Neuroscience Applied to Architectural Design

PARKASSOCIATI

Quote by Sarah Williams Goldhagen - The Salk Institute by Louis Kahn - Photo by Adam Bignell 2019

Index

01 Introduction

What is N.A.A.D.?

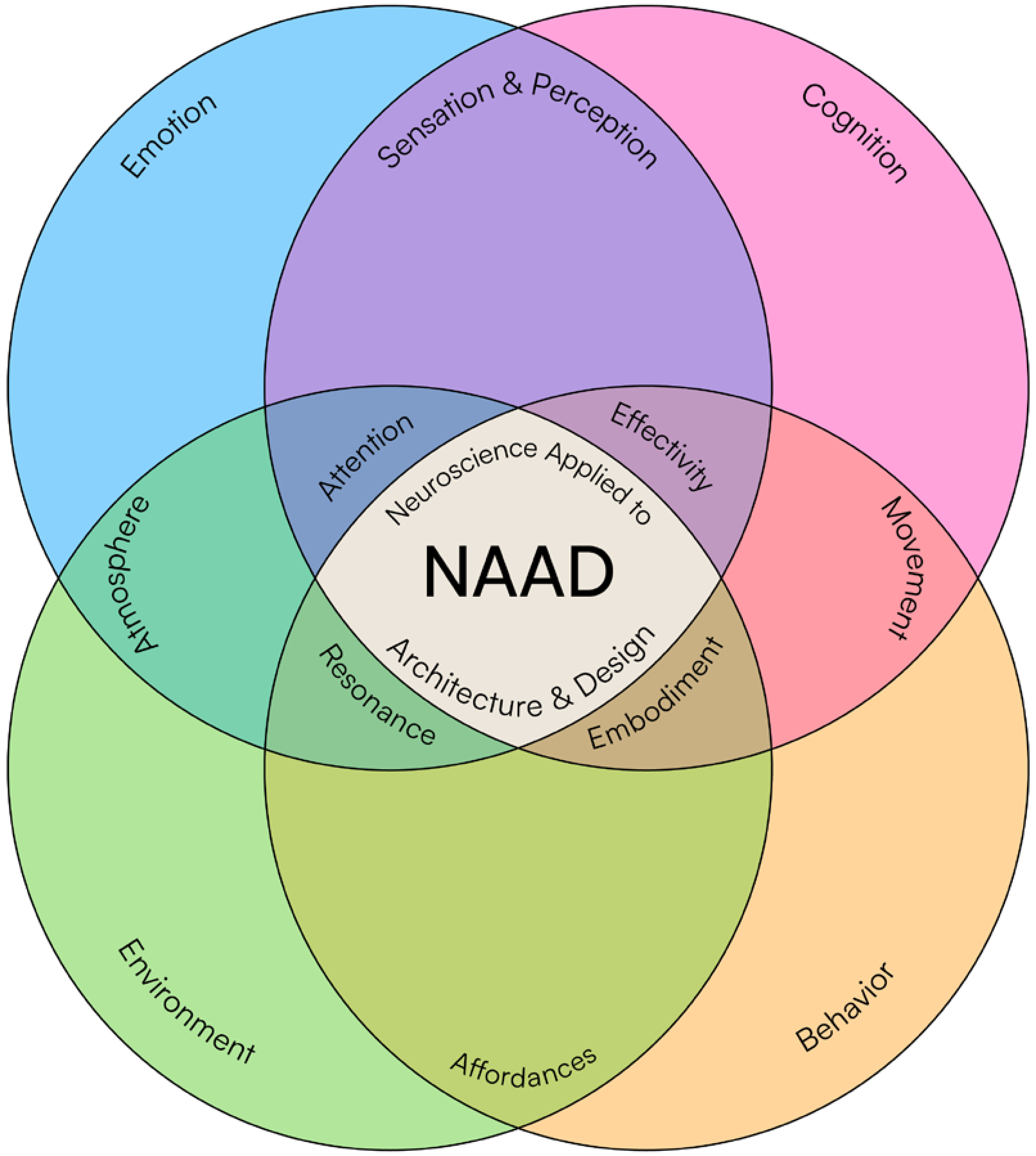


Diagram 1: The N.A.A.D. Web Diagram

Brief Overview

Neuroscience applied to architecture and design (N.A.A.D.) is a niche and new field that explores the inextricable link between the brain, body, and environment. The primary question for this field is, “How does the built environment impact our well-being, including emotional, mental, and physiological health?”

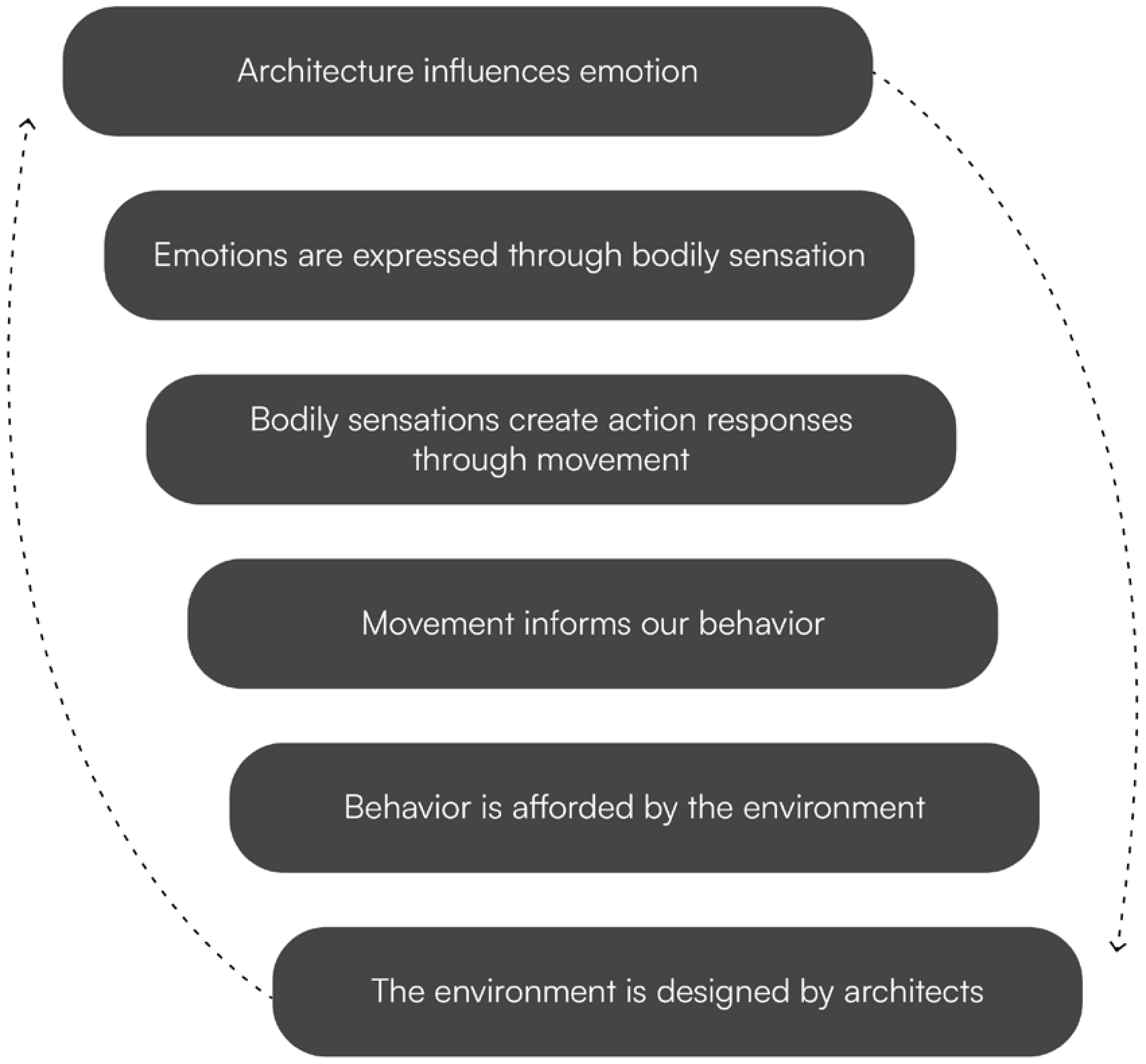
N.A.A.D. extends the natural intuition of architects and designers into strategies informed by a growing body of scientific literature and research. By actively and creatively implementing neuroscientific principles into design, we can create healthier buildings that inherently promote well-being at every corner by meeting the dynamic cognitive, behavioral, and emotional needs of users and building occupants.

The N.A.A.D. Web Diagram provides an overview of this topic, how cognition, behavior, emotion, and the environment are deeply intertwined and cannot be examined without acknowledging their inherent connection. Throughout the course of this presentation we will uncover how to leverage insights from each topic of the diagram to improve the built environment.

“Architecture is the art of reconciliation between ourselves and the world, and this mediation takes place through the senses.”

Quote by Juhani Pallasmaa - The Zentrum Paul Klee Museum by Renzo Piano - Photo by Ricardo Gomez Angel in 2017

In theory



This “theoretical equation,” shown in Diagram 2, allows us to expand upon the N.A.A.D. Web Diagram and connect each topic to the other. Observed is a circular interaction between architecture, emotion, cognition, behavior, and the environment.

Architecture inevitably influences the emotions of those who experience a particular space. Emotions are expressed through bodily sensations or signals that trigger action responses. How we respond or move within a space is provided by the inherent features of the environment, which are carefully designed by architects.

In sections to come, we will dive into the neural mechanisms, processes, and expressions of emotion, bodily sensations, movement, behavior, and how they relate back to the environment through architecture and design.

Diagram 2: Theoretical Equation of N.A.A.D.

In Practice

Diagram 3: *Physiological Markers of Environmental Experience*

In recent years, N.A.A.D. has evolved to include direct experimentation with architectural features and their effects on both bodily measures and reports of subjective experiences. For example, researchers can measure and compare skin conductance (sweat), cortisol levels (stress), brain activity, heart rate variability (arousal), and other physiological responses to different environmental simulations, both real and virtual. Frequently, information collected through questionnaires and conversations (qualitative data) with research participants are incorporated to provide additional contextual support for the quantitative data.

For example, the photo on the left shows the research lab of Bob Condia and Elisabetta Canepa at Kansas State University. Here, the primary goal is to "conduct series of experiments to investigate emotional responses to architectural atmospheric qualities." And they have accomplished just that and more by producing many studies involving specific architectural features and their implication on human psychology and physiology. Their "RESONANCES" Project can be thought of as the future of N.A.A.D.[1]

1 "RESONANCE Project." Kansas State University, 2022. www.resonances-project.com.

Limitations

Applying N.A.A.D. calls for the creative interpretation of current research on the matter. While using the latest scientific findings to inform design is valuable, it is important to recognize that this field is still under construction. Much of the research focuses heavily on the visual system, often neglecting how other sensory systems are influenced by environmental factors. Studies also tend to isolate specific features or sensory systems, which may not fully capture how we experience the world holistically. Additionally, experimental results can be influenced by numerous factors that complicate their interpretation and applicability across different contexts.

However challenging our task, the goal of this presentation is to inspire thoughtful design by using scientific insights on how architecture impacts well-being, as indicated by bodily markers of stress and health. Due to the limitations of current research, we will pose questions to bridge neuroscience and architecture, relying on you to translate these ideas into effective design solutions that elicit anticipated physiological responses from building occupants.

Relaxation in Luxembourg Garden - Photo by Alina Rossoshanska in 2023

Benefit

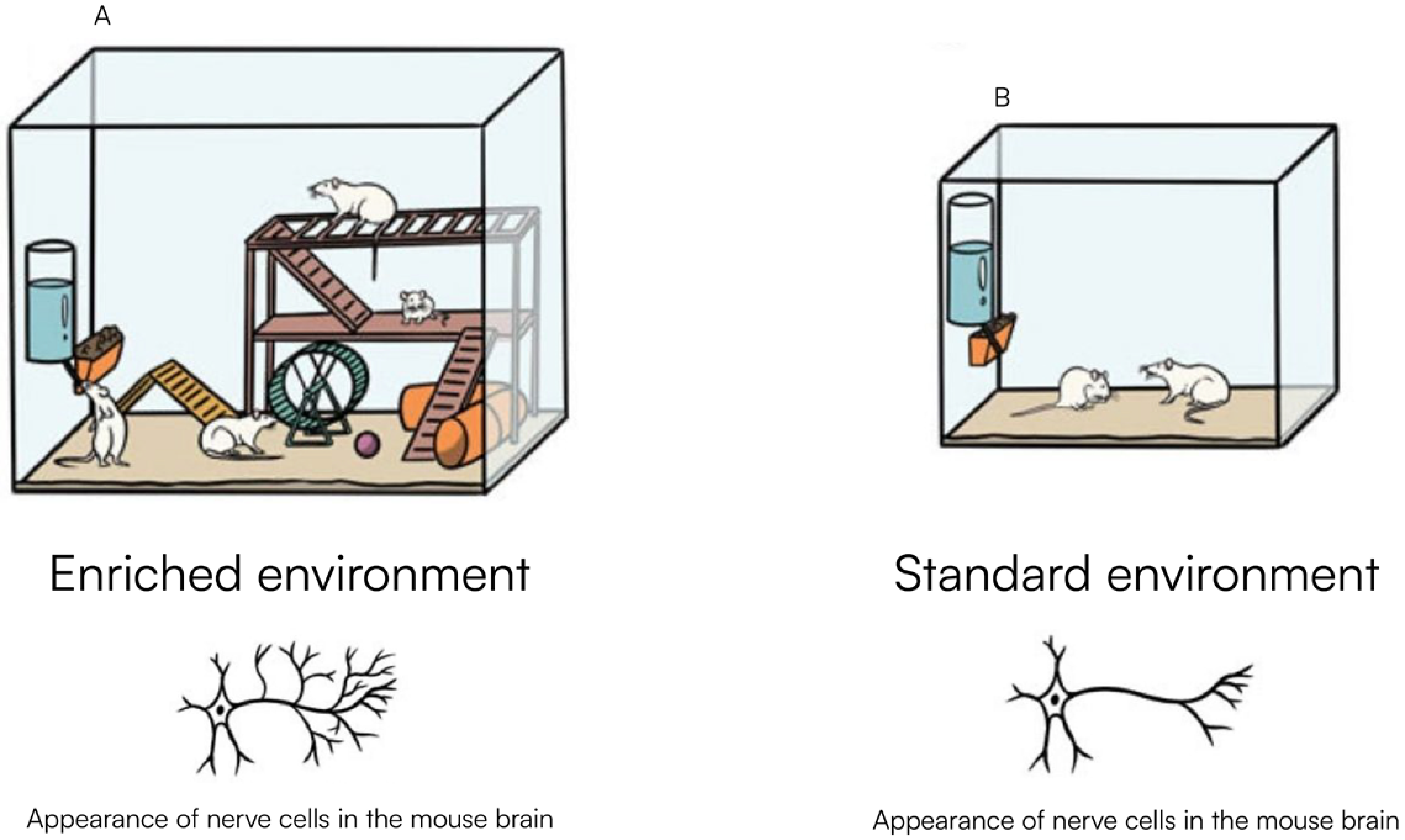


Diagram 3: Sensorimotor Environmental Enrichment for Mice [3]

N.A.A.D. has the potential to produce environments capable of enhancing learning and memory, reducing stress, promoting health and restoration, implementing exercise through exciting movement and engaging all the senses.

The most informed example of this concept involves experimental research with mice in enriched environments. Mice who spent the early parts of their lives in these enriched enclosures scored better in a variety of tasks compared to the ones who lived in the control environments. In this example, the improvements observed in cognitive performance is directly attributed to the design of the space, as it affords greater opportunity for social interactions, cognitive stimulation, and exercise.[2]

If the idea of enriched or "multisensory" environments works to improve performance in itty-bitty mice, one can imagine a similar yet profound impact for humans. Architects and designers must construct spaces rich in engagement, memorability, and emotional value to move beyond the mere visual realm and extend into the multisensory world using N.A.A.D.

2 Yuan, Zhenyun, et al. "An Enriched Environment Improves Cognitive Performance in Mice from the Senescence-Accelerated Prone Mouse 8 Strain: Role of Upregulated Neurotrophic Factor Expression in the Hippocampus." PubMed, vol. 7, no. 23, 15 Aug. 2012, pp. 1797—804, www.ncbi.nlm.nih.gov/pmc/articles/PMC4302529/, https://doi.org/10.3969/j.issn.1673-5374.2012.23.006. Accessed 24 May 2024.

