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Master's Thesis
Academic Year 2020

Designing Professional-Driving Atmosphere: A Dynamic Acoustic Setting with Implicit Interactions

Keio University
Graduate School of Media Design

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A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

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Abstract of Master's Thesis of Academic Year 2020

Designing Professional-Driving Atmosphere: A Dynamic Acoustic Setting with Implicit Interactions

Category: Design

Summary

The networks have brought substantial convenience and flexibility for us to fulfill our duties, no longer limited to particular professional places. For some people, this freedom has also accompanied the incompatible perceptions, impairing their working performance. Environments have a remarkable influence on our cognitive actions, either supporting or impairing. When people are enabled to do professional tasks in a leisure environment with technology support, the professional atmosphere also needs to be available for perceptive support.

This paper introduced the concept of creating a professional-driving atmosphere in an individual monotonous environment to improve working performance and mental satisfaction. The conceptual design approach emphasizes other people's presence based on the *Social Facilitation* researches. The prototype was implemented as a tool kit, including two wearable devices, the control server, and an audio set. It attempts to create an implicitly-connecting dynamic acoustic atmosphere among the users, emphasizing the designed perception of the correlated motions in real-time. After the user study, the evaluation is based on perceptual measurements and physiological observation of head orientation. We compared the two experiment results of the Original (without using prototype) and the Applied (using prototype) to evaluate the prototype's effect on working performance improvement.

Keywords:

ambiance design, social facilitation, sound design, working performance, remotely sharing space

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Chapter 1

Introduction

1.1. Backgrounds

1.1.1 Flexible Activity Location Choice by Remote Communication

With the rapid development of information and communication technology, people's activities gradually eliminate the limit of distance. Modern amenities have undoubtedly made life easier and simplified the places for activities either for duties or entertainment. Indoor time has unconsciously dominated our life. According to YouGov's global survey in 2018, the final statistics show that people think they spend 66% of their time indoors, while actually they spend 90% of their time indoors(Figure 1.1) [13]. The necessary indoor places in daily life are relatively steady and in few choices, such as home and office. Easy accessing the needed information even allows staying in one place and doing all of the needs. Video calling technology has developed for years as the most convenient and direct way to communicate across space. Many new tools also came out for remote cooperation in recent years, such as cloud editing soft-wares. However, these tools all oriented in communicative efficiency; in other words, we only send and receive the necessary information consciously.

Figure 1.1: The Indoor Generation (Source by YouGov VELUX [13])

1.1.2 Environment Impact on Actions

The dominant view holds that actions are essentially brought about and guided the agent‘s attention, while Merleau-Ponty offers an alternative account that actions are primarily initiated and guided by the agent’s apprehension of her environment [21, 27]. The environment here stands both for situation and physical environment. In his opinions, intention may still play a role of bringing about actions, but they are not essential, the way of influencing behavior is conceived differently [21, 27].

Indeed our senses constantly perceive the unconscious information from our physical surrounding environment. Architecture and spatial design are prominent examples of physical environment attempts to design behaviors, perceptions, and experiences. Especially the architectures of strong identity are undoubtedly dominate people‘s concerns, for example of the cathedral‘s towering vault that was designed to emphasized the sacredness. A variety of elements contribute the final performance, such as scale, material, light, color, and texture. At the same time, these designed elements are fixed in its specific location.

1.1.3 The Compatibility between Behavior and Environment

Habits are likewise forms of behavior that one produces in certain situations [27], and they are often built under the unconsciousness. The forming of a habit demonstrates there is the comparability of doing that action in that setting. Some environments with distinct identities are more likely to correspond to specific actions in our perception, such as a school for study and an office for work. From starting to learn the word as a child, the common perception rooted and our own experience approved that identity as growing.

Though remote study allows staying anywhere nowadays, the statistic (Figure 1.2) shows that almost half of the share online college students live under 25 miles away from the closest campus [8]. Accessing the place is essential. However, people might have to do their duties by changing the conventional places for some occasions. For example, a student might have to live far from the campus for the rental budget, which means he would be less likely to study at campus if it is unnecessary. Even doing the same duties, the changed settings, or the setting in which we perceived its primary function does not correspond to that activity. The experience would be affected by unconsciously. It is not vital but powerful.

The compatibility between the place and its activity draws the public‘s attention, especially in 2020. The number of people who study and work partially or fully remote has been on the rise for years. The Covid-19 pandemic catalyzed this trend and eliminated the free-environment choices to the only one, home (Figure 1.3) [17]. In 2020, the chances of accessing different places have remarkably reduced, while our duties and needs were not decreased. This worldly occurred phenomenon arouse a general voice that people were eager to perform their activities in different outside locations.

1.1.4 The Need of Mediating Atmosphere and Its challenge

For the indoor generation, the moment of feeling struggled mostly occurred during the studying-working process at home. With continuous distractions from many digital information streams and increasing workstation density, workers need a space to focus and recharge to work effectively [12].According to the research

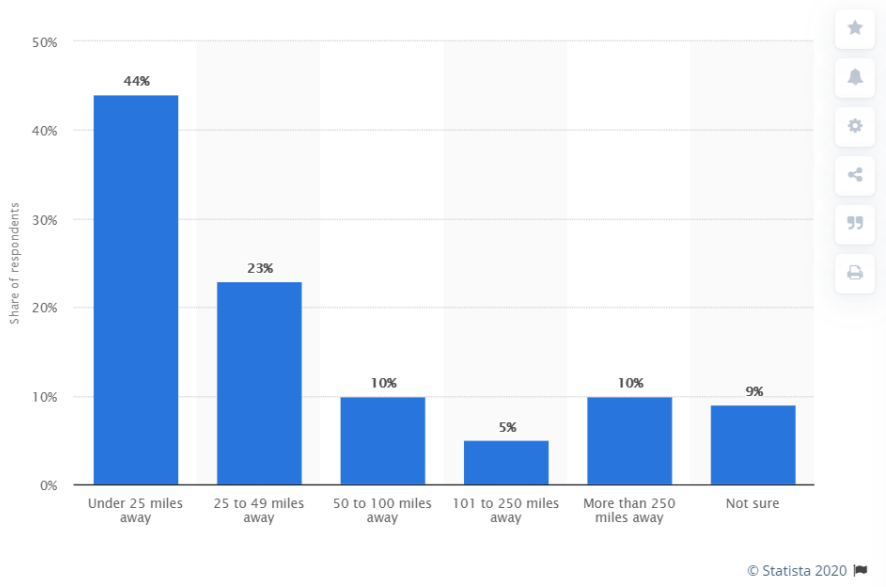

Figure 1.2: The Statistic of Living Distance to the Respondents‘ Enrolled College/University (Source by Statista [8])

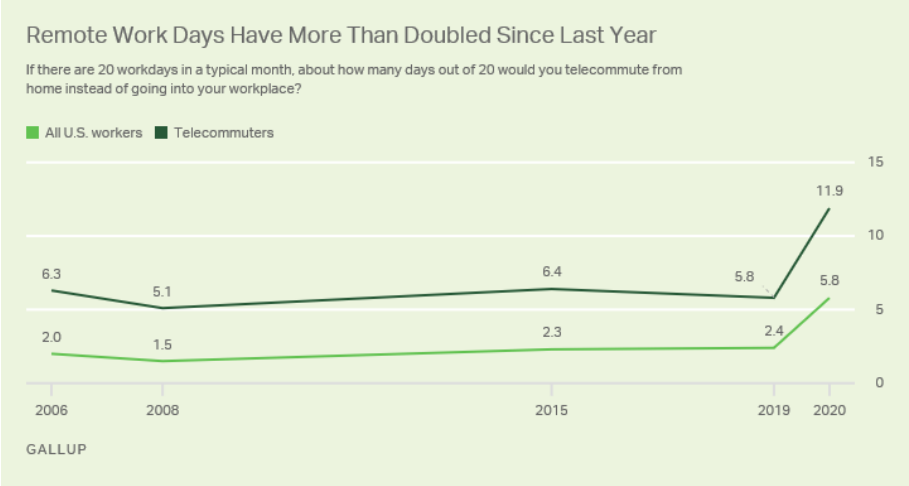

Figure 1.3: Remote Workdays Rise in Recent Years (Source by Gallup Group [17])

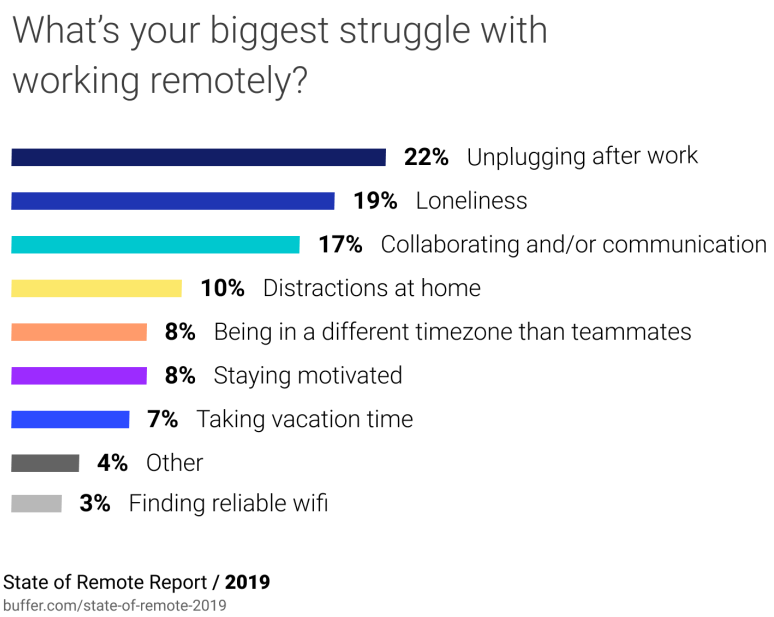

Figure 1.4: What's Your Biggest Struggle With Working Remotely (Source by Buffer [11])

by State of Remote Report, the top issue faced by remote workers was the status of "plugging" and "unplugging" (Figure 1.4) [11]. Without the clear-cut change of location and defined office hours, many people had a more challenging time dividing their personal and professional status. When this boundary is blurred, the quality of leisure and work productivity are both affected. As mentioned above, communication technology allowed people's activities beyond the limitation of the places, designed for action and experience also needs to catch up with this trend. Thus, designing for studying-working at home is necessary to improve motivation, productivity, and mental satisfaction.

1.2. Designing Atmosphere for Social Facilitation

The general definition of *Social Facilitation* is that Individuals were found with improved performance when in mere others' presence rather than alone. The relevant theoretical researches will be discussed in Chapter 2. The sense of being watched and the awareness of others' actions result in positive pressure to help people self-regulate more rationally. On the contrary, subjective and instinctive thoughts are more likely to dominate within an individual environment. Social facilitation well explained the different cognition status of staying in the private or public space. It also demonstrates the presence of people as an essential element of an environment. So when we are looking for how to mediating atmosphere within personal space, home, instead of modifying the physical environment, which is inflexible and limit for change, the virtual presence of other people is possible to explore. This paper will discuss how to leverage the effect of social facilitation to improve performance in an individual's environment.

1.3. Proposal

The design concept aims altering an individual's monotonous atmosphere into a designed dynamic public setting, in order to provide constant positive interventions for productivity and mental satisfaction. It will simulates the particular acoustic atmosphere to switch the perception of where being in. More details about the concept is discussed in Chapter 3. To create the atmosphere, I focused

on achieving the implicit and subconscious connections across the physical space. I mainly worked on acoustic performance to mediate the atmosphere. The designed acoustic composition consisted of two parts. The ambiance sound provides a place setting, and the interactive sound interprets the inter-correlated actions among users. The sound message is generated by real-time parameters and sent in real-time, and they will perform in the directions. These hear-able motions enable the user to perceive a live person sharing a particular space with him implicitly and subconsciously. The whole prototype setup consists of physical materials and the processing software. The physical part consists of a wearable kit of collection motion data and the audio set. The used processing sofware mainly are the virtual driver (*Voicemeeter* or *Blackhole*), *Max Msp*, and *Zoom*, More details about the concept is discussed in Chapter 4.

