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[Bio and Summary]

Chapter 2: (The Brain)
"Living Narratives: Neurobiology of Empathy"

- **Erik Jahner, Ph.D., Educational Neuroscientist, Office of Educational Research, National Institute of Education, Singapore**

This chapter will examine the neurobiological models of empathy particularly taking the perspective that empathy is a dynamical skill that needs to be developed and its foundations vary based on our cultural experience. I will review the neurobiological evidence of how our personal narratives and body maps are neurobiological tools used to perceive others. We will begin with a deep review of the neurobiology which affords us the opportunity to feel our bodies and selves in the world. We will then examine some research which suggests ways we may perceive not only the feelings but also the intentions and motivations of others. Informal educational experiences can be central to the creation of these personal narratives by assisting in the building of a variety of internal maps that are used for perception and action.

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Chapter 2: (The Brain)

"Living Narratives: Neurobiology of Empathy"

Erik Jahner

During a football game in Shanghai two teams were in a fierce battle. The score was 1:1 and nerves were on edge. Dumba Ba raced down the field to cut off Sun Xiang. Successfully intercepting him, the two players collided. Sun Xiang fell hard against Dumba's shin snapping it at its midpoint twisting it onto itself at an unnaturally acute angle; Dumba's face twisted in excruciating pain. He laid there trembling, the limb shaking in agony.

Notice the changes in your body, likely your attention increased, you may have altered your facial expression, your skin may have goosebumps or sweat, you may feel slightly sick to your stomach and maybe even recoiled your leg in response to an injury that did not happen to you directly. Without a direct impact on you, how did your body respond? Clearly biological processes enabling us to feel the physical pain of others allows us to learn though observation.

A 13-year old Pakistani girl, Malala Yousafzai, sits on a sandy stoop next to her father who is clearly proud of his daughter. She values an education and wants every opportunity to learn. However, in the city of Swat in Pakistan, the Taliban does not believe that girls should be educated. They had bombed this girl's school to restrict her access to education. The young girl looks at the camera holding her hands tight in her lap between her knees. She says with some tension in her voice, "I want to get an education," she pauses and swallows her pride, and with cracking voice and eyes straining to avoid tears "I want is to be a doctor." She raises her hand to hide her tears and her father turns to comfort her.

In this second situation your emotional response may be more complex. It may not only result in an experience of shared sadness, but may encourage personal reflection on your education, it may in fact move you to feelings of compassion and a perception of a sense of injustice and a violation of your values. Perhaps you have been moved to share this story with others, perhaps you long to reach out and give Malala a hug to comfort her. As humans, our ability to understand and emote with these stories has evolved as part of our perceptual process, but this process is not all automated and in fact has some cultural underpinnings and flexibility which is free for learning.

Millennia of biological and cultural evolution have built neurological machinery enabling this complex sharing and transference of experience through observation or imagining. Here we shall try to explore and understand a model of how this biological system works and how the two narratives above are not only related in the sense of shared experience, but also in a shared biological machinery. I shall take you through a way of thinking about shared experience by taking you on a phenomenological tour of the biology of the brain. I intentionally use the term shared experience broadly: cognition, perception, and emotion differ in arbitrary ways and are artificially categorized for research purposes to reflect the spectrum of experiences without clear delineations. Popular definitions of empathy suggest a shared emotional experience, but the idea of 'shared' misses a central idea found in the study of the neurobiology of empathy: I perceive you through me. We cannot directly experience the other; our body must be used as an interpreter of what we see. To do this, we have the power of narratives, our cultures and experiences write the narratives into our biology from which new narratives are written affording new perceptual experiences. Beginning this exploration, let's look inside that three pound collection of cells built through our bio-cultural history by reflecting on it as a map with continents, shores, and oceans each with some unique characteristics which construct our perception of the world. To share a common language we will begin with some neural anatomy (Figure 2.1), but this discussion of how neural organization affords perception will build directly toward our representations of empathy. Empathy, here, is treated as a form of perception, and so a large part of this chapter explains the biological foundations of perceptual phenomenology.