3 Vive, Sara, et al. "Enriched, Task-Specific Therapy in the Chronic Phase after Stroke: An Exploratory Study." Journal of Neurologic Physical Therapy, vol. 44, no. 2, Apr. 2020, pp. 145—155, https://doi.org/10.1097/npt.0000000000000309.

What constitutes an enriched environment for humans?

Toronto Montessori Bayview Campus by Farrow Partners

02

Content

“The brain is a complex biological organ of great computational capability that constructs our sensory experiences, regulates our thoughts and emotions, and controls our actions.”

Quote by Eric Kandel - World Trade Center Transportation Hub by Santiago Calatrava - Photo by Luis Dalvan

Cognition

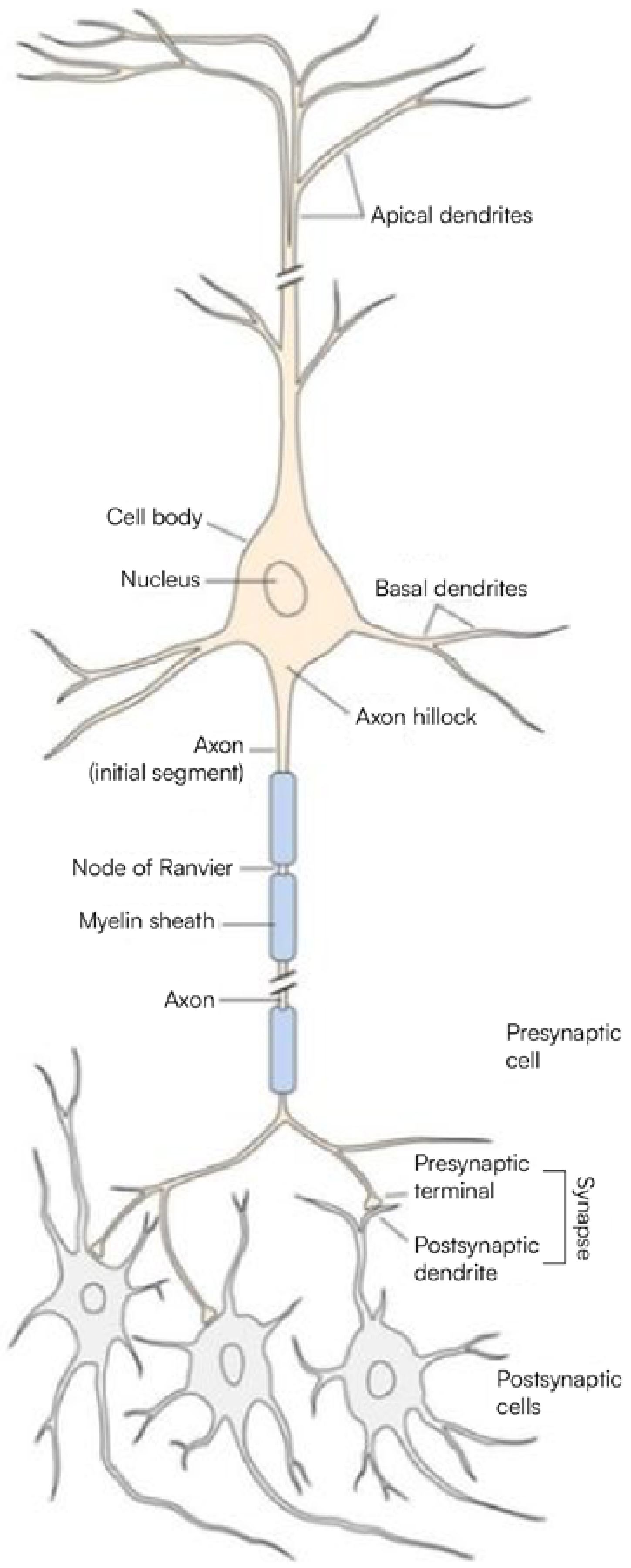
Brief Overview

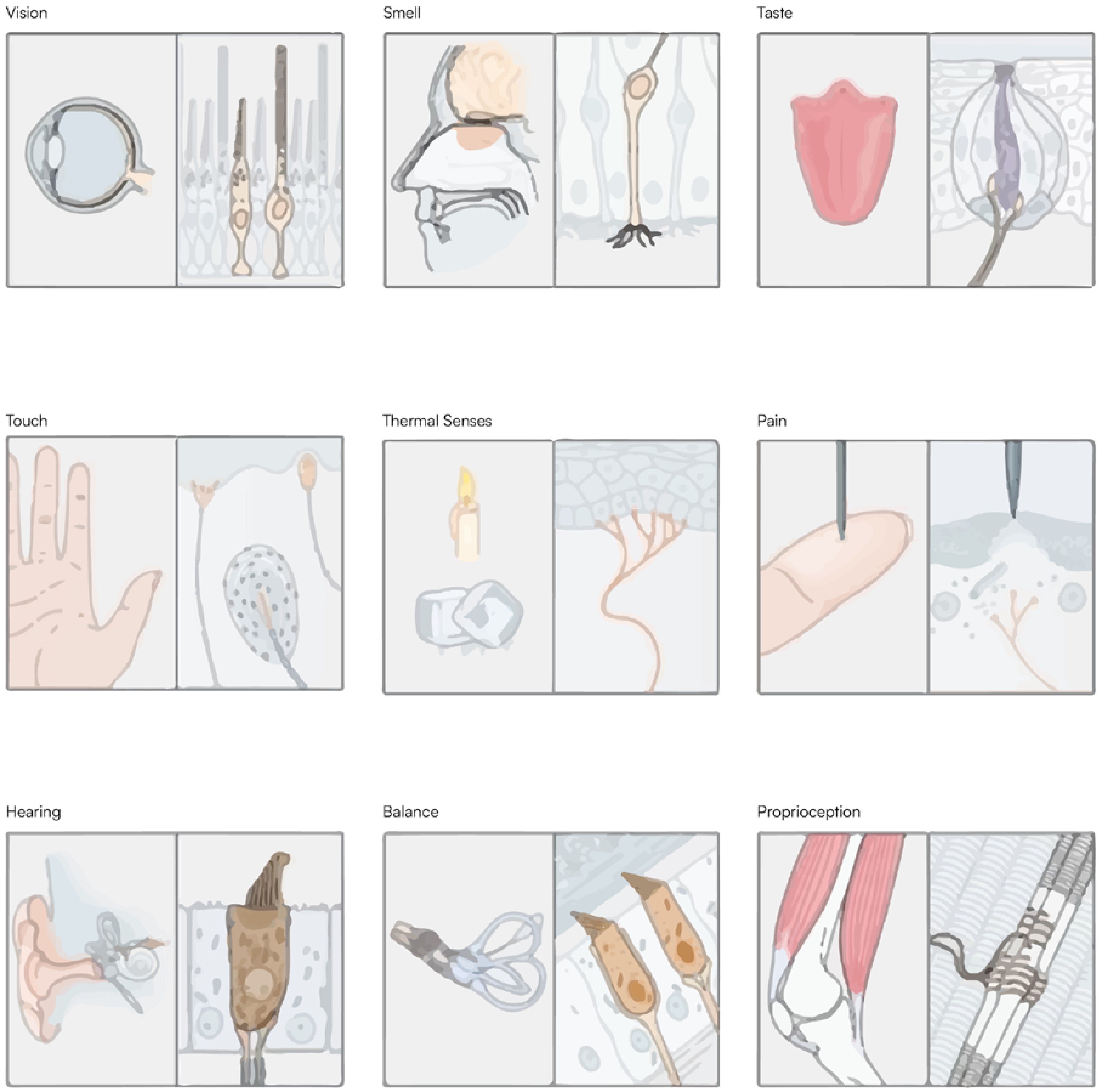
Cognition encompasses various brain functions, including attention, learning, memory, language, sensation, perception, and thought. These processes enable us to remember information, learn new skills, converse, pay attention, and process incoming information. They involve higher-level brain functions that start at the neuronal level and follow different neural pathways. Cognition inevitably paves the way for how we understand our surrounding environment.

In this section, we will explore neurons and neural communication, the sensory systems, as well as how the brain puts them all together through perceptual mechanisms. We will provide explanations of how these systems operate individually and holistically while relating concepts to architecture. We will provide questions about each topic to consider for implementation in the design process.

Streets of Florence in Italy - Photo by Taylor Smith in 2019

Neurons and Networks





To elucidate the complex mechanisms that give rise to our thoughts, behaviors, and emotions, we must first discuss the smallest functional unit of the brain that makes it all possible... the neuron!

Neurons are brain cells capable of receiving information from the environment, body, and brain. They process loads of information and transmit signals through various pathways in the brain and body. There are distinct types, structures, and functions of neurons, but it is most important to understand that they relay information through neural networks providing the basis for cognitive processes. This basic mechanism applies for all the sensory systems, with each sensory neuron composed of specialized receptors that respond to specific stimuli, as if it were lock and key.

Diagram 4: The Neuron

Diagram 5: Sensory Systems and Corresponding Receptors [4]

4 Source of Diagram Images - Kandel, Eric R, et al. Principles of Neural Science, Sixth Edition. McGraw Hill Professional, 5 Apr. 2021.

“The human brain has 100 billion neurons, each neuron connected to 10 thousand other neurons. Sitting on your shoulders is the most complicated object in the known universe.”

Quote by Michio Kaku - Photo by Bhautik Patel in 2024

Neurons and Networks

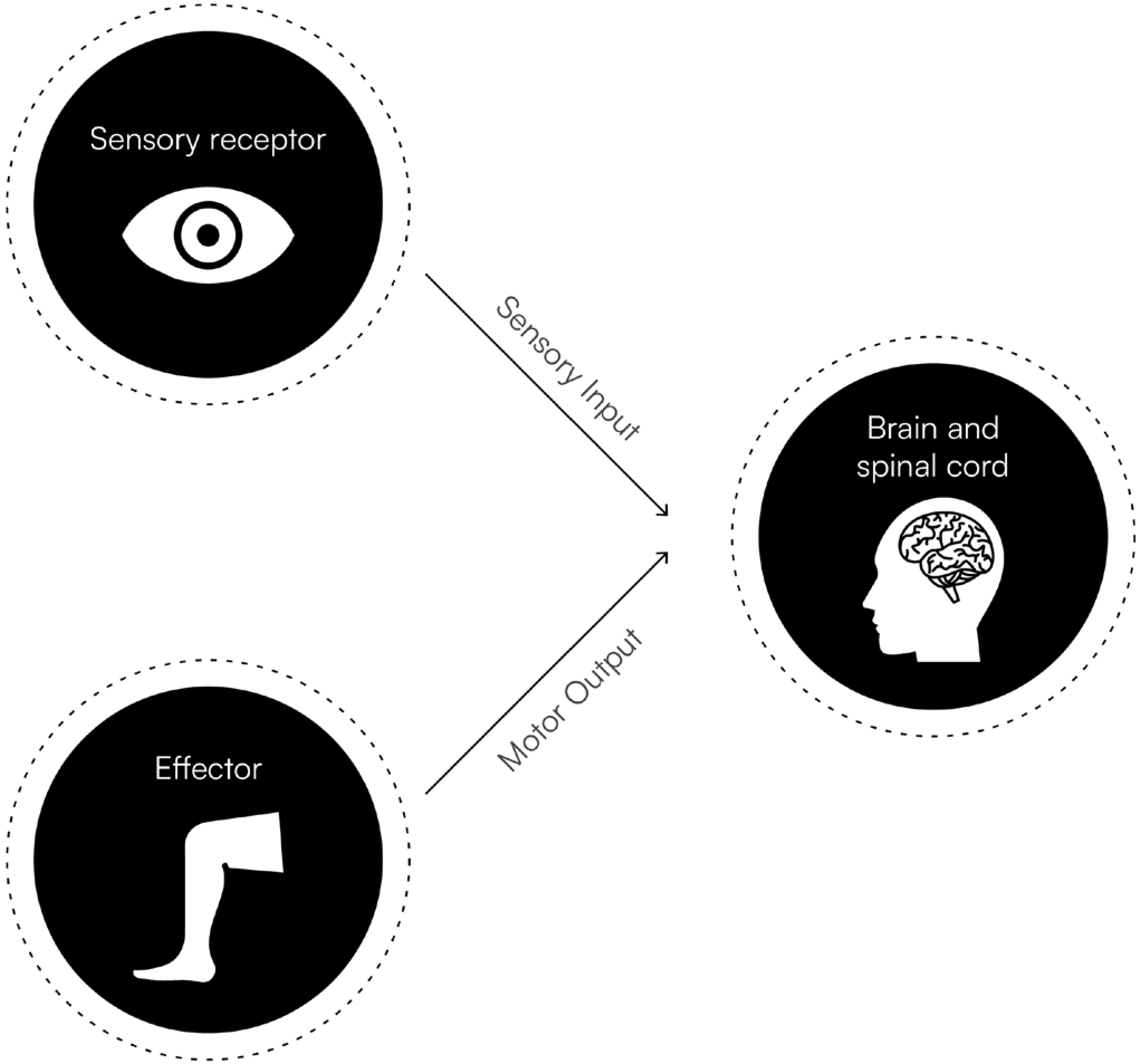


Diagram 6: Sensory Encoding, Processing and Action

When it comes to understanding neurons and how they are able to communicate information from the environment to the brain and body, it is important to understand is that...

(1) Information from the environment is encoded and transduced into electrical and chemical signals by various corresponding receptors of each sensory system

(2) The information is processed among different pathways in the brain that enable the integration of multiple sensations, prior experience, and emotional evaluation

(3) The brain comprehends and interprets the stimuli to produce a motor or action response.

Sensory Systems

01 Visual System

02 Auditory System

03 Somatosensory System

04 Olfactory/Gustatory System

01 The Visual System

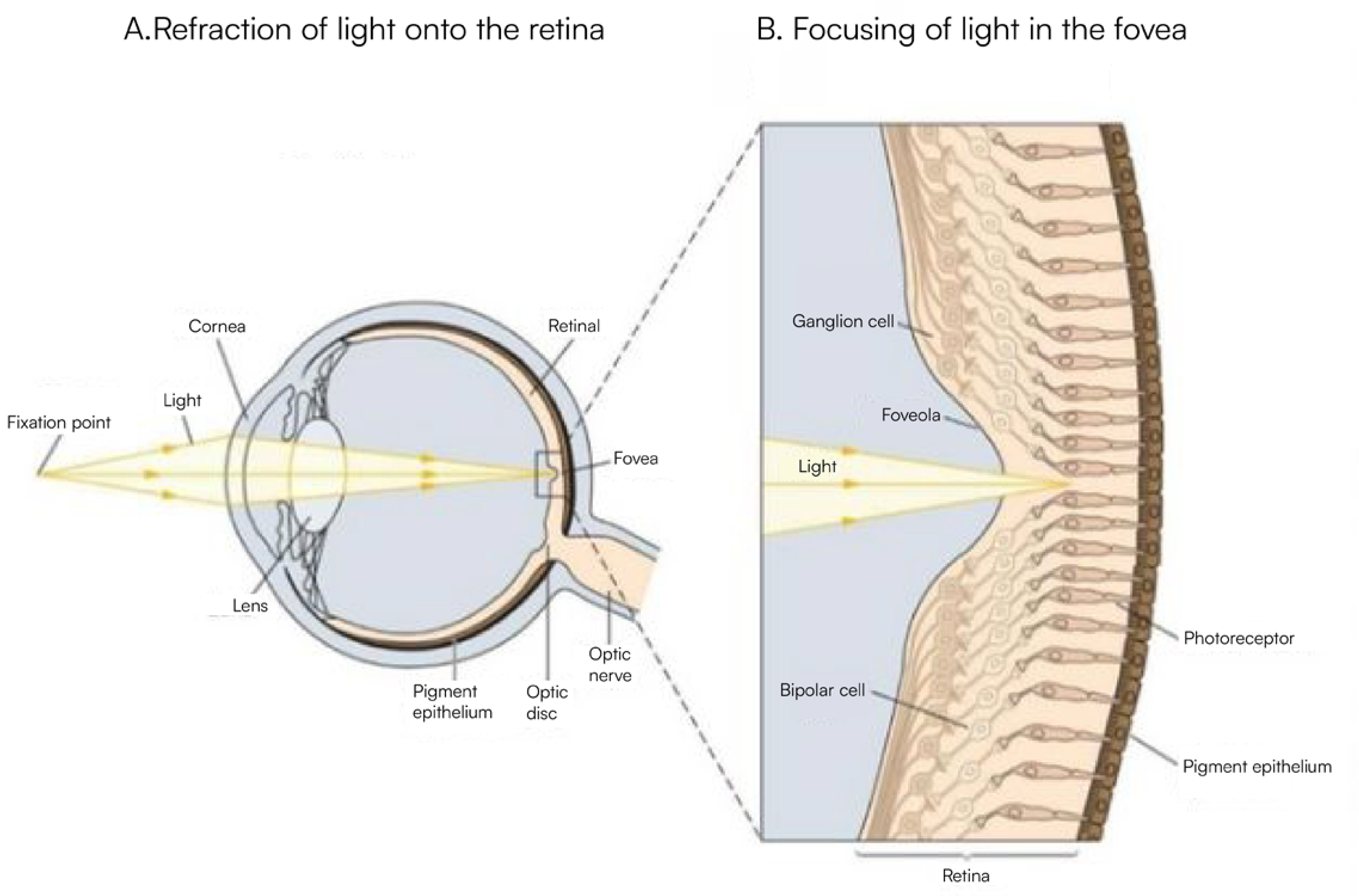


Diagram 7: Components of the Visual System [5]

The visual system is responsible for encoding and processing visual stimuli within the environment. It is actively engaged every time our eyes are open and is why we can see what we see.

