Figure 1. Mural of the Battle of Cacaxtla, reconstructed by the Art and the Brain Project, based on original photographs provided by the UNAM Institute of Aesthetic Research Pre-Hispanic Murals Project.

Cecilia Rosen*

How Our Brain Sees Art

Interview with

Francisco Fernández de Miguel**

Cecilia Rosen: Tell us about the Art and the Brain Project and what advances it has made since beginning.

Francisco Fernández de Miguel: The project began almost by chance. We were working on the Experiment Project for Teaching Science, making a virtual reality laboratory for high school students. The idea was to create a virtual, three-dimensional gallery where the students could distort vision to explore the aesthetic experience. That allowed them to see art works like a fly or a cat would or reproduce visual distortions like those that influenced some of the works of Rembrandt or Monet. When I was talking about this with Dr. María

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All photos are courtesy of doctor Fernández de Miguel.

Teresa Uriarte, who I admire and am very grateful to, she asked me if we had thought of using pre-Hispanic murals for the experiment. That opened up a completely new perspective for me, because the pre-Hispanic murals' content is tremendously sophisticated but was expressed in relatively simple formats. For examples, the murals of the Battle of Cacaxtla at first seem very beautiful; but they contain images of tremendous slaughters.

Also, the pre-Hispanic murals, seen from the perspective of neurophysiology, offer magnificent advantages for studying the fundamentals of visual perception. They're two-dimensional, with no depth or perspective, and they generally use primary colors, forming contrasts between opposites, like green-red or blue-yellow. These contrasts activate our visual neurons naturally.

CR: And how was the idea concretized?

FFdM: At that time, Dr. Uriarte was planning the UNAM Tlatelolco Museum in collaboration with the National Institute of Anthropology and History, and she invited me to contribute with a neurosciences project as a permanent part of the museum. I proposed combining research and socialization of science in a hall where we would explore how we perceive pre-Hispanic murals. We would invite museum visitors to participate as subjects in the study: they would loan us their brains to register their electrical activity (through an electroencephalogram) in response to images selected from the murals. So, museum visitors would experience science from the inside and would know how it's possible to experiment by logging electrical brain activity in response to works of art.

CR: Of course. And there are many aspects that can be studied...

FFdM: Yes, the simple visual exploration of the murals sparks different emotions. For example, the mural of the battle produces a combination of beauty and violence, while that of the Green Goddess of Tetitla sparks a sensation of warmth. With that in mind, we started doing experiments in my lab to determine the way we would move ahead in the museum. The project required having a solid foundation, so we invited our colleagues from the UNAM Institute of Cellular Physiology to carry out pilot experiments. One technique that enriched the

project was suggested by Lilly Dabdoub, who studies psychology and was part of the project from the very start. She suggested using semantic networks to quantify the perceptions of each artwork. So, we had dominant qualifiers for the works, with which we programmed a keyboard where the participants could press a button with the best qualifier to describe the images. That allowed us to start a log of the brain waves and design the sessions for the Tlatelolco museum. Also, the semantic networks gave us the basis for digitally modifying specific components of the images, like the color of the background and testing specific hypotheses about the determining factors that changed each perception. That was how we confirmed that the Battle of Cacaxtla murals were perceived as beautiful despite the killings they depict, with spurts of blood and the intestines of the victims hanging out. We came to the conclusion that in these murals, the opposing factors weren't beauty and ugliness, but beauty and violence.

CR: How do you interpret these two apparently contradictory perceptions?

FFdM: The color scheme in the backgrounds of the mural modulates our perception of the levels of violence and beauty. Here, it's worth mentioning that, to do these studies, we opened a social service project that has been wonderful.[1] Young, enthusiastic students in training came on board. The engineers deal with computer services and the equipment; the biologists and psychologists log the results; the mathematicians, computer scientists, and physicists develop tools for analysis for our neural responses. Working together, we've shown that the amount of Mayan blue in the battle mural's background intensifies the sensation of beauty and reduces the feeling of violence. Something similar happens with the white clothing. On the contrary, the amount of reds and ochres in the figures of the warriors intensifies the sensation of violence. The images in Figure 2 clearly show that the feeling of violence is located in the warriors and the background modulates the perception.