>Insert Figure 2.1 here<

Sensory Continents

A useful way to imagine this perceptual organ is to first notice that there is a thin layer of neuronal material at its surface about 2 mm thick. This neocortical material is a folded and crumpled material containing a map of the body that if unfolded would cover an area roughly the size of a bicycle wheel. Some of the continents on this map are arranged in reference to the outside world with individual cells having receptive fields representing some sensory region: The topography of the occipital cortex, a visual region in the back of the brain, maps images of the world as they are projected on our retinas. Spanning across the top of the brain from ear to ear is a prominent infold; on either side of this valley are the sensory and motor cortices. On the posterior side of the fold (toward back of the head), a map of the human body is stretched with some areas such as the fingers and lips exaggerated to represent the higher resolution of sensations in these physical regions. On the anterior side of this fold (closer to front of head), the musculature of the body is roughly laid out in ways that represent the body's musculature with fingers and mouth displaying exaggerated representations in congruence with the necessity of their fine-tuned articulatory movements. If we were to look at an image of the brain from the side, a peninsular shaped lobe (the temporal lobe) is formed by a large fold running along the side of the brain with the tip pointing forward. Auditory cortex is on the rear upper surface of this peninsular region: this is yet another body map representing the way sound is mapped onto the organ of the body known as the cochlea. The cochlea of the ear is sensitive in different regions to different frequencies of sound: this tonotopic mapping is recapitulated in the auditory cortex of the brain. But the brain does not only map the outside world but also maps the inside, the internal milieu. Pulling back this fold in cortex, an island (aptly named the insula, Latin for island) continues to map the body by representing the internal viscera enabling us to feel butterflies in our stomach, interpret homeostatic feelings such as body temperature, both painful and sensual touch, and enabling awareness of our own heartbeat.

These landmasses of sensation on the surface of our cortex are where we map the world as it is seen, felt, and moved through. To map the world, the brain first maps the body. But maps are insufficient for perception. On the beaches of these continents of sensation a reorganization of first level maps allows for that essential cognitive capacity of hierarchical categorization which is central to ideas including language, object, and social recognition. Rather than perceiving each receptor, we perceive the emergent whole of the world and its phenomenologically grouped parts.

Shores of Reorganization

Along the edges of these continents there are regions which reorganize the information into useful representations enabling both ways to move in the world but also ways to experience the world. Detailed studies of single cells in the premotor strip, just anterior to the motor strip, have been critical for our understanding of how actions are organized. But before we dive into single cell representations, we need to think about what a single cell representation means. It does not mean that the information is stored IN the cell (timing information is an exception). Instead, it is the cell's position in a network that allows it to act as a hub for an idea, no cell ever acts in isolation, it brings together information from multiple sources. Thus, if we are talking about a single cell having a function, what we are really saying is that the cell's associations give it a unique feature.

In the 1980s, work conducted in Parma, Italy was examining single cell responses in the premotor region of macaque monkey brains. They found that this area has some interesting hierarchical properties and an organization which is now critical to how we think about neural representations leading to theories for neural foundations of empathy.

This lab at Parma painstakingly implanted electrodes into single cells of the premotor cortex in living monkeys.[1] Activity in specific neurons were recorded as a number of action potentials over a period of time during which, the monkey was incentivized to perform a specific task. If the number of action potentials increases or decreases with one type of task and not another, we would say that this specific neuron is likely involved in the performance of the action. They were attempting to map neurons with actions.

Some simple yet surprising results have been gleaned by this research. At the most concrete level, it has been found that premotor neurons organize actions in a hierarchical way. For example, two different types of grasping might be represented by two different cells. Grasping a raisin involves some precision grip whereas grasping an apple does not. While motor cortex may match body topography, premotor cells are much more broadly generalized. For example, when a broad reaching action is initiated this cell is activated prior to the cells in the motor cortex but the resulting action may have context dependent variation not coded by this cell but instead detailed coding at the motor strip. This is not unique to this region but is core to how the brain organizes and other research has show similar organization in language, reading, and vision. Cells act as hubs pulling various levels of complexity together to form variations on conceptual organization.

Bringing Maps Together

Most of the remaining cortex is made of what is called association cortex. These seas of association represent multi sensory information about objects, but this information is not connected across the surface of the cortex, much of it involves linking rivers known as white matter which run deep within the brain. Those streams which are established early in development, such as in the regions of the brain mapping the body and vision mentioned above, are partially responsible for its wrinkled shape. Early connections in these connections build foundations for later development and as the brain grows, these connections remain pulling the cortex into its wrinkled appearance.[2]

Many of these rivers connect cortex to structures buried deep in the brain which are responsible for the very actions that keep us alive, but are also association areas building necessary representations from our perception into meaningful representations tied to and gaining meaning though their association with midbrain regions central to survival implicated in regular functioning of our viscera, heart, and breathing.[3] Core to motivation and instinct the search for food, the motivation to consume, the regulation of our breath and heart give survival context to our sensory perceptions. One well-known hub is the almond-sized amygdala associated with automated emotional processing. These regions are further tightly bound to the body's release of hormones and neurotransmitters that change our physiology allowing us to rapidly escape an oncoming car. These deep structures gathering and sending information from our sensory cortices keep us in homeostatic balance. [4] When these processes do not go as predicted the sensory cortices mentioned above enable us to feel the lack of homeostasis moving our cortical tissues toward preparations for action and awareness of our bodies and emotions.