The eyes detect patterns of light and work with the brain to create images. Light reflects off objects and enters the eye through the cornea, then passes through the pupil. The iris, or the colored portion of the eye, regulates the size of the pupil and thus how much light may enter. The lens focuses this light onto the retina at the back of the eye, which contains photoreceptor cells. These cells convert light into electrical signals that the brain can use to interpret and understand the incoming sensory information. Each eye captures a slightly different view, and the brain merges these to create a single, depth-perceived image, a process known as binocular vision. The eyes are constantly making tiny movements called saccades to explore and collect information from the environment. These rapid movements can be tracked by different software as a bodily indicator of visual attention in experimental settings, providing insight into what people observe as they move through a space.

5 Source of Diagram Image - Kandel, Eric R, et al. Principles of Neural Science, Sixth Edition. McGraw Hill Professional, 5 Apr. 2021.

In a complex hospital environment, simple and colorful floor wayfinding guides visitors and patients, bringing security and easing stress within the chaotic entrance hall.

Visual Processing in the Environment

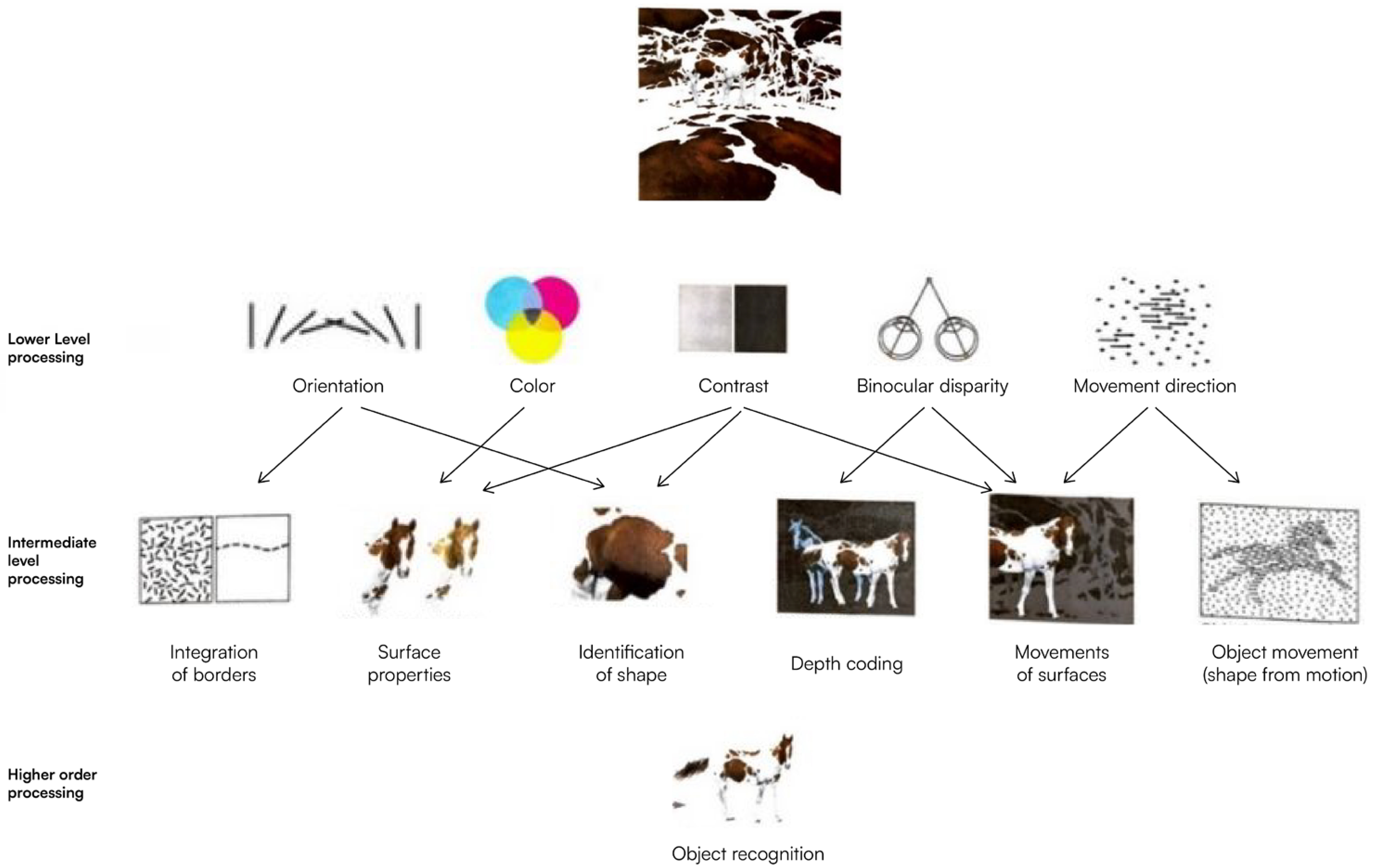


Diagram 8: Visual Processing of an Image

“A visual scene is analyzed at three levels. First, simple attributes of the visual environment are analyzed (low-level processing). These low-level features are used to parse the visual scene (intermediate-level processing): Local visual features are assembled into surfaces, objects are segregated from background (surface segmentation), local orientation is integrated into global contours (contour integration), and surface shape is identified from shading and kinematic cues. Finally, surfaces and contours are used to identify the object (high-level processing).”[6]

6 Kandel, Eric R, et al. Principles of Neural Science, Sixth Edition. McGraw Hill Professional, 5 Apr. 2021.

Experimental Examples of N.A.A.D. and Vision:

Experimental Examples of N.A.A.D. and Vision:

1. Next to natural light, several experiments show shorter wavelength light (below 500 nm) elicits increased alertness, attention, and performance among people as well as reduce daytime sleepiness. For example, the strategic implementation of blue light in an office space or library could aid sustaining attention and maintaining or improving performance of building occupants.[7]

2. Expanding upon principles of color psychology, the perception of color influences performance and creativity in a number of experiments. For example, seeing the color red before an important test significantly impaired performance.[8]

3. However, when experimenters examined the effect of seeing red before athletic performance, they found better results (increased power and strength) than other colors (blue, green, gray, etc.).[9]

4. In another experiment, researchers examined greater levels of creativity after participants were exposed to the color green compared to blue, red, and gray.[10]

5. It is important to note, there are an abundance of studies conducted on the visual system and different architectural features. The few examples listed here are just the tip of the iceberg...

7 Lockley, Steven W., et al. "Short-Wavelength Sensitivity for the Direct Effects of Light on Alertness, Vigilance, and the Waking Electroencephalogram in Humans." Sleep, vol. 29, no. 2, 1 Feb. 2006, pp. 161—168. Oxford Academic, https://doi.org/10.1093/sleep/29.2.161. Accessed 9 July 2024

8 Elliot AJ, Aarts H. Perception of the color red enhances the force and velocity of motor output. Emotion. 2011; 11(2):445

9 Elliot AJ, Maier MA, Moller AC, Friedman R, Meinhardt JJJoepG. Color and psychological functioning: The effect of red on performance attainment. 2007; 136(1):154.

10 Lichtenfeld, S., Elliot, A. J., Maier, M. A., & Pekrun, R. (2012). Fertile Green: Green Facilitates Creative Performance. Personality and Social Psychology Bulletin, 38(6), 784-797. https://doi.org/10.1177/0146167212436611

Stuttgart City Library by Yi Architects in Germany - Photo by Max Langelott in 2018

Questions to think about:

1. In what ways can visual architectural elements give rise to environments that are stimulating, exciting, overwhelming, or boring?

2. What patterns of visual elements do you find most pleasurable or disastrous?

3. What elements or combinations of elements can capture our visual attention?

4. How can what we see in the environment inform or motivate our behavior and movement (ex.: run, play, explore, hide, etc.)?

5. What visual elements make an environment coherent (ex.: signage, materials, etc.)?

6. When designing for the eye, what other senses are also engaged? Can you think of some examples?

Architectural Elements to Consider:

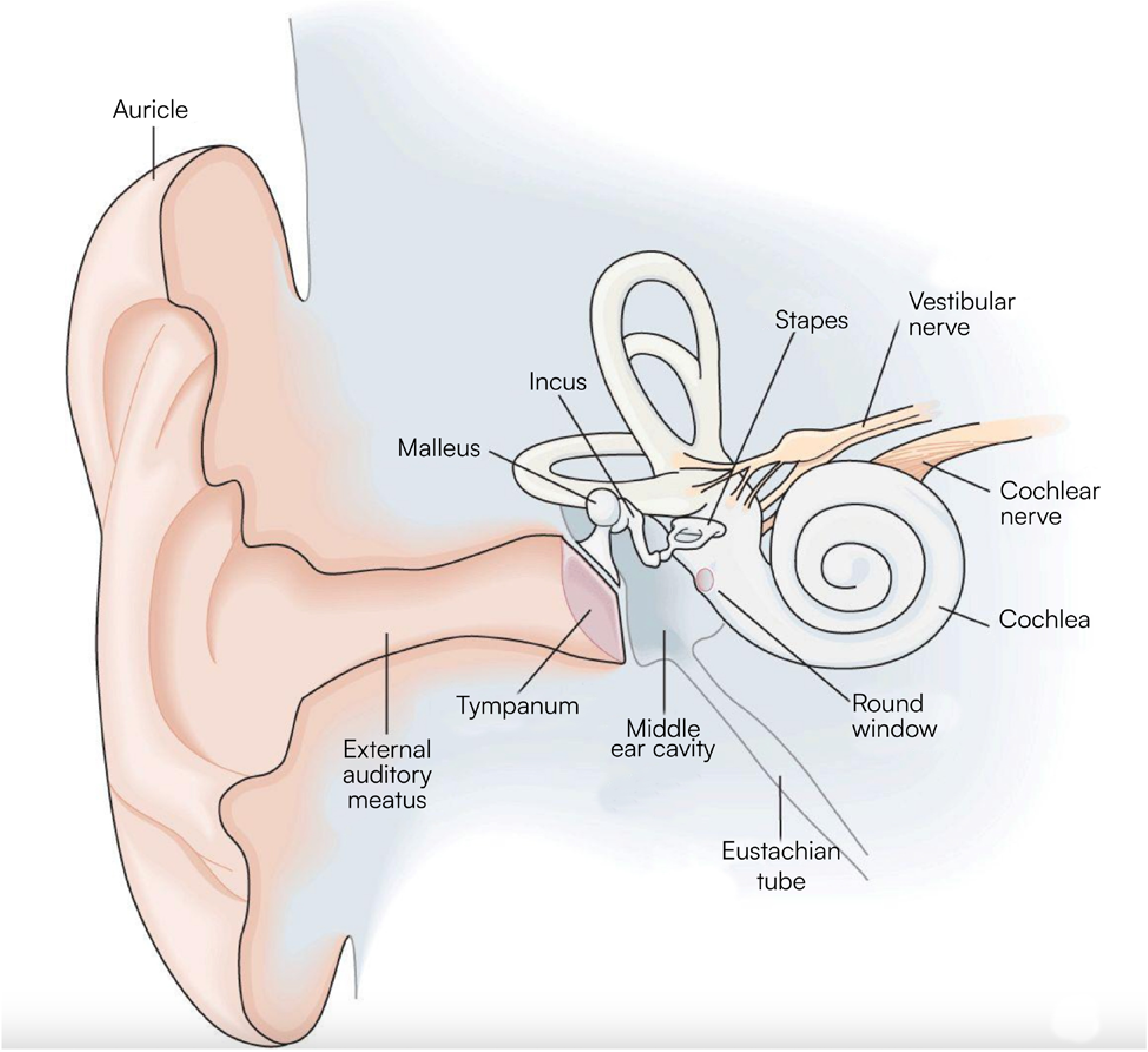
Lighting, Brightness, Contrast, Colors, Saturation, Materiality, Texture, Form, Structure, Shape, Geometry, Rhythm, Complexity, Patterns, Fractals, Size, Dimensions, Proportions, Scale, Mass & Weight, Proximity, Nature, Openings, Enclosures, Permeability, Furnishings & Decoration

Streets of Hong Kong - Photo by Nic Low in 2017

“Designed by Frank Gehry, the Guggenheim Museum in Bilbao, is an architectural marvel that balances complex geometries and innovative materials to create a visually captivating experience.

The fluid, organic forms of the building, combined with its reflective titanium surfaces, engage viewers’ attention without overwhelming them. The museum’s design evokes fascination and curiosity, inviting exploration and admiration through its harmonious yet dynamic visual appeal.”

02 The Auditory System



<u>Diagram 9:</u> Components of the Auditory System [11]

The auditory system provides the mechanism for which we hear. Located in the ears, the system starts with tiny acoustical detectors packed into a space no larger than a pea. These microscopic hairs in the ear canal respond to sound's intensity, volume, frequency, rhythm, and position. They convert vibrations into signals sent to the brain for higher levels of processing. Unlike the visual system, ear receptors respond a thousand times faster, allowing rapid reactions to acoustical cues by orienting the head and body to new or potentially threatening stimuli. Acoustical information, integrated with other sensory inputs, informs movement and behavior, influenced by emotions and prior experience.

11 Source of Diagram Image - Kandel, Eric R, et al. Principles of Neural Science, Sixth Edition. McGraw Hill Professional, 5 Apr. 2021.

Researchers showed how people exposed to natural sound as opposed to noisy urban environments tended to recover from stressful situations faster.[12]

Central Park in New York - Photo by Dana Andreea Gheorghe in 2022

12 Alvarsson JJ, Wiens S, Nilsson ME. Stress recovery during exposure to nature sound and environmental noise. International journal of environmental research and public health. 2010; 7 (3):1036-469

Questions to think about:

1. How can sound afford building occupants or users with different behavior (ex.: a noisy cafeteria is a sound hotspot, creating opportunities for conversation, while a library provides a quiet atmosphere deterring noise and exuberant activity)?

2. How can different material interactions between a space and users create sound that is rhythmic and musical?

3. How does noise allow co-creation of the atmosphere of the space with users?

4. How can sound to enable wayfinding and navigation (ex.: a building with a central chamber can amplify the level of noise of the space, which can later provide users with a “sound landmark” to recall where they are in the area)?

