

EXPLORING THE CEREBRAL ACTIVITY THROUGH MUSIC AND VISUALS.

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SUMMARY

SUMARIO

ACKNOWLEDGMENTS

0.1 HÈCTOR

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Gerard, Jesús, thank you for your unconditional support with the project. You are both fundamental parts of my professional and personal life.

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ACRONYMS

INTRODUCTION

1.1 MOTIVATION AND RESEARCH PROBLEM

This project was motivated by a mix of academic interests and personal experiences. A strong curiosity for both audio and video has always been shared by us. Coming from backgrounds in audiovisual engineering and graphic design, we tend to approach creations with a critical and analytical eye. When it came time to choose a topic for our final master's project, we realized quickly that our interests were closely aligned. After engaging in numerous in-depth dialogues, we arrived at the decision to concentrate our research into two primary areas: the realm of visuals and music, along with the dynamic interplay between these two forms of expression. This intersection felt like the natural place where our skills, passions, and professional perspectives converged. Después de investigar un poco nos dimos cuenta de que en muchos shows, los visuales no tenían relación con la música. Aunque muchos visuales realmente son increíbles, como por ejemplo los hechos por Anyma, estos tienen simplemente un propósito estético.

1.2 HYPOTHESIS

2

THEORY

2.1 VISUAL PANORAM

The world of screen visuals is a rapidly evolving field that brings together art, technology, and design. Far from being limited to the simple reproduction of images, this discipline encompasses a wide range of techniques, styles, and audiovisual tools. It includes everything from digital manipulation and real-time rendering to generative art and immersive installations. Today, visuals play a central role in technological art, contributing not only to aesthetic expression but also to musical and interactive experiences.

The origins of this practice can be traced back to the 1960s with the introduction of Sony's Portapak, the first portable analog video recorder, shown in figure 1. This device made it possible for creators to experiment with video outside of traditional television studios, opening the door to new forms of artistic expression. Among the first to explore its possibilities was Nam June Paik, who used magnets and electromagnetic filters to distort electronic images and create innovative visual effects[1, 4]. At the same time, artists such as Steina and Woody Vasulka focused on developing analog synthesizers capable of modulating waves and altering electronic signals in real time [7]. Although these early explorations often intersected with scientific experimentation, they laid the foundation for what would eventually become a recognized artistic field.



Figure 1: Sony Portapak camera (image source: [3])

During the 1980s and 1990s, with the advent of digital video, new techniques for editing, production, and temporal manipulation emerged. At this point, artists such as Bill Viola began to explore new techniques using extreme video slow motion and careful compositions [8]. Pipilotti Rist experimented with modifying images by altering saturation and distorting them to create expansive projections [6]. At the same time, in the field of electronic music, VJing was invented, a practice that consisted of mixing images in real time while music was playing. This concept quickly grew with the development of software such as Modul8, VDMX, and Resolume [5].

2.2 BRAIN FUNCTIONS

The region of the brain that is in charge of receiving, processing and interpretate the information that arrives through our eyes is called visual region. As seen in Figure 2, the main structure for that is the visual cortex, placed on the back of the brain, in the occipital lobe. The light enters through the eyes going through the retina. In the retina, there are special cells (cones and rods) that transform the light into electrical signals. Those signals travel through the optic nerve to a station called the thalamus (specifically to the lateral geniculate nucleus). Finally, the information arrive to the visual cortex.

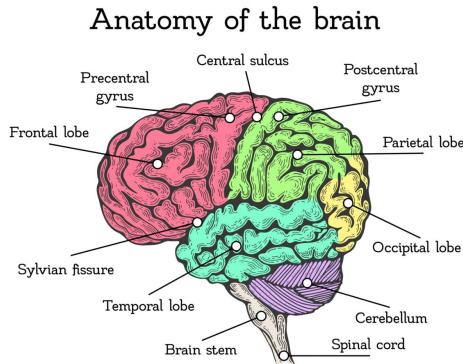


Figure 2: Areas of the brain, by CogniFit Blog. *Three main parts of the human brain*, 2015

As it is explained in the first chapter of the book *Neuroanatomy, Visual Cortex* [2] the visual cortex is divided into five different areas (V₁ to V₅). As shown in Figure 3, those areas are classified according to their functional and structural characteristics. As information moves through the different areas, it becomes increasingly more specific. Neurons in the visual cortex are typically activated by stimuli within a specific receptive field. Each area contains neurons that are sensitive to different types of stimuli.

