Neuroscience and Multisensory Experiences

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Abstract – Neuroscience is an intriguing topic to discuss in the field of UX design. The study of neuroscience is an emerging field that helps UX designers generate a solid foundation to make better design decisions and solutions. One popular topic in UX is Multisensory Experience and interaction. Multisensory experiences are the impressions formed by specific events whose sensory elements were carefully crafted by someone. They deal with coupling multiple modalities to provide a robust, flexible, adaptable, and familiar experience to their users. The contribution of neuroscience in design and creating multisensory experiences in the reality-virtuality continuum is discussed in this study.

Index terms – experiences, multimodality, multisensory, neuroscience

1. INTRODUCTION

Neuroscience is the scientific study of the nervous system. It focuses on the brain and its impact on behavior and cognitive functions.[1] It is an interdisciplinary field that works closely with other disciplines like User Experience(UX). UX is a multidisciplinary concept (including interaction design, information architecture, visual design, usability, and human-computer interaction) practiced to create products that provide meaningful and relevant experiences to users. With the evolution of technology and its exponential use, developing products that fulfill user needs and provide the desired experience has become crucial. Neuroscience has been contributing to understand, gain insights and then analyze user behavior and interaction with products. The frontal lobe of the brain is the center of our emotions and cognitive networks. Some essential functions of this lobe facilitating UX are reward & motivation, decision making, and predicting the consequences of an action. The parietal lobe plays a crucial role in sensory perception and integration. The temporal lobe in processing the auditory and meaningful audio or signal assignment.[2]

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2. NEUROSCIENCE & HCI

Cognition is complex. To understand how people behave with products, UX researchers perform focus group interviews. When they ask - Why did you do that? - there is a high chance that interviewers will not be able to answer it. [4] Our brain functions as two different systems, Reactive and Analytical. Reactive is fast, automatic, and responsible for instinctive cognition. Analytical is slow, calculating, and applied to more complex scenarios. The brain works with a survival mechanism - where it recognizes patterns and takes shortcuts so that it spends less energy while a piece of information is processed. Most of our decision-making falls into system one, fast-thinking, so it becomes difficult for UX researchers to understand the preferences of a brain. [6] Neuroscience techniques have helped them study electrical

response in the brain with electroencephalography, attention & perception with eye-tracking cameras, and emotional response & arousal with skin sensors and facial analysis, and that has assisted researchers in understanding design psychology.[4] This helped in establishing some general guidelines for design - maintaining congruency (temporal, spatial & semantic), predicting user priming & impressions, organizing for lazy readers, taming text as per different modalities, visual prominence with color, using geometry for object recognition, and many more.

3. NEUROSCIENCE & MULTIMODAL

To understand how neuroscience helps designing the desired experience, we should elaborate on what an experience is. Generally, experience is - i) direct observation of our participation in events as a basis of knowledge; ii) practical knowledge, skill, or practice derived from direct observation or participation in events; iii) something personally encountered, undergone, or lived through; iv) the conscious events that make up an individual life. [3] Elizabeth Churchill, director of UX at Google says, "An experience is a moment of embodied awareness. An experience can be made by focusing your attention on being in a specific location and time, or it can be something that happens to you and draws your attention, focus, and conscious knowledge of being in that particular time and place. An experience affects you, invites learning, and potentially changes you." Designing a good experience for a product or an interface requires us to understand what makes an experience memorable. Neuroscience tells us that humans have a stronger recollection or impression of moments that evoked our sensations successfully during an event because senses are the key to our experience. So, if a product or interaction provokes or triggers our senses (multisensory), our brain stores that information in the long-term memory and can easily recall it in the future. Multisensory Experiences are impressions formed by specific events, whose sensory elements were carefully crafted by someone. "They are synthesized from the senses of sight, hearing, taste, smell, touch, plus balance, movement, and proprioception. The senses interact and affect each other. Notably, experiences are not made from senses alone; emotion and attention modulate the senses as well" - Elizabeth Churchill, director of UX at Google. Multimodal interactions provide different options for users to interact with a product & acquire knowledge at their convenience. Two modes are Interacting and Perceiving like (Interact - Perceive) gaze - vision; speech - audio; direct touch - vibration; gestures - facial expression; proxemics - smell, etc.[5] Proprioception, somatosensory, chronoception, kinaesthesia, and other Aristotelian senses shape our experiences. These several modalities allow us to stimulate the respective senses.

