

## THE WELL TEMPERED ENVIRONMENT OF EXPERIENCE

*(Neuro)Scientific Methods for Data Collection, Analysis & Visualization*

KRISTINE MUN<sup>1</sup>, DANE CLEMENSON<sup>2</sup> and  
BIAYNA BOGOSIAN<sup>3</sup>

<sup>1</sup>*NewSchool of Architecture & Design*

<sup>1</sup>*kmun@newschoolarch.edu*

<sup>2</sup>*University of California Irvine*

<sup>2</sup>*gclemens@uci.edu*

<sup>3</sup>*University of Southern California*

<sup>3</sup>*biayna.bogosian@gmail.com*

**Abstract.** In our ever increasing media(ted) world, the robustness of digital communication networked environment is transforming how we relate to our environment. With the rise of the Internet of Things (IOTs) and other ubiquitous mobile communication devices connecting our bodies to our environments, our spaces are requiring a recalibration of the ‘well tempered environment’. As technological devices are becoming seamlessly fused with our everyday lifestyles, habits and spaces, articulating experience is one of the most important topics to discuss in human-centered approach to design. This paper presents the initial methods for a data-driven process to enhance human experience as the central motivation. Combining knowledge from neuroscience and experimenting with embodied medias such as Virtual and Augmented Reality (+ MR), the inquiries into the human dimension is explored in novel ways. The aim is to show how data-driven experiments could be used to assist designers find better performative solutions and that new collaborations between scientist and designers are on the rise as data moves fluidly between bodies and spaces like air in our 21st century.

**Keywords.** Experience Design; Human-Computer-Interface; Emotion; Neuroscience; VR, AR & Mixed Reality, Human Centered Design, Data-Driven Design; Interactivity.

### 1. The Well Tempered Environment of Experience

In 1965, British architectural theorist Reyner Banham critiqued architects as covering technology in-between the walls, dismissing the real system that keeps the space tempered for comfort. Systems that lay between the walls, i.e. plumbing, ventilation and electrical, deliver all the necessary components for a well tempered environment but it was not championed by architects, leaving architecture unable to perform at its highest level. As such Banham described a ‘Well-Tempered Environment’, a triadic equilibrium of Human, Technology, and Environment

*Intelligent & Informed, Proceedings of the 24<sup>th</sup> International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2019, Volume 1, 573-582. © 2019 and published by the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA), Hong Kong.*

as the ultimate architecture. While two of the three branches are always an ongoing development of building technology, the third branch, Human, have been addressed the least in architecture. In the 1960s, the era of counterrevolutions and new visions to challenge authority gave rise to liberal expressions and cultural experimentations and the growing field of psychology contributed to rethinking social agendas a great deals of focus shifted into the subject of the mind. Concepts related to *experience* as a critical factor for design came through other disciplines than architecture, especially as a topic of Environmental Psychology in urban planning. In 1961 Jane Jacobs, a prime mover of enforcing ideas of social relationship related to planning layout, began to devise principles that became part of the practice of Environmental Psychology urban planning. Her infamous *The Death and Life of Great American Cities* (1961), Jacobs describes the problems of modernist urban planning strategies that hitherto followed strict rules devised through mechanical reductionist thinking that removed the organic complexities and diversity of a society. Just before, one of the more radically known cartographic mapping of the city that insists on human welfare would come from France in 1955-57 by radical group led by Guy Debord, *Internationale Situationists*. They created cartographic maps representing the organic 'drift' of the society to counter the *agenda* of maps set forth by government and the class who bids for them. Data collected and re-presented were internal dialogues of power and struggle of social, political and economic drives that created the experiential dimensions. User experience in architecture has gained most traction in recent years but the main relationship is in the discipline of Product design, where closer attention to ergonomics of objects directly affecting the human body is being explored. User Experience (UX) design, has been around since the 90s, when it was a term coined by cognitive neuropsychologist and designer Don Norman. User Experience can however be traced back to early practices in the Far East of Feng Shui about 4000bc and even to the ergonomics found in Greek text in 5bc by "Hippocrates (who) described how a surgeon's workplace should be set up. He refers to the lighting in the room, the surgeon's positioning - "the surgeon may stand or be seated, in a posture comfortable for him" - and the arrangement of tools; "they must be positioned in such a way as to not obstruct the surgeon, and also be within easy reach when required." (<https://careerfoundry.com>) In space planning and systems thinking, it is Taylorism invented by mechanical engineer Paul Winslow Taylor that have made the biggest impact in the 20th century of how efficiency of production is associated with a plan layout. "In 1911, he wrote "The Principles of Scientific Management" in which he asserted that systematic management is the solution to inefficiency. Although Taylorism was widely criticized for the way it reduced people to mere cogs in a machine, Taylor's focus on optimizing the relationship between humans and their tools is certainly reminiscent of some key UX principles." (<https://careerfoundry.com>) Today, to engineer our environment, designing with human at the center of design means to bring *experience* at the center of discussion and through new medias and mediated environments it becomes the major factor to the idea of living with wellness in our cities. With ubiquitous mobile devices gathering an enormous amount of data unlike ever before, our data-centric world of information is becoming more