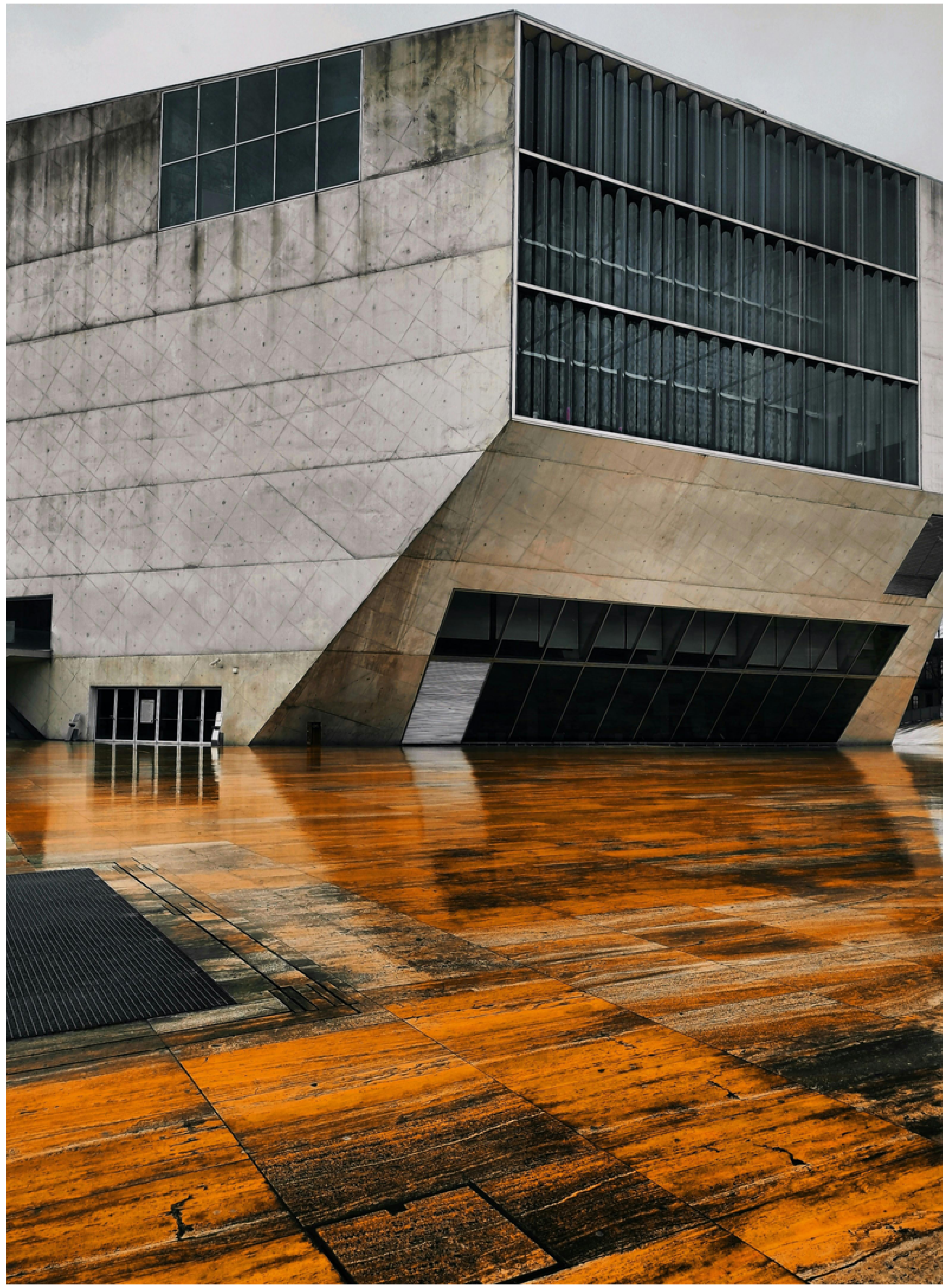
5. Where does the sound travel and do people follow?

6. Ask, how does what we hear impact our behavior, emotion, cognition, and well-being (ex.: clicking sounds in the office can be irritating causing a lack of focus and decreased performance)?

Architectural Elements to Consider:

Pitch, Volume, Pollution (mechanical and technical sounds), Acoustic Reverberation (travel ability), Acoustic Absorbency (echoes)

Library for the Blind & Visually Impaired in Mexico by Mauricio Rocha + Gabriela Carrillo - Photo by Sandra Pereznieto



“In this concert hall, the architects carefully considered the acoustical properties during the design of the spaces. The surfaces and materials were chosen and configured to optimize sound quality and ensure perfect acoustics in every corner of the hall.

Casa da Música features a spatial configuration that facilitates navigation through the use of sound. For instance, the different areas of the hall have unique acoustic characteristics that can guide people in their movements. Visitors could potentially navigate with their eyes closed, using the variations and reflections of sound to determine their position within the space.”

Quote by Park Associate - Casa da Musica in Spain by Rem Koolhaas - Photo by Porto de Honra in 2019 & Casa da Musica Interior - Photo by Yevhenii Omettsynskyi in 2022

03 The Somatosensory System

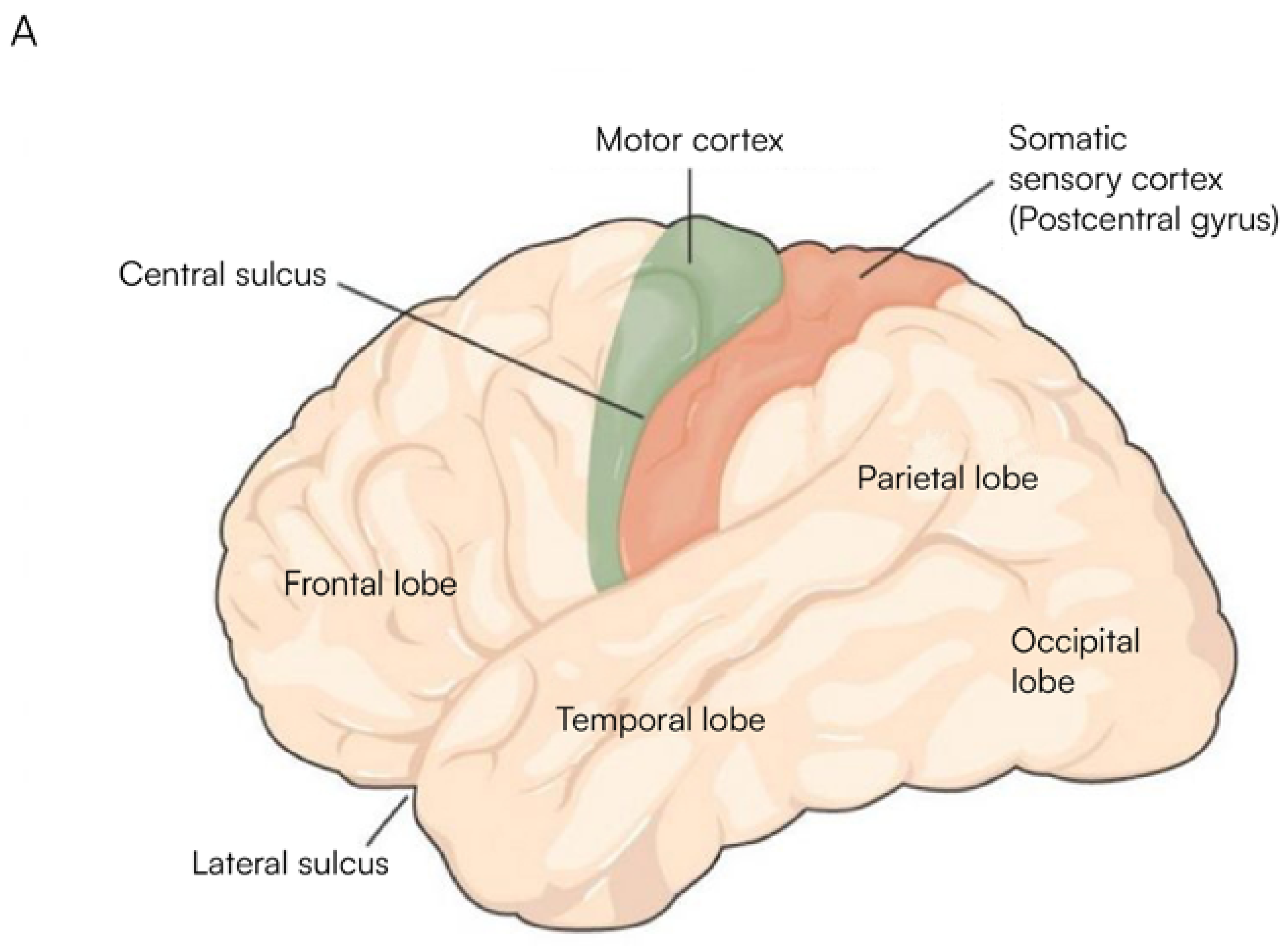


Diagram 10: The Somatosensory System: This diagram shows the position of the somatosensory cortex in the brain as well as other important regions. Each area observed can be connected to different functions in the brain. For example, the decision making in the frontal lobe, vision in the occipital lobe, hearing in the temporal lobe, and the center for associative processing in the parietal cortex

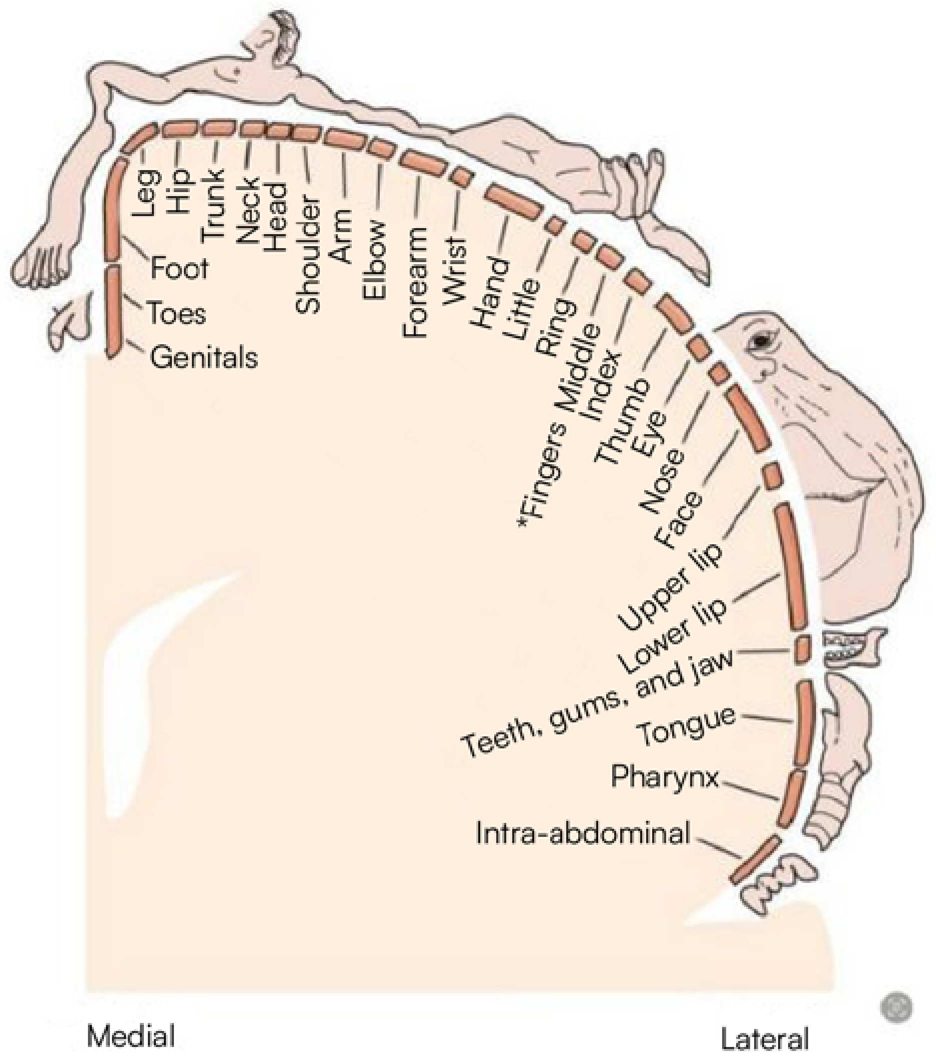


Diagram 11: The Sensory Homunculus [13]

Involved in the sense of touch, the somatosensory system illustrates the interaction between sensory systems and motor system (the motor system we will explore later). Information from all over the body surface travels through sensory relays of the spinal cord to the brain. These messages inform the brain of which type of motor programs it should activate. Decisions can be made rapidly and automatic or slow as the translation of sensory stimulation provides muscles with assignments to relax or contract.

Each part of the body surface is represented in the brain and has varying amounts of "space" dedicated to its processing. From the Homunculus Map, shown in *Diagram 11*, the hands, mouth, and face overall have higher levels of representation dedicated to perception and action compared to that of the leg or arm. These strange "body maps" show how our brains represent our body schema and later we will see how they are connected to the perception of space.

On a smaller scale, mechanical receptors in the skin encode a variety of information (heat, pain, pressure, etc.) when in contact with or in proximity to different environmental stimuli. Each receptor transduces the environmental stimuli into signals the brain can integrate, process, analyze, understand, interpret, and respond to (sound familiar). *Recall Diagram 5, to see the different forms of proprioceptive mechanisms.*

13 Source of Diagram Images - Kandel, Eric R, et al. Principles of Neural Science, Sixth Edition. McGraw Hill Professional, 5 Apr. 2021.

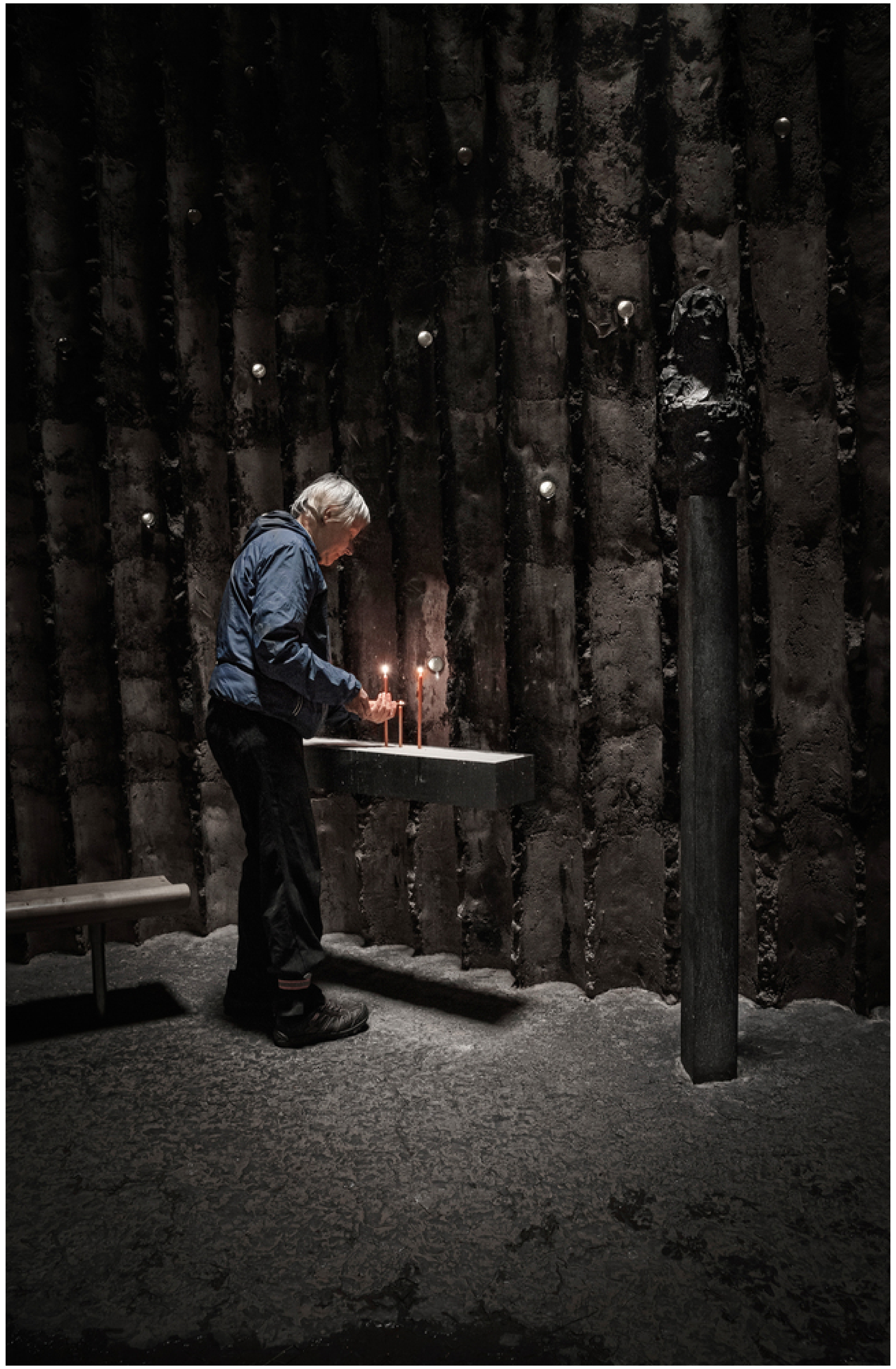
Questions to think about:

1. What objects or properties of a structure do people touch (ex.: door handle)?
2. What do these objects feel like or what affective meanings are associated with the experience of touching the objects (ex.: metal handle is cold, reflective surface is hot when in the sun, stone is cool in the shade, etc.)?
3. How does what we come into contact with in a space inform what kinds of behaviors are appropriate (ex.: floor feels smooth and slippery, with socks we can glide around)?
4. How can tactile elements enhance our experience within a space?
5. How can you creatively incorporate multisensory and accessible tactile elements in the built environment?