Chapter 2

Literature Review

2.1. Action and Environment

In Merleau-Ponty‘s view, what an agent apprehends his environment initiated and guided his doings, without the need for any intervening mental states, such as intentions [21]. The fundamental way of his apprehending approach is perceptional. Merleau-Ponty holds that an agent perceives the world as having a value for him in terms of hers capacities for action, rather than neutrally processing merely the ‘objective’ properties such as size or shape [21]. For example, he will perceive the bed as for sleeping, cake as for eating, and pens for writing. ‘Having a value’ in this situation, the specific interpretation includes ‘requiring’ or ‘demanding’ or ‘being appropriate’ for certain actions [21]. Gibson in 1977 has called ‘affordances’ as the values for action that the agent perceives [9].

Perceiving an environment consists of a series of fragmentary perceptions about every element within that. The opportunities for possible actions as perceived differently in their ‘attractive power’, which varies with their saliency. The factors affecting the saliency of perceived affordances are also various, including but not restricted to the agent‘s current task, emotional state, and desires. [21]. For example, when a person feels bored of studying at home, the television just next to him is more likely to draw him to turn it on and lay on the sofa for the whole afternoon. While if he stays in the campus library, he would be more likely go to the first floor to grab a cup of coffee for a short break, after a short chat with acquaintances and then back to the seat. The attractive power of the potential

actions in an environment varies. If we want the best performance as we initially intended to do, then the best practical way is acting within the environment at which could continually provide the consistent salient suggestion for that cognitive tasks.

In the more recent papers, Romdenh-Romluc in 2013 considered both the dominant and Merleau-Ponty‘s views. He holds two factors, ‘Habit’ and ‘Attention’ both contribute to our actions and they can incorporate though [27]. Romdenh-Romluc holds that habits are likewise forms of behavior that one produces in certain situations, e.g, I used to compulsorily go to the school for study from the primary to the high school, is a particular sort of behavior that I produce in a particular part of the world. Similarly, when a person develops a habit, he will acquire both a pattern of behavior and a way of perceiving the world - one comes to perceive relevant parts of the world as offering opportunities to perform the habitual actions [27]. Romdenh-Romluc argued that the dominant view could not adequately explain how habit and attention contribute to the agency. However Merleau-Ponty‘s theory offers an excellent explanation of his argument cases. This gives the reason to prefer his view to the dominant.

2.2. Environment Components and Social Facilitation

Environment is defined as an inseparable whole and is constituted by the interacting systems of physical, biological, and cultural elements, which are interlinked individually and collectively in myriad ways [24].

When we try to describe what we perceived about a specific environment, the substantial still elements are more likely to be depicted. These still elements compose the scene of the environment and suggest the identity of its environment, such as texture, color, size, and objects. Moreover, there are dynamic elements in the contrast of the still element, such as people, sunlight, airflow, and sound. If we are trying to depict an shot of the environment by time, we can see the motion-blurred elements and the still elements (Figure 2.1). The dynamic elements vary their status by time. They are temporary, unpredictable, and spontaneous. Environments where resources are unpredictably distributed in space and

time foster the evolution of mechanisms to select significant stimuli for priorized processing [19] [15].

Figure 2.1: People in Motion by Realistic High Poly Scanned 3D Camera (Source by Ronenbekerman [2])

However, dynamic elements almost disappeared within an individual environment, maybe merely the sky outside the window or the cellphone with unpredictable notifications. While these digital devices' interventions mostly hinder our intended action, which could distract our intention easily. Those triggers are fun and dynamic, feeding our appetite for the thirst for freshness. Thus, the type of useful intervention is needed to direct us from that distraction to the right destination, which should have stronger concerns and can facilitate our initial intention, the set tasks.

The presence of other people can bring useful and right interventions, which is the characteristic dynamic element within the public environment(Figure 2.2). *Social Facilitation* demonstrates the positive value of the presence of people. *Social Facilitation* is defined as improvement in individual performance when working with other people or merely with the presence of others, rather than alone. While this does not mean the presence of people always brings positive re-

sults. The *Yerkes-Dodson law* (Figure 2.3, 2.4), originally developed by Robert M. Yerkes and John Dillingham Dodson in 1908, indicates an empirical relationship between pressure and performance [26]. Performance increases with physiological arousal, but only up to the peak, then performance decrease. Here the arousal works in two statuses, the energizing arousal and the negative arousal. Task differences also determine what a proper level of arousal is. For unfamiliar or intellectually demanding tasks may require a lower level of arousal to facilitate concentration. For well-learned tasks that demand stamina or persistence may perform better with higher arousal levels to increase motivation. When Yerkes-Dodson law applied to *Social Facilitation*, the mere presence of other people will elevate the performance on well-learned tasks, and decrease on complex or novel tasks; the levels of drive also affect, performance will increase with moderate amounts, but decrease with low or high amounts of drive [30]. By considering these theories mentioned above, the approach of adjusting atmosphere for improvement of productivity and mental-satisfaction can be interpreted to design the proper energizing arousal for the best performance according to different situation needs.

Figure 2.2: Students Study at Library, Photo by Elizabeth Andrews [1]

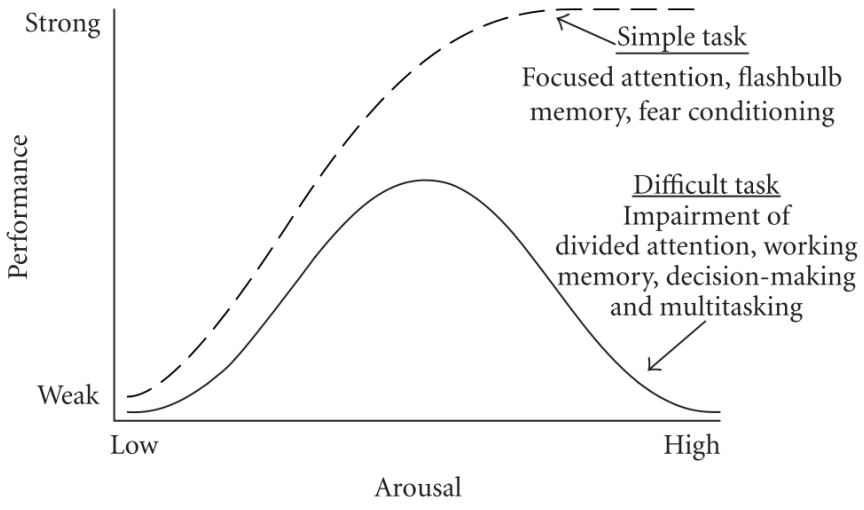

Figure 2.3: Original Yerkes–Dodson law [26]

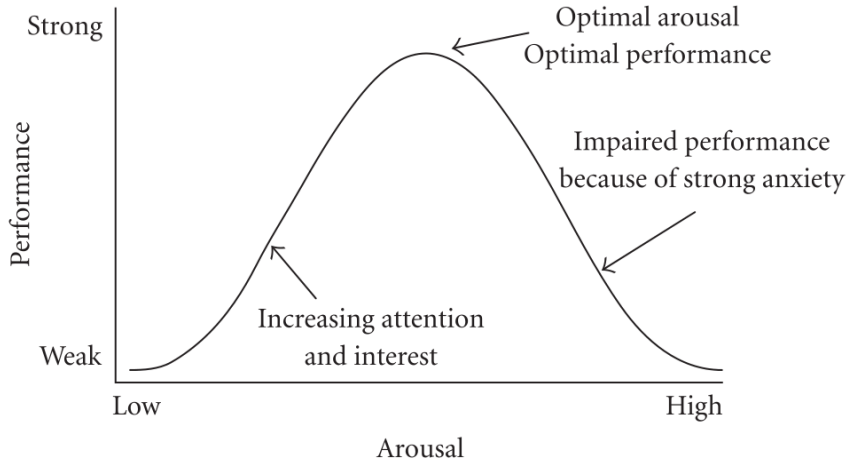

Figure 2.4: Hebbian Version of the Yerkes–Dodson Law: This Version Leaves Out That Hyperarousal Does Not Adversely Impact Simple Tasks [26]

2.3. Auditory Perception of Dynamic Environment

In principle, the perception of the environment is multi-modal. To perceive a dynamic environment, only the dynamic representations could achieve optimal performance. For example, many exhibitions with immersive design have become tremendously popular as it applied dynamic representations. As we discussed in section 2.2, the presence of other people is the dynamic element, or moving element, which is the characteristic where an individual environment lacks. Perceiving the presence of a real person interprets to perceive his dynamic features.

Undoubtedly, the visual representation was prominently and extensively developed in the surrogate medium for decades. Environment perception research has also focused almost exclusively on the visual attributes [10], even though it was also generally acknowledged that 'Many sounds and smells in natural settings surely also influence our feelings' [29]. However, this consistent preference is not equivalent to the validity. The validity of the presenting medium generally depends on the sufficiency of the medium to represent important elements of the environment [16].

Brown and Daniel (1989, 1991) found systematic differences between a static and dynamic representation for a dynamic environment [4] [16]. They concluded that the static surrogates, color slides, did not sufficiently preserve dynamic environmental features, while the dynamic surrogate, video, produced flow-related differences in ratings of scenic beauty. In 2003, J. Hetherington et al. conducted the *Pilot Study* to estimate the ability of surrogate to reproduce important environmental information between different representational media (Figure 2.5). From his study, motion without sound produces similar results to the static digitized image condition, while motion with sound suggested a consistent polynomial relationship between perceived scenic beauty and flow [16].

In a summary, in terms of perceiving motion in a dynamic environment, sound attribute plays an indispensable role in the environmental representation preference.

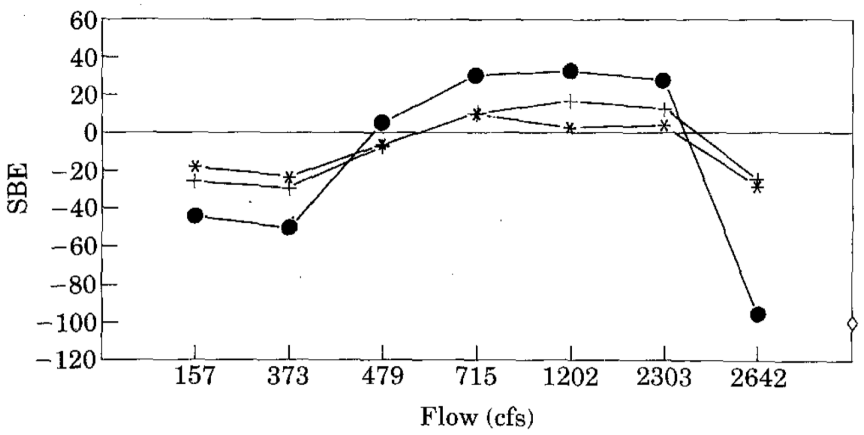

FIGURE 4. Relationship between flow and scenic beauty, main experiment. (—●—), Video/sound; (—+—), video/no sound; (—×—), static/no sound.

Figure 2.5: The Experiment Result by J. Hetherington et al. [16]

2.4. Precedent Designs

The latent power of environmental atmosphere on mental mediation was generally recognized, but the practical application was still relatively limited, usually in the spatial design. In recent years, some other attempts begin to come out to adjust the atmosphere by manipulating devices. Some precedent works will be introduced in this sub-section 2.4. Though these projects emphasized different designing approaches, their goals seem closed, aiming to bring better adaptable experiences for users' mental status under particular circumstances, either for concentrating stage or relaxing stage.

2.4.1 *Mediated Atmosphere*

Mediated Atmosphere (MA) is a smart office prototype developed by the Responsive Environment Groups, MIT Media Lab. MA uses multimodal media - video projection, lighting, and sound to computationally create different atmospheric scenes (forest, library, kites, city, neutral). They equipped the space with modular real-time collection infrastructure and integrated a set of biosignal sen-

sors [31]. The control server manages all coming real-time data and processing algorithms to control the outputs in real-time.

- **Output Performance**

  These three outputs perform as a synchronized composition. For light output, they use twenty individually controlled light fixtures in the ceiling, and each fixture has five channels. For sound output, they have two options: one is using four speakers to playing ambience sound, to bringing spatial sound experience by the direction-array. The other option is using headphones, working for the same function but can cancel the noise from the surroundings. For video projection, they use a high-luminosity output projector and a 1.83m by 0.76m light-diffusing acrylic board for projection displaying. It is placed in front of the desk, as a mimic of the wall divider [31](Figure 2.6).

