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Exploring the Intersection of Human Emotions and Space Experience

Pranav Mistry[a] and Diya Gupta[b]

[a]Masters in Engineering Management, Trine University, Angola, Indiana, US.
mistrypranav1996@gmail.com
[b]Dept. of Interaction Design, Karnavati University, Gujarat, India.
ua2125193@karnavatiuniversity.edu.in

Abstract. A multisensory experience involves mind and body with intentionally designed environments that also engage all five senses. Spatial elements impact human psychology, well-being, and productivity. To assess the positive relationship between space and emotions, a survey of 25 people (18-40 years old) was conducted in 3 stages. The first stage evaluated their perception by analyzing how a human interprets their surroundings. Individuals described smell as their preferred sense despite sight being the dominant one. It also stated memories influence present spatial experience and how a human brain forms an episodic memory every time an emotion is triggered. On listening to low musical notes depicting sadness, users felt relaxed supporting Russell's affect theory. In the second stage of validating the role of senses, a user was asked to describe their journey of adapting to a sensorial space. As per Concepts, Processes, and Principles (CPP) & Critical Decision Method (CDM), the findings challenge the impact of the dominance of sight revealing it is the fastest but least accurate senses to align with human moods. In their journey, the probability of critical error of miscalculated stimulus triggering undesired emotions was surfaced by the SHERPA method. In the last stage, the cognitive workload for being productive was measured using NASA TLX. Users' mental workload and factors that affected it were analyzed. In today's world, with busy and complicated lives, innovative smart technology gives a new direction to a multisensory environment. In conclusion, this study proposes the integration of emotional IoT to be used to bridge the gap in empathetic interaction and the field of spatial design using human senses.

Keywords: human emotions, space, sense, perception, cognition, emotions in IoT.

1 Introduction

"In memorable experiences of architecture, space, matter and time fuse into one singular dimension, into the basic substance of being, that penetrates our consciousness. Architecture is the art of reconciliation between us and the world, and this mediation takes place through the senses"- Finnish architect Juhani Uolevi Pallasmaa (2005).

Spatial perception involves the integration of multiple sensory modalities, including sight, smell, hearing, touch, and taste, to provide a comprehensive understanding of one's surroundings. By engaging all five senses, a space can be infused with a three-dimensional quality. However, in our perception and cognitive processes, the sense of sight often takes precedence, leading to the neglect and inhibition of other sensory inputs. Therefore, it is essential to carefully manage various factors such as sound, light, smell, objects, forms, and temperature to shape the spatial experience effectively. Designing an intentional environment can stimulate both the mind, through perception and cognition, and the body, through physical sensations, creating a meaningful experiential journey. (see fig.1) (Reghukumar A, 2019). Throughout such multisensory encounters, individuals form memories that are deeply intertwined with the places they have visited.

Fig. 1 The system of mind, body and environment

The link between spatial design and humans has equal parts functionality and psychology. The psychology of spatial design encompasses the dynamic interplay between individuals and their environments. It explores how different aspects of a space impact the human mind and cognitive processes. The arrangement of space significantly influences mood, emotions, behavior, and overall physical health. A well-designed space should not only be aesthetically pleasing but also contribute to people's emotional well-being, ensuring that it elicits positive feelings and sensations. Author Chloe Taylor (2016) explains that the idea of a multisensory environment is not something new, the conception of this idea dates back to traditional times just without the help of technology - the Indian Vaastu Shastra, the Chinese Feng Shui, etc. While traditional architectural practice has been dominated by sight, because of the rise of neuroscience, scientists suggest spaces affect humans' multisensory mind. Research has demonstrated that spatial design elements possess the capacity to elicit either favorable or unfavorable emotional reactions from individuals. These discoveries pave the way for the intentional manipulation of decorative elements within spaces, aiming to foster creativity, tranquility, and joy. (Taylor C, 2016).