Architectural Elements to Consider:

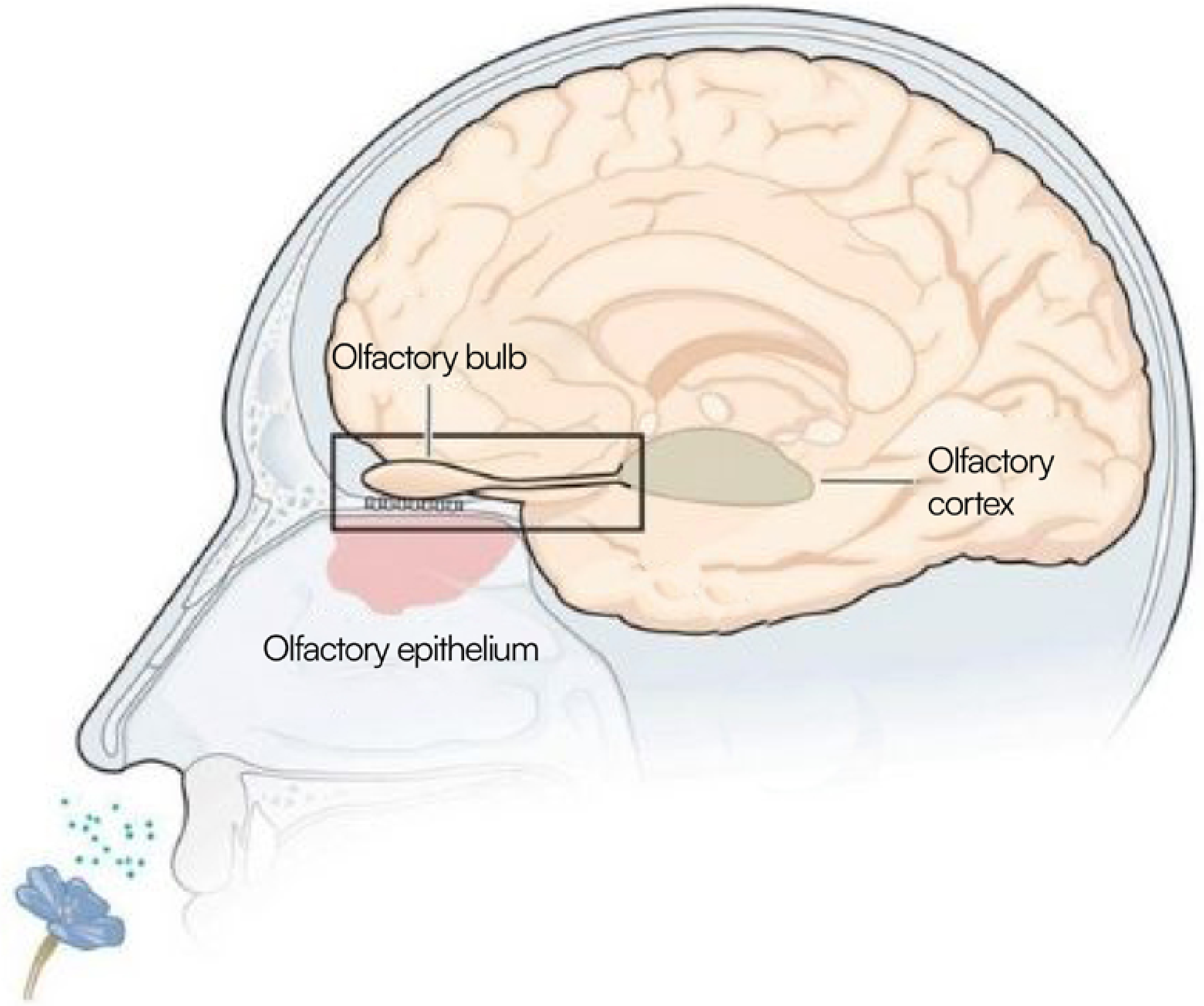
Shapes, Materials, Textural properties, Temperature, Ergonomic properties, Haptic feedback

The High Line by James Corner Field Operations, Diller Scofido + Renfro and Piet Oudolf in New York - Photo by Iwan Baan



Bruder Klaus Field Chapel by Peter Zumthor - Photos by Aldo Amoretti

04 The Olfactory and Gustatory Systems



Smell and taste are two senses closely related in the form of mechanism and activation. They require close proximity to or direct contact with the individual like the somatosensory system. Their receptors involve the transduction of chemical stimuli into information the brain can use to interpret smells or tastes of sweet, sour, salty, bitter, and umami (savory meaty taste). Both senses provide important contextual information in addition to visual, auditory, and somatosensory stimuli and can greatly enhance the experiential quality of the built environment. Moving forward, we will focus our attention on the olfactory system, as the gustatory system of taste is difficult to achieve through architectural intervention.

Diagram 12: The Olfactory System: This system detects and interprets odors as odor molecules bind to receptors in the nasal cavity, triggering electrical signals sent to the olfactory bulb. These signals are processed and relayed to the brain's olfactory cortex and limbic system, allowing for the perception and emotional response to smells [14]

14 Source of Diagram Image - Kandel, Eric R, et al. Principles of Neural Science, Sixth Edition. McGraw Hill Professional, 5 Apr. 2021.

Experimental Examples of NAAD and Smell

1. There are strong links to improving memory with the sense of smell in experimental settings. For example, researchers found olfactory cues to serve as powerful and effective reminders of experience, even more so than visual cues.[15]

2. One study examined how olfactory cues can aid in wayfinding within large architectural spaces such as airports, shopping malls, and hospitals. It looked at the effectiveness of scent in guiding people through complex environments and enhancing spatial orientation.[16]

3. Another study investigated how emotional responses elicited by scents in various architectural settings, can enhance or detract from the emotional experience of a space. Researchers naturally found, pleasant scents enhance positive emotions; unpleasant scents induce negative feelings. Contextually appropriate scents and those evoking personal memories have stronger impacts.[17]

Venice, Italy - Photo by Damiano Baschiera in 2018

15 Chu, Simon, and John J. Downes. "Proust Nose Best: Odors Are Better Cues of Autobiographical Memory." Memory & Cognition, vol. 30, no. 4, June 2002, pp. 511—518, link.springer.com/article/10.3758/BF03194952, https://doi.org/10.3758/bf03194952

16 Lee, Robert. "Scent and Wayfinding: The Use of Olfactory Cues in Architectural Spaces." Journal of Environmental Psychology, vol. 12, no. 1, 2020, pp. 22-37.

17 Brown, Emily. "Emotional Responses to Architectural Spaces: The Impact of Olfactory Stimuli." Architectural Psychology Review, vol. 8, no. 4, 2017, pp. 112-128.

Questions to think about:

1. How can smell enhance user experience?

2. What smells are pleasant or unpleasant and how can this relate to the program of a space (ex.: stinky bathrooms near the entrance or hidden in the back)?

3. How can the incorporation of nature enhance the experience of smell in the environment?

4. How can smell and the prospect of taste motivate or guide movement and behavior?

Architectural Elements to Consider:

Proximity to cafes, bars, and elements of nature (ex.: plants, water, etc.), Spatial programing, Circulation and Air flow

The Opera Park in Copenhagen by Cobe Studio

The Perception of Space

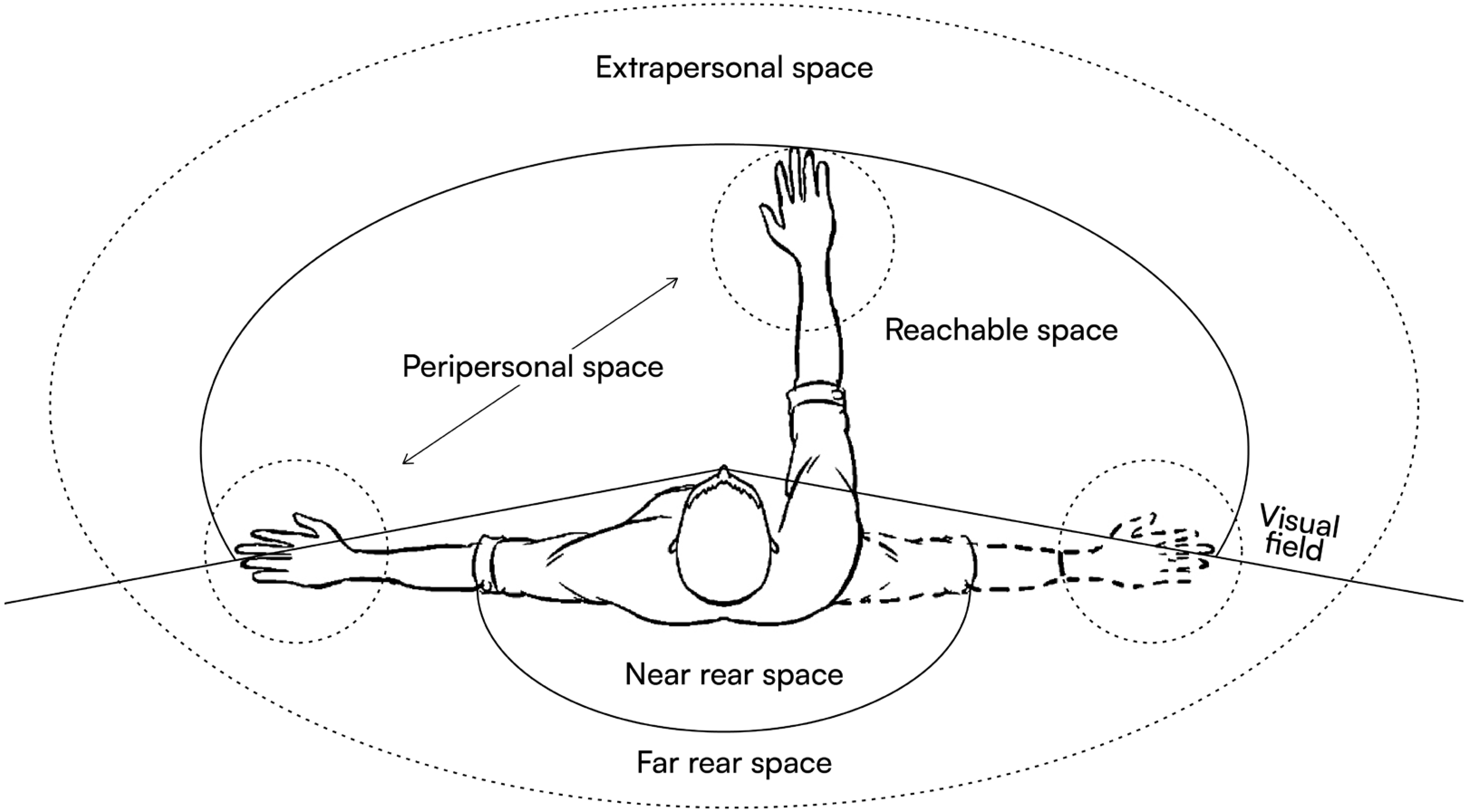


Diagram 13: Divisions of Space Around the Body

Space perception is how our body represents and understands its position in the environment while enabling interaction with objects in our surroundings. Retaining important environmental cues of depth, distance, and action potential, our perception of space is strongly influenced by the visual and motor systems, even if all the senses play a role in how we perceive the environment.

We have a unique type of neuron that is capable of encoding both visual and tactile stimuli. These so-called "bimodal neurons" look at the position of different objects in the space while simultaneously making note of the different actions for that space. When we interact with the environment, these neurons are abundant and selective, meaning some will respond to stimuli near the body or far from it.[18] It is thanks to the neurons being "picky" that we can distinguish between objects within our "peripersonal" or "extrapersonal space." The brain is so smart, "embodying our environment" is an automatic, nonconscious process, and the influence of architectural features could unleash a variety of cognitive, behavioral, and emotional expressions below our threshold of awareness. This claim reminds us of how important it is to accommodate our perception of space with well-thought architecture and design.

18 Melzack, R. E. W., and P. J. Wall. "Bimodal Neurons in the Monkey's Cortex: Evidence for Cross-Modal Sensory Integration." Science, vol. 150, no. 3698, 1965, pp. 101-103.

Experimental Examples of N.A.A.D. and Space Perception:

1. In an experimental setting, researchers found visual attention is strongest towards objects that are near us or within the graspable field. In this way, our visual attention is organized hierarchically and biased towards things in our immediate surroundings.[19]

2. Perception of enclosure and our corresponding behavior are topics heavily investigated in the field of neuroscience. For example, researchers found increased stress responses in participants exposed to enclosed architectural forms.[20]

3. In another study, the proportion of narrow spaces was associated with greater pupil dilation which is a bodily indicator of increased arousal and potential stress. This finding suggests that narrow spaces may trigger a fear-based, stress response.[21]

Jewish Museum by Daniel Libeskind in Germany

19 Garrido-Vásquez, Patricia, and Anna Schubö. "Modulation of Visual Attention by Object Affordance." Frontiers in Psychology, vol. 5, 2014, https://doi.org/10.3389/fpsyg.2014.00059.

20 Shemesh, A., Leisman, G., Bar, M., and Grobman, Y. J. (2022). The emotional influence of different geometries in virtual spaces: a neurocognitive examination. J. Environ. Psychol. 81, 101802. doi: 10.1016/j.jenvp.2022.101802

21 Valentine, Cleo. "The Impact of Architectural Form on Physiological Stress: A Systematic Review." Frontiers in Computer Science, vol. 5, 4 Jan. 2024, https://doi.org/10.3389/fcomp.2023.1237531. Accessed 12 Jan. 2024.

Questions to think about:

1. How does our perception of a space influence how we feel?

2. How does our perception of a space inform and motivate patterns of behavior?

3. How do objects or architectural features in our peripersonal space demand our immediate attention and provide means for interactive environments?

4. What architectural features can provide strong and beneficial multisensory experiences, thus enhancing sensory perception?

Architectural Elements to Consider:

All features previously mentioned under other sensory systems, including compression and expansion, enclosure, monumentality, grandeur, curvature, proximity to tactile elements, etc.