4. NEUROSCIENCE & REALITY-VIRTUALITY CONTINUUM

The reality-virtuality continuum is a continuous scale/spectrum going from real to virtual events. Key elements of this continuum are - Reality, Mixed reality (comprising of augmented reality and augmented virtuality), and Virtuality. Reality or Real Events are those events that encompass only physical elements. Augmented Reality is where digital elements are augmented onto real ones. Augmented Virtuality is where real objects are augmented (or merged) into a virtual world. Virtuality or Virtual Events are entirely created through multisensory technology and do not involve a physical object whereas they might be inspired by reality.[3] Neuroscience has helped designers understand how the brain interprets the senses and it is crucial to focus on how our senses perform

individually and how they interact with each other. Congruence among the input provided and the output received respectively helps us interact with a product easily. Researchers have provided the following six fundamental concepts/principles that are essential for analyzing and designing controlled multisensory interactions.

1) Temporal Congruence - whether two or more senses are present with information at the same time or not, for instance - it feels unnatural when you use a stylus and it is not able to draw a line and align itself with the pointer harmoniously. 2) Spatial Congruence - Whether the information presented to two or more senses is coming from the same place (source in space) or not, for instance - it would not make sense if the car and sound of the car horn are asynchronous. 3) Semantic Congruence - is when the information presented to two or more senses share the same identity (or meaning), for instance - showing a picture of an elephant and playing the sound of a dog will feel uncomfortable. 4) Crossmodal Correspondences - Refers to the associations and compatibility between various unisensory features (such as auditory pitch and visual size), for instance - Edward Sapir highlighted the speech sounds /a/ and /i/ with object size that most people associate the nonsense words /mal/ and /mil/ with large and small objects respectively.[7] 5) Sensory Dominance-when one sense prevails over the others in certain settings, for instance - the pattern of sensory dominance differs in healthy and pathological aging, favoring auditory-dominant behavior. (detecting sounds faster than flashes).[8] 6) Sensory Overload - when something overstimulates one or more of our senses because too much information was provided. This usually leads to detrimental effects on the experience, for instance - a child would find it arduous to make sense of a place like Times Square in New York City on his first visit.

The user experience and interaction will be more fluid if we design by adding one or more of these concepts because alignment in terms of these concepts can lead to more compelling experiences (super-additive). Although we can not deny that inconsistencies in these concepts can lead to less engaging experiences because it depends on where you fall on the reality-virtuality spectrum. Next, we cover examples of different experiences on the reality-virtuality continuum.

4.1 Multimodality examples on reality-virtuality continuum

Example 1 - Programmable Pasta[9]

This example is situated in the continuum's reality space which implies how a change in the visual sense can possibly affect how people taste food.

Event: Cooking or eating a meal with pasta that converts from a 2D to a 3D shape.

Sensory elements: Imagine a chef pours boiling water (temperature) on pasta sheets on your dining table and the flat shape of the pasta changes into any potential shape (allowing for visual movement). The sheets convert from a 2D to a 3D curly shape where colors, forms, textures, and flavors vary.

Concepts: Since your expectations based on the static pasta are defied with the movements of transforming pasta, the visual sense dominates the experience. The ability to change the shape of the pasta offers greater flexibility in terms of the pasta's identity or meaning (semantic congruence).

Enabling technology: This experience is enabled through new fabrication and 3D printing techniques that allow control over the physical appearance of food while still using common food materials (protein, cellulose, or starch). Users can customize food shape transformations through pre-defined software where they can select the shape, tune the density, orientation,

thickness, texture, and other properties of the food. Based on this design, they can then fabricate the designed pasta patterns using a 3D printer. The transformation process is triggered by water adsorption during the cooking process, which can be part of the presentation at the diner's table as described above.