Working together, using another mural, the one of the Green Goddess of Tetitla, from Teotihuacan, we found that the same color scheme, but with a completely different design, produced completely different perceptions.

CR: What does this image tell us?

FFdM: By reconstructing the images using identical palettes to those we find today in each image, we once again encountered the red-green, blue-yellow, and yellow-white contrasts.

> Museum visitors would experience science from the inside and would know how it's possible to experiment by logging electrical brain activity in response to works of art.

Figure 2. Segmented pairs of figures from the mural of the battle showing different levels of beauty and violence. The blue background in the image on the right reduces the perception of violence and increases that of beauty. The images were prepared digitally by the artists in the Art and Science Project using photographs provided by the UNAM Institute of Aesthetic Research Pre-Hispanic Murals Project.

Figure 3. The image on the left is a digital reconstruction of the Green Goddess of Tetitla done by participants in the Art and the Brain Project using photographs of their own. In the image on the right, the colors have been digitally inverted.

The original image from Tetitla seems beautiful to us and produces a sensation of warmth. But, when we digitally invert it, it continues to seem beautiful, but the warmth turns cold. Surprisingly, if we eliminate the colors, the monochromatic image maintains the essential lines, and, despite continuing to be beautiful, the feelings of warmth or coldness are replaced by indifference.

These perceptions are the same regardless of the viewer's sex, age, level of schooling, or whether he/she has had any art education. That is, it is a perception that depends on neural pathways, independent of experience. This means they are sensations independent of culture.

CR: What happens with the other murals that you have studied the perceptions of?

FFdM: The Cacaxtla mural has very different effects. The beauty is associated with a semantics dominated by cultural experience. People associate beauty with the historical, the pre-Hispanic, the clothing, or the feathers, in addition to mentioning aspects associated with artistic design, like the color blue or the proportions. In contrast, the violence sparks a different, more elemental, direct semantics: pain, blood, death, etc., sometimes accompanied by aesthetic attributes like the chromatics.

CR: And so?

FFdM: What we're interested in looking at is when it is so violent. If we bring back the blue background to the pairs of warriors, the perception of violence drops significantly. However, the red background increases the perception of violence. So, the chromatic contrasts add to the warriors' forms and attitudes to modulate perception. We can also state that the perception of violence depends on the sex of the viewer: the electroencephalographic logs, which we're still analyzing, show that women are significantly more reactive to violence than the men, with activity in the frontal cortex associated with decision-making.

CR: And, based on these findings, where will the project be headed?

FFdM: It has diversified in several aspects. The Cacaxtla murals showed us another unexpected attribute: the presence of a complex background structure like that of paintings from other cultures and periods. For example, one of the pairs of warriors in the Cacaxtla mural is standing on a triangular structure similar to that of scenes of violence in murals from Babylonia and that also appear in an enormous collection of European paintings from different centuries, until arriving at Picasso's *Guernica*. We also found that the structure of the background can be divided into thirds, displaying the same or a similar golden ratio as the one used in Europe. This suggests, on the one hand, that the Mesoamerican cultures applied mathematical knowledge to their pictorial designs. On the

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other hand, it also leads us to speculate that pictorial exploration in cultures from different times and places were able to find solutions to put forward their ideas —what Carl Jung called archetypes. Based on this, we're systematically exploring the presence of similar structures in other Mesoamerican murals, although unfortunately, we haven't found more examples to support this hypothesis.