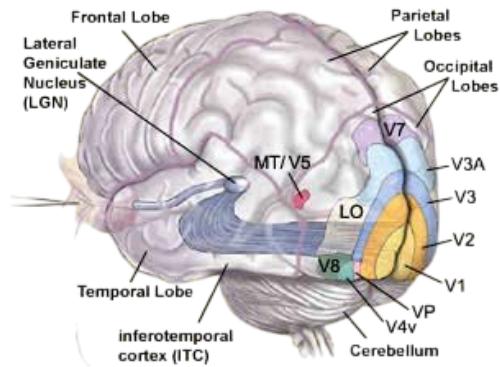


Figure 3: Areas of the visual cortex, by Leonard J. Press, O.D., FAAO, FCOVD. *The Visual Centers of the Brain*, 2018

- **V₁ - Primal visual cortex:** V₁ is located around the calcarine sulcus. It consists of a laminar organization of six layers with a columnar architecture of marked ocular dominance and orientation. This area is the first cortical receptor of the retino-genicular cortical pathway. It receives information from the thalamus

in layer 4 and sends projections to section V2 and other areas where all the information captured by V1 will be processed.

The main function of this area is to break down the image into its most basic concepts. It is responsible for detecting retinotopic positions, edge orientation, contrasts, spatial phases, and direction of movement. It also has a very precise retinotopy with very small and well-defined receptive fields, along with a fairly high spatial resolution.

- **V2 - Secondary Visual Area:** This region surrounds V1 and acts as an interface between V1 and other extrastriate areas. It continues to maintain rhinotopy, but its columns show a rather different organization from the previous region. It receives information from layers 2 and 3 of the V1 region and sends projections to V3, V4, and V5, as well as returning information to V1 for feedback.

This area is essential for the grouping of elements and the differentiation of figure and background. The main function of V2 is to integrate the output of V1. This area has larger receptive fields that allow it to reflect more complex properties than those detected previously, especially with the detection of textures, edges, color contrasts, and spatial frequency. Some types of cells in V2 participate in the detection of figures and boundaries. In addition, V2 participates in routing to the dorsal and ventral pathways.

- **V3 - Visual Area 3:** Region V3 is located next to V2, on the dorsolateral surface of the occipital lobe. It receives signals from V1 and V2 and projects them to intermediate dorsal and ventral areas. This region has even larger receptive fields than the first two and is responsible for deciphering and processing very complex spatial patterns that the other two areas are unable to process. It does not have a specific role or a fully designated function, but rather acts as an intermediate node for processing and transmitting complex information to the following areas. It is the area responsible for transmitting information to the following more specialized areas.

- **V4 - Colour specialized area:** The V4 region is located on the ventral and lateral surface of the occipital lobe. It is responsible for receiving inputs from V1, V2, and V3 and projects them to more ventral temporal areas. This region is responsible for color recognition, not only detecting the wavelength of the signal, but also registering color constancy under variations in lighting. By detecting and processing this information, it ensures that the brain reacts to colors according to the information detected in this region. It also has neurons that respond to curved shapes, corners, and combinations of lines and textures. It is responsible for visual attention. This part of the brain modulates strongly according to attention. It increases when attention is paid to a stimulus within the receptive field.
- **V5 - Movement Specialized area:** V5, also known as MT (middle temporal), is located in the lateral/dorsal temporal region and is responsible for receiving information from areas V1, V2, and V3 and sending it to regions of the dorsal parietal pathway. This region is responsible for detecting the direction and speed of movement, as its neurons are highly selective for this. It integrates local signals to encode global movement, an essential parameter for visual tracking and motion perception.
- **V8 - High level Color Processing:** This area, also called V4 plus, is located in the ventral region of the occipital lobe and was recently discovered through fMRI studies, when an area was observed that became highly active when color was perceived and analyzed. V8 is heavily involved in interpreting color, but in a much more complex way than V4. It specializes above all in achieving color constancy. It ensures that even if the intensity of the color changes, we can still identify the actual color being perceived. This ability requires complex calculations that depend not only on the information entering the retina, but also on spatial and contextual comparisons. It is a region that contributes to the identification of complex color patterns and boundaries defined by color differences.

3

PRACTICAL PART

3.1 PAPERS

3.1.1 *Introduction*

This project aims to provide users with an agent that operates entirely offline, without performing any searches or retrieving information from the internet. The core objective is to ensure that every response the agent generates is grounded in trustworthy, scientifically validated knowledge. To achieve this, the project focuses on building a carefully curated database composed solely of verified scientific information.

