Dreams, as Faithful as Flames

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On a silent, brisk evening in 1877 in Turin, Italy, the snow from a passing winter still on the ground, something extraordinary was occurring in a side room down a long, darkened dormitory hall of an insane asylum: a human dream was being carved in smoke. This startling scientific feat was accomplished by a true innovator and artist/scientist hybrid, the Italian physiologist Angelo Mosso (1846–1910). As with many of his experiments into the recesses of the brain, the line between data and poetry was provocatively blurred. If this moment is remembered today at all though, it is not necessarily remembered as an important marker in the still young field of neuroaesthetics. As an artist fascinated by the collaborative possibilities between the arts and neuroscience, I reflect on this day quite a bit as it taps into so many things I feel bond those fields: pushing the threshold of the sensitivity of observation, driving the innovative use of materials in making the invisible visible, and creating new questions, images and models that probe and provoke our never-ending desire to investigate the nature of consciousness, creativity, and being.

As I curiously set foot into this world of creativity and the brain—even becoming a test subject and collaborating on neuroscientific studies with viewers interacting with my artwork—I am open and ready to contribute to and absorb whatever new layers of meaning modern neuroscience can bring to my understanding of the creative life I have committed to. But as is often the case in my work, my historical curiosity sets in and my mind turns to those who have come before. I start to ponder, How is the real time recording of the blood flow and electricity in my brain even possible? When, where and who first attempted to record materially the long-assumed immateriality of thoughts, emotions, memories, creativity and dreams? Was this a problem best suited for physiology or metaphysics?

We live in an incredible era of images and their making. There are over eight billion videos viewed a day on Facebook, the Hubble telescope inches closer to seeing the first starlight ever to flicker on in the universe, and we have clear images of individual neurons firing in our brains. Two of the fundamental technologies we use today to image the brain, the fMRI and EEG, are so commonly in use that, even for the public, the idea the we *can* image a living human brain in thought, experiencing emotion or battling disease, is no longer so remarkable. If anything, and especially from the more vocal criticisms within the humanities, we are in a full brain-imaging fatigue-stage, with numerous popular science articles claiming such things as love, addiction, faith, aesthetics and other complex mental states of being are somehow "explained" through mapping blood flow through the brain. This contemporary criticism is fair, further probing long-held explanatory divides between scientific measurement and one's lived experience in the construction of meaning. However, before we could ever have such debates, today I would instead like to focus on the remarkable beginnings of the first attempts to physiologically image the interior of our living brains. In the grand arc of scientific history, this capability is very recent and it is worth pausing and reflecting on it, from both an artistic and scientific point of view, as one of our greatest achievements in making the invisible visible. Even if today we have lost some of our awe when it comes to peering into the human brain, when we revisit this cold night in the asylum in the late 1870s, when Angelo Mosso essentially invented the modern concept of real-time brain imaging, we can be reminded of what a radical leap into the unknown it was, and the palpable sense of joy, curiosity, and even melancholy that such tests produced.

Angelo Mosso was a brilliant scientist and inventor with far reaching interests, writing books on everything from the pulse, the brain, emotions, fatigue, and archeology. As a physiologist though, he continually turned his interest to the problem of blood flow and mental states. Today it may be common knowledge that mental activity requires blood flow to the brain but up until the late 19th century this was unproven. At the time, because of the difficulty of accessing and probing a living human brain, it was still unclear how physically to study such a phenomenon. Mosso's search was no less than a quest to prove the *materiality of consciousness*. With all the difficulty and debate such a quest raises even today, we can properly imagine his dilemma over a century ago.

Mosso's confidence in the subject was partly built on recent technological strides made on that other organ of great mystery and scientific debate—the heart. The term he would coin in his studies on the brain—the "cerebral pulse," or the heartbeat in the brain—point to this lineage. Only a few decades before, other great scientists such as Karl von Vierordt and, especially, the French physiologist Etienne Jules Marey had built the recording machines (the kymograph, sphygmograph and cardiograph), and the conceptual methodology (the graphic method), that allowed for the permanent visual inscription of interior physiological processes in the living body.

Frustrated with the limitations of the human senses, language and memory to record and archive fast moving, imperceptible and internal biological phenomena, these scientists, through the graphic method, revolutionized the field of medical imaging by translating these phenomena *outside* the body through another medium. Marey was especially suspect of the role of language in scientific communication stating in his landmark 1878 publication, *La Méthode Graphique*, "Let us reserve the insinuations of eloquence and the flowers of language for other needs; let us trace the curves of phenomena that we want to know and compare them." For Marey, language was a system of communication devised long before the objectives of science, and he simply did not trust it was sufficient for expressing and transmitting this interior narrative of life because of its fluctuations and possibilities for misunderstanding.

