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PERCEPTION AND VISUAL "COMMON SENSE"

The map is not the territory.

—Alfred Korzybski

Our eyes are truly wondrous windows on the world. The last of our senses to evolve and the most sophisticated, they are our main source of information about the world, sending more data more quickly to the nervous system than any other sense.

Yet what our eyes register is not a picture of reality as it is. Rather our brains combine information from our eyes with data from our other senses, synthesize it, and draw on our past experience to give us a workable image of our world. This image orients us, allows us to comprehend our situation, and helps us to recognize significant factors within it. To clarify how we see, perceptual psychologist J. J. Gibson has made a distinction between the image that appears on the retina, which he called the "visual field," and the mental creation that composes our "visual world." The visual field is created by light falling on our eyes; the visual world, however, interprets these patterns of light as reality. The visual world, then, is an interpretation of reality but not reality itself. It is an image created in the brain, formed by an integration of immediate multisensory information, prior experience, and cultural learning. In short, it is a mental map, but it is not the territory.

This is why although Alfred Korzybski's first principle of general semantics—"the map is not the territory"—may seem at first to state the obvious (who would confuse a road map for the real landscape?), the statement implies much more. It suggests a separation between perception and reality that is fundamental—it is, in fact, a gulf that is never closed. What we refer to as "reality" is really a maplike mental image, the end product of a process that begins with light refraction in the environment and ends in the intricate and complex dynamics of the mind.

What we perceive, then, is no more "real" than a painting of a still life is edible: perception always intercedes between reality and ourselves. The surrealist painter Rene Magritte continually commented on this gap in such paintings as "The Key of Dreams," where word captions seem to contradict the meaning of the images above them: the head of a horse is captioned "the door," a clock "the wind," a pitcher "the bird," a valise, "the valise." Because we see things consistently, we have also come to believe that we see truly. Ultimately, however, we see more what we expect to see than what really "is."

Even when we watch television, we misunderstand approximately 30 percent of what is shown to us. Our emotional state, our mindset at the time, and our prior experience all seem to conspire against our seeing things as they really are.[1] We go about our lives, however, mostly assuming that what we see is what really "is," as if there were no intermediary process—in other words, as if the map were indeed the territory.

On the other hand, much of this assumption is for the most part justified and continually reinforced through experience: when we see a chair in front of us and then sit in it, we know our senses weren't fooling us. Because our evolutionary survival as a species has depended on our ability to recognize and derive meaning from our surroundings, the very fact that we are here tells us that the mechanism of perception is working. If our perceptual maps didn't work, we wouldn't survive to pass along the genes that preprogram the process.

But the trust we have in our senses and our own sense of objectivity is rarely if ever completely justified. Not only are we biologically tuned to overestimate certain aspects of perception, such as height compared to width, but we are also rarely even conscious of the variety of factors impinging on our perspective, especially those derived from subconscious and even primitive forces or from the vagaries of personal experience. Our image of the world is governed by evolutionary principles; it is to a great extent shared by others with the same cultural background; yet it is also uniquely nuanced in each individual.

Evolution, Emotion, and Subliminal Perception

Etched into our perceptual system is the whole evolutionary process of humankind. The reptilian brain, geared for land survival, still operates within us, regulating basic bodily functions below the level of our awareness, and responding to survival threats by preparing the body for fight or flight. The brain's amygdala, the seat of our emotions, dates back to the reptilian era and still plays a primary and dominant role in all our perception. It is the seat of our ability to accurately read facial expressions, for example, as well as to key into the spirit of conversation or to sense the subtle social cues that signal appropriate behavior. It is this "tuned in" quality of emotional synchrony that is most often found lacking in autistics.[2]

The mammalian brain, which evolved from the reptilian brain about the time of the Ice Age, developed a cortex, which is generally thought of as the seat of our intelligence. Biologically limited in size by the birth canal, the cortex nevertheless expanded as humans continued to evolve until it was forced into folds in order to fit within the skull. Less than a quarter inch thick, the cortex filters the outer world and makes sense of it. In today's human cortex, 100 billion neurons chatter with each other over more than fifty thousand connections; trillions of neural networks allow different areas of the brain to communicate with each other through electrical and chemical signals. Only a small part of this conversation becomes manifest as conscious thought.