critical to the enhancement of our lives. Our obsession with health is found with the proliferation of the current health-centric technologies massively popular with biotech wearable design. Bio-tracking sensors everywhere are playing a significant role in the development of smart homes, such as ‘ambient assisted homes’ for senior citizens.

## 2. Collaborative Practices

In the expanded field of science, neuroscience in particular is providing information that verifies that the relationships between the body and space are intricately connected. This project brought neuroscience and architecture together to form a dialogue and to aim for an evidence-based approach to human-centered design. Although the intuition and talent of a designer is not to be underestimated to afford us with great design, a look into data driven approach to human factors in the environment is becoming more and more important for a couple of reasons, 1) many building codes have been set long before evidence was possible, and 2) the concerns for health and wellness is becoming a greater concern in a pressure filled modern society. As the integration of technologies in our every day life is becoming more seamlessly fused, the field of architecture requires a wider collaboration with new disciplines. As a discipline that by nature operates as a collaborative practice, advances in new technologies are opening new relationships to other specialized disciplines of engineering. Conventional engineering related to architecture such as structural and mechanical engineering are enhanced by another branch that probes deeper into the body. By acquiring data of the *internal* body, gathering numerous amounts of biological and chemical information from an individual or groups of people, we are creating new dimensional relationships between the body and space that has its benefits, as well as limits. The collaborative team was formed based on the objectives of Dr. Mun’s year-long design studio in the Neuroscience for Architecture, Urbanism, and Design program at the New School of Architecture & Design in San Diego. The goal of this collaboration is to develop data-driven research projects on architectural or design elements to see the influence of these elements on human behavior.

## 3. Experiments, Methods and Data Collection

### 3.1. PROJECT BACKGROUND: UX @ SAN DIEGO AIRPORT

With the frequency of air travel increasing, airports today are crowded more than ever and they are no longer solely a transit center but becoming a ‘mini-city’ in itself. Situated just three miles from the bustling downtown, the San Diego International Airport with its prime location at the edge of the waterfront is one of these destination airports that is welcoming the local residents as well as the visitors. However, the prime location is also the reason for many challenges. Many factors surrounding the airport is a health concern, for the individual as well as its very close neighboring communities. The mounting pressures around the airport and the stresses felt by the chaos of travel procedures are causes for concern and the aim to design from the inside out, with experience as the primary inquiry, is

of critical matter. The students delved into researching this topic and were then asked to propose a hypothesis and the plan for data acquisition. The students created abstract 3D models of spatial constructs to be tested. Throughout, students conducted experiments methodically and collected project-specific databases.

### *3.1.1. Mapping Visual Continuity in Airport Design (Isovist)*

A graduate student, Madhavi Natarjan, focused on the problem of visual continuity in airport design and its relationship to the user's stress levels. This research examined the visual wayfinding strategy as a primary dictating architectural decision to create a better spatial mapping of the airport terminals through the visual perception. Therefore, the student focused on creating novel methods of spatial mapping in order to facilitate efficient movement within the terminal. There are two general approaches to such a project. The first is a case-study approach in which we use examples from the real world to try and determine if there are features of visual continuity already in place that can promote positive spatial navigation through the airport. Exploring what works and does not work can help to inform and allow us to create testable hypotheses. The second approach is more controlled and experimental.