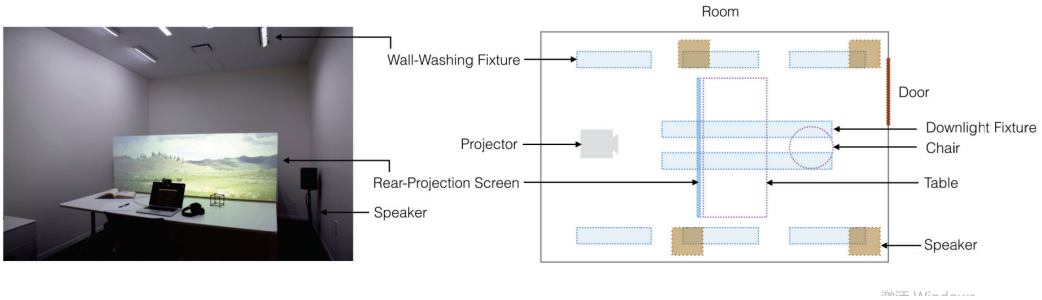

Figure 2.6: Physical Layout of The Room of MA [31]

- **Input Data**

  The input equipment includes three sensors to provide incoming data, therefore producing the personalized output. The incoming data are from a physiological monitoring chest strap, a wrist-worn biosignal monitoring device, and a mini camera on the desk capturing videos.

- **Result Analysis**

  The group evaluated the final result for the effect of MA from the perspective and physiological observations. For the perspective effect assessment, they

used the rating questionnaire to collect the participant‘s personal feedback. For physiological measurements, they analyzed the biosignal data: heart rate variability, head orientation, facial expression, and direct attention by the Necker Test [31] [5].

- **Contribution**

  MA introduced a prototype system that is able to dynamically mediating its atmosphere and processing occupants' physiological signals in real-time. The user study demonstrated MA‘s effects on occupants' ability to focus and restore from a stressful situation. The research team also compared multiple signal processing approaches for quantifying changes in occupants' physiological state.

- **Reflection (Comparing with this paper)**

  MA‘s is one of the successful attempts towards personalized control of the ambient atmosphere to support well-being and productivity [31]. Though the final goals of supporting well-being and productivity are alike, *MA*‘s design focused on human-centered computing, which is different from this paper‘s concept. Firstly, the interaction happened in *MA* are between one subject and his surrounding computing environment, which is to say, all the variables are collected from the only user within that physical space. Secondly, the generated output is chosen from the preset designed performance. Although it is responsive to the user‘s bio-signals, there is only communication between human and machine, merely like a customer choose his preference from the menu. Thirdly, *MA* is providing the most pleasant atmosphere for the subject in time. It is trying to support well-being and productivity by curing people‘s negative feelings.

  While in this paper, the interactions happened not only between one individual and his physically surrounding environment, and also among the multiple users by different locations, at least two. The users will create the ambience together, which means the variables come from multiple generating sources. The total performance is also responsive in real time, but it does not fully depend on the preset designs; multi-users motion data will

be included in the whole performance that is temporary, unpredictable, and spontaneous. Furthermore, this paper's central concept is based on the theory of Social Facilitation, the responsive environment is not trying to please the users but consistently providing useful pressure and positive arousal for them to achieve better performance.

Lastly, in terms of the prototype application purpose, *MA*'s prototype consists of many large pieces of infrastructures, and the components are in a relatively big number. *MA* is more suitable for the public infrastructure, such as campus or company office, where it is relatively spacious and empty, and occupying with simple objects. In contrast, this paper's design proposal (detail in Chapter 3,4) is more like a sub-support kit for individual use, like home. It is more flexible for places and easy to set up.

2.4.2 *Light Cloud*

Light Cloud(Figure 2.8) is a smart lighting system newly developed by E.C.Kodama et al.'s MIT Media lab group in 2020. Based on the numerous research that demonstrated light induces a substantial effect on people's cognition and behavior, *Light Cloud* is a lighting system that enables each user to create and control their own dynamic light source in a shared enclosed space to enhance social interactions and work experience [18].

Similar to *MA*'s project, they deployed the prototype system in a specific workplace, a windowless room with dimensions 4.2 lengths, 2.8m width 2.6m height. Six wall washing luminaries ad two down-light luminaries were installed. A total of 20 programmable light fixtures are installed in the ceiling; each light fixture contains 5 color channels. These light fixtures are networked to the local server and be controlled in real-time.

The *Light Cloud* features are achieved by manipulating color temperature and luminance of the lighting effect, such as Light Following (Figure 2.7), Color Changing, Dynamic Resource Allocation(Figure 2.8), Light Morphing. Except for tracking users' physical features, *Light Cloud* enables dynamic changes for purposes. It generates Calm Notification, which provides information for the user to choose to attend to or ignore what they are engaged with. It visualizes the social interactions to augment the individual's behavior in a surrounding context.

It mediates the environment and monitors health. *Light Cloud* shows a prototype of Light AI assistance in the future vision, extend the limits of using light merely for aesthetic effect or practical illumination.

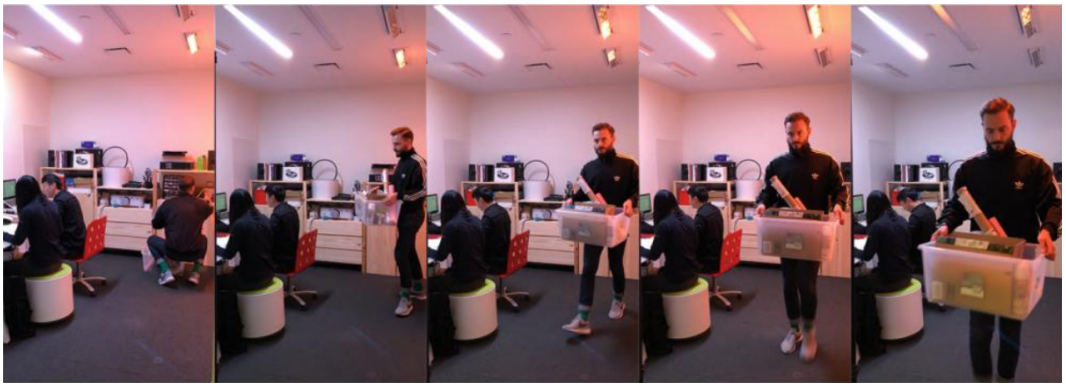

Figure 2.7: The Red Light Source Follows Its User Out Of The Room [18]

2.4.3 *The Relating Mobile Apps*

In the following table , two types of apps were introduced. One is having a goal for the enhancing of focusing ability. The other one is having the goal of creating the ideal acoustic atmosphere for wellbeing. These apps shows the possibility of bringing interventions by the least device. The table below will cover their distinct functional features, out-standings and short-backs.

- **Timely**

  Feature: Provide AI time-manage suggestion for dividing into small tasks.

  Out-standings: Keep AI learning from the user‘s habit for better customized suggestion.

  Short-Backs: No reward or punishment; user‘s performance depend on self-regulation.

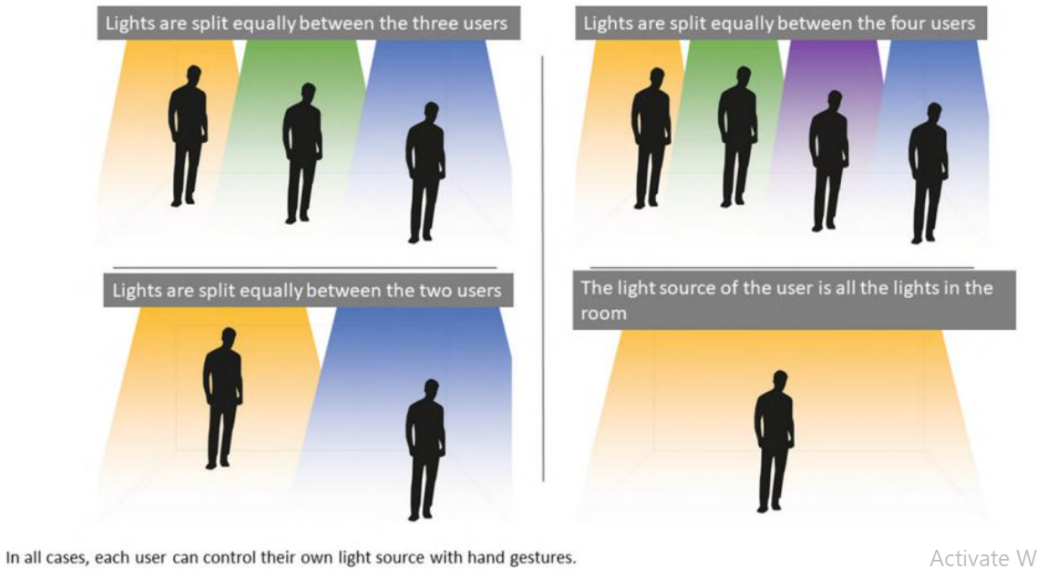

Figure 2.8: Equitable Light Sharing For Dynamic Resource Allocation [18])

- **Forest**

Feature: Set timer for concentration with reward for tree planting.

Out-standings: Having reward in the real world to stimulate motivation.

Short-Backs: user‘s performance depend on self-regulation.

- **Noisly**

Feature: Create sound environment by customized options.

Out-standings: Enjoy a customized preferred sound environment by the sound elements in real-world.

Short-Backs: Manually manipulate by preference, and the sound does not vary when no adjustments.

- **Endel**

Feature: Generating sound environment by personal data, such as location, weather, time, etc.

Out-standings: Synthesized sound varies in real time

Short-Backs: Synthesized sound cannot provide scene in common sense.

In a short summary, the above apps provide possible solutions to intervene users for their psychologically mediating ability. The interaction only happen between the user and the machine.

Chapter 3

Concept

3.1. The Problem to Solve

3.1.1 When Incompatibility Occurs

As mentioned in *Chapter 1. Background*, remote communication technology started to enable the first step of fulfilling our duties, such as study and work, regardless of the fixed place requirement. Nevertheless, this convenience has not been accompanied by adequate enjoyment for the performing experience. A specific environment usually corresponds to the particular atmosphere, as it is built and designed for its primary function, embodied on its spatial design and the occupied objects. When people start to use the environment for other actions, that particular atmosphere may not support useful mental suggestions but even bring detrimental feelings, especially those usually conducted within the contradictory atmosphere. This is the situation when incompatibility occurring between the environment perceptions and the intended action.

As discussed in *Section 2.1*, perceiving the environment is the privileged processing of perceiving the opportunities for possible actions, 'affordances,' by their different levels of attractive power [21]. These environmental cues are perceived as emotional stimuli. Emotional stimuli and cognitive stimuli decide our act together, but usually not in a peaceful agreement. Emotional stimuli can be divided into 'useful' and 'useless' by their compatibility for cognition. When it is defined as 'useful,' it integrates and supports the cognitive tasks by producing extra pos-

itive feelings (such as motivation and positive pressure) to accomplish the tasks. When it is defined as 'useless,' specifically by irrelevant (such as distraction) or opposite (such as indolence, procrastination), it interferes with our performance.

There are two circumstances that the incompatibility between environment perceptions and cognition is more likely to occur, which is when and where we tried to design a solution.

- **The useless stimuli from the external environment:**

  The staying environment is suggesting most irrelevant perceptions that will impair the cognitive tasks, which is to say, the place does not fit for the action, like working at home with sofa for relaxing and TV for entertainment and bed for sleeping.

- **The useless stimuli from the internal perception:**

  Even facing the same object or the same environment, the perception of its affordance is different when staying alone or with others, by personal habit or social norms. For example, people tend to be addicted to playing smart-phone when staying alone, especially for the preferred personal entertainment, such as gaming, Youtube, or TikTok; while someone else is near, they might be less likely to play their phone for fun but use it as a tool, whether it is out of considerations of politeness to others, or the possible embarrassing moment that may arise by the content shown on the little screen or their facial expressions towards the phone. Those awareness will suggest the privilege of its perceived affordance differently.