These devices all worked under a similar method, which was to absorb the energy of bodily movement (a pulsing artery, inhalation, electrical discharges, interior sound waves), through an air or water-filled membrane or spring that would then make an attached stylus pulse in unison. The stylus would then trace out the white curvilinear forms on a piece of blackened paper, which was attached to a rotating drum. Needing a frictionless and exquisitely sensitive medium for the stylus head to carve the tiny vibrations into the paper, these scientists harnessed a material humans used to record images of themselves with since the time of caves: the powdery residue of soot from a flame. Although it was simply a material practicality of the time, it is no less a poetic moment of astounding fragility to know the first heartbeats and pulses ever scientifically recorded were traced in the residue of candle flames that burned and were extinguished over 160 years ago.

Like Marey, Mosso believed that movement conditioned all life. From chemical interactions within cells, the electricity propelling muscle contraction or kinesthetic movement like inhalation or walking, to move was to live. For Mosso, consciousness must also have a corresponding relationship to movement and the graphic method was the best system science had in place to uncover it. But to only understand the graphic method as advancement in scientific measurement would be to miss the more complex ambitions of the effort. Historically, the heart, and eventually the brain, were the two most contested sights in the body in ancient debates about the physical location of one's identity, emotions, intellect and even the immortal soul. Across time and cultures the heart, for example, was considered the literal conduit for the soul between the material and immaterial realms and therefore largely considered unknowable and off limits to scientific investigation. Even if physiologists could overcome the seemingly insurmountable technological hurdles of accessing the interior living body, for the sciences to probe, touch, measure, operate or even look upon a living human heart or brain was a taboo of the highest order.

If some scientists of this era were willing to venture past these taboos, there were still remnants of unresolved entanglements between the mystical-religious and scientific. We can glimpse this in the language of their ambitions. Mosso, as Marey did before him, spoke of a universal "natural language of life" hidden just past our sensory capabilities which awaited decipherment. Like a hieroglyph holding the potential of ancient wisdom, each crest or trough in the waveform was a possible letter in this invisible grammar. Mosso hoped "to wrest from Life its secret," which would be revealed by continually refining inscription devices sensitive enough to peer into this ephemeral movement of life. Very literally, Mosso wanted to “see how the brain writes when it guides the pen itself.”

One of his significant adaptations to these graphical devices was the invention of the plethysmograph. This apparatus used a water-filled glass cylinder fully encased around the arm or foot, allowing for the pulsations in the limb to expand and contract the water pressure, which was controlling the movement of the recording stylus across the soot-covered paper. The device was so successful that it led the esteemed psychologist William James, who was at the time working to build the principles of human psychology on physiological foundations, to echo in his 1890 publication, *The Principles of Psychology*, the scientific hopes of finally revealing the hidden mysteries of the interior living body:

The researches of Mosso with the plethysmograph have shown that not only the heart, but the entire circulatory system, forms a sort of sounding-board, which every change of our consciousness, however slight, may make reverberate. Hardly a sensation comes to us without sending waves of alternate constriction and dilation down the arteries of our arms.

With the success of this device, Mosso’s great leap in thinking was to ask if the blood flow to the surface of the brain also acted as a sort of sounding-board to the changes in our emotional and intellectual states. However, like the problems of working on a living, beating heart, there was no way to non-invasively access and record the living, thinking brain in real time. Mosso was left with the unfortunate task of searching for patients in hospital wards who had, usually through a terrible accident, a large enough head injury that part of their skull was removed, exposing sections of the brain that were only covered by a thin layer of skin.

To this end he used an adapted version of Marey’s cardiograph—a device designed to record heart sounds directly from the chest wall. This made practical sense as he was essentially trying to record pulsating movement from the brain, like the heartbeat produced through the chest wall. Mosso faced unique problems with his patients regarding how to secure a recording device into the crevices of damaged skulls. He solved this problem by perfectly fitting a molded plate of gutta-percha (a natural latex) into the skull opening, maintaining a slight air gap between the plate and the brain surface, which produced an airtight fit. The plate was equipped with a glass tube at its center, so that when the pulsating brain forced air out, the pressure change was transferred to a recording arm inscribing the waves into the soot-covered paper.