Beyond the Present

The brain is therefore intricately tied to the body and through the body to the environment where the body is situated at any moment. But, the brain also maps itself, its history and its future possibilities both real and imagined. A region known as the hippocampus (named after its seahorse like shape) is curled up under the temporal lobe. This is the region known for building memories. It is a unique association area, in that it pulls together multiple representations through time and space and completes patterns. It takes the relatively concrete sensory representations completing the pictures with observed information utilizing the hierarchical arrangement of concepts described above in this process. The hippocampus can be thought of as a region which reaches out to the map and pulls together representations for short term before they are manipulated and stored in more permanent forms. When this region is damaged, we have problems building new memories and must instead rely on those that are part of our past or more procedural memories built up through other associations in the cortex and midbrain. One often cited example of hippocampus degradation is Clive Wearing, a musician who suffered an attack from herpes simplex encephalitis which selectivity attacked the cells of the hippocampus.[5] In his journal are infinite scribblings of "waking up for the first time" he does not remember events more than a few minutes and thus each time his wife enters the room he is overcome with joy as if she has returned from a long trip which she went on before the damage took hold. Despite this, Clive is still able to conduct an orchestra and play the piano particularly well, illustrating the expert level procedural storage of information in the maps of the cortex.

We shall now turn to three other brain regions which stabilize relatively late. Traveling up the cortex and down into the central valley which separates the two hemispheres is a large structure called the corpus callosum which connects the two hemispheres of the brain in a tight bundle of connecting fibers. Wrapped around this connection fiber is another series of folds which form a down facing C shape around this central connection bundle. These series of folds are broadly referred to as the cingulate cortex. In the posterior cingulate is a remarkable association area called the precuneus. Like the hippocampus, the precuneus is a major hub highly interconnected with the rest of the brain. This region is associated with self-reference and social reference.[6] It is this region that is the core narrative of who we are. It has been associated with thinking about the future, memories of our past, and the mind wandering and imaginative aspects of self.[7] As one could imagine it is tightly coupled in activity with the hippocampus. The precuneus can be thought as a map of self or more aptly due to its temporal aspect, a narrative of self or a record of one's life project.

All of these regions are imperfect representations of the world, they use what information is available in associated networks to construct and create memories and self not as as they are and were but as we imagine them to be.

Building New Maps

The prefrontal cortex is yet another crucial hub bringing together the maps from many other regions into a behavioral or perceptual blend. It is thought that this region temporarily maintains rules which can override automated responses, it is very flexible in the generation of these rules but is modulated by connections to subcortical structures via the anterior cingulate.[8] Essentially, disruptions in homeostasis will affect the subcortical structures which will signal the anterior cingulate that something is amiss. Regulations of behavioral sequences stored in the prefrontal cortex are differentially activated through the intervention of the anterior cingulate. The anterior cingulate basically sets up a gateway allowing some processes to be automated and then allowing for the exertion of effort to overcome automated processes and the regulation of our attention to relevant behavioral rules. This process is associated with creativity, higher cognition, ability to delay response and urges.[9] This cooperation regulates actions and allows us to eventually develop into relatively well-functioning adults compared to our teenage selves. What is of key importance here is that these regions by allowing temporary storage of rules afford us the opportunity to blend new perspectives based on previous experiences and then temporarily scaffold the development of new novel ways of thinking. Through these regions we gain some additional control over our perspective and regulation of our biases.

It is of note that these last three regions (the anterior cingulate, the precuneus, and prefrontal cortices) and the white matter tracts connecting them develop relatively late in adolescence, in our twenties and thirties.[10] These are the prime times that we become active members of society integrating ourselves but also developing a core identity which will guide much of our future behavior.

Structural Changes Based on Learned Expertise

The storage of information in the cortex and its connections has been well documented based on expertise. Expertise in an area results in more connections made between neurons and as these connections increase, the number of neurons retained is also increased. While we know that the brain continues to make new neurons throughout its lifespan, the largest structural changes after early childhood are due to neuronal loss. Neurons with less use slowly wither and die and new skills link the remaining neurons. Neuroscientists scanning the brains of mathematicians, chess players, musicians, and the like have shown greater thickness in associated motor, premotor, and association areas.[11] When individuals gain literacy at a later age regions specializing in associating maps for reading are similarly thicker in similar ways to early age readers. Similarly, some regions of the hippocampus are associated with movement through space generating mental maps of the world. A rather famous study of London Taxi Drivers found these regions of the hippocampus to have thicker cortex than the average Londoner.[12]

Developmentally, we also develop expertise as infant and children. Our sensory regions mentioned above rapidly develop and stabilize early in life, they reduce their thickness rather early, while the association areas and edges to these sensory continents remain flexible into early adulthood.[10] Thus, maps of the body stabilize early, but maps of association stabilize later. These regions of expertise are made of detailed maps which will become resources for perception. Expertise is not only used to act in the world but also as a source of information which we use to perceive the world.