Markthal by MVRDV in Rotterdam - Photo by Dieter de Vroomen

03

Behavior

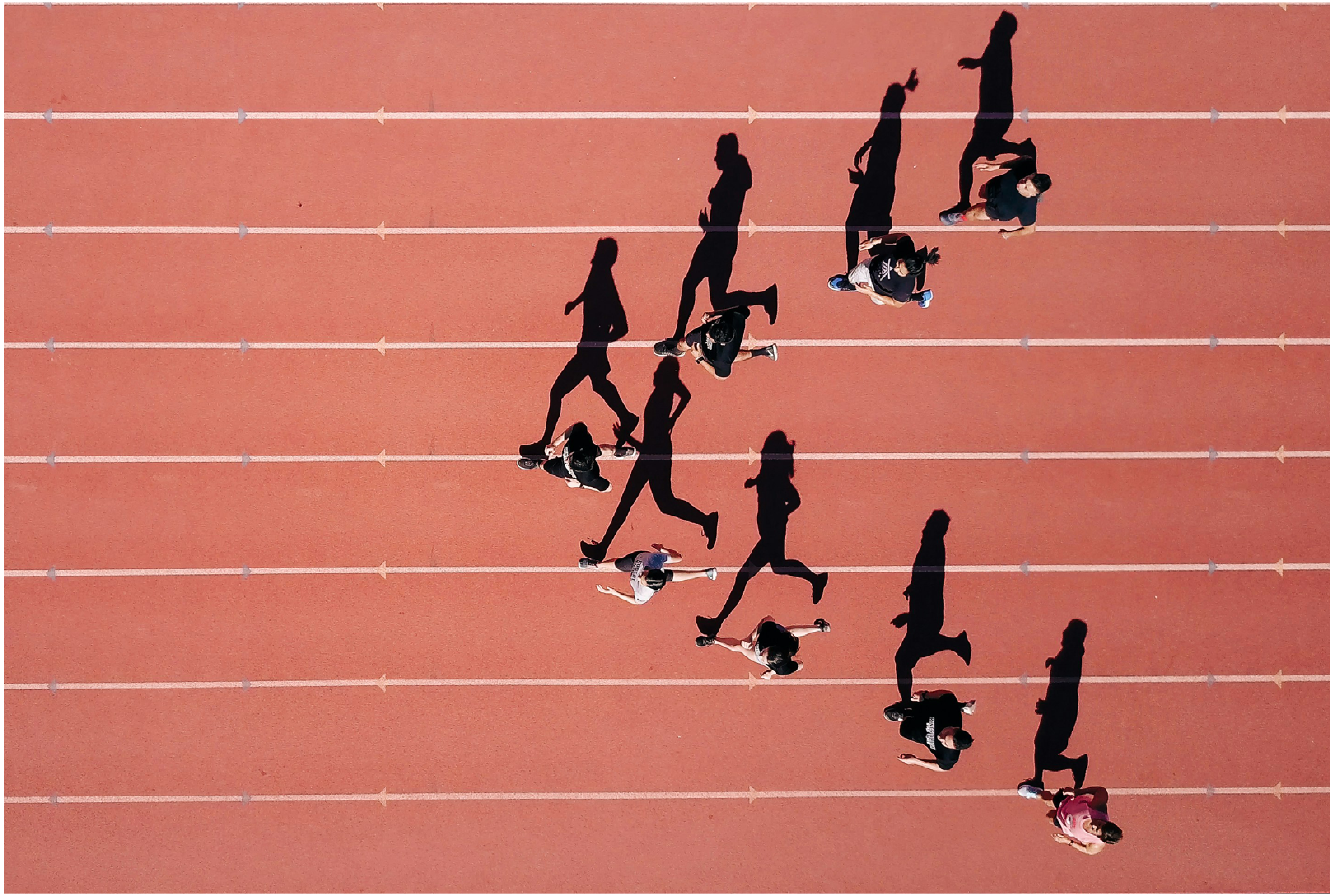
Behavior

Brief Overview

Behavior refers to how individuals and groups interact with and within built environments, encompassing the actions, movements, and responses of people in relation to spatial layouts, design features, and environmental qualities. Architects and designers create spaces that are intuitive, functional, ergonomic, supportive of diverse activities, and conducive to positive human experiences. A proper understanding of behavior on a neuroscientific level can inform the construction of environments that enhance behavior, movement, and well-being.

In this section, we will explore the basis of human behavior through movement and the motor system, briefly touching on the mechanisms behind planning and executing motor actions in relation to body effectivies and environmental affordances. The emotional influence on behavior will be uncovered in greater detail in the following chapter.

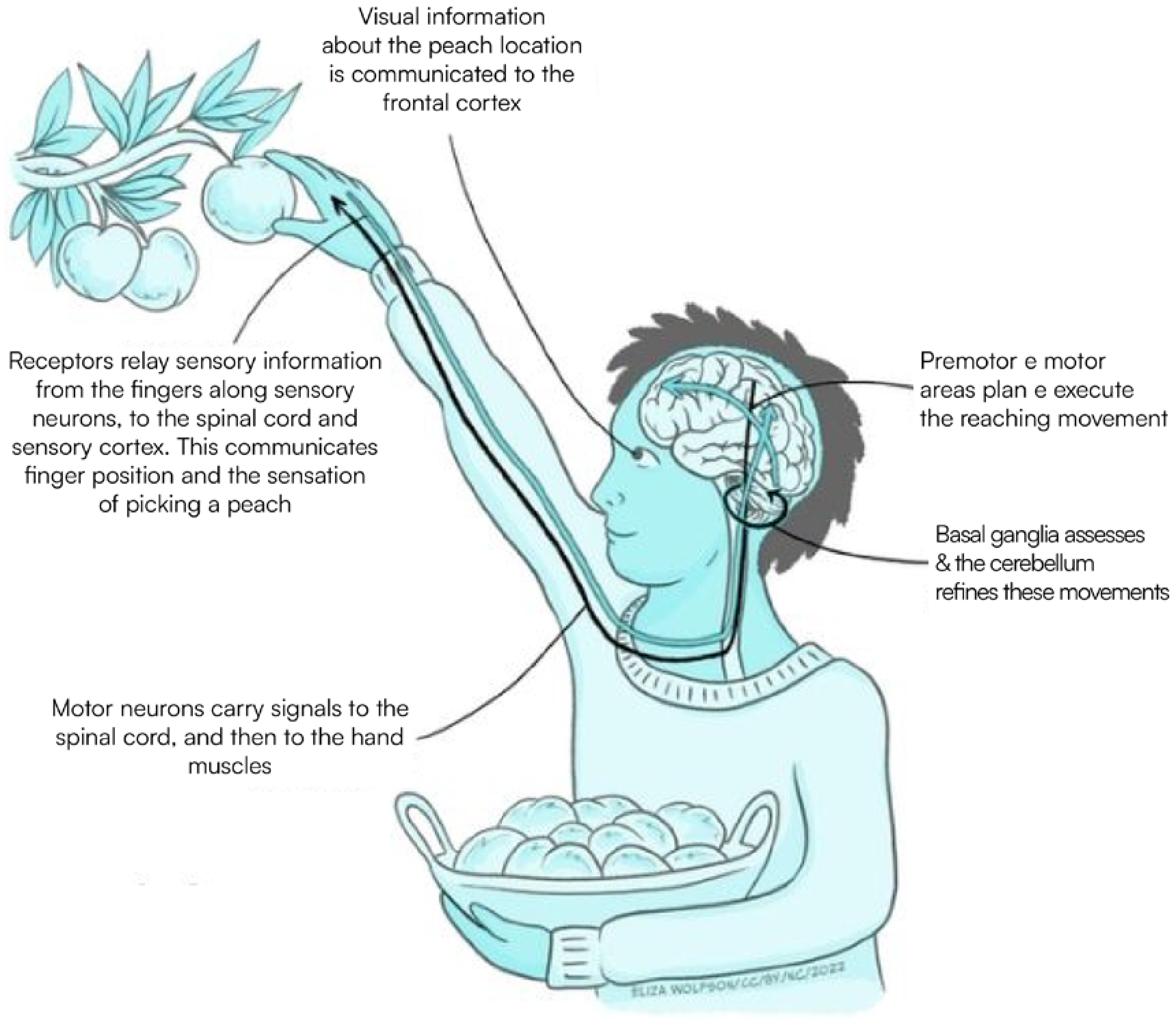
Palazzo Sistema by Park Associati



Motor System

The motor system is a fundamental component of the nervous system responsible for movement. It plays a crucial role in everyday activities and is essential for interacting with and navigating through the environment. This system is composed of three main parts: the primary motor cortex, the premotor cortex, and the supplementary motor area. Within these three parts, motor actions are planned, prepared and executed while functioning through projections of neurons extending through the spinal cord to muscles throughout the body. The motor system depends heavily on sensory information from the environment and bodily feedback to make informed decisions, behavior, and actions

Photo by Steven Lelham in 2017



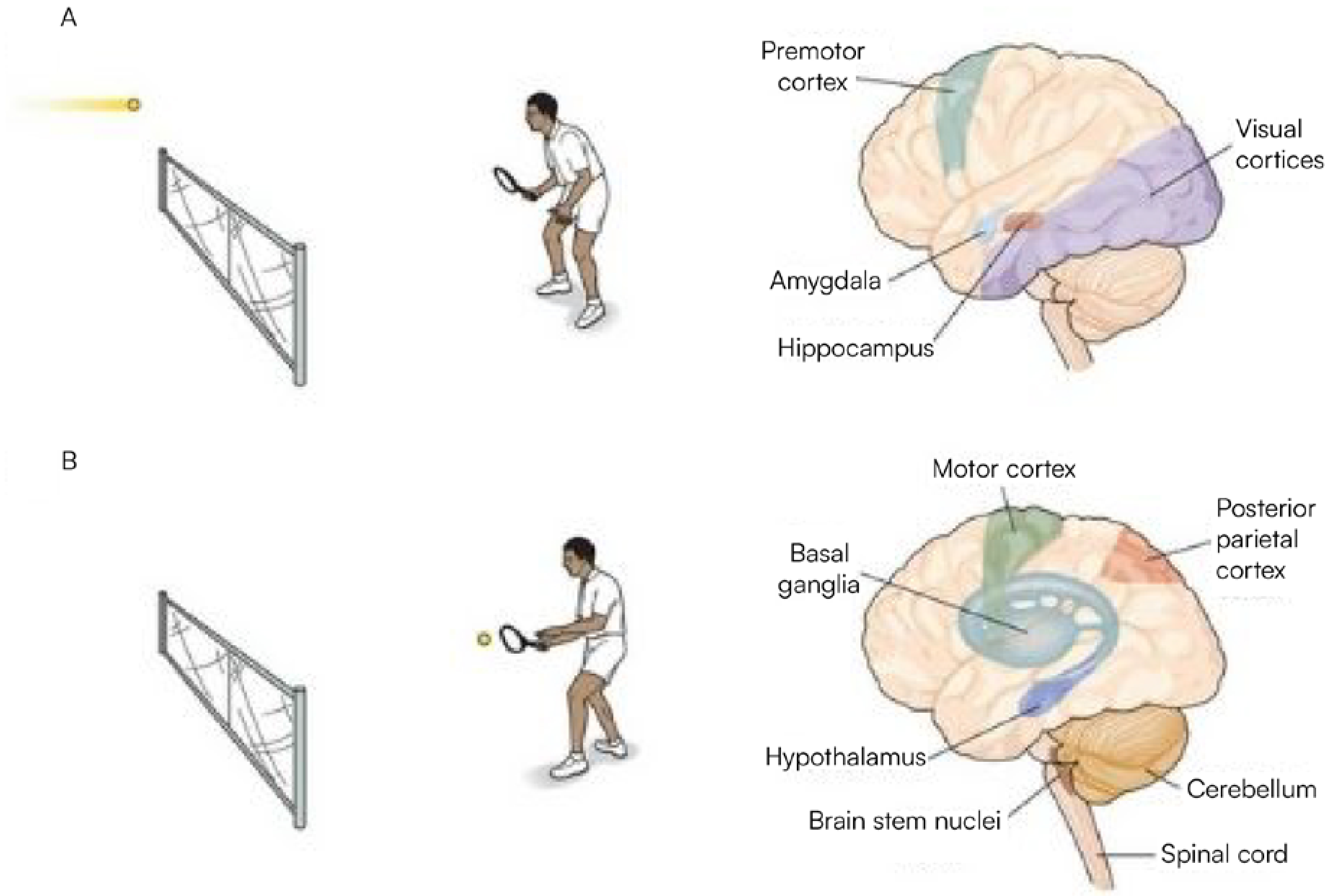


Diagram 14: How the Motor System Works: Visual information about an object location is communicated as the premotor cortex prepares grasping mechanisms. The motor cortex executes the grasping action as other brain regions assess and refine the movement. Motor neurons carry the signals from the cortex, through the spinal cord, and then into the muscles of the hand. Sensory receptors in the hand and fingers relay proprioceptive information about the object to the brain. This process shows how complex simple movements are.

Diagram 15: Premotor and Motor Cortex: Before an action occurs the premotor cortex is activated in planning for movement. Over time and with practice the premotor cortex can respond faster to intended movements and improve performance.[22]

22 Source of Diagram Images - Kandel, Eric R, et al. Principles of Neural Science, Sixth Edition. McGraw Hill Professional, 5 Apr. 2021.

Effectivities

Effectivities are actions that one can take depending on their sensory, cognitive, and motor capacities. Inevitably, user effectivities set the stage of constructing a personalized foundation for experience in daily life. You can view these "effectivities" as potential risk factors users may experience and accommodate for them through architectural and design protective factors.

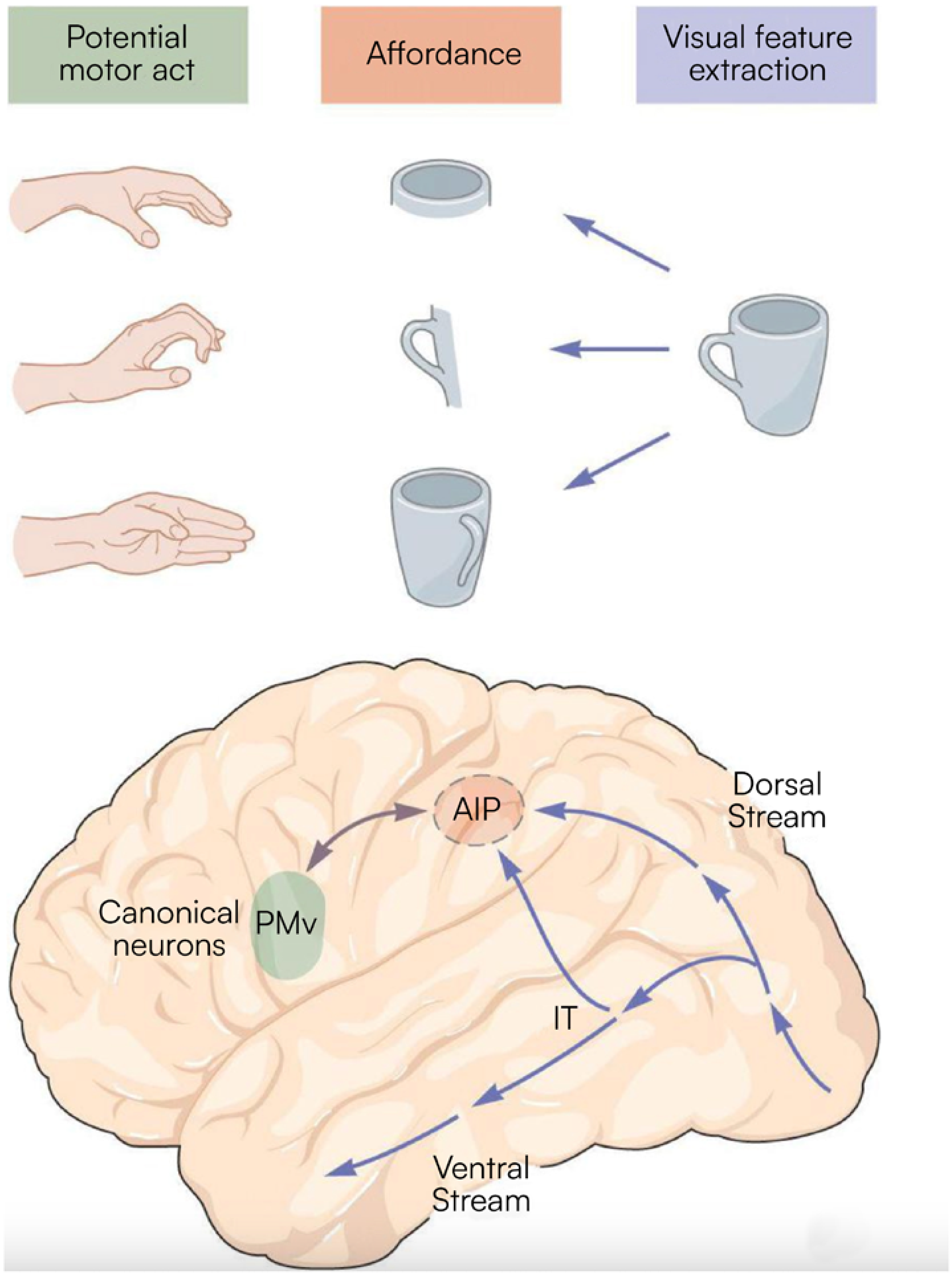
For example, there are several clear opportunities for the implementation of accessibility throughout a project. Imagine the route a person may have to take to access an elevator or lift and what their sensory experience will be. From having to take an alternative route, is their experience reduced or is it naturally embedded within the main approach of the space? How can the design work for those with a sensory impairment (ex.: blindness, deafness, etc.)? Can they still navigate and find their way? Will they feel like they are welcome and belong in the space? The process of making a space or building accessible should be of primary importance and enhanced through careful considerations of user and occupant effectivities.