Components are environmental stimuli that trigger emotional responses according to the user's interaction with the space using their senses. Vision and hearing provide us with perception of events or objects in far spaces. Touch, smell, and taste provide insights into the immediate environment, known as haptic space. The sense of smell triggers reminiscences in the visual memory, evoking forgotten images and subconsciously transporting us back to spaces erased from retinal recollection. The tactile sense conveys intimacy and proximity, contrasting with the eye's role as the organ of distance perception. While the eyes observe and regulate, the haptic architecture connects and harmonizes.

The goal of this investigation is to gain deeper insights into the development of inclusive spaces accessible to all individuals. It aims to explore the significance of sensations and emotions in shaping architectural designs. The primary aim of this research is to analyze the present status of emotional considerations within the realm of spatial technology.

When a human enters a space, the human brain perceives the spatial (physical attributes, layout, lighting, colors, arrangement of objects, etc.) and emotional (elements aligned with their mood) environment around it. Then it analyses using mental strategies like memory recollection and pattern recognition. Based on this cognition, it gives a response. This may include adjusting and adapting to the space to influence emotions and interaction. This whole process majorly focuses on functions like, perception, attention, memory, information processing, reasoning and learning. Human brain has an episodic memory, which recalls and recognizes the past interactions in a space. This influences the actions and reactions. Every outcome from such interactions registers a new memory as a learning which forms a mental model of the related space. This may also be a cause of biased attention. This configuration is called the Circumplex of Affect, since the pattern was circular (see Fig 2). It is proposed that all affective states originate from two fundamental neurophysiological systems, one pertaining to valence (a continuum of pleasure to displeasure) and the other to arousal or alertness. Arousal indicates the level of a person's involvement in reaction to a stimulus. Also, people have a different understanding of emotions, depending on their social and cultural background. (Russell, 1980).

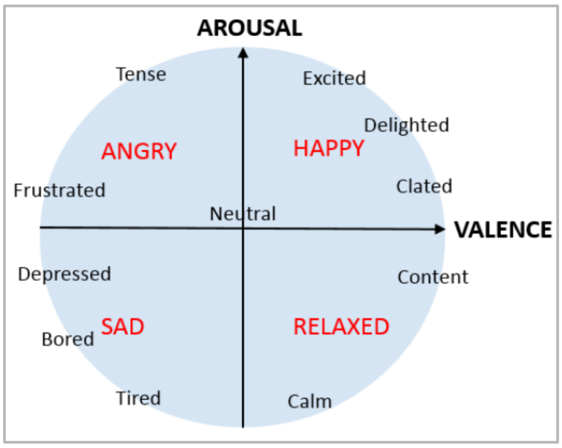

Fig. 2 Russell's circumplex of Affect

1.1 Context of Emotions and Wellbeing

Emotions are inherently connected to various work-related issues, including productivity, interpersonal relationships, stress-related sick leave, leisure pursuits, and sales performance. According to recent studies, constant negative emotions lead to heart disease, headaches and other health issues. Lately, social problems appear to be on the rise due to the absence of proper diagnosis for psychological issues such as depression and anxiety. Emotion recognition techniques can improve both psychological therapy and human-computer interaction. (Shu, L. Yu, Y, Chen W. Hua, H, Li Q. Jin, J. and XU, X, 2020). Offering a personalized experience that caters to the user's present requirements and anticipations, while also evolving to enhance user satisfaction, is a key objective. The prospect of leveraging the user's interaction history with the system to anticipate their current emotional state and deliver an adaptable response holds promise for the future of IoT. (Alaman, J and Lacuesta, R. Magarino, I. Lloret j, 2020). A crucial aspect of this system is ensuring that users can define their ultimate desired emotional state, which will be achieved through the utilization of intelligent algorithms.