With these brain "autographs," as he sometimes referred to them, Mosso laid the foundation for a vital scientific field of today: brain imaging as it relates to blood flow. From cave walls to canvases, in the context of the millennia-long artistic exploration of how much we can reveal about ourselves through the simple act of drawing a line on a surface, he had also invented an entirely new scientific visual language of self-reflection: hidden aspects of our psyche were now made manifest in the ripples of a wave. Mosso was deeply interested in the physiology of emotional states that seemed beyond our conscious control and conducted many groundbreaking experiments into phenomena such as pallor, blushing and trembling, even writing the first book length study devoted to the human emotion of fear. Along with these pioneering studies he would also go on to record the brain under several scenarios—solving math problems, inducing emotions, inhaling ammonia or other drugs, fasting, epileptic fits, and even forcing patients to pass out. But as groundbreaking as these recordings were, Mosso went further. He did not only want to establish that there was a physiological connection between general psychological states and circulation, he wanted to know if the *specificity* of emotions, or the exact conditions present when consciousness arises were recordable. Was there undiscovered meaning bubbling in the shape of the curves? He clarified his investigation in his 1896 publication *Fear*, writing:

The serious aspect of the question is, that physiologists would like to catalog many qualities which we have always considered as the most noble of our character, the most sublime feelings of human nature, amongst the automatic movements and more material instincts in the lower story of the brain.

From the still ongoing efforts to define consciousness to the investigation of the neurobiological underpinnings of emotions or aesthetic experience, Mosso's original quest still resonates with us today in ways he could not have imagined.

As he refined the sensitivity of his machines Mosso turned his attention to a little explored and long thought inaccessible experience: waking from sleep. From ancient folklore to Greek philosophers, the mysterious condition of sleep has confounded many great thinkers. Why, for example, did one lose their self-awareness, agency and consciousness while sleeping? In other words, where did "you" go when sleeping and how were you restored with full memory and continuity of self each time you awoke? Mosso's hope was that the unconscious mind would reveal some new relationship between matter and thought, and the threshold between sleeping and waking states would potentially be the crucial moment to measure the cerebral blood flow as the material conditions for consciousness were regained.

In 1877, Mosso continued his investigations into sleep states with experiments performed on an 11-year-old boy, Giovanni Thron, who had been living in an insane asylum. The young boy, when he was only 18 months old, had taken a terrible fall from a terrace that fractured his skull, causing a major concussion to the brain. He would soon develop epileptic fits and signs of insanity, causing his family to commit him to the asylum for the rest of his life. The damage to young Giovanni's brain was so severe that it ceased his intellectual development, forever locking him in a mental state before his fall. Mosso would become quite fond of Giovanni, remarking on his beauty, smile and sweet nature, not unlike a large baby. But it was the deep tragedy of Giovanni's stunted life that most impacted Mosso's time with him. Although the boy was now mostly mute, a single intellectual remnant, now turned into an unobtainable plea, persisted for his short life—he would repeat, "I want to go to school" constantly throughout the day. As tragic as Giovanni's state was, Mosso realized the rare opportunity before him and began a series of recordings that would capture recesses of the mind even he had not predicted.

When Mosso visited him in the insane asylum he had a large opening in his skull above the right eye, the fracture never having closed. Because of the delicacy of the recording device and absolute stillness that was required, Mosso would wait with care and patience night after night for the often-agitated Giovanni to fall into deep sleep.

As he first set out to explore these unknown recesses of the brain, as seemingly remote as the still unknown true depth of the bottom of the sea, the difficulty and macabre melancholy of the moment was never lost on Mosso. By the light of a small lamp, he quietly passed by the darkened corners and rooms filled with asylum patients unmoored from their minds. With some patients naked in the freezing winter night, sitting up or bound to their beds, he would plead with them to remain still and quiet as he worked on Giovanni, only to be met with shrieks and vacant eyes. Even under ideal conditions, he was already pushing the edge of capturing delicate and precise measurements. Under these conditions, many nights he left alone and discouraged, wondering if his experiments would succeed.

But one evening, after a severe epileptic attack had exhausted the boy, Mosso had the stillness he needed to probe this sleeping/waking boundary. Although normal skin had since covered the gap in Thron's fractured skull, the pulsating brain was still clearly felt under the surface. Crafted perfectly to fit into Giovanni's wound, Mosso would apply the gutta-percha plate to the opening and was able to record the boy for a few hours while he slept. In the tracing shown, the cerebral pulse of the upper line is a representative example of Thron's rarely calm mind. Like a scientific lullaby, Mosso tested his theory of unconscious perception by calling out the young boy's name, "Giovanni," in between minute-long pauses. As is seen in the second and bottom tracings at the arrows marked "G," the young boy's brain perceived the calls to him, signified by the increased blood flow, whether he understood the meaning of them or not.

But one night something unexpected happened that would offer Mosso an insight he had not anticipated:

It was one of the most interesting sights to observe in the stillness of night, by the light of a little lamp, what was going on in his brain, when there was no external cause to disturb this mysterious life of sleep…then came stronger blood-waves which flooded the convolutions, raising the height of the pulsations, which were automatically marked by the apparatus applied to the brain. We scarcely dared breathe. The one who was observing the instruments communicated with the other, who was watching over the patient, by pressing his hand. Looks full of interrogation and wonder would meet, and exclamations had to be forcibly repressed.