Surprisingly, the pandemic favored the project, since working at home gave us the opportunity to incorporate many young people from diverse disciplines who worked — and some continue to work with us — in interdisciplinary groups dealing with different topics. For example, we had students of actuarial science, computer science, physics, and applied mathematics. They've developed complex statistical analyses and applied artificial intelligence networks to analyze the brain's electrical impulses. Accompanying these ideas, we have sought to generate timelines and correlations between the murals in Bonampak, other Mayan murals, and those from Teotihuacan, Oaxaca, and El Tajín. To do that, with the help of a magnificent group of historians, we're carrying out a meta-analysis of the information available about the murals in different cultures and how they partnered commercially and culturally to create timelines that will explain to us the possible appearance of mathematical elements in these paintings.

Parallel to this, the project's visual artists have reconstructed and segmented different murals looking for identical traits in different cultures. The faces offer an interesting possibility, since they appear in all the cultures with characteristic features of each one. Using the work of the mathematicians, physicists, and actuaries, we now have an artificial intelligence network that identifies the provenance of the different faces, including those of Japanese paintings and others found in Egyptian tombs.

Using a second artificial intelligence network, we have identified golden ratios in the faces in the murals of different cultures. The oldest are in murals in Oaxaca, painted before the Bonampak Mayan murals. This surprised us because we tend to suppose that the Mayas had the mathematical knowledge, even though it could have existed before them in other cultures or have been used in Mayan murals that have been lost. This study must still be complemented with a rigorous analysis of faces on pots or stelae from different regions and periods.

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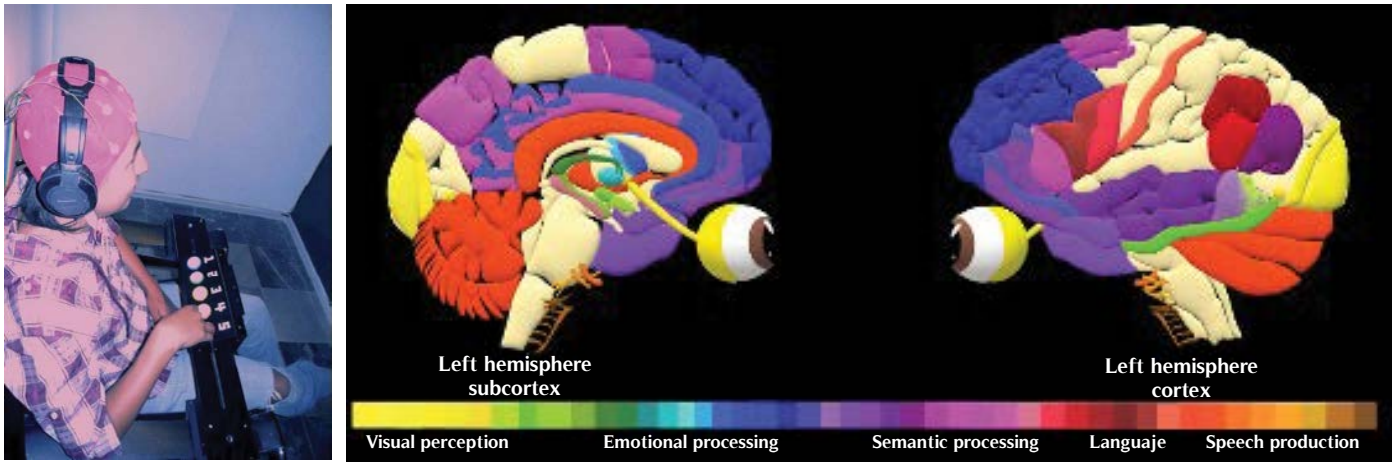

Figure 4. The image on the left shows an experiment in which the participant is wearing a cap with electrodes to take electroencephalographic measurements and earphones that transmit instructions. The numbers on the keyboard correspond to the semantic grade the subject gives the image. On the right is the range of colors in the regions participating in the visual perception. The diagram on the left shows the interior of the left hemisphere of the brain; the image on the right, the cortex of the left hemisphere. The color codes on the bar indicate the modes of processing in the brain that are activated during a perceptual experience until a semantic classification is issued through speech. The images were produced for the Art and the Brain Project by psychologist Karina Salazar.