3.1.2 The Need of Professional-driving Atmosphere

The mediating atmosphere attempts are widespread in our daily life, such as playing music, using aroma, or lighting a candle. Admittedly, these attempts mostly aimed to create extra pleasure for mediating the current atmosphere, such as relaxing, tranquility, or romance. The attempt of redirecting to the professional condition is rare. The professional status usually is driven by proper pressure, adequate motivation, and a clear mind. It is undoubtedly indispensable in our daily life. There are two reasons supposed to explain why it did not develop as

the mediating purpose. Firstly, people generally take it for granted, as this type of atmosphere was very accessible in some specific places where we go in our daily life, such as campus and office, whether compulsorily or voluntarily. Secondly, the general attitude towards pressure was overcoming rather than utilizing.

This Covid-19 year provided an opportunity to let many people realize the significance of the professional-driving atmosphere. According to the Google Mobility report [7], the mobility trends of accessing work places has significantly decreased in 2020 (Figure 3.1).Though the convenient home-life allows us to do those duties at home, it seemed not to bring the expected efficient lifestyle for many people, especially for those who often commute for their duties to the particular places. Home is an environment suggesting relaxation and coziness, which conventionally stands opposite the pressure and motivation. Therefore, this extra convenience can weaken motivation and concentration ability, and finally slow the performance down.

Country	Mobility Trends for Places of Work
United States	-38%
United Kingdom	-55%
Canada	-44%
Australia	-33%
Italy	-63%
Spain	-64%
Germany	-39%
South Korea	-12%
Japan	-13%

Figure 3.1: COVID-19 Mobility Report by Google for the first half year of 2020 [7]

In fact, it is not merely for the consideration of the Covid-19 year; it is time to rethink the necessity of commuting since the communication technology nowadays has already satisfied most remote working needs. Commuting to particular occupational locations is still the mainstream. This lifestyle severely limits the daily route, a mere round trip between home and company, who became one of the indoor generations, spending 90 percent of time indoors [13]. When people can do their works anywhere, why do their companies still prefer them staying

in the office? The atmosphere is the answer. The unique working atmosphere is believed to stimulate optimal working performance by growing team integrity or group competitiveness. Except for the compulsory commuting requirements, the self-driving thought of going to a specific place to do their intended tasks (e.g. library for study) can also be ascribed as the place can provide the appropriate atmosphere to do that thing.

So people actually admitted the importance of a professional-driving atmosphere and only bound this need to the specific environment by their subconsciousness. When communication technology tools enabled performing professional tasks regardless of place limits, the professional-status atmosphere should not be ignored as it can efficiently improve working productivity and mental satisfaction. Only both of them accompanied; they would truly benefit our working experience and life.

3.2. Design proposal

3.2.1 Concept

The design concept initiated creating a professional-driving atmosphere in an individual monotonous setting, thus supporting work productivity and mental satisfaction and alleviating the self-struggles of distraction and indolence. This designed setting would serve as a plug-in switch for people to divide their personal and professional time, which they lack during home working.

As discussed in *Chapter 2*, the impact of environmental perception on people's cognitive performance is acknowledged. Instead of being affected by the environment passively, this paper aims to explore an actively adjustable atmosphere that could serve and support the intended purposes when it is in need. Atmosphere, the sensory qualities of an environment, should not only bind to a particular place, just like the professional activities are free to choose locations where to conduct. The practicality of action and the suitability of the environment should come together; to support optimal performance.

3.2.2 Future Envision

Remotely fulfilling the professional duties would inevitably become the future trend with the technology development, merely because it can allow most people to live more freely, no longer limit to physical distance, or compromise personal time. Simultaneously, the only acceptance that the organizations could give is the prerequisite of guaranteeing the sufficiently positive working performance. Except for rigid conditions, such as tools and facilities, the working atmosphere plays a crucial role in deciding the working performance.

The virtual space for conducting professional duties is fundamentally necessary for the popularity of remote working. It should provide a platform for information communication or cooperation as the basic function and also provide the corresponding environment atmosphere to simulate users to reach their professional mental status immediately and maximize productivity and efficiency. Although most people choose home when they remotely work, the virtual space still should not be fixed to home. It should be accessible and portable anywhere, either for a person who lives a roving life or a rooted life.

The virtual work-space's future envisions more likely to be achieved by an immersive displaying device, such as holographic projection. Early in 1998, the research of *The Office of The Future* has initially practiced the spatially immersive displaying techniques (Figure 3.2) to present the real-time dynamic vision, as the precedent of holographic projection application for office [25]. Even nowadays, the well-performed displaying projection still requires the complex giant infrastructure, which prevents ordinary use in daily life and is more commonly applied in the shows or exhibitions. Thus the future design of the immersive displaying virtual work-space needs to emphasize accessibility and portability.

Remotely sharing visual and acoustic perceptions is more likely achievable in the future by the development of immersive presenting medium technology. Moreover, the designs of sharing other senses, such as haptic and olfactory, also need to be included if possible. An ideal imaginary vision of the future virtual work-space is created by an atmosphere-presence kit, which may include a sharing-olfactory aroma, an immersive projector, a haptic chair and desk, and a location tracking device. The immersive holographic projection will create a virtual space with the dimensioned map. The location tracking device will give distance parameters to

let the other devices to refer to work. It can allow the user to walk physically walk to talk with or pat the colleague, send the talking sound in directions and via distances, share the smell stimuli by individuals like a cup of newly made coffee.

Figure 3.2: The Office of The Future [25]

3.3. Detailed Design Approaches

The central approach of designing an adjustable atmosphere is producing the useful arousal, an appropriate positive pressure by Social Facilitation phenomenon, thus to improve the performance of accomplishing the professional tasks in when they are staying in an incompatible environment. In this section, the detailed design approaches will be discussed in detail from three aspects of consideration.

3.3.1 Create An Useful Atmosphere

The design strategies for creating the professional atmosphere consist of alleviating the useless stimuli and producing or augmenting the useful salient emotional stimuli, which can draw us from the hindered perceptions and capture our intention to the cognitive tasks.

To be able to cover the exciting perception, only if the feeling of presence in a specific environment is vivid enough. This vividness of creating an atmosphere mainly depends on the validity of presenting its important elements [16]. The important elements include both still and dynamic ones as we discussed in Section 2.2.

The still elements usually assign the identity of a specific place. They powerfully and constantly affect cognition but only through visual perception. Thus to create an atmosphere of considering its still element, the only possible manipulating approach is using the visual surrogate, video projection, which *MA* did in their designed prototype [31].

Nevertheless, unpredictable resources are primarily perceived as significant stimuli from the evolutionary perspective within a dynamic environment [15]. This priority of the dynamic element will certainly be more powerful when it occurs within a relatively still environment in contrast, which is the individual monotonous environment we designed for. The dynamic element is the time-based feature; hence the feeling of presence in real-time is substantially essential; in other words, the designed outputs‘ performance should be generated from the real-time incoming data. To create an atmosphere of considering what the dynamic elements include, there is the most common feature among those public places when compared with the individual setting, the presence of other people.

3.3.2 The Essential Stimuli: Other People

Essentially, the whole created-environment aims to produce useful arousal that can be **stronger enough** to capture attention and bring **useful** emotional stimuli (such as motivation, self-regulation, competitiveness) for the intended tasks (working and studying). The dynamic element of other people‘s presence can play this role.

Firstly, other people‘s presence is the most potent dynamic element as they are perceived both visually and acoustically. Comparing with other dynamic elements unrelated to people, such as sunlight and airflow, the possibility of occurring the dynamic changes is also larger because people are spontaneously acted for their internal thought and responsively acted to external stimuli. Thus, it is easier to alter the self-perception when staying with other people‘s presence than alone, as it usually fosters more inter-correlated interactions.

Secondly, as discussed in *Section 2.2*, there are substantial studies of *Social Facilitation* that demonstrate an empirical relationship between the presence of other people and individual performance improvement. Although this relationship is not always proportionally positive, the designing atmosphere of *Social Facilitation* aims to provide the appropriate arousal by the adjustable elements, such as people number and the intimacy between them, therefore helping to achieve the optimal performance.

Moreover,**implicity** is the fundamental attribute of the designed perception of others‘ presence. Perceiving the atmosphere is a continuous process of sensory qualities. When it is designed to serve for the cognitive action, perceptions from the surroundings should be supplementary, rather than dominating the consciousness. Since the most direct way to perceive the other person's presence over space is talking as communication, the tools used for this function have existed for years.

An optimal environment for concentration might not need absolute quietness. However, those comprehensive information in words undoubtedly result distractions. According to the experiment of acoustic and visual distraction on cognitive performance by Andreas Liebl et al., they found that that even low level background speech of high intelligibility significantly impairs short-term memory, reasoning ability and well-being, and in the contrast, the tested persons preform better if background speech of low intelligibility was combined with static lighting [20]. Hence, the implicit connection needs to be created, which only sends simple perceptions about the others behavior, not intelligible communication.

3.3.3 Sound as the Presenting Medium

To present a dynamic environment, visual and sound both are essential. Nevertheless, this paper only emphasizes the sound medium in terms of the specific

applied setting, the individual monotonous environment; the supporting arguments are below.

- **Applicability and Utility**

  Initially and primarily, the product is designed to work as a supplement tool by the flexible and easy way of use, in terms of the applicability in personal space, usually in a home setting. It should support the users to work naturally and physically comfortable, not impairing the user's familiar working process. The personal spaces are usually relatively small and filled with many personally preferred objects. Big infrastructure and heavily wearable devices (Virtual Reality) are not considered in this situation, as any large or heavy piece would raise unnecessary awareness and spatial inconvenience. The final prototype is expected to be a portable light kit, which could easily set up and only rise its presence when it works, not be concerned when it is off.

  The adjustable visual surrogate commonly used in immersive experience design is projecting; for example, its application in *MA*'s prototype [31]. Even if we can utilize the wall as a projection screen, it is still difficult to guarantee the consistent designed performance as people staying in their own places may not have a smooth empty white wall in their visual range when facing the desk. By considering this possibility, the visual-presenting approach is also less preferred.

- **The Ability of Sound**

  Sound is sufficiently master in imaginary-creating ability. It could demonstrate the diverse element in the meantime, such as resource identification, motion, direction, and distance. These elements make up the scenario presence or called ambiance sound.

  Sound can augment the unique motion-perception, which the visual could not. J. Hetherington et al.'s research has proved that sound could add the incremental benefits of representing the dynamic environment: motion (video) without sound produces the low responsive perception in both conditions of the static image or video, while motion with sound drawing salient attention to the observer perceiving the dynamic element, flow, in that study [16].

Furthermore, sound can also alter our sense of the environment beyond the limited visual window, for example, of conveying the spaciousness or openness of a place [14]. Psychoacoustic investigations have proved that a quasi-objective measure of auditory spaciousness can be derived through a model of binaural signal processing, which takes interaural arrival-time differences as well as interaural level differences into account [3]. This principle is utilized among the prototype design criteria. Though visual may also expand the spaciousness but only valid when there is a giant screen or surrounded view (VR) available, that is not considered in this design as mentioned above in section.

- **As the Subordinate Perception**

  There are considerable researches about the priority of visual perception than other senses. For an example of H. Nakanel et al.'s experiment has proved that the priority of the auditory information was lower than that of the visual one in both the central and peripheral visual fields [22]. Comparing with visual, the acoustic distraction is more likely to be accepted comfortably to continue focusing on the cognitive behavior as long as it is at a proper loudness level. That explains why sound is more often used as an ambience mediating tool in daily life, there are many examples of using sound for mediating atmosphere in our daily life, such as background music, white noise or TV drama. Hence sound is more widespread accepted as an implicit intervention.

Chapter 4

Proof of Concept

4.1. Overview

In this chapter, the functional prototype was built to explore the concept. It is a practical attempt to merge the individual settings into an acoustic sharing virtual space, creating the professional-driving atmosphere among a group of users, hence stimulating the individual‘s cognitive performance improvement. The prototype system utilizes sound as the fundamental presenting medium to construct the atmospheric scene. It emphasizes the implicit perception of other people‘s presence in real-time who is doing the similar actions, thus to achieve the *Social Facilitation* effect.

This chapter will cover the prototype system to explain the design strategies, the experiment details for the user study, measurement approaches applied in the analysis, and the analyzed results.

4.2. Prototype System

4.2.1 Design Criteria

The prototype would be implemented in the individual‘s own familiar and private space, ‘home’ is applied in this situation. Considering the applicability of the place and the prerequisite of maintaining a familiar working habit without bringing unfamiliar awareness mentally or physically, big infrastructure and heav-

ily wearable devices (VR) were not considered in this situation. The prototype is presented as a supplemental tool kit, which would only be taken out for use when it needs, rather than planting into the nature of the existing space. The prototype system allows to connect among multiple users and each user uses the one set up(Figure 4.1,4.2).