What Mosso is implying here, in his barely controllable excitement, was: Had the team just recorded what was once thought beyond the reach of accessibility—the first physiological evidence of a human dream?

It is worth reflecting for a moment that even in the context of his era, as scientific tools of observation were undergoing a technological revolution, Mosso's work stands out. By the late 19th century, the microscope, telescope, and photography had revealed once unimaginable realms of the material world, redefining expectations on what scientists and the public had access to visualize and record. The invisible was literally made visible through such images as the first photographs of the sun's surface, lightning, magnetic fields, or the teeming microbial life in a droplet of water. The goal of Mosso's research, to detect the material conditions of consciousness as it was restored from a state of sleep, was equally stretching the threshold of poetic, philosophical, and scientific notions of sensitivity. But if correct, and the team had recorded the seemingly more distant phenomena of the materiality of dreams—a boundary line no device had ever traversed—this wasn't only a startling demonstration of the viability of Mosso's approach but a radical conceptual reordering of the assumed scientific limits of observation.

But the difference between physiologically recording a possible dream-state and deciphering its personal meaning was vast. Having opened the door to the possibility that dreams, like consciousness itself, had a material basis through blood flow was a groundbreaking discovery. It revealed many new physiological and psychological questions to explore. These questions and techniques of recording are in no small part why we can have conferences today about the neuroscience of art and aesthetics. I am deeply intrigued by where those questions will continue to lead, but I'd like to end tonight with some thoughts about the emotional and creative reflections that come with such milestones in history.

Fortunately, Mosso's particular brilliance and openness allowed him to ponder these moments with young Giovanni in poetic ways no less important than the physiology, even going as far as stating that he did not need to "conceal the artist side of their investigations from the fear of desecrating science"—a courage across disciplines that is to this day no easy task for a scientist to embrace. Unsure yet of how to interpret the meaning of these unexpected disturbances, or what he was so lyrically referring to as "undulations," the always reflective Mosso gives some moving possibilities of what could be bubbling in this frail young mind:

Did the face of his mother and the recollections of his early childhood grow bright in his memory, lighting up the darkness of his intelligence and making his brain pulsate with excitement? Or was it perhaps only a morbid phenomena, like the jerky movements of a broken wheel, or the index of a machine out of order, swinging idly to and fro? Or was it an unconscious agitation of matter, like the ebb and flow of an unknown and solitary sea?

Of course, dreams, love, fear, aesthetic experience and the myriad emotional experiences that define our humanity are not fully "explained" through the single lens of blood flow to the brain. Over a century after Mosso's breakthrough we are still struggling to define emotions and consciousness. It is interesting that even with all the promised hope of the graphic method and automatic inscription devices, with their potential for universal scientific clarity, bypassing the need for verbal or written language, it is still poetic language Mosso turns to when confronted with the inscrutable mystery of another's dream.

Watching Giovanni suffer through the seizures, sleeplessness, confusion and agitation obviously left a deep impact on Mosso. "Of all the experiments I have ever performed with human subjects, these have cost me the greatest effort and have left the most profound impression," he remarked. The tragic irony of this breakthrough could not have been lost on Mosso: the first glimpse into a long thought impenetrable depth of our inner selves, our dreams as "unknown and solitary seas," was communicated to us through a broken mind that could no longer know itself. Giovanni would pass away soon after this test from acute anemia, but these few minutes of etchings in soot of his still-living and dreaming brain would immortalize him in a way the etchings on a gravestone never could.

As we explore forward in the conference this week, I hope we will all pause a moment to remember all those scientists and test subjects who first established the paths we continue to tread. Brain imaging has of course revolutionized brain research, diagnostics, treatments, therapies and machine-brain interfaces, while the relationships between the brain and creativity, dreaming, daydreaming, meditation, intuition, the subconscious, and the default mode network, to name a few, are some of the most exciting fields of research within the arts and sciences today. It is humbling to reflect on the fact that close to 150 years after Mosso's experiments, we are gathered here today, just as curious, and, although great strides have been made, just as mystified by the waking, let alone the dream states of our creative minds.

Perhaps on a still dark cave wall there is the earliest attempt by a human to give form to their night apparitions. Certainly our poets and priests, through inspiration or revelation, have been struggling for millennia to translate and find meaning in their unconscious visions. Rivaling these previous attempts with poetic and material fragility, and with profound physical and philosophical implications, we should remember Mosso and young Giovanni's offering to this ancient quest: the first dream recorded and preserved through the smoke rings of a candle flame.