Seeing with Stored Representations

While our experience often feels like we watch and perceive the world as it is projected onto us, perception itself is heavily dependent upon top-down processes. It must be remembered that the maps described above are not accurate representation of the world nor are then accurate representations of ourselves, they are representations that enable us to productively move through the world. Our biological predispositions in the form of epigenetic development, and our previous experiences build the perceptual apparatus enabling sensation and perception. The perception of the world depends on how the maps of the world are built within the brain. Some of the biases in these maps lead to almost irreversible illusions. Using the classic example of the Müller-Lyer Lines (Figure 2.2), Merleau-Ponty pointed out an illusion is not something that does not exist, it exists simultaneously both in the mind and physically in the body.[13] In this example, the outward directed arrows on edges appear to compress the length of the line when compared to the same line with inward facing arrows at the edges. While one can always measure the lines and show that they are the same length, perception always overpowers empirical knowledge and the illusion persists. Therefore, the illusion must somehow be grounded in our perceptual apparatus. Illusions must not come from the world, but from our internal knowledge in the form of our neurobiology. Our maps bias our perception.

>Insert Figure 2.2 here<

In a similar fashion Merleau-Ponty also noted, having been a physician in the war, that when an individual loses a limb, the perception of that limb remains. This phenomenon has been explored further by V. S. Ramachandran and his colleagues.[14] The altered body needs to be remapped onto the brain. While phantom legs are compensated for early due to their continued use, the phantom arm remained a problem. It is only after repeated attempts to use the limb are met with inconsistent feedback that the sensory and motor cortices remap this region. In other words, we perceive our body through maps that are present in the brain and when the body is altered in some way, our perception is not. Perception is not dependent on reality, it is dependent on our representations used to grasp reality. Only with repeated inconsistent feedback can we begin to rebuild our biological circuitry and change how we perceive.

To further illustrate this point notice the two incomplete words in (Figure 2.3). It is without effort that we read the words “THE CAT.” However, upon closer inspection it is clear that the letters “H” and “A” are actually exactly the same shape. Clearly, perception involves very strong top-down influences. Also, note that in this example we are perceiving things we cannot see. The shapes are completed by the brain. This is clear in many of our everyday experiences, even if we only see half a car, because half of it is behind a building, this does not mean we do not perceive that the whole car is there. Returning to Merleau-Ponty’s phenomenology, he points out that even in our basic sight we continue to perceive the continued world, and in fact never truly see the edges of our visual perception, because our mind fills in the missing information we perceive a continuous world outside our visual field.

Our representations of others work in a similar fashion, they are based on our previous knowledge and biological apparatus.

>Insert Figure 2.3 here<

This is not to say that we cannot see things we do not have previous representations for in some misleading Whorfian sense like where words for snow limit our ability to see snow.[15] Instead, our biologically entrenched categories act as bias in perception. We use them to see, but we are also capable of blending and merging ideas into flexible new representations by means of the frontal cortex. If we were limited by a simple matching of top-down and bottom-up processes, we would be unable to recognize various forms of handwriting or view objects from different angles. Instead, our mental representations appear to be hierarchical, highly influenced by context, and messy allowing for blending, recombination and alteration. But as this theory goes, we cannot see something completely novel, instead we combine established neural networks to see and interpret the novel within our existing perceptual framework. Networks do not allow for the spontaneous generation to perceive. Everything is contextual to the history of our organism.

Motor Representations are more than Assembled Sequences

To better understand how we interpret the emotions and motivations of others we need to first understand how simple motor actions are organized as a model. Briefly returning to the premotor cortex and the explorations at Parma, while researchers were studying the function of single cells they began to realize that the picture was much more complicated than simple perceptual maps. Cells associated with precision grip were not always active before a precision grip was enacted. A second feature was necessary before they reliably increased their firing rate. If the precision grip was used for the picking up of a food item some cells would fire, however, if the similar precision grip was used for a non-food item, these cells would not fire.[16] Cells appeared to be selective for goals and not just movement. The intention of the action mattered to how it was represented in the brain. Neurons as hubs were bringing together intention with action.

Further discoveries included an association of an object in sight with a particular type of grip. Cells associated with precision grip would fire at the mere sight of a raisin.[17] In these cases, no action was even necessary. Gibson called this association an affordance or a relationship between an object and the perceiver.[18] These affordances appear to be neurologically encoded. It is this affordance or relationship between an object in the world and our understanding of how our body interacts with it that influences our perception. It is interesting to also note that the premotor cortex is dependent upon not object recognition but ability to actually act on the object. If the monkey sees a picture of a cup it does not activate this region, or if it sees a cup which is too far to reach it does not activate this region. As the cup approaches the monkey, or if it is within reach, this affordance relationship is stronger and thus the premotor cortex for grasping is more strongly activated.