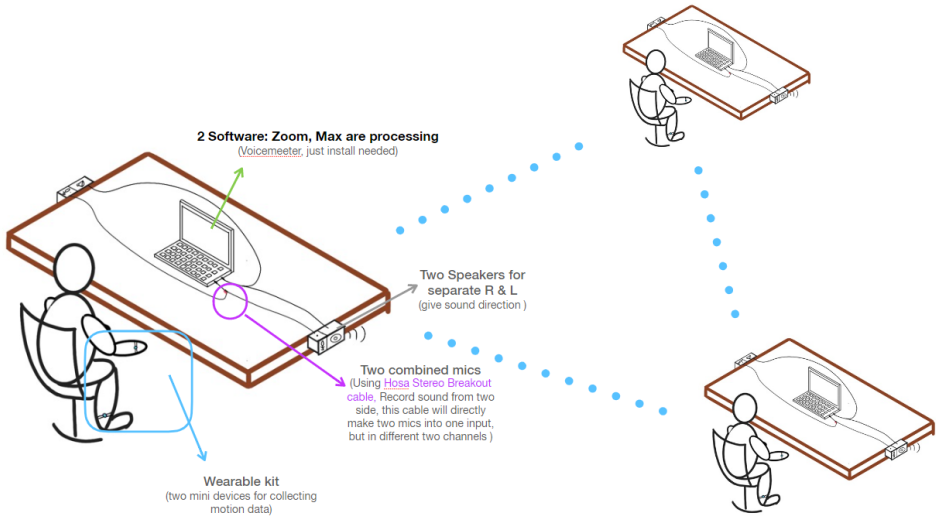

Figure 4.1: The Technical Setup Among the Multiple Users

The atmosphere-creating kit consists explicitly of a wearable kit, a computer as the control server, and the audio set(Figure 4.2). These modules will construct the network to output the sound composition at the control server, which will be sent via *Zoom* shared remotely among three users.

The overall acoustic atmosphere aims to construct the particular professional-status scene, sharing a table with two other people in a particular environment. Thus, the involved users will share the same output performance and spontaneously send the input parameters, affecting the whole atmosphere. The sound composition could convey the latent information, such as distancing, spatial dimensions, scene background, and people's dynamic motion, thus augmenting the physical characteristics of an environment from the real world.

Figure 4.2: The In-situ Set-up at the One Participant‘s Home Photo

4.2.2 Sound Design

Three streams of sound outputs would compose the sound performance. They harmoniously mixed to present the scene of sitting at one point with other people in an specific environment. The three outputs vary the different audio volume levels to produce the vivid perceptions of the acoustic atmosphere .

- **1.The Preset Scene‘s Ambience Sound**

  The background noise sound, often know as the white noise, specifies in different scenes. The sources used in the prototype were all recorded from the existing real-word. The ambience sound plays the role of augmenting spaciousness and constructing the specific scene for users to extend their senses to another environment. In this prototype, four scenes are included: library, project room, cafe, beach. They differ from the conventional impressions of exposure level (indoor/outdoor), crowded level (people number), and the leisure degree. In the experiment, we used the existing resource files downloaded from the internet.

- **2.Synthesized Motion Sound: Two Wearable Devices**

This part of the sound design aims to augment the sensory interactivity and represent the visual motions to be hearable. Considering the desk working or study for most people are relatively quiet at home, usually making some rustling sound that is soft and slight. Since only the acoustic system is applied in this prototype, the mere recording function is not vivid enough. Though the central concept brings the implicit perceptions of others‘ presence, it is not wise to completely ignore the visual perceptions. To perceive the other's presence like in the real world, we need to recognize some motions that can draw people's attention very easily but actually have no sound, such as stretching oneself, waving one's hand, and walking tones. These motions in the film presenting methods usually come with the particular exaggerated sound to convey, especially for those early films without speaking, for example of *Tom and Jerry*(Figure 4.3), which kindly proved J. Hetherington et al.'s research that sound is indispensable to present motion [16].

Figure 4.3: Tom and Jerry Poster

To present these visually concerning motions to be audible, two wearable prototype devices were built to collect the movement data at the wrist and ankle separately, implying different motion sound types. They will send the movement parameters to make synthesized motion sound at the control server in real-time. These sounds will also mix into the background sound, but only send to others and not be heard by the one who is making the mostion. This part performs the primary role of augmenting the interactivity of the prototype, emphasizing the features of dynamic and real-time.

Both devices are two potable light bracelets, composed of Arduino modules and soft silicone skins(Figure 4.4)(Figure 4.5). They are light and portable to wear at user's arm and ankle respectively(Figure 4.6). Each device's components include an Arduino Nano board for program processing; an NRF2401 module set for data transferring wirelessly from the bracelets to the receiver board at the PC; and a power supply set: a rechargeable Li-po battery, a TP4056 charging module, and a toggle switch.

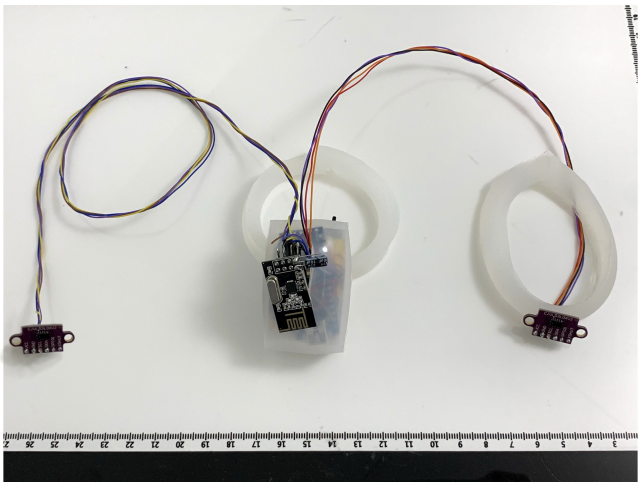

Figure 4.4: The Arm Bracelet

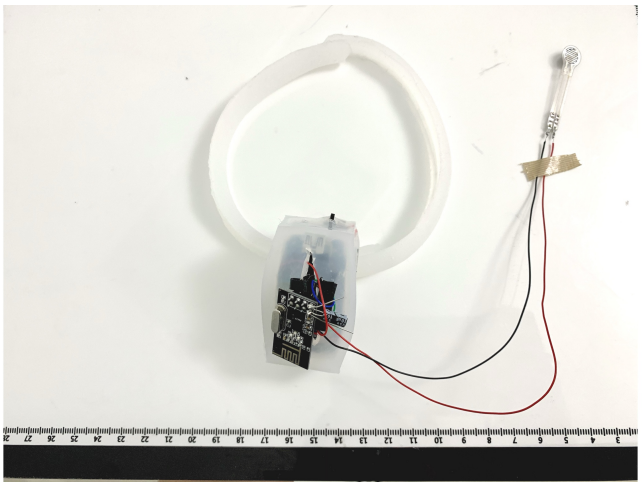

Figure 4.5: The Ankle Bracelet

– **Arm Bracelet**

The arm bracelet uses two Vl53l0x laser distancing sensors to detect the wrist orientation and head orientation.

The first one piece is placed at the palm side(Figure 4.7)of the wrist when wearing it. The prototype is designed for the typical scene of desk work. When people concentrate on desk work, such as typing a keyboard, holding a mouse, writing, and holding a pen, the most used hand, right or left, is mostly pronate or neutrally positioned(Figure 4.8). Hence the sensor would detect a short distance, either the wrist facing downward to the desktop or holding something neutrally. There are always many obstructions around the desk or the body to be detected in a short distance. Only when the hand is leaving the desk or supinating to the air can the large distance gain, and these gestures often imply a moment of rest, such as waving hands or stretching oneself. We mapped the distancing number into a new range of 50-250 at the control sever and applied them as the frequency parameters to make the synthesized swoosh sound. Swoosh sound interprets a sudden rush; in this case, the output through the algorithm is a little exaggerated but easily recognized as movement sound, just like what the film production often used.

The second piece is fixed to the glasses arm or the hairpin(Figure 4.6), which uses for collecting data of head orientation. This data steam would not be used for synthesize motion sound. It is used for analyzing head orientated status during the experiment.

– **Ankle Bracelet**

The Ankle Bracelet uses a Force Sensitive Resistor sensor. It is a thin film, which can be stick to the socks or feet when using it, and the connecting rest part is worn at the ankle (Figure 4.6). Sitting would not cause foot pressure on the floor. Only leaving the desk and walking would gain pressure data. Likewise the designing scene of desk work at home, people often wear slippers or bare feet, and the floor is often carpet or wood. The walking sound is hard to be concerned about, or

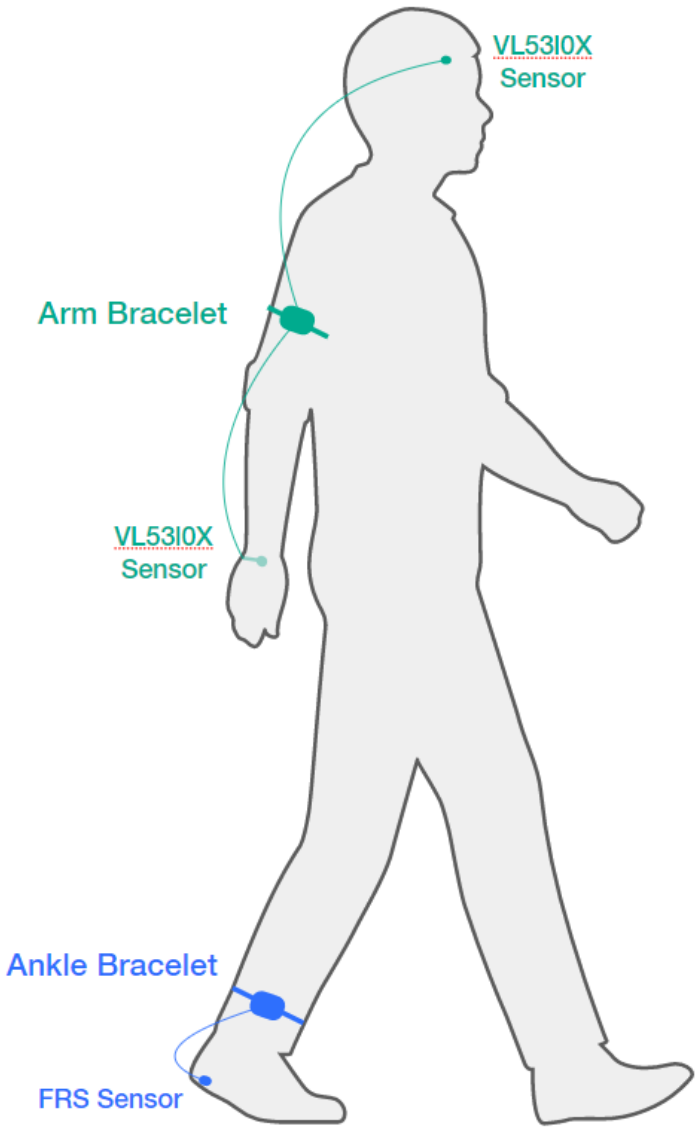

Figure 4.6: Wearing Two Bracelets On Body

Figure 4.7: Place The Vl53l0x Sensor At The Green Point

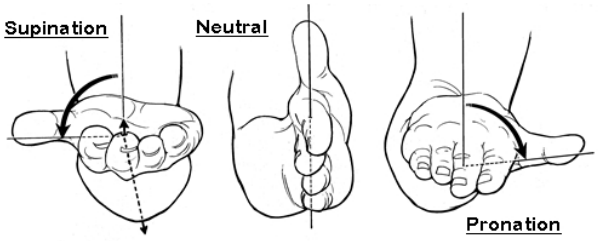

Figure 4.8: Wrist Orientation Types

merely the little rustling sound could be recorded. While in the public professional places, the walking sound is significantly different: people tend to wear shoes with stiff soles and heels (e.g., leather shoes, high heels), and the floor generally prefers hard materials like stones and tiles. The clicking sound often occurred in public spaces. To create the vivid perception of staying in a public sharing space, this device would state the individual's walking status and send the data to the control server to make the synthesized walking sound.