The most reliable way to guarantee the accuracy and credibility of the agent's knowledge base is to manually compile and review scientific articles. By selecting only high-quality studies and extracting the essential findings, the project ensures that the agent embeds information that has already been thoroughly vetted. This approach prevents the introduction of unverified, misleading, or low-quality data and allows the agent to operate with a high degree of scientific integrity. As a result, users can interact with the system confidently, knowing that its responses are based solely on pre-approved, evidence-based sources.

3.1.2 *Research*

The goal is to provide users with guidance supported by solid research. To do it an extensive review was conducted focusing on studies related to color, visual and auditory frequencies, and their effects on the human brain. After several hours of analysis, approximately 60–70 papers were selected for each topic, prioritizing those that offered the most reliable and impactful insights for the tool's development.

Once the papers had been selected, the next step was to construct the database. To organize the information systematically, a CSV file was created to store and classify the key details from

each article. The following structure, shown in Figure 4 was chosen:

- **Title**
- **Author**
- **Year**
- **Summary:** This section contains a condensed version of the paper's abstract. Because abstracts are typically accessible for free, they provide enough information for the system to understand the essence of each study without requiring full-text access.
- **Keywords:** Keywords were included to enable the system to retrieve the most relevant papers based on the prompts provided by the user. When embeddings are generated, these keywords help the system match user queries with the scientific articles that best fit the topic, ensuring accurate and efficient information retrieval.