Example 2 - Crystal Universe Experience[10]
This example is located in the continuum's augmenting reality space, which allows for the development of new and unknown impressions not found in nature or ordinary life.
Event: People can interact with a light sculpture (representing the universe) via a mobile device in an art installation.
Sensory elements: Soundscapes accompany the installation's lights, which vary in color, hue, and brightness. Because visitors are required to roam around the installation, proprioception is also vital. Visitors walk on a mirror-like surface, which gives them a unique tactile feeling.
Concepts: There is Spatial Congruence in this installation since all signals are oriented in the same location. Some of the lighting patterns and noises have a Temporal synchronization as well. Semantic Congruence is evident as both lights and noises depict elements of the universe, such as stars, grandeur, emptiness, amazement, and darkness.
Enabling technology: This augmented environment experience uses thousands of suspended colored LEDs in a 3D space. Sensors capture visitors' movements and create changes in the installation. Visitors can also interact through an app that will allow them to select the elements from space and view changes.

Example 3 - Meta Cookie[11]
This example uses advancements in AR and VR technology to demonstrate the next stage of immersive multisensory experiences. The user wears equipment, such as a headset, and the designer can manipulate what the user sees and smells digitally, transforming a plain cookie into a delicious cookie.
Event: Eating a digitally augmented plain cookie.
Sensory elements: The senses of sight, smell, taste, and touch are all involved in the experience. Chocolate, lemon, almond, tea, strawberry, and maple are a few flavors that may be produced by adjusting visual and aroma. The cookie also has its qualities, such as texture and mouthfeel.
Concepts: Spatial and Temporal congruence is achieved by increased aroma intensity when the user brings the cookie closer to him. Semantic congruence is managed by controlling visual and aroma following a given flavor, such as chocolate.
Enabling technology: The technology involves two cameras, a head-mounted display (HMD), and a multi-scent delivery device. The camera recognizes markers on the cookie and superimposes the desired visual on the cookie as seen through the HMD. As the system sees the cookie approaching the user's nose, an air pump sprays out the scent of the chosen flavor.

Example 4 - TREE VR
This example is located at the continuum's Virtuality end. It expands on current multisensory encounters by allowing users to have a full-body experience as a tree, rather than a human. The virtual world radically changes the user's perspective and provides a reality that would not be feasible without growth in technology.
Event: An installation to witness the lifecycle of a tree, from a first-person perspective, in the context of deforestation.
Sensory elements: Users are given the impression that they are a Kapok tree that develops from a seed to a tall tree and then chopped down by humans. Dynamic lighting, shadows, real-time vibration patterns, and scent

(Earth peat, foliage, living gun smoke) are used to achieve this experience.
Concept: All sensory aspects are linked by temporal, spatial, and semantic congruence. As a seedling, the user emerges from underground into the heart of a forest, smells the leaves, and at the end, when the tree burns and is chopped down, smells smoke—a reminder of the difficulties society is facing in the face of increased deforestation (Semantic Congruence). As the tree falls, the haptic sensation on the user's back becomes more intense, in addition to the aroma (Temporal Synchrony). People are also represented graphically in the virtual world, as their arms and hands form tree branches (Spatial Congruence).
Enabling technology: A VR headset, a haptic feedback device (Subpac—a backpack that vibrates on the back), a multi-scent distribution device (OWidgets system), and ambient heating and fan units are used to produce the experience.

We must always consider the question of what is real. Even if we completely immerse ourselves in a digitally generated world that transfers us to a completely virtual event, we are still experiencing some reality. Furthermore, given that perception is, in some ways, the best guess at the sources of sensory information present in the events we experience, it is possible that we already live in mixed reality, i.e., in what our minds construct of the physical world.[3] It is important to remember that impressions crafted are received differently by different people and that depends a lot on their prior experiences, preferences, expectations, and choices. People are not passive receivers but active actors in the generation of experiences. Therefore, it is crucial to consider the receiver carefully and give them a choice. Multisensory experiences should be used for good and not for harm, and the recipients should be treated equitably when deciding what impressions they wish to create by various sensory elements. Also, when they create such experiences, they capture some of the biases, and maintaining transparency is important which might not be visible to the receivers all the time but accessible whenever wanted.

5. CONCLUSION

It is important to keep in mind that we are, to a certain level, in control of what multisensory experiences we design for and can utilize these opportunities for good.[3] The senses are a fundamental part of what makes us human and at the same time, technology has also become a fundamental part of our life. Neuroscience has contributed to understanding human brains and behaviors and helped design better experiences for people. As of now, it is comparatively difficult to capture smells or touch in a multimodal experience. However, several researchers are working to make that possible in the future. While this interface is currently limited, it is clear that many of our everyday life experiences take place in mixed reality, where sensory aspects of the physical and digital world merge seamlessly.

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