These two designs aim to augment the sender‘s self-awareness of his spontaneous behavior during the professional time and the other receivers‘ awareness of a real person's presence.

- **3.The Audio Set**

  The initial ideal plan aimed to simulate the scene of three users sitting around a table; hence there is always a real person sitting at every subject‘s left and right side(Figure 4.9). To emphasize the sound source direction, a set of stereo speakers are implemented for every subject by two sides; accordingly, each speaker (separately in the left channel and right channel) will play the spontaneous motion sound from the different side-sitting persons(Figure 4.9). For example, Subject A‘s left speaker states the source from Subject B, and A‘s right speaker states the source from Subject C. Initially, we planned to use two mics to record sound from the left and right sides separately, send it as the one stereo input via Zoom, and let the receiver‘s control server decide to play at the left or right speaker. However, we did not found a solution to recognize whose sound is making on Zoom. Thus the undefined origin could not tell information to the control server which side speaker to turn on or off.

  Therefore, we applied the sacrificed plan; each subject sends their motion sound input in the mere one channel(Figure 4.10). Subject A only sends his L channel sound, Subject B only sends his sound of L channel, and Subject C only sends his sound of R channel. By this plan, A will hear his speaker L playing sound from B, speaker R playing sound from C. B will

hear his speaker L playing sound from A, speaker R playing sound from C; B needs to exchange the side location of his speakers, speaker L to the right side, speaker R to the left side, then the perception of sitting location will integrate with A. C will only receive the L channel sound, both from B and A, thus he has to sacrifice the direction perception of the motion sound. In this case, each subject only needs one mic to record.

4.2.3 Control Server

The control server composed of three independent software that needs to process in the same time, building the full architecture of the mediating acoustic atmosphere. These three software plays the roles respectively for sensor controlling, output processing , and platform sharing(Figure 4.11).

Arduino IDE programmed the two wearable devices and the data-reading receiver connecting to the computer, which could allow the computer to read all incoming sensor data steams on the serial port in real time. Then *Max MSP* can refer the sensor data from the serial port in real time to synthesize the sound composition. *Max MSP* is the editing processor for all the acoustic output. According to *4.2.2 Outputs*, the three types of sound output would merge together through the algorithms in *Max MSP*(Figure 4.12). The final output from the *Max MSP* will send to the virtual audio driver: we used *Voicemeeter* in Windows, and *SoundFlower* in Mac IOS. For the last step, *Zoom* enables the virtual audio driver to set as its input, then the edited sound composition can be shared as the acoustic atmosphere among the group of users, and they can interact their motions via sound. Since the *Zoom* is a meeting-function software, the normal setting is for voice. There are two particular options need to be adjusted for this prototype system. Firstly, the function of enabling stereo is necessary to turn on, then it could enable the sound directions designed in the sound composition. Secondly, it needs to turn on the original sound as *Zoom* normally automatically choose echo cancellation and audio-enhancements (notice: once it shows 'turn off the original sound' it means the original sound is on).

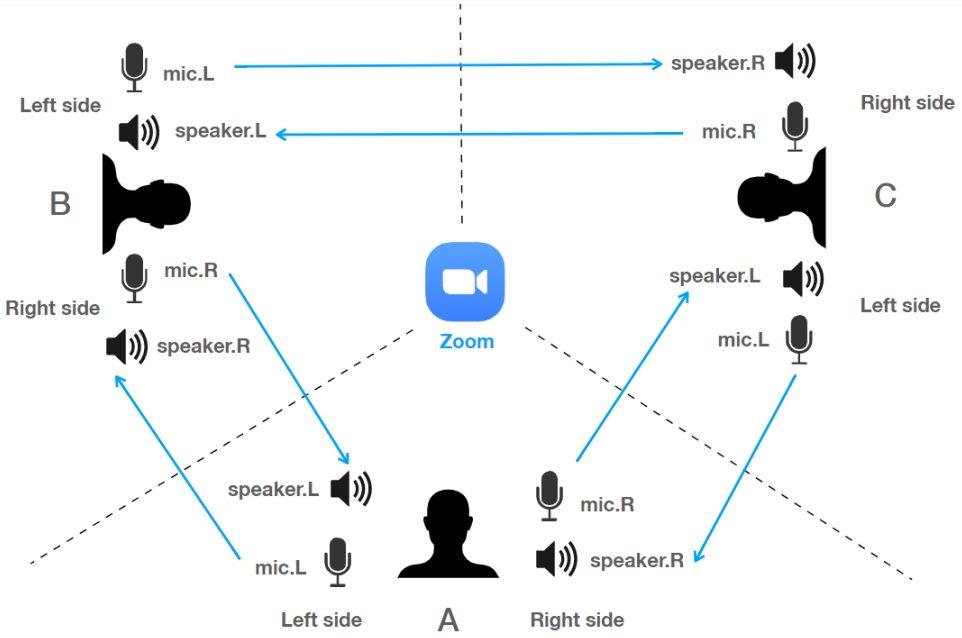

Figure 4.9: The Original Plan of Connection Graph

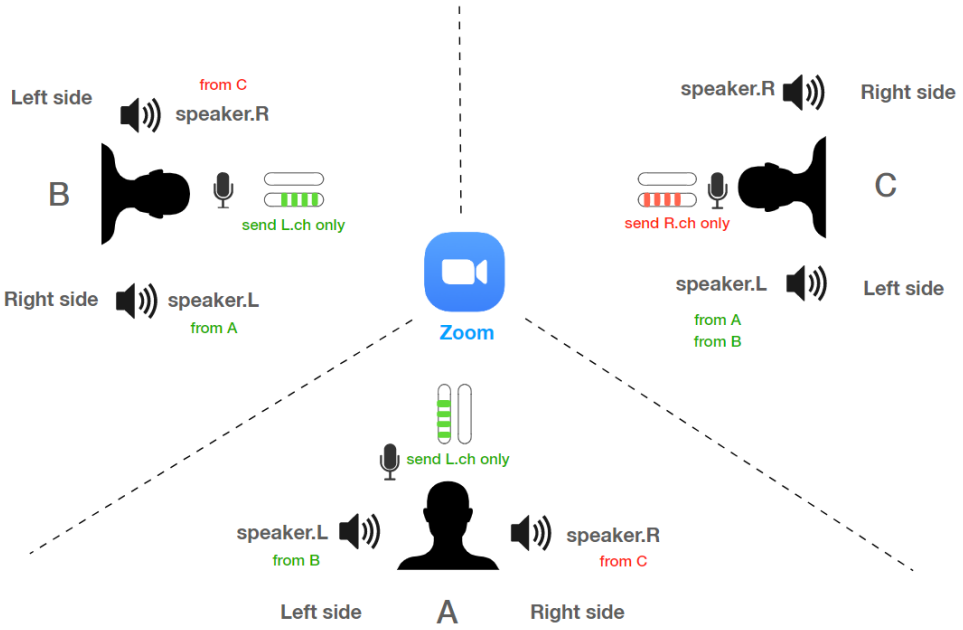

Figure 4.10: The Sacrificed Plan of Connection Graph

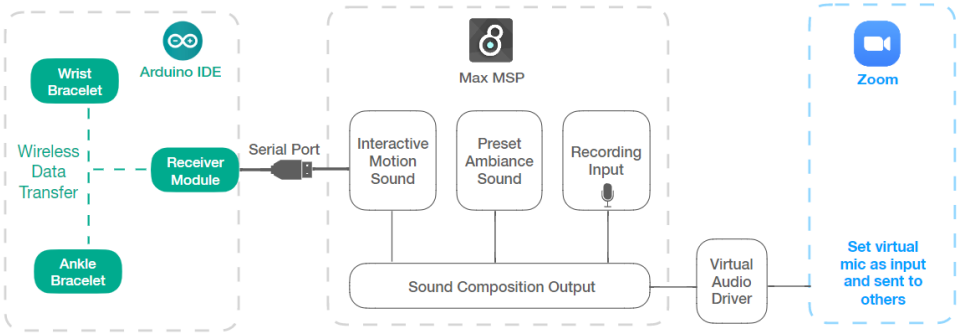

Figure 4.11: The Overall Signal Processing Graph

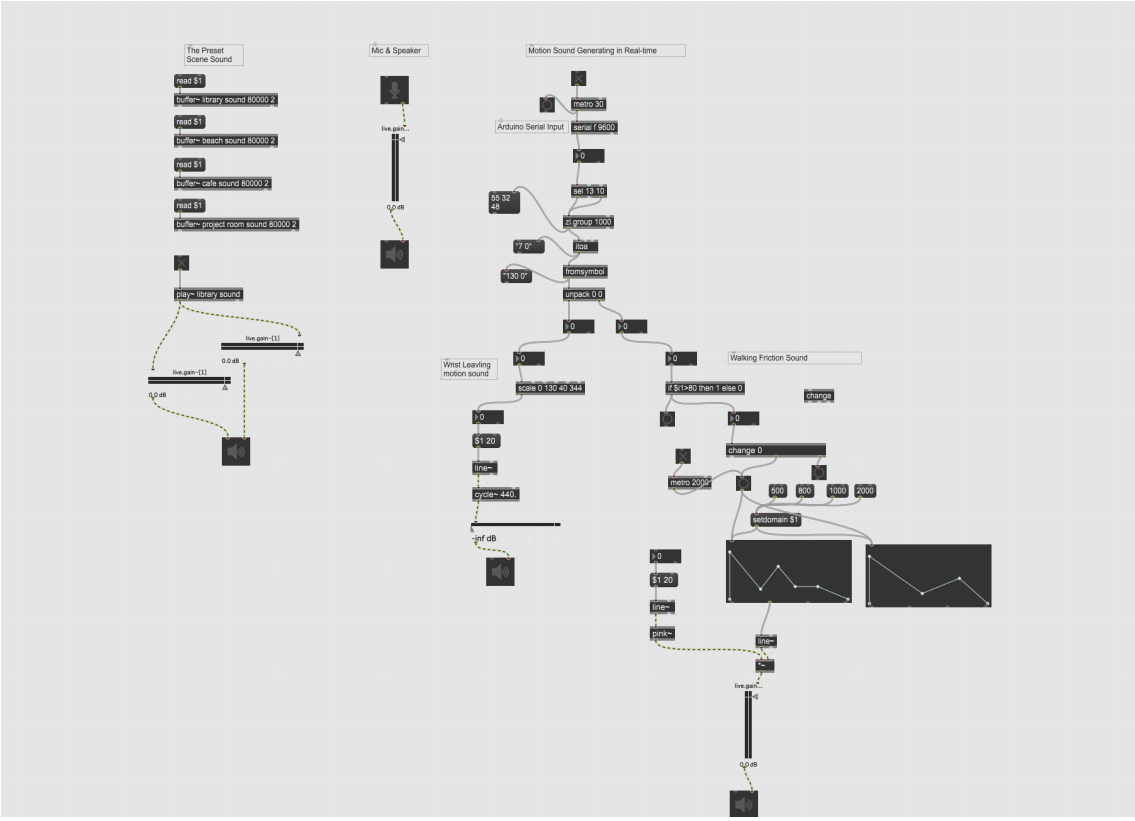

Figure 4.12: Max MSP Processing Diagram

4.3. Experiment

The goal of the experiment was to evaluate the effect of the prototype on the perceived interventions and the physiology influence.

4.3.1 Experiment Design

We conduct the two experiments for every participant to prove the prototype‘s performance by comparing the results.

- **The Original Experiment**

  The is the first step for every participant to do. It aims to observe the normal performance when the participant doing their professional tasks by themselves at home without using the prototype. The process does not involved many extra interventions. Only the Arm Bracelet (the simplified version with one sensor)(Figure 4.13) needs to be worn for collecting head orientation data, which could provide some objective measurements with the questionnaire. The participants would be told to study or work for an afternoon, from lunchtime until dinner time, roughly about four hours.

  They were encouraged to do as much normally as they used to do in the daily life. No other requirements are given. It is fine to have break at anytime or even quit from doing that. There is no need to set a particular goal for that afternoon if the participant does not have the habit of making plan in advance. After that afternoon, there is questionnaire for them to fill up, including the subjective and objective questions for evaluating their self-performance.