Based on some of the elements we isolate from the case-study approach, we can begin to systematically investigate and test individual variables that we believe are most important to visual continuity at the airport. Even before we begin to choose airports for our case study, it is important to understand the metrics we are going to use to determine airport performance as it relates to visual continuity. How do we tell if an airport has "good" or "bad" visual continuity? While there several metrics we could use, some better than others, each one will have its own issues to consider. A simple straightforward metric is, how do people miss their flights? We might assume that because visual continuity is related to navigating through the airport, airports with less missed flights are easier to navigate and therefore have better visual continuity. By collecting data and comparing the number of missed flights across airports and we can visualize which have the most and least amount of missed flights. The caveat with this metric is that there are numerous other variables to consider that can interact with missed flights. Date, time of day and number of people at the airport are all going to affect the number of missed flights, regardless of visual continuity. Despite these other variables, there are several ways we can reduce the influence of these variables. For example, we can compare the number of missed flights across light (ex. Tuesday and Wednesday) and heavy travel days (ex. Thanksgiving). By comparing airports on both ends of the extreme, we can begin to rule out the effects of crowds. If visual continuity of the airport has a direct influence on missed flights, then differences between the comparisons will arise regardless of how crowded the airports will be. The other variable we should consider is the size of the airport as naturally a big airport is harder to navigate than a small airport. To account for this, we simply need to compare across airports with similar numbers of terminals or gates. Taking both of these concerns into consideration, comparing airports that are similar in size (number of gates) and across both heavy and light travel days, will allow us to identify airports whose ease of travel might be related to the visual continuity

of the airport layout. Once we have identified both “good” and “bad” airports, we can collect data, using methods such as isovist, to quantify the differences between airport layouts. As an example, for every unit of space, isovist provides a quantitative measure of visual space. In other words out in the open, one would have a full 360 degree view, whereas in a corner of a room, one would only have 90 degrees of view. We can average this number across every possible point in the airport to obtain a total visual continuity measure that we can use to compare across airports. Analyzing this data will help determine the individual elements of successful airports that are important for visual continuity.

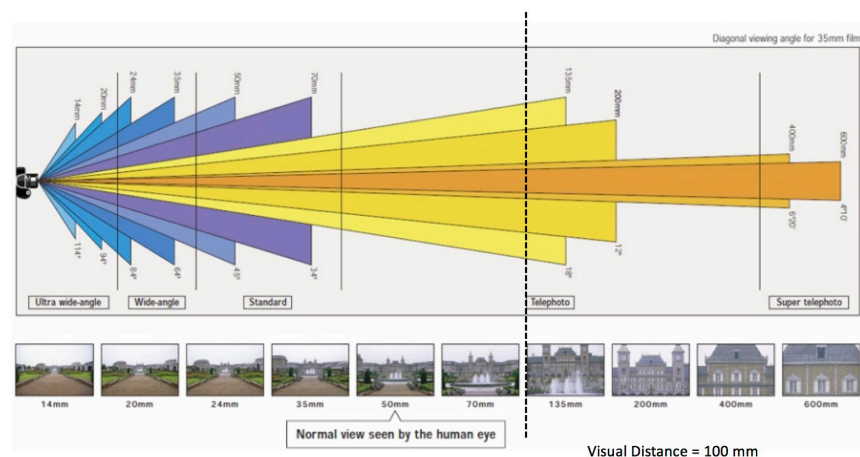


Figure 1. Viewing angles relative to distance.

After identifying significant factors of visual continuity, we can take a more experimental approach to isolate and systematically manipulate each element to gain a better understanding of its effects and ways to optimize it in terms of wayfinding and navigation. While data collection is in the early stages there are several variables such as viewing distance and viewing angle that we will consider. Viewing distance does not just refer to the total distance between an object and your eye, but rather the relevant distance. At what distance do people consider objects part of the background? While background objects can still provide spatial cues for navigation, people attend to them significantly less than objects in the foreground. Therefore, we have to understand both at what distance these objects begin to lose their relevance and if objects must be in the background, how can we make them relevant to the user.

