial system with a design science approach.

Overall, it seems that cyber-physical systems could be very helpful to change the configuration and sensorial qualities of a room, which could signify an improvement on the wellbeing and mental health of people who are forced to WFH during the pandemic. It is important to understand that the solution presented in this paper is one of the many ways in which this problem could be addressed. The main contribution of this paper is to start a conversation and provide an example of the merge of technology and home environments as a way to address mental health issues during the pandemic. We believe that the insights of this paper will help developers, interior designers and interaction designers to collaborate together and create better technology-supported environments.

7. References

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