1.2 Architecture of Emotions

Space components arouse people's emotions in two ways. a) Emotional expression- deals with the user's emotions by itself in space. b) Emotional exchange- Interaction of user and space. (Reghukumar A, 2019) Now Emotional architecture has three main parts (Caballero, A. Rodrigo, A. Pastor, J. Castillo, J. Monasor, E. López, M. Zangróniz, R. Latorre, J. Sotos, A. 2016):

1) Emotion Detection involves the examination of collected patient data. Geometric facial attributes are derived from the contours or prominent points of key facial elements like the mouth and eyes.

2) Emotion Regulation provides individuals with various musical compositions and color/light configurations. It examines how factors such as the timing of emotional occurrences and their expression are impacted.
3) Emotion Feedback Control establishes a feedback control loop to evaluate the impact of emotion regulation on detection.

1.3 Emotions in IoT

The Internet of Things (IoT) comprises a network of interconnected devices equipped with sensors and networking capabilities to collect and share data. Presently, these systems can adjust or tailor themselves according to users or their requirements. The emotional IoT system aids in forecasting user emotions, offering real-time updates based on user reactions, and adjusting environmental conditions to tailor the user context and achieve the user's desired states. (Alaman, J. and Lacuesta, R. Magarino, I. Lloret, J. 2022). As per the methodology outlined by Javier Navarro Alaman and additional researchers, there are six stages to implement in the creation of an IoT system. This framework can similarly be utilized for the development of an emotional IoT algorithm. The stages are (Alaman, J. and Lacuesta, R. Magarino, I. Lloret, J. 2022):

1) Establishment of System Requirements and Data Selection: Identify the context in which the system will operate, including user characteristics, activities to be monitored, frequency, and location. The literature suggests that the Russell Affect Grid is a potentially suitable tool for examining emotional states, as it focuses on the dimensions of valence and arousal.

2) Study of Device Requirements: Determine the sensors and devices necessary to gather the identified data.

3) IoT System Logic and Architecture: Develop the logical processes and framework for the IoT system.

4) Data Analysis: Analyze the collected data to understand how users' emotions are influenced. The algorithm examines the relationships between data and emotional changes, as well as the behaviors that provoke these changes.

5) Data Prediction: Select predictive models to analyze the correlations between system performance and user data obtained in the previous stage. This involves structuring the data, representing it, interpreting it, and evaluating the chosen model.

6) IoT System Implementation: Design an algorithm that enables the IoT system to recommend or adjust itself (redefining activities or IoT actions) to help users achieve their objectives.

1.4 Smart Environment

An ecosystem of the physical world with an invisible interconnected network of sensors, displays, and IoT embedded in everyday objects to provide a seamless experience to users. It is a digital technology with no intention of hindering the actual world experience. Smart environment works on reliable networks of communication through internet, Bluetooth, learning human behavior and various other factors. Smart home technology has introduced a variety of smart devices such as security, refrigerators, lights, alarms, air purifier, sound systems and thermostats. With this technology flourishing in every range of products, a human experience can be enhanced when devices become empathetic towards humans. When human emotions are also studied. Emotion regulation refers to the processes by which emotions are analyzed and influenced how they are experienced and expressed. When the audience is upset, the whole mechanism is to shift it to the pleasant side of Russel's valence-arousal affect grid.

Smart home devices and virtual assistants such as lighting, air purifiers and Alexa provide a more intuitive way to interact with the technology we use every day. Despite all these advancements, smart devices seem to:

1) Lack ability to empathize towards human emotions- While they can respond to voice commands and provide contextual information, they are unable to interpret tone of voice or body language that play a vital role in human communication. This limitation is particularly evident when it comes to empathetic responses and meaningful conversations.