This structured approach ensures that the agent can navigate the database effectively and rely on well-organized, high-quality scientific data.

```

1 1;hors,year,summary,keywords
2 sion","gegenfurther, K. R. & Kiper, D. C.",2003,"This paper reviews the neural mechanisms underlying color perception in humans. It describes how the retina encodes color
3 demonstration of functional specialization in human visual cortex","Zeki, S.",1991,"This study demonstrates that the human visual cortex is organized into functionally s
4 etical stages of colour processing in the human brain","Zeki, S.",1998,"This paper describes three cortical stages in color processing in the human brain. The first occur
5 tecture of the colour centre in the human visual cortex","Bartels, A. & Zeki, S.",2000,"This study analyzes the functional organization of area V4, considered the "color
6 al encoding of color in the brain","Bird, C. M. et al.",2014,"This study investigates how the brain encodes colors into perceptual categories. Using fMRI, the authors fo
7 cuse to colour in the human visual cortex: an fMRI review","Mullen, K. T.",2019,"This study analyzes fMRI studies on how different areas of the human visual cortex resp
8 activity patterns predict behavioral performance","Bannert, M. M. & Bartels, A.",2018,"This study shows that neural activity in the V4 area of the human brain predicts p
9 g the effect of red and blue on cognitive task performance","Xia, T. et al.",2016,"This study analyzes how the colors red and blue influence cognitive performance. The re
10 essing of color preference in the brain","Racey, C. et al.",2019,"This study investigates how the brain processes color preferences and which neural areas are involved. U
11 nified theory of visual area V4","Roe, A. W. et al.",2012,"This paper proposes a unified theory on the function of the V4 visual area, integrating findings on color, sh
12 ation of perceived object shape by the human lateral occipital complex","Kourtzi, Z. & Kanwisher, N.",2001,"This study demonstrates that the lateral occipital complex (l
13 ateral occipital complex and its role in object recognition","Grill-Spector, K., Kourtzi, Z. & Kanwisher, N.",2001,"This study delves into the role of the lateral occipital
14 ception reduces activity in human primary visual cortex","Murray, S. O. et al.",2002,"This study reveals that coherent perception of form reduces activity in the primary
15 e-scale organization of shape processing in the human visual cortex","Freud, E. et al.",2017,"This study explores the large-scale organization of shape processing in the human visu
16 g material versus geometric properties of objects","Newman, S. D. et al.",2005,"This study examines how the brain differentiates between imaging the material properties
17 tate visually evoked potentials: paradigms and perspectives","Vialatte, F.-B., Maurice, M., Daubies, J. & Cicchetti, A.",2010,"This article provides a comprehensive review
18 dy-state visual evoked potential in vision research","Norcia, A. M. et al.",2015,"This review analyzes the use of steady-state visual evoked potentials (SSVEPs) in vision
19 aristics of steady-state and transient responses evoked by modulated light","Regan, D.",1966,"This classic study analyzes the brain's visual responses to modulated light
20 G responses to 100 Hz flicker: resonance phenomena in visual cortex","Hermann, C. S.",2001,"This study examines how the human brain responds to intermittent visual stimuli
21 of strong harmonics during visual entrainment","Heinrichs-Graham, E. et al.",2012,"This study investigates the generation of strong harmonics in the visual cortex during
22 gamma-band entrainment of visual cortex","Nietro, N. M. et al.",2024,"This study explores how the human visual cortex responds to entrainment in the gamma band (>30-100 Hz)
23 entrainment and its relationship to visual perception","Chow, C. et al.",2016,"This study analyzes how rods (low-light-sensitive photoreceptors) contribute to cortical entrainment an
24 ed fast SSVEPs during sleep","Sharon, O. et al.",2018,"This study investigates how steady-state visual evoked potentials (SSVEPs) are affected during sleep. Using EEG, th
25 imulation at either 4 Hz or 10 Hz, generates distinct responses","Ritter, J. L. et al.",2025,"This study analyzes how different frequencies of visual stimulation affect co
26 flicker fusion frequency in a narrative review","Makowski, N. D. et al.",2021,"This narrative review analyzes the critical flicker fusion frequency (CFF), which is the sp
27 evel crossmodal pitch/visual associations","Sciortino, P. et al.",2023,"This study explores crossmodal associations between sound (pitch) and visual perception using sto
28 mulated with behavioural tasks in perception research","Wittenberg, C. et al.",2019,"This study combines steady-state visual evoked potentials (SSVEPs) with behavioral t
29 computational neuroaesthetics","Ayaz, S. et al.",2009,"This article analyzes the emerging field of computational neuroaesthetics, which combines neurosciences, psychology,
30 fine arts, and neuroscience to understand the aesthetic brain. Emerging perspectives","Atiyeh, B. et al.",2025,"This narrative review addresses neuroaesthetics and visual perception, exploring ho
31 and reshaping the aesthetic brain: emerging perspectives","Kirsch, L. P. et al.",2016,"This article reviews how aesthetic experience modifies brain activity and visual per
32 ceptual brain imaging on perception and appreciation of pictures","Maglione, A. G. et al.",2017,"This study uses electrical neuroimaging (EEG) techniques to investigate h
33 color and luminance from responses in human visual cortex","Bannert, M. M. & Bartels, A.",2013,"This study investigates how the human visual cortex encodes color and lumin
34 ence, and attention in the human visual cortex","Bartels, A. et al.",2008,"This study explores how the human brain simultaneously processes color, motion, and attention
35 tribution of area V4 to human color vision","McKeefry, D. J. & Zeki, S.",1997,"This study analyzes the role of the V4 area in color perception in humans. Using fMRI and le
36 gited neural systems for shape perception","Kourtzi, Z. et al.",2003,"This study investigates how the brain perceives shapes using a distributed neural network that include
37 trial EEG analysis reveals burst structure during flicker stimulation","Oppermann, H. et al.",2024,"This study uses EEG analysis in individual trials to examine the struc
38 ture design affects harmonic content of SSVEP responses","Solf, B. et al.",2020,"This study investigates how the design of visual stimuli influences the harmonic content of SS
39 perspectives on gamma-band visual entrainment","Duecker, K. et al.",2021,"This article critically reviews studies on visual entrainment in the gamma band (>30-100 Hz)."
```

Figure 4: Example of a CSV with the Structure of the project

The next step involved processing the information contained in the CSV file. To ensure that the agent could generate embeddings effectively, it was necessary to remove any characters that

might interfere with processing, such as accents, apostrophes, and other special symbols. These characters can cause inconsistencies or errors during embedding generation, so cleaning the data was essential.

To accomplish this, a script was created to automatically convert and sanitize the CSV files, ensuring that all entries were standardized and compatible with the agent's requirements. This script, titled `Papers_clean.py`, performs the necessary preprocessing steps and prepares the dataset for seamless integration. The full code for this script is included in the appendix [B.1](#).

4

CONCLUSIONS

4.1 conclusions

A

TIPS AND GUIDES FOR THE SETUP

A.1 HOW TO CONNECT AN AGENT WITH MEMORY

To interact with an agent, you typically use the addMessage operator, which sends a message to the agent and receives a response as seen in Figure 5. This works well for single exchanges: you ask something, the agent replies, and the interaction ends there. However, addMessage does not support memory, so it cannot maintain an ongoing conversation. Each new message is treated as an isolated request.