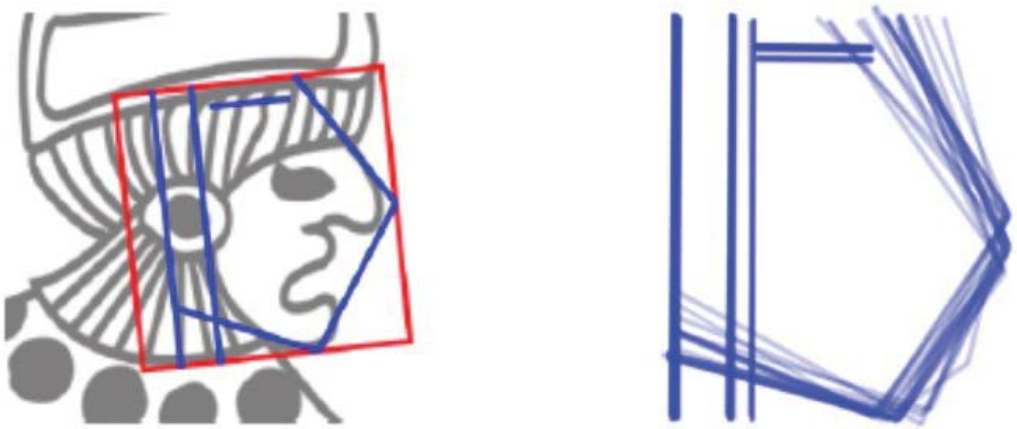

Figure 5. The image on the left is a segmented face from Tomb 105 in Monte Albán, Oaxaca. Here, we have overlaid a golden ratio grid based on Albrecht Dürer's proposal. On the right are the corresponding outlines of nineteen faces from the same mural.

The arrival of the anthropologist and magnificent curator Dr. Adolfo Mantilla was fundamental for the project. He strengthened the use of tools to analyze semantics as a tool for knowledge and later organized an exhibition about diversity at the Diego Rivera Mural Museum. Based on the national and international body of graphic work belonging to the Mexican Academy of Art, we explored the feelings of joy and sadness given different perspectives of cultural diversity. The enormous quantity of information that we obtained during our presence in the museum is still a reason for ongoing analysis and processing. Another great addition to our group has been Dr. Yoko Takane, from the UNAM Institute of Mathematics. She has made very significant contributions to our understanding of the mathematic processes required for analyzing our data.

CR: What are the scope and limitations of this kind of analysis?
FFdM: We can only pose a hypothesis. The painters of the murals were familiar with mathematics. We didn't discover that. For example, there's an entire treatise about the Tetitla Green Goddess that presents evidence of the use of golden ratios. Our focus, then, is on the search for evidence of where they came from. These hypotheses, however, are difficult to prove with current technology and the knowledge we have about several pre-Hispanic cultures that disappeared without leaving written records.

CR: What technical challenges do you face when analyzing perception from the viewpoint of the neurosciences?

FFdM: Certain technical problems exist that limit the scope of the study. For example, the functional magnetic resonance imaging is slow because it shows the blood flow as slow response to neural activation. It's also not ideal to experiment with electroencephalograms because they only register the surface of the brain, although they're very fast. We decided, however, on the electroencephalograms for a practical reason: the rapidity of the signals and because we could set them up inexpensively in the museum or a laboratory. We're developing mathematics in combination with artificial intelligence to analyze which regions of the brain respond to brain waves. However, we lack essential information about information processing in the brain's central regions. Eventually, we'll be able to test hypotheses combining magnetic resonance imaging with the electroencephalogram. However, the project inspires us to keep moving ahead, developing ideas, technology, and attempting to take the research to its fullest potential. At the same time, we socialize our results and inform our population about essential aspects of interdisciplinary scientific work, fostering their participation in the museums where we've set up the project. VM

Notes

1 The UNAM requires students to do a volunteer semester of what is called social service in their field to graduate with a bachelor's degree. [Translator's Note.]