2) Lack of common-sense reasoning- Human common sense is a product of their lived experiences, cultural context, and innate understanding of the world. In contrast, smart devices lack the innate human ability to infer, deduce, and apply logical reasoning based on incomplete information. (ChatGPT, personal communication, August, 2023)

Progress has been made in overcoming such obstacles, with numerous concepts still under development. The industry is integrating IoT with sensor technology to gather data on vital signs such as heart rate, blood pressure, and temperature, enabling the determination of an individual's emotional state. For instance, medical smart mirrors represent an evolution from traditional mirrors, capable of detecting medical indicators like facial expressions, emotions, skin conditions, and body posture. (Bianco, S. and Celona, L. 2021). Another innovation is a garment designed at the University of New South Wales, Sydney, which illuminates according to the wearer's mood. Equipped with sensors that detect pulse, muscle tension, and proximity, the clothing translates physical cues into colored light displays that mimic emotions such as excitement, anticipation, and nervousness. (Verma, S. 2021). Furthermore, a smart baby monitoring system, utilizing IoT and machine learning, offers real-time updates to parents, including room temperature, humidity levels, and cry detection monitored by various

sensors. (Alam, H. Burhan, M. Gillani, A. Haq, I. Arshed, M. Shafi, M. Ahmad, S. 2023).
Additionally, a bracelet has been developed to gauge emotions through electrodermal activity. Its display reflects heightened emotional states by measuring subtle changes in skin conductance and temperature.

Development of the technology will depend in large part on companies understanding the value that it can offer. It's not the underlying technology that needs to evolve; it's the way that it is packaged and marketed to a particular industry. Although privacy concerns have little technical merit, the devices are incapable of processing unless the trigger word is recognized. Main challenge is the technologically fragmented ecosystem of connected homes. The smart home is currently connected by a variety of networks, standards, and devices, which causes interoperability issues and makes it difficult for the consumer to set up and manage numerous devices. (Britt, P. 2023).
Consumers will struggle choosing smart home systems until compatibility issues are resolved. "Closed ecosystems" are somewhat a short-term answer to this issue. They are made up of devices that can be controlled from a single point and are compatible with one another. (Tropf, J. 2017)

Choosing an object that the target audience already owns is a smart choice. Hence, it appears evident that converting an ordinary device into a smart technology with the capacity to detect and assist users emotionally, both in the short and long run, is a logical step forward. (Bianco, S. and Celona, L. 2021)

2 Methodology

Questionnaires and NASA TLX worksheet is used. A structured approach was opted for the survey.

Stage 1: Beginning with some experiential senses evaluation cycle to validate the perception about control, vision and haptic space. In regards to environment and emotions, 'imagine the best space for you to be productive?' and 'suppose you are frustrated because of deadlines, what surroundings do you expect yourself to be in?' were asked. They responded to these questions by explaining their emotions in a particular space.

Stage 2: Then human cognition and errors analysis to validate the relationship between emotions and space and probability & criticality of errors occurring there. For cognitive task analysis, Concepts, Processes, and Principles (CPP) & Critical Decision Method (CDM) were followed. For human error identification, 'Systematic Human Error Reduction & Prediction Approach (SHERPA) was followed.
Stage 3: To analyze the mental workload individuals, face when experiencing a space, the NASA TLX method opted.

Almost 25 field surveys were conducted in person that are considered appropriate for emotion evaluation.

3 Results

A) Primary senses: People were asked about the order of sensory experience (table 1). Although sight being considered the dominating sense, people still chose other senses (here, smell) as their preferred mediums.

Table 1

Ratio of primary senses identified.

Age Group	Primary sense	Ratio
18-25	Sight & smell	7:3
25-40	Sight & smell	3:2
40+	Sight	-

B) Sight and feel: An image was shown in the survey to analyze how people perceive the space with the mood of action to be performed there (fig. 3, 4).

Fig 3 A living room with different lighting.