If you want to create a continuous dialogue with an agent, one in which the agent remembers previous messages, you should use the agentSession operator instead. As shown in Figure 6, this operator allows you to establish a session that preserves conversational context. To use it, open the operator, go to the Agent Session section, and attach the agent you want to interact with. Once connected, the agent will be able to maintain memory throughout the session.

Additionally, you can enhance the experience by connecting a chatViewer element to the agentSession. This provides a more intuitive, user-friendly interface for viewing and conducting the conversation.

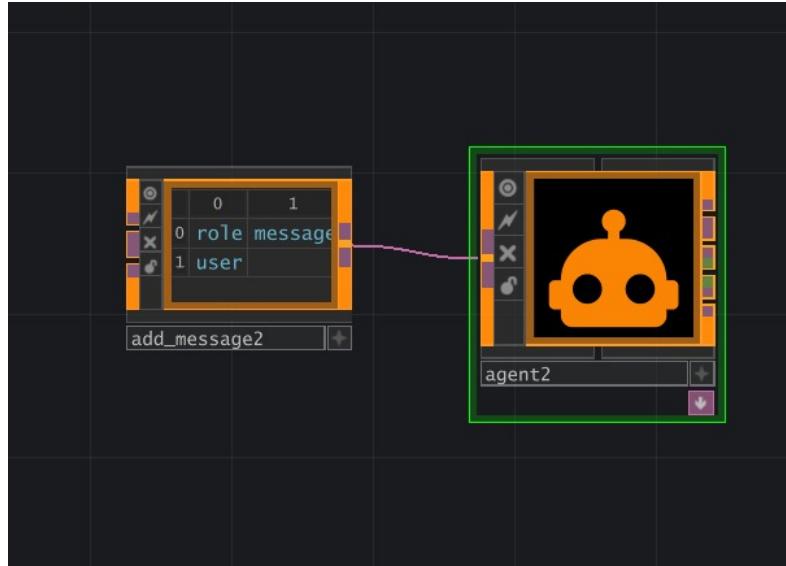


Figure 5: Connection between the operator addMessage and an Agent in Touch Designer

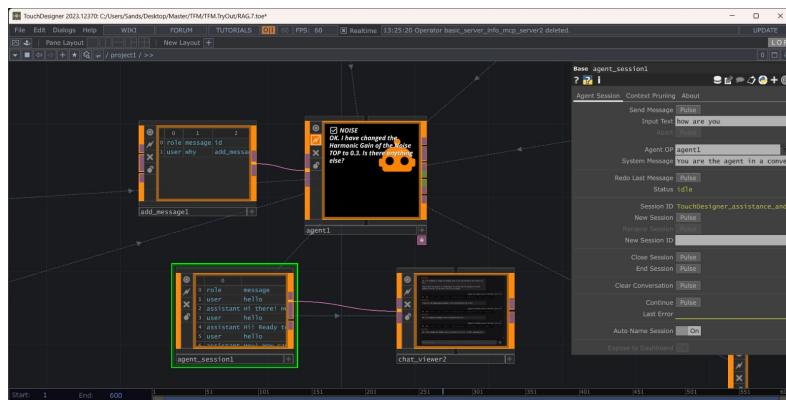


Figure 6: Connection between the operator agentSession and an Agent in Touch Designer

CODES USED FOR THE PROJECT

B.1 PAPERS_CLEAN.PY

Listing 1: Python code to clean problematic characters

```
import pandas as pd
import re

df = pd.read_csv("Papers_Sumary.csv")

def clean_text(text):
    if pd.isna(text):
        return ""

    # Remove references like [number] or (year)
    text = re.sub(r'\[\d+\]|\(\d{4}\)', '', text)

    # Replace multiple spaces with one
    text = re.sub(r'\s+', ' ', text)

    # Remove special characters (ASCII-safe)
    text = re.sub(r'[\-\.\']', '', text)

    # Trim and convert to lowercase
    text = text.strip().lower()
    return text

df["title"] = df["title"].apply(clean_text)
df["summary"] = df["summary"].apply(clean_text)
df["keywords"] = df["keywords"].apply(clean_text)

df.to_csv("papers_clean.csv", index=False)
print("Clean CSV saved as papers_clean.csv")
```

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