- **The Applied Experiment**

  The prototype system is applied in this experiment. Every three participants would be the one group and they have known each other rather strangers. In this experiment, they would be told to attend the study session in a specific setting, choosing one scene among the four options (library, project room, cafe, beach) by their discussed agreement. The time length is same with the original one: roughly about four hours, from the lunchtime until the

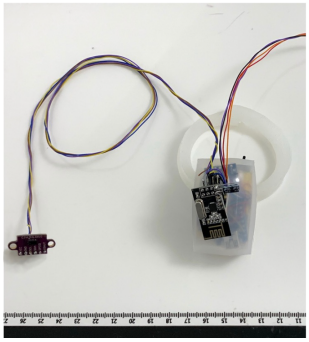

Figure 4.13: The Simplified Version Of The Arm Bracelet With Only One Distancing Sensor

dinner time. The time management of Pomodoro Technique [6] is applied with the timer bell sound for reminding. Each pomodoro interval consists of 25 minutes of doing tasks and 3-5 minutes of break. After every four pomodoros, a longer break of 20 minutes. It is not required but encouraged for subjects to follow the time management. Since the audio is connecting all the time,only the break is allowed to talk with each other.

The questionnaire would be given after the experiment to collect the perceived response of the interventions by prototype. The results from the questionnaire will indicate the prototype‘s performance from the subjective view. The questionnaire is attached and the measurements is described in *Section 4.4.1*. The phyisicolgical responses of head orientation is also recorded in this experiment, using the complete version of the Arm Bracelet. It will be compared with the result from the Original Experiment to examine the effect of focus-maintaining ability.

- **The Simplified Experiment**

  The two above experiments consist of the complete experiment. By considering the limits of sending devices and expanding the subject's scope, the simplified experiment was organized. It still consists of two steps. Firstly, filling up the first questionnaire asks their perceptions of the specific situation: studying or working in a dull individual environment, which requires intense and prolonged intellectual effort in the meantime. It is encouraged for the participants to recall their own remote work or study experience at

home in daily life. The questions will be the same as the Original Experiment questionnaire. Secondly, they will listen to a sample of the audio, which is a part of the full audio performance composed of the three outputs mentioned in Section 4.2.2. It will describe how these sounds were made and ask them to imagine working or studying within that audio atmosphere. It is important to let them know that it is the real person making sound and interacting within that atmosphere. Then the second questionnaire will ask their perceptions about this kind of atmospheric intervention. The questions will be the same as the Applied Experiment questionnaire.

4.3.2 Participants

The target users are mainly the people who have to stay home to work or study but lack sufficient motivation and self-regulation ability, often struggling with procrastination, indolence and loneliness. The experiment subjects are university students, N = 16, with an average age of 24, 70% is female. Only eight people did the complete experiment; the other eight participants did the simplified experiment. Since this experiment was conducted in the Covid-19 pandemic period, university students were required to study remotely.

4.4. Measurement and Results

4.4.1 Perception

The measurement used the five-point Likert scale range from -2 ('very low') to 2 ('very high'), referring to the approaches used in the research of Mediated Atmosphere [31]. In the Original Experiment and the Applied Experiment questionnaires, the questions are matched correspondingly but a little different. They are designed to compare the subjects‘ perceptions between the typical individual setting, and the intervened setting, thus assessing the acoustic atmosphere's performance. The questions were inspired from the prior researches of [31] and [23], measuring the three variables. Each variable is defined by the mean score of every five questions(Figure 4.14)(Table 4.1). All of the questions were attached in the appendix.

Question 1 to Question 5 assesses the Focus Driving Potential (FDP). The questions asked about focus maintaining ability, focus efficiency, and distraction resistance ability. The mean score increase from 0.06 to 2.13, which means the focus qualities are improved significantly.

Question 6 to Question 10 assess the Perceived Compatibility Potential (PCP). The questions asked how suitable is the environment for doing their cognitive tasks. The mean score increase from -0.14 to 0.9, which shows the users feel the prototype more compatible for working than the mere home situation. They are positively stimulated, motivated, undistracted, and properly pressured by the atmospheric intervention.

Question 11 to Question 15 assess the Personal Liking Potential (PLP)of the acoustic atmosphere. These questions asked about how do the users feel about using the prototype. The question 11th shows the participants are generally positive to feel other's presence while they are working. The 15th question is only asked in the Applied questionnaire about wearing the device. And the value shows is near 0, which means the awareness of wearing the device is neutral.

In summary, the participants‘ perceptions are positively intervened by the applied prototype from the compared results. Moreover, some other positive feedback over the expected ones were also given during the after experiment interviews. Two participants have mentioned that the prototype could provide them a sense of formality during the wearing-devices process. It gives them a strong suggestion that is a switch to start study, and this self cognition do help them to be easier to focus.

	mean.ori	mean.apl
FDP	0.057	1.13
PCP	-0.14	0.9
PLP	0.14	0.62

Table 4.1: The Table of Mean Comparison by the Complete Experiments

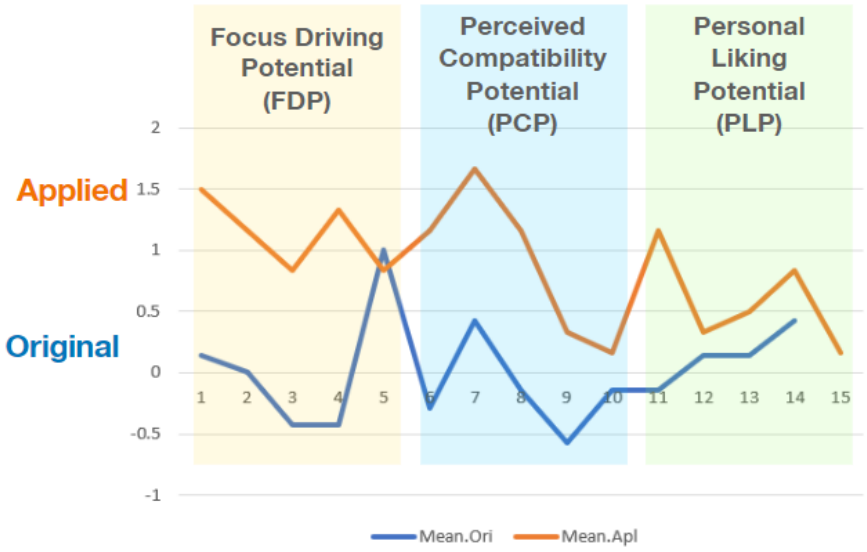

Figure 4.14: The Mean Comparison Diagram for Each Question Between the Original and the Applied by the Complete Experiments

4.4.2 Physiology - Head Orientation

Head orientation was measured to assess the prototype‘s Focus Driving Validity as an objective reference to support the perception results. Head orientation data enables to estimate where participants directed their visual attention [31]. When one focuses on desk work, his head would face the screen or downward at a relatively stable distance. When they look up or turned heads, the distancing would significantly change from the stable range, indicating the moments of distraction.

Each participant was recorded 1 to 2 hours differently but analyzed with the same time length to compare her two experiments results. We record the sensor‘s serial data by *CoolTerm* software and then plot the data into the line graph by*Excel*. The segment of the leveling changes can be observed. The leveling of keeping the stable line longer time means the greater tendency of focusing time. This hypothesis was proved by the following two pair graphs (Figure 4.15) (Figure 4.16) that long segments are more likely to occur in the Applied Experiment. After gaining the Head Orientation data, we found that every participant‘s stable

tendency differs from the leveling range as their working habit and the working environment are different. So we decide to set the different stabling reference ranges to analyze every participant. We choose the range of 20mm between 30-80mm. For example, the (figure) shows the one sample pair graphs from the one participant, whose data was analyzed with a stable range of 60-80mm as the stabling range. The (Figure 4.15) shows another participant whose data was analyzed with a stable range of 30mm-50mm (Figure 4.16).

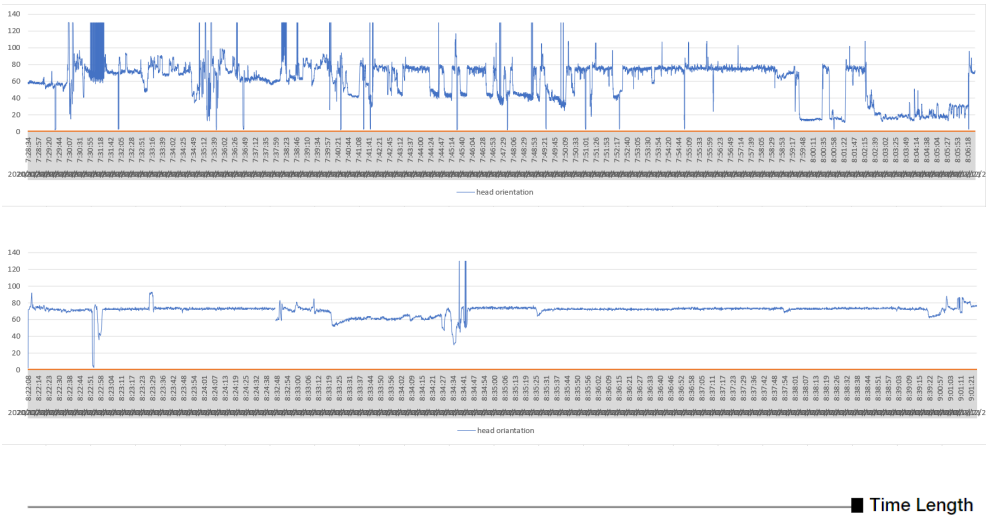

Figure 4.15: The Compared Pair Graph from the One Participant: the Up Graph is the Original, the Below is the Applied.

The prototype's Focus Driving Validity can be interpreted by two variables assessed from the recording data. Firstly, Focus Duration Percentage (FDP) is assessed by calculating the percentage of the stable leveling moments accumulated occurring within the whole recording period time. The results are presented in (Table 4.2) with the mean number, maximum, minimum, and median. The mean number shows the FDP rises around 27%. Secondly, the grading system to measure Long Focus Potential (LFP) was applied. The one continuous long segment implies more focus driving validity than the accumulated segments for the same time length. LFP is calculated by the stable range occurring times of 5min, 10 min, and 15 min. 5min occurs once is giving 1 score, 10min occurs once is giving 3 scores, 15min occurs once is giving 5 scores. The result table (Table 4.3) shows

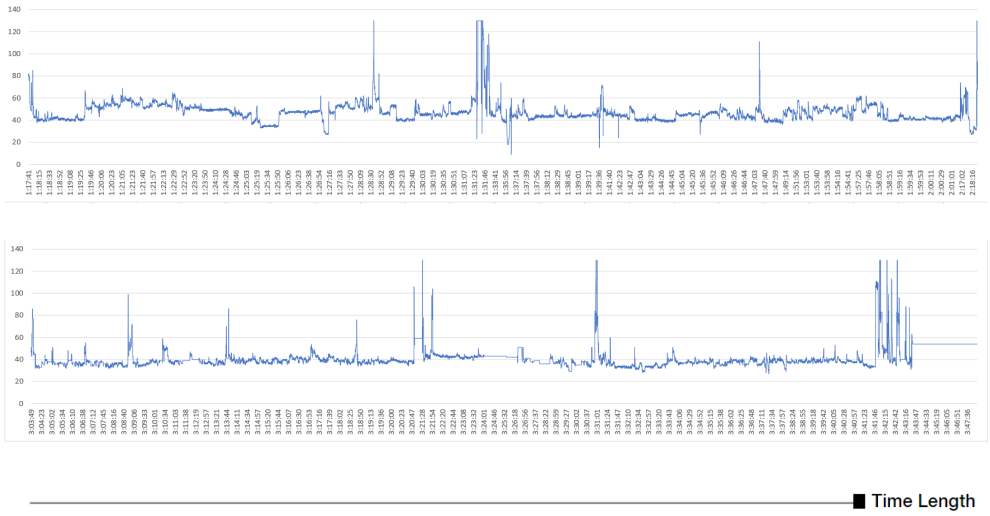

Figure 4.16: The Compared Pair Graph from Another Participant: the Up Graph is the Original, the Below is the Applied.

the mean value of the score of LFP increases from 10.4 of the Original to 17.6 of the Applied.

	mean	maximum	minimum
Original	49.38%	66.27%	31.64%
Applied	77.94%	88.22%	69.25%

Table 4.2: The table of Focus Duration Percentage

	mean	maximum	minimum
Original	10.4%	13%	6%
Applied	17.6%	28%	10%

Table 4.3: The table of Long Focus Potential

4.4.3 Summary

In summary, the results showed that the prototype positively stimulated the participants from both perception measurements and physiological measurements. It shows that focusing on ability, motivation, and mental satisfaction was improved using the prototype while doing their cognitive tasks. Though it is necessary to consider the personal bias as the participant number is relatively small, these experiments could support and evaluate the design concept's validity. 5

Chapter 5

Conclusion

Chapter 1 introduced the background researches about the problem. The problem initiates from the rising phenomenon of doing professional duties (e.g., work and study) at home remotely. Substantial researches have denoted that environment can essentially affect people's action. Therefore, cognitive incompatibility often occurs during the working time at home as it conventionally suggests the contradictory actions toward one's professional status. Hence the perceptual struggles from the surrounding environment often impair people's cognitive performance, such as distraction, procrastination, loneliness, and indolence. Mediating atmosphere for the professional-driving status is needed under this circumstance.