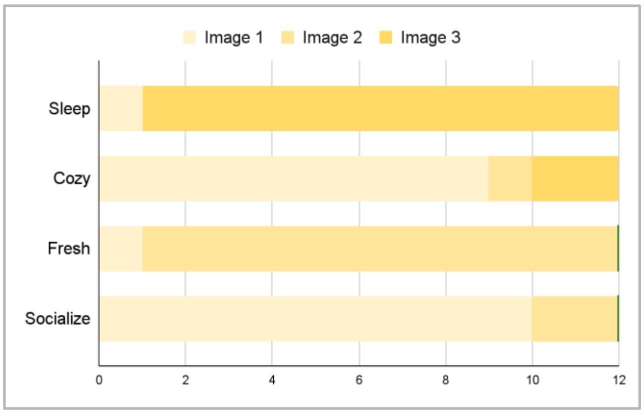

Fig 4 Mood of action to be performed.

A single space triggered a variety of moods, stating it is based on past experiences and their cognition and perception.

C) Hear: A low note sound was played to observe the emotions it triggered.

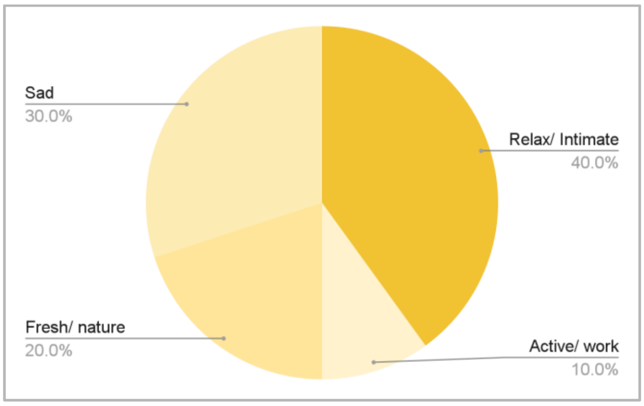

Fig 5 Emotions triggered on listening to a sound.

Low notes depicting sadness relaxed 40% of users. The other 30% had a different effect than sadness (fig. 5). The positive outcome states how every stimulus has a purpose in dealing with people.

D) Cognitive task analysis: An individual was asked to describe how their senses perform in a space (fig. 6).

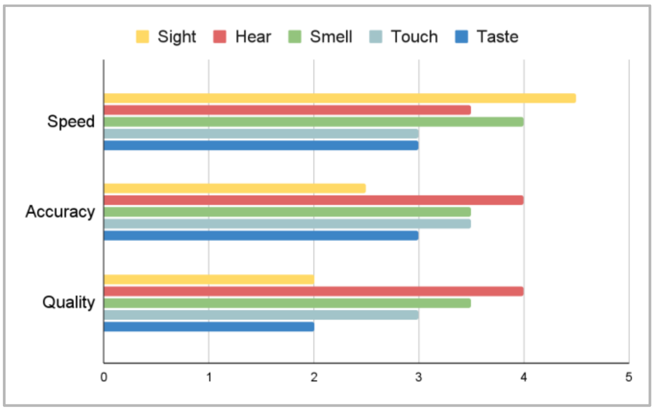

Fig 6 CTA factors on altering sensory mediums

Results were shocking as traditional designs have been concentrating on sight, but here the person feels sight is the fastest but least accurate to align with the emotion. Whereas auditory changes excel in accuracy and quality.

E) Human error identification: Possible errors at different stages of the task were identified and analyzed (fig. 7).

Potential errors	Error category	Consequences	Recovery	Probability	Criticality
Primary sense- vision might dominate other senses.	Action error	Other senses might not align with the current mood.	Intensify other senses more as compared to sight to balance all.	■■■	■■□
Misinterpreted stimuli triggers the emotion.	Communication error Retrieval error	Intensity of emotions might heighten up.	Personalised stimuli.	■■□	■■□
Mood might lead to confirmation bias.	Action error Communication error Selection error	Stimuli no longer has original impact now.	Constant real time updated stimuli.	■■■	■□□
Pattern recognition & memory recollection might cloud the decision.	Retrieval error Selection error	Barricading the chances of new experiences.	Align the stimuli with earlier experiences with smooth and not drastic changes.	■■□	■■□
Miscalculated stimuli might worsen the trigger.	Action error	The purpose behind the designed environment remains unfulfilled.	**Constant real time updated stimuli.**	■■□	■■■
Unclear formation of memory	Communication error	Experience is unlikely to be remembered as it was desired.	The end purpose has to be to please the mood, so revise the pre-recorded data for next time.	■□□	■■□