Altogether we can say now that observing an object in the world is not simply allowing the photons to enter our eyes and be observed by some internal self observing the theater of mind. Instead, we generate patterns of interaction in the form of perceived goals, ways of interacting with the object, and combine this with a history of the object to produce a complex hierarchical arrangement of properties. Identifying a coffee cup involves activation of the necessary grip, the need to consume coffee, the variety of hierarchical visual features and the social history we have with this object. It may even involve the activation of rules which allow us to overcome the desire to add sugar and choose the healthier option.

Armed with this knowledge of cortical functioning, we can begin to think about how we not only observe objects but observe the actions of others.

Mirror Neurons

Over the course of several years studying cellular specialization in premotor cortex, something was noticed by the researchers at Parma.[19] Periodically while the macaque monkeys were connected to the neuron monitoring equipment neurons associated with grasping would fire when the monkeys just stood still. Upon further evaluation and insight, they discovered that this firing was systematic. The neurons were reacting to observations. When the experimenter would reach for something the neurons associated with reach in the monkey reacted with a burst of activity. This observation began the development of the mirror neuron hypothesis.

Two additional important observations were made. First, it was observed that these neurons linking goals and actions would only be activated when the observed actions were in the monkey's behavioral repertoire. If, for example, a peanut was picked up using tweezers, which use a similar precision grip and match in the goal of consuming, the neuron associated with precision grip and the consummatory goal did not increase firing rate. The monkey does not normally use the tweezers to pick up the peanut, and so its representation of motor-goal response could not be matched or approximated. However, once the monkey was trained to use the tweezers to pick up the peanut, the mirror neuron did fire for precision grip whether with or without tweezers. This further illustrates the phenomenology described above. We rely on biological maps of our body, our expertise, and our memory to perceive.

Additionally, the entire action need not be observed, if the monkey could reasonably infer based on previous exposure that the reason for the reach was to pick up a peanut even though the peanut was not observed during a particular reach, the neurons would fire. This is an important feature. As described above in the perception of letters, it is not only bottom-up processes that allow perception but top-down processes. Similar to obscuring parts of the letter and the representation of the whole letter being activated by context, so too can the representations of actions be completed by the representation of goals. The temporal priming of the network through a previous action also readies the network for a response.

Now lets move along the evolutionary chain back to homosapiens. We seldom do these kinds of invasive studies in humans but instead rely on fMRI studies. These studies are informed by, but not exactly parallel to, single cell recordings. The fMRI image approximates changes blood oxygen level dependence for three dimensional cubes of brain called voxels (a three dimensional pixel) these cubes typically measure around 2 mm. The cubes contain thousands of neurons, we are not directly measuring neuron activity but instead estimating metabolism in the area of these large populations, and we can only make measurements about every one to two seconds. With these limitations in mind, and they are large limitations, we are attempting to evaluate whether observing another's actions will stimulate the premotor cortex in a predictable area to evaluate predictions of mirror neuron theory.

As we remember from the discussion above, mirror neurons are specific to the action repertoire of the individual. If this is the case, then certain populations of cells in the premotor area should respond more when an expert who has a specific repertoire of actions observes others conducting those highly practiced actions. An experiment done by Beatriz Calvo-Merino and her colleagues examined expert ballet and capoeira dancers tested this hypothesis.[20] Dancers from each group watched a series of videos in which someone was performing either capoeira or ballet dancing. As predicted, when capoeira dancers observed other capoeira dancers their premotor cortex was differentially more activated than when they observed ballet dancers; the same was true in reverse for ballet dancers. The dance moves were part of the dancer's repertoire and therefore were perceived in a neurologically different way. This parallels findings from the monkey studies. We use our expertise to perceive.

Remembering that mirror neurons in monkeys mapped intentions as well, Marco Iacoboni examined intentions.[21] Individuals were presented with two different tea table settings. In one setting the table looked as if tea time had just ended, in the other setting it looked as if tea time was about to begin. In each of these contexts they saw someone picking up a mug. If mirror neuron systems were encoding motor patterns based on intentions, then these two situations should show differential activation based on whether they thought the hand was clearing the table or grabbing the cup to sip some tea. This is exactly what they found. A different set of voxels displayed reliably different levels of activation based on the perceived intention of the context. They verified that this was not due to a difference in grip type or context alone separately, and this was not the case. It appears that different sets of neurons in the premotor cortex react to this action in different contexts suggesting that the mirror neuron systems also represent the "why" of human behaviors. In this way, it appears that mirror neurons give us at least some primitive representations of the intentions of others. It is very likely that this intentional aspect will be tied to these neurons acting as hubs of information pulling not only sensory representations, but the maps found in the midbrain connecting instinctual urges with sensory maps of the world.