Using methods like VR, we can place people in controlled environments and systematically alter the distance between users and objects (such as signs) to see at what point they begin to disregard background objects. Eye tracking can be used to analyze the amount of time people spend viewing objects at different distances. In neuroscience, a water maze is commonly used to assess spatial memory and wayfinding. In VR, participants have to find the location of an invisible platform

within an arena. In order to successfully navigate, participants have to use spatial landmarks (a mountain or tree) placed outside the arena. By systematically moving the landmarks further away from the arena and observing both their performance in the task and the amount of times they gaze towards the landmark, we can begin to understand at what distance people perceive the background as relevant. Using the same methods, we can also systematically change the objects themselves (color, shape, size, etc.) to better understand how we can make these background objects able to grab the attention of the user. Similar to relative viewing distance, we have to consider the viewing angle as it relates to the user. Unlike some animals that are able to see almost directly behind them, humans have a viewing angle closer to 120 degrees for binocular vision and an additional 30 degrees for peripheral vision (but no depth perception) from the front (Rafael, 2009). In terms of navigation, visual continuity may only be relevant up to 120 degrees and therefore a waste to consider anything close to 360 degrees. In addition, we also have to consider 3D space and vertical viewing angle. Elevation gives a significant advantage in spatial navigation and wayfinding as it allows us to see beyond physical objects on the horizontal plane. Using the same VR methods, we can design experiments to test how angles can influence both navigation through an environment or the placement of objects (signs) within the environment. The explicit and systematic design of these experiments can provide us with a data-driven approach to better understand optimal solutions of visual continuity in wayfinding.

### *3.1.2. Mapping Acoustics in Transitional Spaces*

Another student, ManYee Lok, focused on understanding how acoustics in transitional spaces, influenced by architecture and design, can affect human emotion.

There are four components to this question: sound, the interaction between architecture and sound, the interaction between sound and human emotion, and transitional spaces. Several of these components are well studied. In physics, sound itself is just an audible repetitive wave, with both frequency (pitch measured in Hz) and amplitude (volume measure in dB), which travels through a medium such as air. In terms of psychology or neuroscience, the sound that we hear is actually an interpretation of that wave, received by our ears and processed by our brain. We also have a solid understanding of the physics behind the predictable nature of how sound waves interact with design and materials. We have both concert halls that are designed to promote specific acoustic qualities and recording rooms created to restrict them. For this project, we want to focus specifically on how sound interacts with human emotion, as it pertains to transitional spaces.

A transitional space is a short-term space that connects one physical area to another physical area, such as a hallway. While transitional spaces can be thought of as a physical connection between two spaces, it is also an opportunity to pre-expose people to a new experience. A pre-exposure is exactly as it sounds; a small taste and chance to prepare someone for a future experience. For example, before starting a new school year children are often pre-exposed to their classroom. This short exposure gives them a chance to see the classroom, meet the teacher, and even interact with other classmates. This has been shown to reduce a child's

anxiety on the first day of school. A pre-exposure is a way to prime the brain to prepare for the upcoming experience, which has consistently been shown to reduce negative behaviors associated with the experience (Sars and van Minnen 2015). In the context of this project, the purpose of working within these transitional spaces is to use sound to help pre-expose people to the connecting space.

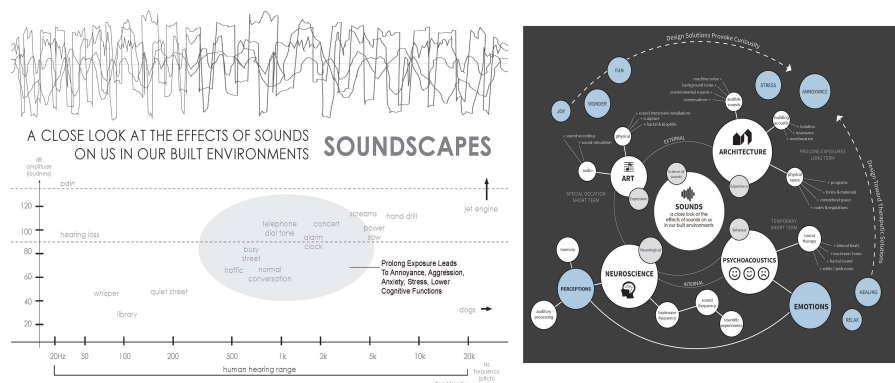


Figure 2. Effects of Sound in our Built Environment + Sound to Environment Relational Diagram.