Fig 7 SHERPA for human error analysis

Most of the errors were related to miscalculated stimulus due to memory bias and hyperactive senses. However, the overall probability and criticality was medium which accurate real time updated stimuli tend to overcome.

F) Mental workload evaluation: A task was described to 5 individuals and they had to compare and rate (on a scale from 0 to 100) factors affecting their mental workload to be productive (fig. 8a, 8b)

	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration Level
User 1	0	5	5	2	2	1
User 2	3	0	3	3	2	4
User 3	4	0	1	4	4	2
User 4	2	0	2	4	2	5
User 5	4	3	1	3	2	2
Total	13	8	12	16	12	14

Fig 8a NASA TLX- Compare sources of workload

	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration Level
User 1	30	80	80	10	40	40
User 2	60	15	70	15	50	50
User 3	15	5	60	5	30	25
User 4	80	70	50	15	40	50
User 5	35	80	20	80	70	20
Total	220	250	280	125	230	185
Weighted*	135	320	158	77	104	116

Fig 8b NASA TLX- Rating scales

The calculated weighted workload was 46.07, which is considered a medium cognitive workload (as per NASA TLX mental workload evaluation). The survey showed how every individual has a different approach when experiencing a space. Factors like performance, mental demand, effort, frustration, and temporal and physical demand affect their cognitive workload. Out of all of these, physical demand seems to affect the most and performance the least.

4 Discussion

One of the main goals of this experiment was to understand the relationship between human emotions and space design based on sensory experience. It was predicted that sight would be a dominating sense and because it has been a focus since traditional practices it would be most effective, but this turned out not to be the case. Our data suggests that sight is the fastest but least accurate to align with human moods. Moreover, our brain adapts every time perception is changed physically as human strategies behave accordingly. Thus, physical demand becomes a factor in increasing the mental workload. The other direction that findings could be helpful is how past experiences of an individual influence how they interpret the space around them. This happens because the human brain recalls previous experiences and starts making sense of the surroundings with the help of its episodic memory. Also, like previous studies based on Russell's mood of affect, our results also seem to state that the purpose behind every stimulus is to please the user, hence there could be a need for real-time updates of human mood. Adding to this, it appears that there are chances of some medium criticality human errors of miscalculated stimulus and thus triggering even worse emotions.

Although these surveys not conducted on 40+ age groups, this will only affect the results in terms of analyzing the cognition of elderly people, who anyways have been habitual of living in traditionally designed spaces. This occurred because they seemed to be unfamiliar with the concept of senses and perception in the initial stage of my survey. I thus plan to repeat my experiment in future work if at all elderly tech-savvy people become the target audience. However, analysis of the uncontaminated samples

(27 in total) supported the initial hypothesis that space affects human mood based on their perception, cognition, and past experiences.

5 Conclusion

I assessed the positive relationship between space and emotions. It suggests that innovative smart technology in an environment gives a new direction to multi-sensory experiences. All correlated senses make the user unknowingly enter an emotional state. Therefore, based on every individual's needs and preferences, there is a need for a personalized experience to enhance the field of spatial design. Existing smart devices seem to lack the ability to empathize towards human emotions (tone of voice, body language) and common-sense reasoning (cultural context). This is where emotion IoT needs to intervene. Not a robot to perform actions, but a technology that makes existing devices smart. Although there may be user privacy concerns, releasing it in the market with ethical constraints can resolve the issue.

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