Emotions and Feelings

The insular cortex plays a special role in the processing of emotions and feelings. Antonio Damasio describes this special position as that which enables the feeling of emotions.[22] He distinguishes between the emotion being the emerging state of the organism as it adjusts its internal milieu to its environment, but the feeling involves the categorization and the hierarchical processing of these events which may be metacognitively available for later processing. Individuals with damage to the isle are blind to not only their emotional state but to the emotional state of others. Thus, it appears that lacking this map of our own internal representations reduces our ability to empathize and feel.

Empathetic pain perception has been a highly studied example. As mentioned above, the insular cortex maps the body in a way that represents pain and the internal viscera. Pain involves a large network of areas which we will not go into detail about, but it appears that when we observe the pain of others, activation of the insula correlates with self-reported measures of empathetic response.[23] This is not true of the rest of the pain system indicating this region is crucial for the perception of others' experiences.

There is however one more point about brain function that is crucial to understanding empathy. Many of the regions discussed above are directly connected to the body's homeostatic mechanism, which are part of an ongoing dynamic system which never stops. As such, the brain appears to act more in a Bayesian fashion. A crucial point to remember about the brain is that it is a living system. By that fact alone, the system is constantly in motion, it has its own intrinsic activity. Lisa Barret articulates this well in her book about constructed emotions.[24] It is a Bayesian system in that it is making predictions about the body and therefore the world through this ongoing activity when the world changes. If there is a conflict between predictions and actual events, it means that the body is not in balance with the world. This constant need for homeostasis is what drives emotional awareness.[22,24]

The model is such that when the embodied brain is inaccurately predicting events, the conflict that emerges alerts the salience network which brings our attention to the body, stimulating both internal and external actions. This adjustment is perceived as conscious feelings. While the specificities of the emotional reaction are unique to each situation, we tend to interpret them as categorical because categories is how we see the world and these categories and maps are learned.

As an example, there appear to be cultural differences in how our brains process emotions. Mary Helen Immordino-Yang has pointed out in an analysis of Chinese and Hispanic individuals who were processing emotions, different parts of the insula correlate with feeling strength.[25] Importantly, the feeling strength is the same for both groups, so she is not saying one culture feels less than the other. Instead, in the East Asian culture where emotional regulation is a prominent cultural feature, individuals appear to rely on feedback from regions of the insula associated with the regulation of the viscera. In contrast, individuals of Hispanic background where emotional expression is part of the cultural values, feeling of emotional strength correlates with the regions which monitor body states, not the regulation. Thus, as Barret points out, emotions do not have fingerprints, instead they involve context and interpretation, and culture is one of those contexts. Importantly, note that culture is learned and not something we are born with. We build maps of expertise based on our culture, these maps are associated in unique ways based on our experience. These maps then act as a source narrative for understanding the intentions of others. As mentioned above, these intentions can range from hunger and survival to what we are now describing as emotional states.

Further research by Immordino-Yang has examined different basic feeling states as they relate to different social emotions. She has explored experimentally the idea that physical pain perception is a springboard for interpreting social pain.[26] Remembering that the insula is a region monitoring pain, observations of physical pain, such as those seen in the Dumba Ba soccer injury above, appear to activate regions of our own insula suggesting that our perception of another's pain is based on our own body. Of importance to Immordino-Yang's study is also the timing of insular activation. The insula reaches peak activation for observation of physical pain earlier than observations of social pain. The slower peak activation of the insula during observations of social pain suggests a slower processing of social emotions allowing for deeper analysis and more integrated processing as context is taken into account. A similar story can be told about her study of admiration for physical skill which is processed quickly as compared to admiration for social skill such as compassion.

These two examples also have another dimension. The more socially engaging activities such as admiration for virtue and compassion for physical pain involve regions of the precuneus that are more posterior. Remembering that the precuneal regions develop later and are representative of the social self and the personal narrative or life project, it appears that we are using our own life stories to understand the intentions and emotional states of others. Our own narratives are used to understand the lives of others.

From Mirroring to Empathy

While there is a large body of research examining this theory, we can now begin to interpret how empathy may be activated via the mirror neuron system. One simple approach is that by observing the motor sequence leading to changes in facial expression or other outward motor behavior, we simulate the motor aspects or facial expression in our own mirror neuron system. We know that even simple sounds or images can also spread through the network such that they can activate a mirroring cell's response but a crucial aspect of this idea is that mirror neurons are only responsive to pre-existing repertoire of behaviors which include our own internally mapped intentions. If, for example, an individual displays an emotional state in a different way, this may not trigger an empathetic response; this may be one of the reasons we find it difficult to empathize with other cultures. Furthermore, the resources for narrative and purpose are built up through our experience. We perceive the feeling states of others based on our own experiences.