All people perceive sound differently and therefore, the same sound can elicit two completely different emotions in two different people. To begin our project, we have to narrow down our question by first defining the emotion we are trying to evoke through sound. In other words, what do we want people to feel as they move through the transitional space? Focus? Excitement? Fear? Awe? Once we have defined the emotion, we need to find a metric to measure the emotion. Fear is a commonly used in neuroscience as there are well defined physiological behaviors that occur alongside fear. Elevated heart rate, skin conductance (sweat), pupil dilation, and even behaviors such as hesitation are linked with the fear response. Unfortunately, no single measure is going to be the best metric as many of these physiological responses are related to most emotions. Excitement can also lead to an elevated heart rate and pupil dilation, but maybe not hesitation. For this reason, it is important that we have a specific question so that we can design an experiment to address it. Once we have defined an emotion or situation to test, we can begin to collect data to explore the ways we can manipulate desired human emotions through sound and ultimately improve transitional spaces.

#### 4. Mixing Realities for Experience Design

Mixed Reality (MR), is the merging of physical and simulated worlds to produce hybrid environments and visualizations capable of real-time interactions. If we view MR as a spectrum between the domain of physical reality and digital reality, Virtual Reality (VR) and Augmented Reality (AR) mark the two ends of the spectrum. (Milgram et al., 1995)

The history of MR speculations and experiments go back to the invention of

stereoscopic photos and viewers in the 1830s. However, it was not until the early flight simulators called the Link Trainer in the late 1920s that scientists began to think about the concept of teleportation and immersive simulation environments as a valuable research agenda. This research was advanced during World War II by projecting flight data on aircraft as an example of early AR and was pushed to the next level in the VR spectrum by Ivan Sutherland's head-mounted displays in the mid-1960s. (Sutherland, 1968) Ivan Sutherland's MR research also became one of the main foundations of the MIT Media Lab which was funded in 1985 by the architect Nicholas Negroponte. Thus, the early conversations about the role of MR in architectural design were triggered by this adjacency. However, due to technological limitations, most of the early application was viewed as walkthrough opportunities for both the designers and the users. However, with the second wave of MR in the past decade, we are able to view the advancements in MR in parallel with mobile communication technologies, as well as big data and IoT conversations. Thus, it is essential for both the design and scientific communities to rethinking information communication methods in MR technologies.

#### 4.1. USER EXPERIENCE FOR NEUROSCIENTIFIC EXPERIMENTS

The history of MR cannot be separated from the history of user experience design. Particularly the parallel contributions of Ivan Sutherland to the fields of computer graphics, as well as computer-aided drawing. For Sutherland and his colleagues at the Media Lab, the main goal of this research was the desire to strengthen Human-Computer Interaction (HCI) in order to heighten the user experience. With the advancement of technology, we are currently able to utilize MR for various purposes such as architectural design and representation, game development, and information visualization. These areas of development have also triggered the scientists' imagination for the process of experiment setup, data collection, and analysis. In this context, a selected number of neuroscientists and behavioral scientists have been interested in exploring the process of experiment setup in these immersive environments. Currently, this research has mainly focused on VR as the scientists are able to completely isolate the user, teleport them to various experimental environments, and transmit instructions through audiovisual cues. In order to record the user's data, scientists have hacked into the standard headsets and developed hybrid devices, such as combining a VR headset with Electroencephalography (EEG) sensors. These hacked headsets present a vast opportunity for the advancements of interdisciplinary researches such as exploring user feedback in different architectural settings.

At the forefront of this interdisciplinary collaboration is the understanding that our collective input is required for the setup and evaluation of each student's experiment. Therefore, it has been essential to regularly meet with the students as a team in order to agree on the direction of each research and the required future steps. This teaching process has also entailed individual and group research reviews, writing reflections and technical tutorials in order to introduce the students to MR workflows. However, it has also been important to establish our individual contribution to each project based on our theoretical and technical backgrounds. This has allowed the students to view the relationship between their projects and



interests to each of our fields. It has also allowed them to learn how to ask specific questions from people with varied experiences.

Currently, each student has a diagrammatic workflow proposal reflecting the larger research agenda. They have also begun to create an immersive and interactive environment in the Unity3D game engine compatible with the standard VR headsets and various neuroscientific sensors suggested by the neuroscientist of the team. This step of the process places a high emphasis on playtesting in order to troubleshoot the technical aspects, as well as making the user experience seamless and curated. While the students have begun the data acquisition process with various brainwave sensors, the next phase of the course will delve into a high-level analysis and correlation of the behaviors in relation to architectural attributes.