Ed Roberts Campus by LMS Architects - Photo by Tim Griffith

What architectural features can make an experience of a space worse based on user effectivities and what features may help resolve the issue?

Atrium at Sumner by Studio Libeskind - Photo by Hufton & Crow

Affordances



The environment provides users with opportunities for interaction that are directly linked to one's personal effectivities. These opportunities are known as affordances, and they arise from the physical properties of a constructed space or an object and the possibility for interaction with them. In essence, affordances are embedded actions within our world. However, just because an object or space retains a variety of affordances, it does not necessarily mean the user will activate the space or object in its intended way. Later we will discuss how environmental affordances can enable users to resonate and attune with different spaces producing a stronger influence on their interactions, connections, and experience through the induction of atmosphere.

Down to the detail of design, small aspects of a space can have severe implications for its inherent nature of interaction with users, resulting in a variety of emotional and physiological associations. For example, door handles afford movements of grasping, pulling, or pushing, windows afford views of nature, daylight and restoration, and seating arrangements in public spaces afford moments for social interaction. Understanding architectural affordances helps in designing environments that not only meet practical requirements but also enhance user comfort, efficiency, and overall well-being.

(1) Source of Diagram Image - Kandel, Eric R, et al. Principles of Neural Science
(2) James J. Gibson, 1979

Diagram 16: Affordances in the Brain: The path of sensory information involving the processing of motor affordances and interactions with a common household object in the brain. The ventral stream processes what the object is (object recognition) while the dorsal stream processes where the object is located in space (spatial location). Together the two streams form a coherent picture to enable engagement with the object as a result of what the body is capable of doing.

“The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. It implies the complementarity of the animal and the environment.”

Quote by James J. Gibson, the Father of Affordances - Musée Atelier Audemars Piguet by BIG + ATELIER BRÜCKNER + CCHE


Mario Cucinella Architects' Kindergarten in Guastalla - Photo by Moreno Maggi

Questions to consider:

1. For each space inside a project, consider the functional or programmatic affordances embedded within.

2. How will the space impact a person when they first enter it?

3. How will the impact of a space change if the person spends more time there?

4. What features afford a person the sensation of comfort, potentially encouraging a longer or shorter duration of stay?

5. What can the person do? How may they behave?

6. What affordances can you imagine exist in the current space you find yourself now?

7. Can one object or feature within a space provide more than one affordance?

8. Architects and designers use windows, for example, to frame a perspective view of a place, attracting attention and movement to that area, providing an "affordance" to users and occupants. What other features can be used to provide such affordances of attention and movement?

Architectural Elements to Consider:

Circulation paths, layout, lighting in particular places, colors and materials, acoustics, open and closed spaces, spaces with built-in affordances, sensory elements, accessibility features, green/biophilic space, temperature, etc.

Projects of Park Associati from left to right: (1) Lybra, (2) Palazzo Sistema, and (3) Bovisa.

Experimental Examples of N.A.A.D. and Behavior:

1. Whyte's research in the 1970s involved observing how people interacted with various public spaces, such as plazas and parks. His work highlighted how design elements like seating arrangements, pathways, and landscaping influenced social behavior, movement patterns, and comfort. Design features that promoted accessibility, visibility, and comfort led to increased social interaction and more effective use of public spaces.[23]

2. Another study investigated how different office layouts and design elements, including lighting, acoustics, and furniture, impacted employee productivity and satisfaction. Open-plan offices with good lighting and acoustic treatments improved employee productivity and well-being, while poorly designed spaces led to increased distractions and decreased satisfaction.[24]

3. Williams examined how architectural design features, such as the layout of public spaces and the presence of defensible spaces, affected aggressive behavior and vandalism. Well-designed public spaces with natural surveillance and clear territorial boundaries reduced incidents of aggression and vandalism. scents induce negative feelings. Contextually appropriate scents and those evoking personal memories have stronger impacts.[2]

4. Ulrich's research investigated how the design of healthcare environments, such as hospital rooms and waiting areas, influenced patient outcomes, stress levels, and recovery times. Healthcare environments with natural views, calming colors, and private spaces contributed to reduced stress and faster recovery for patients.[26]

Photo by Tomi Pomar in 2022

23 Whyte, William H. The Social Life of Small Urban Spaces. Project for Public Spaces, 1980.

24 Hedge, Alan. "The Impact of Office Design on Employee Productivity and Well-being." Journal of Environmental Psychology, vol. 18, no. 2, 1998, pp. 217-229.

25 Williams, Geoffrey P. "Environmental Design and Aggressive Behavior: Evidence from Public Spaces." Journal of Environmental Psychology, vol. 22, no. 1, 2002, pp. 31-44.

26 Ulrich, Roger S. "View Through a Window May Influence Recovery from Surgery." Science, vol. 224, no. 4647, 1984, pp. 420-421.

04

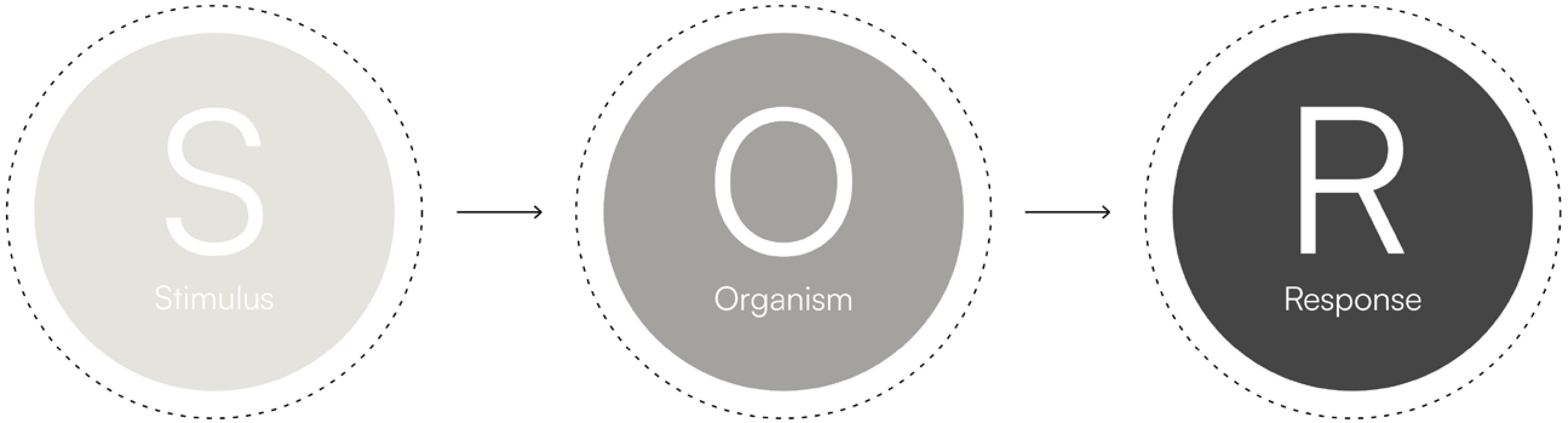
Emotion

Quote by Luis Barragán - Casa Gilardi in Mexico - Photo by Salvador Torres

Brief Overview

S.O.R Model

Mehrabian, Albert, Russell, James A. (James Albert), 1947



Diagrams 17: The S-O-R Model: A basic theoretical framework for understanding behavior. The theory suggests that an environmental stimulus produces a drive state in the individual or organism which then triggers a behavioral response. This "drive state" is a motivator for action or change.[28]

Emotions are deeply intertwined with bodily sensations, brain activity, and movement, arising from our dynamic interaction with environmental cues. Perceivable bodily sensations, such as warmth, coldness, pain, tension, and relaxation, are associated with physical changes like altered heart rate, hormone levels, sweat production, and brain activity. These "body markers" are detected as a disruption to its homeostasis or balance point creating the motivation or "drive state" to return to baseline activity.[27]

Such a process is communicated by the activation of different brain regions and the expression of different neurotransmitters that correspond to different types of emotions. For example, fear is represented in the amygdala, disgust in the insula, anger in the orbital frontal cortex, and sadness in the anterior cingulate cortex. Also, the expression of dopamine is associated with reward or joy, serotonin is related to punishment or sadness, noradrenaline corresponds to fear or anger, and oxytocin with love and attachment. Connecting to architecture and design, we may hypothesize that certain environments that strongly evoke a particular emotional state may achieve activation in corresponding brain regions or trigger the expression of different neurotransmitters in the brain (see the following page for Diagrams 18 & 19).

As emotions provide homeostatic signals to the body, they influence and generate a swift and appropriate behavioral response while also helping us reassess our values and priorities through a number of biochemical processes. Thus, an environmental scenario that evokes a profound emotional response is bound to impact one physiologically and psychologically. The degree of impact will depend on the timing of exposure (short- vs. long-term) and personal determinants or effectivities.

27 Bechara, A., & Damasio, A. R. (2005). The somatic marker hypothesis: A neural theory of economic decision. Games and Economic Behavior, 52(2), 336—372. https://doi.org/10.1016/j.geb.2004.06.010 emotion

28 Mehrabian, Albert, and James A. Russell. "The Basic Emotional Impact of Environments." Perceptual and Motor Skills, vol. 38, no. 1, Feb. 1974, pp. 283—301, https://doi.org/10.2466/pms.1974.38.1.283.

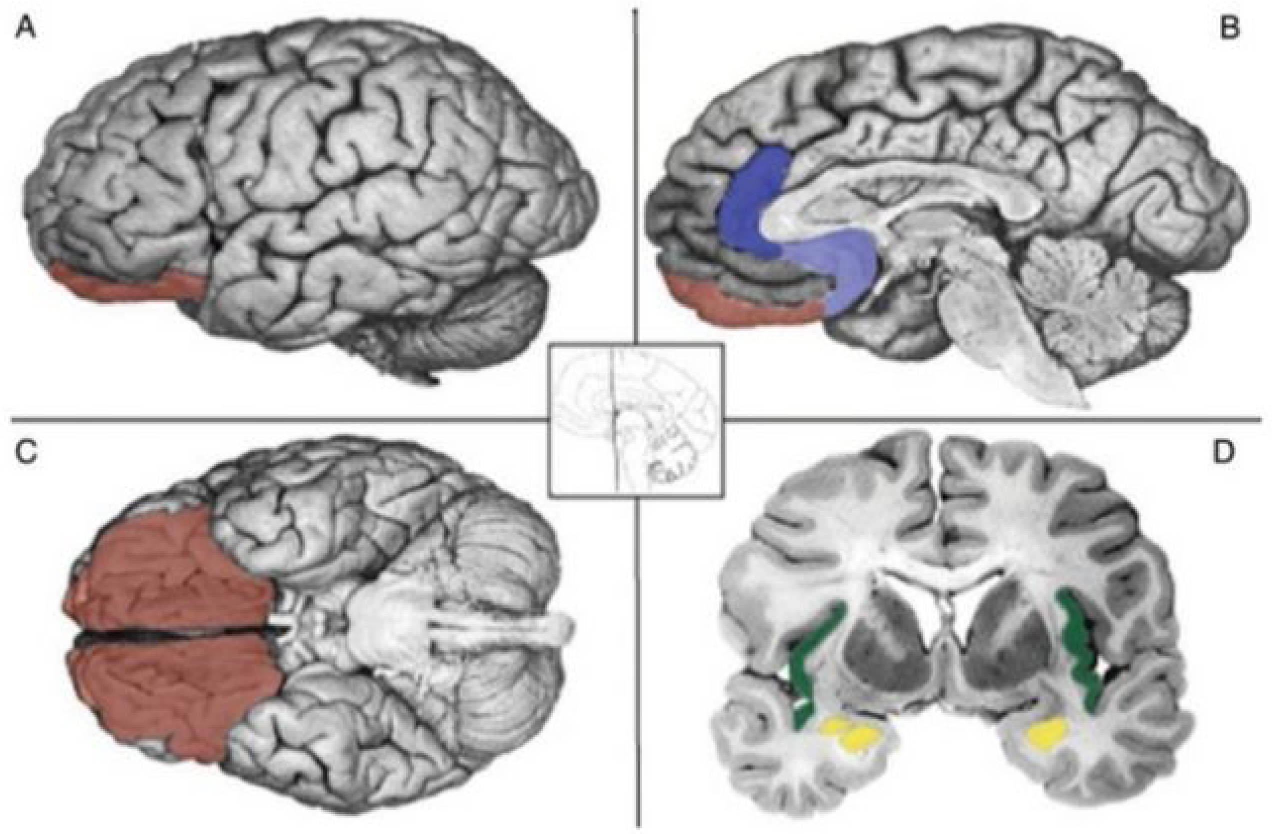


Diagram 18: *Brain Regions and Emotion: A. Lateral View, B. Sagittal View at the midline, C. Ventral View, D. Coronal View, Fear: Amygdala (Yellow), Disgust: Insula (Green) Anger: OFC (Red), Sadness: ACC (Blue).*[29]

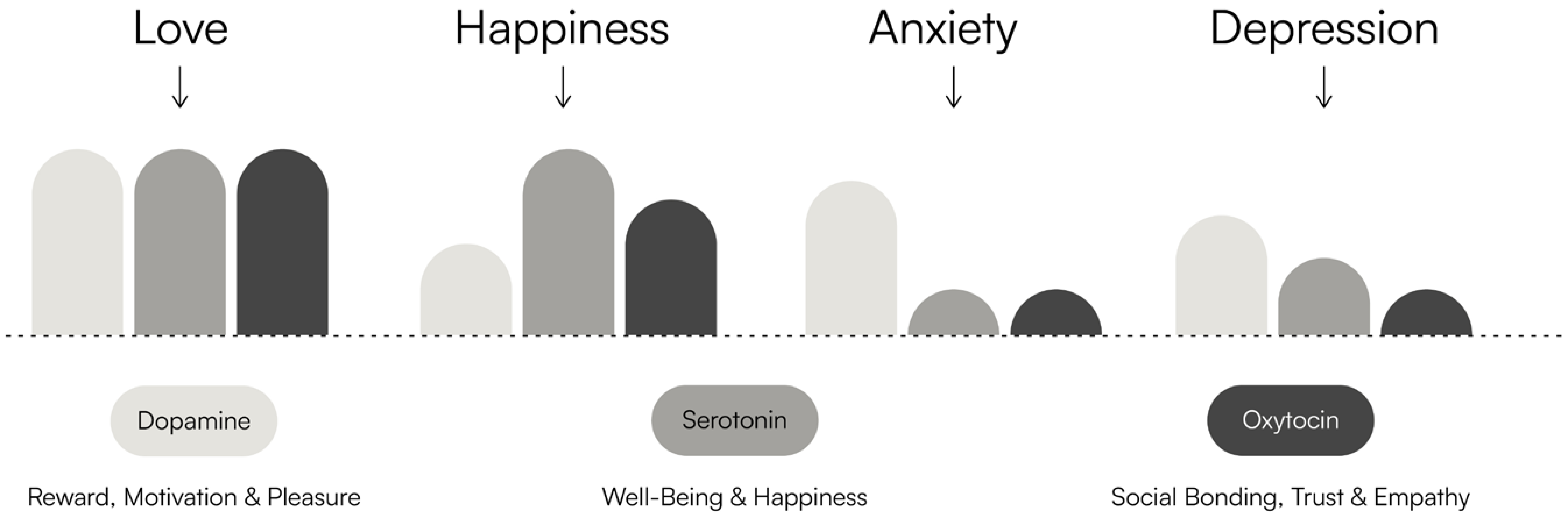


Diagram 19: *Neurotransmitters and Emotion: Different combinations of neurotransmitters in the brain give rise to different emotional states. For example, love is characterized as having greater expression of dopamine, serotonin, and oxytocin, while each neurotransmitter is expressed much less in states of anxiety and depression.*[30]

29 Lindquist, Kristen A., et al. "The Brain Basis of Emotion: A Meta-Analytic Review." Behavioral and Brain Sciences, vol. 35, no. 3, 23 May 2012, pp. 121—143, www.ncbi.nlm.nih.gov/pmc/articles/PMC4329228/, https://doi.org/10.1017/s0140525x11000446