Let's pull together these ideas. The brain makes maps of the body, these maps are related to each other to create higher order maps of concepts. These maps are not to simply see the world, but to see the world in connection with our own biological needs and motivations tied to our biology for simple survival (breathing, heart beat, etc.). These maps are further extended and given purpose though their connections with the precuneus and hippocampus which construct a cohesive narrative of self. We experience the world through these maps. It is these very maps that are used to understand others. To effectively override the automated processes of understanding others only through our own maps, we need to build personal experiences. We also need to be alerted and metacognitively aware when it is important to activate stories, and blend narratives from new combinations of our previous experiences. The frontal cortex and anterior cingulate play important roles in this self regulation and creative recombination of maps and narratives. These association regions develop late and are very plastic giving us a way to intervene in development throughout the lifespan, to build empathy, to build now maps, and enable new perception.

What is our role in map making?

It is here where the educator has a special role. Educators in the form of teachers, parents, peers, and experience designers in museums are cartographers of perception. We cannot assume that seeing or listening is enough to build the new perceptual machinery, we need to actively build narratives with the individual to allow them to see the world in a new way, generate new narratives from which to draw our perceptions. We act to build new perceptual apparatuses in the museum goer or participant learner by attempting to give them a new experience. This involves not simply showing, but scaffolding the construction of new personal narratives on which to draw. The role of the museum also needs to move beyond a simple construction of experience, it needs to build the mechanism for salience. It needs to be designed in such a way that it pushes the individual out of homeostasis. The individual needs this destabilizing experience to force the adjustment into the new situation. They need to be thrown off balance and out of homeostasis to move beyond prediction to active reorganization of maps. A learned response which will then not only act in a way to get their attention in situ, but to train the brain to boost signal to new rules being generated in the prefrontal cortex that will allow the construction of new narratives and will train their neural system to do this each time a similar experience is undergone. Educators do not only build experiences, they are building perceptual tools by changing the neural mechanisms of their guests and students. The maps we build in others will be their source for both perception and active engagement of regulation to understand and to feel the other through the self.

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Chapter_2_Jahner
Figures

Figure 1.1. Basic Neuroanatomy.