Chapter 2 discussed the relative theory and the design works to review the problem and inspire the proposals. Firstly, the environment could primarily affect action over the attention. This is a privileged process of perceiving the possible affordances of every element within the environment. In other words, the element with the most attractive power could affect people's actions most powerfully. Secondly, "People" as the unique dynamic environmental component can easily win saliency in the perceiving process. The psychological effect of Social Facilitation indicates that the other people's presence is a useful intervening element to affect the working performance. Thirdly, for the dynamic presenting validity, the auditory perception was found as crucial as the visual. These researches initially inspired and support the design concept to achieve the goal. Moreover, the precedent designs of mediating atmosphere attempts by manipulating the sensory medium were also introduced, including Mediated Atmosphere, Light Cloud, and

the relevant apps. By reflecting and learning from these precedents, this research's design explored the new attempt to achieve the goal.

Chapter 3 starts with analyzing why and how the incompatibility occurs between the environment and action, then giving the solution proposal, which is mediating the atmosphere to adjust the compatibility between them. Hence the design proposal was derived. It centered on creating the professional-driving atmosphere that can be switched on in an individual monotonous setting, thus subconsciously improving cognitive performance. The design approaches consist of augmenting the useful environmental arousals, including the specific scene and the other people's presence, utilizing sound as the primary presenting medium. The future vision about the design concept emphasized the possible approaches to sharing individuals‘ physical space via sensory interactions.

In Chapter 4, the designed prototype introduced an attempt of the evaluation of the concept. The physical prototype setup consists of the audio pairs, the wearable devices, and the control server. This prototype was designed to create the acoustic professional-driving atmosphere, which is composed by the interactive sound design, including the scene white noise, live connecting audio, and the synthesized motion sound. This virtual acoustic space provides a specific professional scene and augments the feeling of others' presence by spatial distances, directions, interactions, and motions in real-time. The experiments designed two types to compare results the Original and the Applied. Then the user study assessed the prototype's performance from the perceptual questionnaires and physiological head orientation observations. In the end, these results evaluate the prototype's positive validity.

In summary, this research aims to help people alleviate the environmental-perceptual struggles to improve work productivity and mental satisfaction when doing professional duties in an individual monotonous setting, usually home. Though the prototype and experiments were still limited in the current stage, the design concept shows its validity in realizing the goal and expects to be further explored.

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References

[1] Andrews, E. Extended opening and more study spaces during revision and exams (2019).

[2] Bekerman, R. People in motion. ronenbekerman architectural visualization blog (2017).

[3] Blauert, J., and Lindemann, W. Auditory spaciousness: some further psychoacoustic analyses. *The Journal of the Acoustical Society of America 80*, 2 (August 1986), 533—542.

[4] Brown, T. C., and Daniel, T. C. Landscape aesthetics of riparian environments: Relationship of flow quantity to scenic quality along a wild and scenic river. *Water Resources Research 27*, 8 (1991), 1787–1795.

[5] Cimprich, B. Development of an intervention to restore attention in cancer patients. *Cancer Nursing 16* (April 1993).

[6] Cirillo, F. The pomodoro technique (2020).

[7] Communities, G. Community mobility reports (2020).

[8] Duffin, E. Share of online college students by distance from university u.s. 2019. Statista (US, June 2019).

[9] Gibson, J. J. The theory of affordances. In *Perceiving, acting, and knowing: toward an ecological psychology*, J. B. Robert E Shaw, Ed., Hillsdale, N.J. : Lawrence Erlbaum Associates (1977), pp.67–82.

[10] Gifford, R., and Ng, C. F. The relative contribution of visual and auditory cues to environmental perception. *Journal of Environmental Psychology 2*, 4 (1982), 275 – 284.

[11] Group, B. State of remote work: How remote workers from around the world feel about remote work, the benefits and struggles that come along with it, and what it's like to be a remote worker in 2019. Buffer (US, 2019).

[12] Group, G. The 2013 u.s. workplace survey. Ggensler Research-Insight (US, 2013).

[13] Group, V. The indoor generation: The effects of modern indoor living on health, welling and productivity. Velux Press (Denmark, May 2018), 4.

[14] hameed, s., pakarinen, j., valde, k., and pulkki, v. psychoacoustic cues in room size perception. *journal of the audio engineering society* (may 2004).

[15] Harald T. Schupp, CA Markus Junghfer, . A. I. W., and Hamm, A. O. Attention and emotion: an erp analysis of facilitated emotional stimulus processing. Lippincott Williams Wilkins (Greifswald,Germany, June 2003).

[16] Hetherington, J., Daniel, T. C., and Brown, T. C. Is motion more important than it sounds?: The medium of presentation in environment perception research. *Journal of Environmental Psychology 13*, 4 (1993), 283 – 291.

[17] JONES, J. M. U.s. remote workdays have doubled during pandemic. Gallup (US, August 2020).

[18] Kodama, E. C., Zhao, N., and Paradiso, J. A. Lightcloud: Future of dynamic lighting in the shared space. In *Proceedings of the Future Technologies Conference (FTC) 2020, Volume 3*, K. Arai, S. Kapoor, and R. Bhatia, Eds., Springer International Publishing (Cham, 2021), 1008–1017.

[19] Lang, P., Simons, R., Balaban, M., and Simons, R. *Attention and Orienting: Sensory and Motivational Processes*. Taylor Francis, 2013.

[20] Liebl, A., Haller, J., Jödicke, B., Baumgartner, H., Schlittmeier, S., and Hellbrück, J. Combined effects of acoustic and visual distraction on cognitive

performance and well-being. *Applied Ergonomics 43*, 2 (2012), 424 – 434. Special Section on Product Comfort.

[21] Merleau-Ponty. *Phenomenology of Perception*. Routledge, 1962.

[22] Nakane, H., Ono, M., Hasegawa, H., Ayama, M., Matsumoto, S., Koike, A., Takagi, K., and Kasuga, M. Perception of the priority between auditory and visual information presented with a certain delay on a wide screen. In *2004 IEEE Region 10 Conference TENCON 2004.*, vol. B (2004), 298–301 Vol. 2.

[23] Pasini, M., Berto, R., Brondino, M., Hall, R., and Ortner, C. How to measure the restorative quality of environments: The prs-11. *Procedia - Social and Behavioral Sciences 159* (2014), 293 – 297. 5th World Conference on Psychology, Counseling and Guidance, WCPCG-2014, 1-3 May 2014, Dubrovnik, Croatia.

[24] RANCHI. Concepts and components of environment. DR. SHYMA PRASAD MUKHERJEE UNIVERSITY (India, 1962).

[25] Raskar, R., Welch, G., Cutts, M., Lake, A., Stesin, L., and Fuchs, H. The office of the future: A unified approach to image-based modeling and spatially immersive displays. *Proceedings of the 25th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH 1998* (07 1998).

[26] Robert M. YERKES, J. D. D. The relation of strength of stimulus to rapidity of habit-formation. In *Punishment; Issues and Experiments*, E. Boe and R. Church, Eds., Century psychology series, Appleton-Century-Crofts (1968), 27–41.

[27] Romdenh-Romluc, K. Habit and attention. In *The Phenomenology of Embodied Subjectivity*, J. R. Thybo and M. Dermot, Eds., Springer International Publishing (Cham, 2013), 3–19.

[28] Sarigiannis, D. A. Combined or multiple exposure to health stressors in indoor built environments. WHO Europe (Germany, 2013), 1–82.

[29] Ulrich, R. S. Aesthetic and affective response to natural environment. In *Behavior and the Natural Environment*, I. Altman and J. F. Wohlwill, Eds., Springer US (Boston, MA, 1983), 85–125.

[30] Wiger, D. E. Yerkes-dodson effect in social facilitation tasks. In *ETD Collection for Fordham University*, no. AAI8918648, Fordham University (1989).

[31] Zhao, N., Azaria, A., and Paradiso, J. A. Mediated atmospheres: A multimodal mediated work environment. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies 1*, 31 (2017).

Appendix

A. Questionnaires for the Experiments

The Original Experiment:

Please rate by the following numbers to answer.

Very low Neutral Very high

-2 -1 0 1 2

1.How fast did you get into working- mode from the start?

2.How long did you keep focus?

3.How easily to focus again after realizing you‘ve been distracted?

4.How successful is your preventing-distraction awareness?

5.Have to ever tend to see the time when you wanna quit for a break, but then continue to work?

6.Do you satisfied with your working performance this afternoon

7.How compatible is your home environment for study/work?

8.How motivated is your home environment for study/work?

9.How undistracted is your home environment for study/work?

10.How pressured is your home environment for study/work?

11.Do you feel positive for staying alone for your working performance?

12.Do you like your room for study/working?

13.Do you like make time management for doing tasks?

14.Did you aware of self-behaviour to be in the working mode (e.g. Sit in a right posture)?

The Applied Experiment:

Please rate by the following numbers to answer.

Very low Neutral Very high

-2 -1 0 1 2

1.How fast did you get into working- mode from the start?

2.How easy to keep focus in a long time?

3.How easily to focus again after realizing you‘ve been distracted?

4.How successful is your preventing-distraction awareness?

5.Have to ever tend to see the timer when you wanna quit for a break, but then continue to work?

6.Do you satisfied with your working performance this afternoon?

7.How compatible about the sharing acoustic atmosphere to study/work?

8.How motivated by the sharing acoustic atmosphere ?

9.How undistracted sharing acoustic atmosphere?

10.How pressured about the sharing acoustic atmosphere?

11.Do you feel positive for the other‘s presence for your working performance?

12.How realistic did you feel about the other people‘s presence?

13.Did you like the Pomodoro time management (25min work / 5min break)?

14.Did you tend to be more aware of self-behaviour than alone (e.g make less sound or sit in working posture)?

15.Have you been aware of the wearable devices very strongly weakly?

For question 4: [Note: the success of preventing distraction means you have a tendency to distract doing something (playing phone, doing home chores, to eat something) but suddenly you realized something, so you give it up and start to focus on working again] If you have the successful moment of avoiding distraction,

please try to describe the process, and what you realized that help you prevent from distraction.

Some Samples for the Writing Feedback

participant 1: Whenever I tend to play my phone, the sound of other people drag me back, making me aware of the 25 minutes work period is not ending yet. And the 5 minutes break surely is an affective motivation for helping me focus on my work in the present.

participant 2: I successfully prevented distraction from playing my phone 2 or 3 times this afternoon. I was about to scroll my phone in the last two shifts of studying time and I realized someone were actually studying together with me, even remotely, by hearing the sharing sounds from Zoom, so ultimately I gave up playing my phone and to continue to study.

participant 3: A sense of formality to wear/ switch to start. I felt it's a good motivation for me to get out of bed and start my study routine, like to sit in front of my desk and open my computer.

participant 4: The sounds of others' turning their pages or writing reminded me of the fact that the environment I was in were for studying or working. Sensing that others are still working hard really pushed me to work a bit harder since I don't want to be left behind. The vibration or notification of my smartphone is the main distraction I came across during the test. Being afraid of the equipment was not working properly distracted a bit as well. But the sound of others' activities really pulled me back to focus on my own work.

participant 5: Although I still distracted to read web pages that not relate to study, but the others who made flipping papers sound reminds me the time is passing