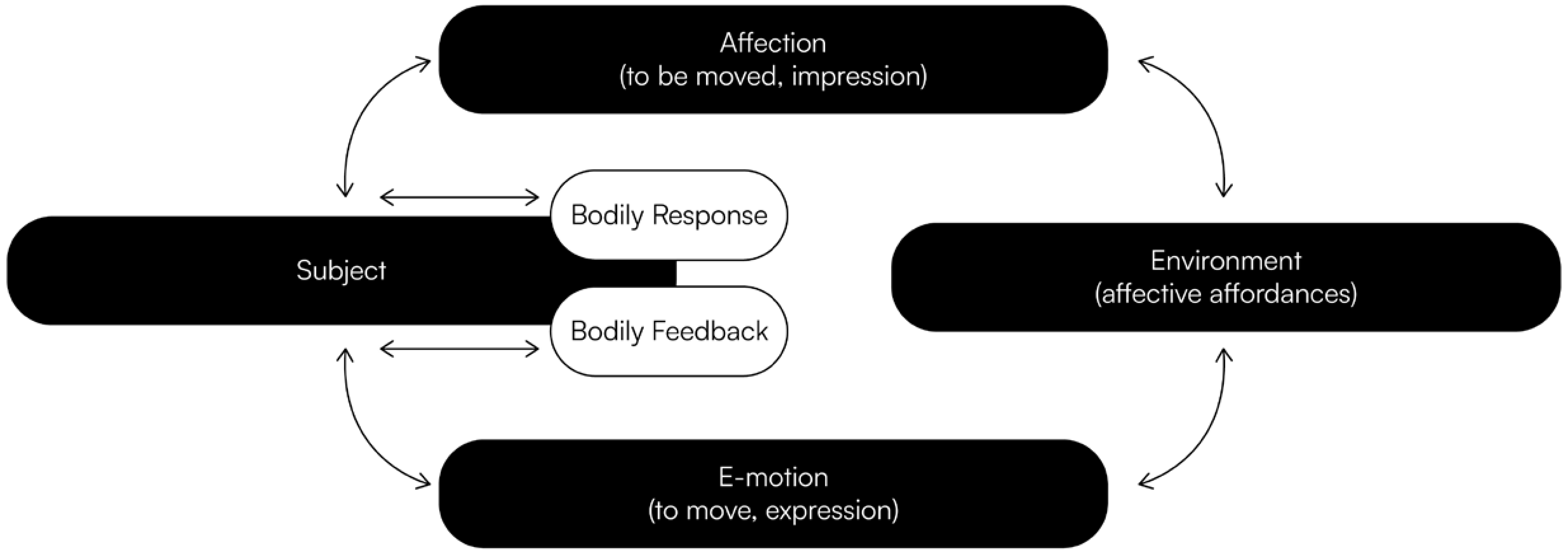
30 Jiang, Yao, et al. "Monoamine Neurotransmitters Control Basic Emotions and Affect Major Depressive Disorders." Pharmaceuticals, vol. 15, no. 10, 28 Sep. 2022, p. 1203, www.ncbi.nlm.nih.gov/pmc/articles/PMC9611768/, https://doi.org/10.3390/ph15101203.

How can architecture influence emotion to enhance well-being?

Aerial dancers perform a musical number on the walls of City Hall as part of the La La Land Day celebration. Eric Garcetti via Flickr Creative Commons

Model of Embodied Affectivity

Fuchs and Kock 2014



<u>Diagram 20:</u> The Model of Embodied Affectivity

As we move forward, the model of "Embodied Affectivity" will provide a useful framework for connecting how we feel to how we behave (Diagram 20). Developed by Thomas Fuchs and Sabine Koch (2014), the model has three main points...

1. Atmospheres: Emotions are regarded as resulting from the "circular interaction between affective qualities or affordances in the environment and the subject's bodily resonance - in the form of sensations, postures, expressive movements or movement tendencies."

2. Motivation for Movement: Motion and emotion are intrinsically inseparable: "one is moved by movement (perception, impression, affection) and moved to move (action, expression, e-motion)"

3. Personal Determinants: "The body functions as a medium of emotional perception: it colors or charges self-experience and the environment with affective valances..." while remaining under the radar.[30]

30 Fuchs, Thomas, and Sabine C. Koch. "Embodied Affectivity: On Moving and Being Moved." Frontiers in Psychology, vol. 5, 6 June 2014, https://doi.org/10.3389/fpsyg.2014.00508.

“Emotions are the foundations of our minds.”

Quote by Jaak Panksepp - Miami SuperBlue Museum by Es Devlin

Atmospheres

"Atmosphere," is a term used to describe a particular emotional or sensory overlay that becomes the defining lens for our perception of the environment. According to Tonino Griffero, it is a "quasi-thing," or something that is not tangible, forever fluid, and omnipresent. This "emotional affordance" is crucial for architects to understand and prepare for as the inherent character, essence, and coherence of a place deeply affects how we perceive, resonate with, and attune to it.[31]

Embodying the atmosphere of a place requires people to resonate and attune to the space. When we talk about "resonance," we mean aligning ourselves with the emotional frequency of a(n) atmosphere, place, or situation.

Imagine, for example, changing the radio station in the car to find your favorite song playing. Perhaps, this makes you excited and happy, priming a joyful atmosphere for the journey ahead. You have "tuned" into the correct radio station and now can adjust your current mental and emotional states to match. The cheery song and your willingness to be cheery combined produce an atmosphere that is also cheery. This process involves consciously embodying and adjusting our emotions and behaviors to match the atmosphere we are experiencing. Whether we feel involved in or detached from the atmosphere, our perception and personal attachment to a place significantly shapes its affective meaning for us.

One thing to consider about resonance and attunement in architectural atmospheres is that architects can only predict and intend for the desired feeling or emotion embedded in a place. However, with N.A.A.D., we can pair desired emotional resonances with bodily sensations, brain activity, and personal determinants to craft environments well-suited to promote well-being.

31 Arbib, Michael A.; Canepa, Elisabetta; Condia, Bob; De Matteis, Federico; Griffero, Tonino; Hart, Robert Lamb; Hewitt, Mark Alan; Reddy, Suchi; and Wynne, Mikaela, "Atmosphere(s) for Architects: Between Phenomenology and Cognition" (2023). NPP eBooks. 51. https://newprairiepress.org/ebooks/51 atmosphere

Photos from left to right: (1) Tomba Brion in Italy by Carlo Scarpa, (2) Sagrada Familia in Barcelona by Antoni Gaudi, and (3) Sky Reflector-Net at the Fulton Center in New York by James Carpenter Design Associates, Grimshaw, and Arup.

The Martinikerk or Martin's Church in the Netherlands

In support of the Model of Embodied Affectivity, emotions can influence behavior through facial expressions, posture, and gesture. The facial feedback hypothesis proposes that facial expressions reflect emotions an d play a role in shaping them. Forming a "face" sends signals to the brain that either reinforce or initiate the corresponding emotional experience. As a result, a feedback loop of communication is formed between the emotional regions of the brain and the motor cortex. Experiments have shown that people instructed to smile report feeling happier, and those instructed to frown report feeling more negative emotions. These effects can occur even when people are unaware that their facial muscles are under manipulation.[31]

Posture and gesture also have the potential to alter physiological responses which in turn affect emotional states. Like the facial feedback hypothesis, certain body movements and positions can influence the brain's emotional related-neural circuits, reinforcing the emotional experience. For instance, research has shown that people who adopt confident, expansive postures report feeling more powerful and exhibit lower levels of cortisol (a stress hormone). Conversely, adopting contracted, submissive postures can lead to increased feelings of stress and lower self-esteem.[32]

31 Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and Facilitating Conditions of the Human Smile: A Nonobtrusive Test of the Facial Feedback Hypothesis. Journal of Personality and Social Psychology, 54(5), 768-777.

32 Carney, D. R., Cuddy, A. J. C., & Yap, A. J. (2010). Power Posing: Brief Nonverbal Displays Affect Neuroendocrine Levels and Risk Tolerance. Psychological Science, 21(10), 1363-1368.

How can the influence of emotion on facial expression, posture, and gesture be understood to craft atmospheres in which people can easily attune and resonate with? Can we create atmospheres capable of eliciting confident, expansive, and happy facial expressions, postures or gestures?

Photo by Alejandro Muñoz

Motivation for Movement

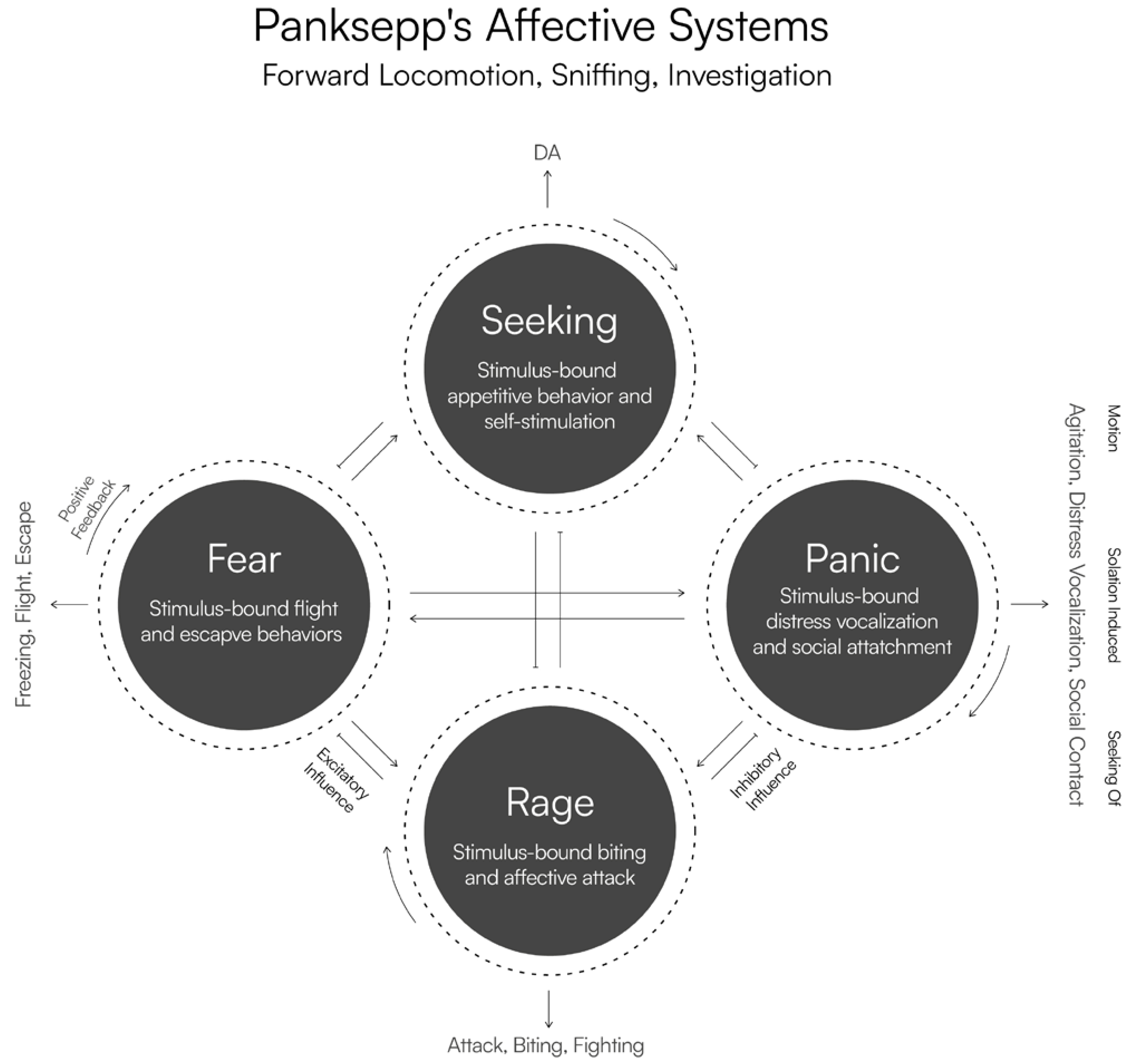


Diagram 21: *Panksepp's Affective Systems of Emotion and Behavior*

Emotions induce specific action tendencies or motor programs directly related to the potential affordances of the environment. For example, whether an individual chooses to enter a space is based on the perception and coherence of environmental cues that signal feelings of welcomeness and safety. Through the communication of these cues, bodily sensations arise that become translated into emotions and then specific behavioral programs of approach or avoidance (i.e.: do we choose to enter or avoid the space). Recall our theoretical equation for this circular interaction.

Jaak Panksepp's theory identifies core affective systems of emotion, linking essential survival behaviors with specific emotional programs. These systems motivate movement and are fundamental to how animals respond to their environment. For example, the seeking system drives exploratory behavior, enabling animals to acquire resources and learn from their surroundings. This framework illustrates how emotions are integral motivators for survival-oriented actions (ex.: flight or fight, approach or avoidance, social comfort, or isolation, etc.). [33]

33 Panksepp, J. (1998). Affective neuroscience: The foundations of human and animal emotions. Oxford University Press. affective systems of emotion.

What features of the environment coat a place in coherence and understanding, making it easier to navigate a space while reducing negative emotions like overwhelming anxiety?

Painting by George Tooker, “The Subway,” 1950: “Architect Vincent Chang, a partner at Grimshaw, one of the design firms involved in the overall project, notes that George Tooker’s painting The Subway served as a reference point for the type of space the architects did not want to replicate as they developed the new transportation hub.”

Determinants of Emotion

Kadinjaca Memorial Complex by Aleksandar Dokic & Miodrag Zivkovic in Serbia - Photo by Roberto Conte

The subjective nature of emotions means that individuals are bound to experience and resolve emotional conflicts differently. Personal, social, and cultural factors contribute to the way in which this process occurs.[34]

Personal factors consist of cognitive effectivities like emotional intelligence, interoceptive awareness, and mental health, while social and cultural factors consist of appropriate ways of expressing and managing emotion in various contexts based on previous collective experiences. For example, a person with severe bipolar disorder experiences extreme emotional states of depression and mania. They have severe difficulties maintaining an emotional homeostatic balance and these emotional states inevitably color and prime their experiences in the environment.

On a social level, for example, a strong support system can provide an individual with a safe environment for the regulation and expression of their feelings. The level of support one may feel from their friends or family can noticeably influence how they respond to different scenarios in the environment. Cultural determinants also influence emotional and behavioral expression. For example, in some cultures men are frowned upon for displaying sadness through tears, as it communicates a sign of weakness and is socially unacceptable. This can lead men to bottle their emotions inside and express them in potentially violent or harmful ways depending on the situation at hand.

These examples illustrate the complexity of human emotions in real-world contexts and how emotions more than simple mental states clouding the brain. Emotions, nevertheless, play a crucial role in guiding our behavior and shaping our values, with our surroundings capable of having a profound impact on our physiological, and psychological well-being.

34 Arbib, Michael A.; Canepa, Elisabetta; Condia, Bob; De Matteis, Federico; Griffero, Tonino; Hart, Robert Lamb; Hewitt, Mark Alan; Reddy, Suchi; and Wynne, Mikaela, "Atmosphere(s) for Architects: Between Phenomenology and Cognition" (2023). NPP eBooks. 51. https://newprairiepress.org/ebooks/51 atmosphere

Imagine a world in which architecture can offer a sense of "non-invasive therapeutic treatment," or an environmental way to protect mental and physical health and promote well-being.

Partial Quote by Tye Farrow - Photo by Tim Cooper in 2019

05

Conclusion

Final Thoughts

As mentioned, there is substantial room for growth in the field of N.A.A.D. This growth is only possible through the collaboration of scientists conducting research on the topic and architects and designers constructing the built environment. Both professions have a duty to be concerned with the variety of implications architectural features impose upon human physiological and psychological well-being.

Allow this information to prime your interest and inspire you to think more about how what you will design can influence the cognitive, behavioral, and emotional states of users and occupants. Remain curious and ask questions even if the answers are not so apparent at first glance. Design for the heterogenous experience of all the senses, paying attention to more than just the visual realm. Craft affordances and atmospheric experiences throughout your spaces. Experiment with the application of these ideas throughout the design process and consider conducting post-construction evaluations. Buy into N.A.A.D. as a means for the remarkable evolution in human-centered design, it will surely be worth the investment.

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