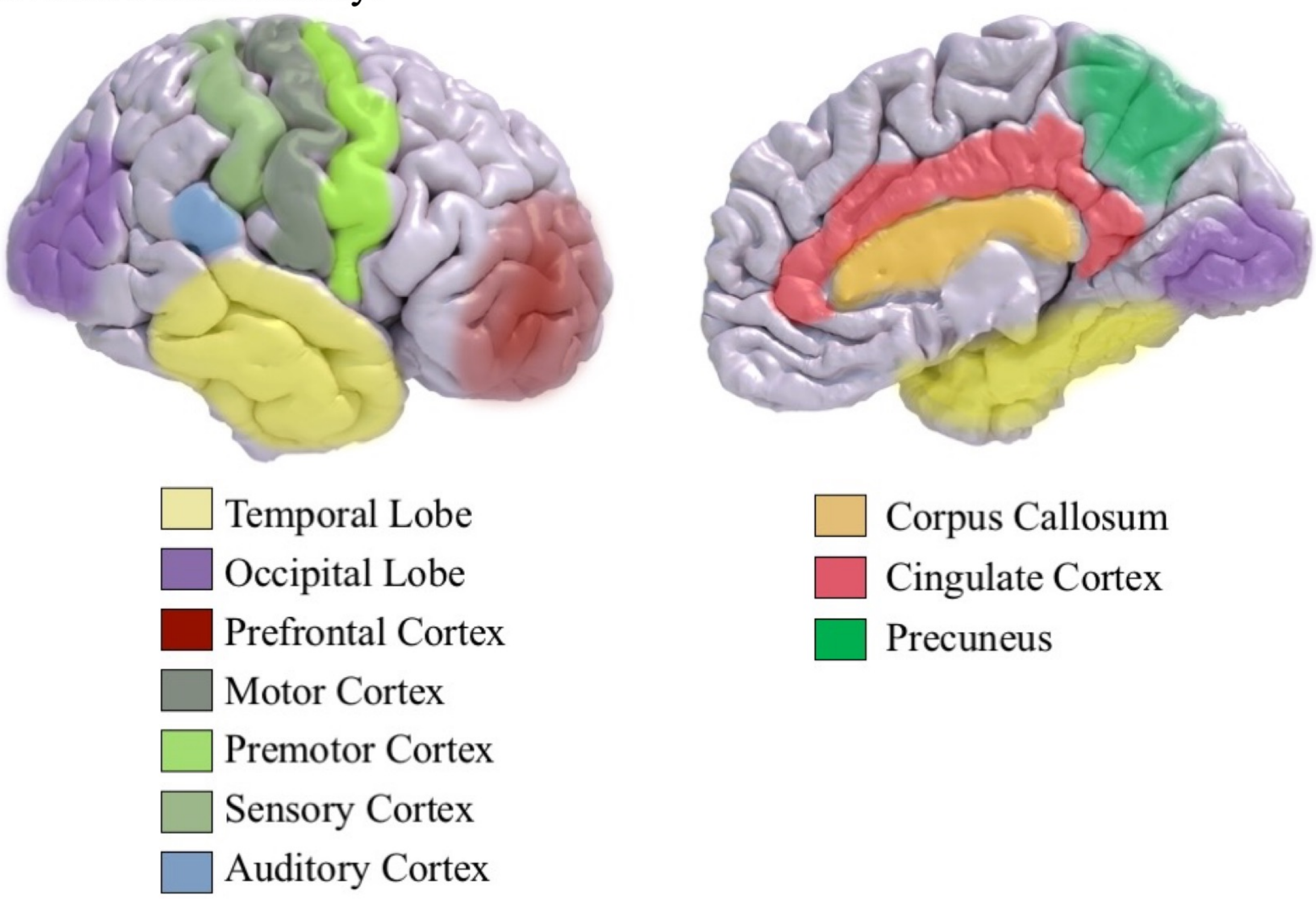

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Figure 1.2. Muller-Lyer illusion.

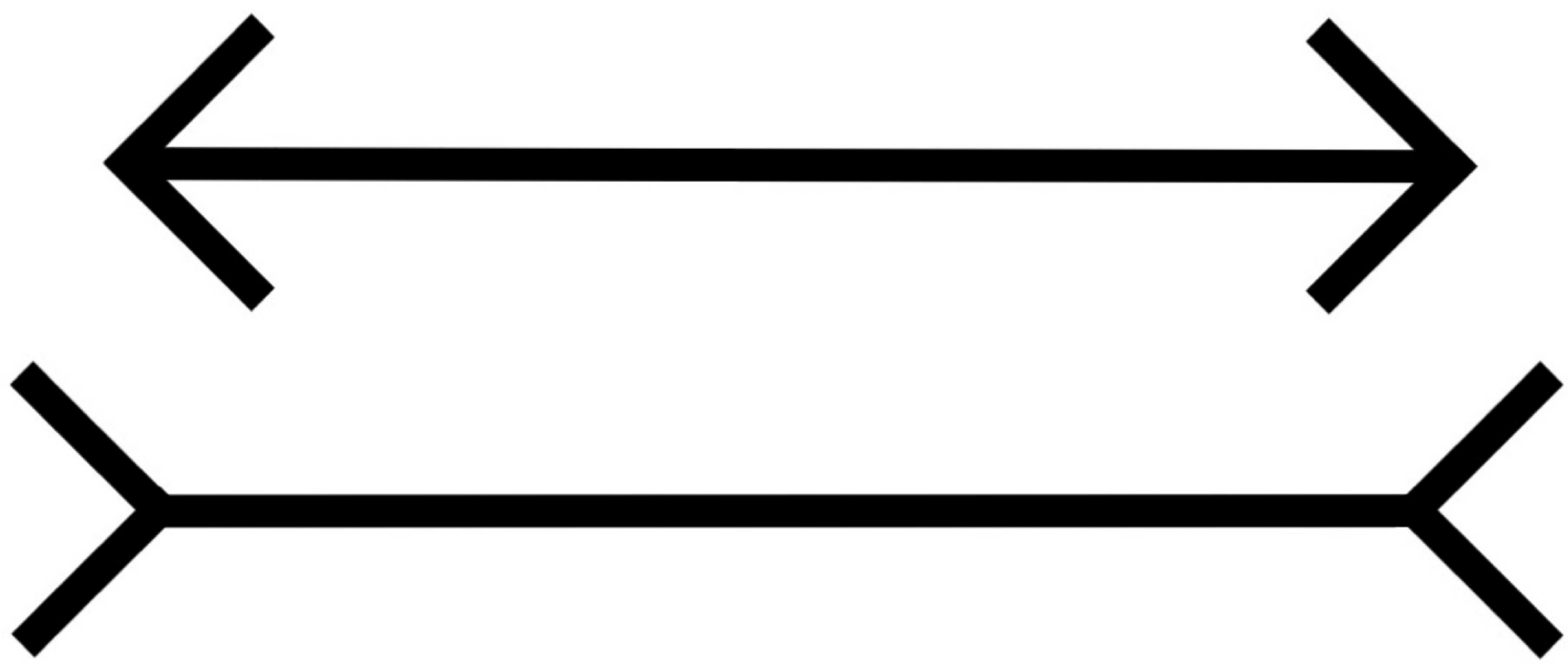

Figure 1.3. Perceptual reconstruction in reading.

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