#### 4.2. QUANTITATIVE DATA COLLECTION AND NEUROSCIENTIFIC ANALYSIS

At the core of neuroscience research is the collection of data and its interpretation. After all, the goal of neuroscientific research is to generate objective and unbiased answers to questions about the brain and human behavior. While there is value to qualitative measures of user experience, we as humans are constantly subject to outside pressures (social, environmental, etc.) that continually influence our responses. The body, on the other hand, is nothing more than a giant sensor that feeds both electrical and chemical signals to our brain. What our brain decides to do with that information is more complicated but the goal of this research is to tap into those initial signals at the beginning of the informational cascade to make informed and unbiased interpretations of the data. Once that data has been collected, we analyze it based on a priori hypotheses and apply statistical methods to determine if the results are real or if they could have emerged by chance. This critical analysis of the data is a crucial part of the scientific process and the way we separate fact from opinion. The goal of this project is to help the students collect quantitative data of human experience, analyze it and learn to make interpretations of the data based on their initial hypotheses. One of the simplest and most straightforward ways we plan to tap into human emotion is by measuring heart rate. When humans are excited (whether through fear or surprise) our heart rate rises. It is an uncontrollable reflex that prepares the body for the experience at hand. For example, using a simple heart rate monitor and a VR headset, subjects can be exposed to 1-min block exposures of experiences in VR. By teleporting subjects instantaneously between different conditions (experimental and control) and continually measuring their heart rate, we can average across these 1-min blocks to objectively measure how “arousing” each experience was for the subjects. Across many subjects, we can use statistics to reveal if these experiences are driving changes in heart rate and arousal. While not particularly complicated, these simple experiments are invaluable at teaching these students the value of quantitative data and the fundamentals of the scientific method.

#### 5. Conclusion and Future Directions

This paper demonstrates an interdisciplinary approach to data-driven airport terminal design through the process of neuroscientific experiment set-up in VR.

Throughout the paper, we have expanded on the background of the research, as well as the process of collaboration, information dissemination, and experiment setup. Currently the students are working on fine-tuning neuroscientific VR experiments which have been designed based on an extensive research on their specific topics and coupling brainwave sensors to the head-mounted devices. Monitoring the users' brainwave activities in the simulation environment will allow the students to find spatial organization attributes correlated with the recorded data. The future steps entail an in-depth analysis of the acquired data in order to highlight the limitations and possibility of each setup and adjust the VR testing environment accordingly. VR experimental environments allow for a complete isolation of the user and creating abstractions of the real-world scenarios. However, the complete immersion also limits the user from walking around in large spaces often due to limited trackable area or tethered headsets. Therefore, we aim to expand the research to AR environments using the same brainwave sensors in order to examine urban and mobile explorations. The goal is to bridge the gap between quantitative and qualitative design parameters and build context-aware environments that enhance the human experience.

## References

- "Fascinating History of UX" : 2014. Available from <<https://careerfoundry.com/en/blog/ux-design/the-fascinating-history-of-ux-design-a-definitive-timeline/>> (accessed 10 December 2018).
- Banham, R.: 1984, *Architecture of the Well-Tempered Environment*, The University of Chicago Press.
- Barrett, L.F.: 2017, *How Emotions Are Made*, Houghton Mifflin Harcourt.
- Eberhard, J.P.: 2009, *Brain Landscape: The Coexistence of Neuroscience and Architecture*, Oxford University Press.
- Jacobs, J.: 1961, 1992, *The Death and Life of Great American Cities*, Random House, New York.
- Milgram, P., Takemura, H., Utsumi, H. and Kishino, F.: 1995, Augmented reality: A class of displays on the reality-virtuality continuum., *Telemanipulator and telepresence technologies. International Society for Optics and Photonics.*, **2351**, 282-293.
- Norman, D.: 1988, *The Psychology of Everyday Things*, Basic Books.
- Norman, D.: 2013, *The Design of Everyday Things*, Basic Books.
- Rafael, N.: 2009, The Optical Design of the Human Eye: a Critical Review, *Journal of Optometry*, **2**, 3-18.
- Sars, D. and van Minnen, A.: 2015, On the use of exposure therapy in the treatment of anxiety disorders, *BMC Psychology*, **3**, 26.
- Sutherland, I. E.: 1968, December, A head-mounted three dimensional display, *Proceedings of the December 9-11, 1968, fall joint computer conference*, **part 1**, 757-764, ACM.