Until the mid 1980s, it was generally hypothesized that data from the senses was sent to the sensory neocortex, then to the cortical association areas, then to the subcortical forebrain, then to the musculoskeletal system, the autonomic nervous system, and the endocrine system. Emotion, it was believed, came *after* conscious and unconscious thought processing and was added through the hippocampus. One outspoken proponent of this theory, Richard Lazarus, argued that emotional reaction required cognitive appraisal as a precondition.[3] Research was inconsistent, however, suggesting that the emotional response to stimuli was more complex; and other researchers such R. B. Zajonc acted as gadflies, insisting that researchers like Lazarus were wrong, that "cognition and affect are separable, parallel, and partially independent systems."[4]

The argument remained open until neurobiologist Joseph LeDoux and others, in experiments dating from about the mid-1980s, mapped the work of the loosely defined "limbic system" more precisely.[5] They came to believe that although emotional functions may be mediated by other brain regions, the amygdala—a subcortical region buried deep within the temporal lobe—plays a crucial role in our emotional response to messages from the external world. Acting as a sentry to ready the body in response to danger, the amygdala attaches emotional significance to incoming data and readies the body to act in intense situations by signaling the hypothalamus to secrete hormones, initiating a fight-or-flight response. It alerts the autonomic nervous system and prepares the muscles for movement; and it warns the brain stem to secrete chemicals that heighten alertness and reactivity in key areas of the brain. All of this can occur independently of a conscious decision to act.

The amygdala gets direct input from all the sensory areas and serves as an intermediary between the sensory environment and internal motor response systems. Experiments show that the lateral nucleus of the amygdala (LNA) responds to both conscious and nonconscious input, leading to the conclusion that it may be the critical site for sensory-sensory integration in emotional learning.[6]

This newer research contradicts earlier thought and reveals how sensory signals from the eye travel first to the thalamus and then, in a kind of short circuit, to the amygdala *before* a second signal is sent to the neocortex.[7] The implication of this is that we begin to respond emotionally to situations *before* we can think them through. The ramifications of this fact are significant, suggesting that we are not the fully rational beings we might like to think we are. What this second emotional route signals, in fact, is the likelihood that much of cognition (what Zajonc defined as "those internal processes involved in the acquisition, transformation, and storage of information,"[8]) is merely rationalization to make unconscious emotional response acceptable to the conscious mind.

LeDoux's neurological research confirms what some perceptual psychologists had long suspected: that there are two routes of sensory perceptual processing. The first, an immediate and crude one, runs through the amygdala and readies the body to act before it can cognitively even recognize the need to act. The second, through the neocortex where the signal can be analyzed and then sent to the amygdala, adds emotional response after cognition. Moreover, the process of attaching significance to what we see in either route occurs independently of our conscious awareness. This, according to LeDoux, may explain why we are so inept at understanding where our emotions come from and how they work: "The cortical systems that try to do the understanding are only involved in the emotional process after the fact."[9]

Psychologist and *New York Times* writer Daniel Goleman has used LeDoux's research specifically to formulate a cogent theory on "emotional hijacking" by which he means that the emotions can become so highly activated that we can be taken hostage by them. This, he says, is the result of the "triggering of the amygdala and a failure to activate the neocortical processes that usually keep emotional response in balance."[10] The prefrontal lobe, which keeps emotional balance by "dampening the signals for activation sent out by the amygdala and other limbic centers" acts as a kind of "off switch" to emotions set off by the amygdala. When we are overcome by a rush of emotion, Goleman explains, we have essentially been "hijacked" by a neural response to which no "off switch" has been sufficiently applied. When we are so upset that we can't think straight, it is because the prefrontal cortex, which is responsible for working memory, has been sabotaged by a kind of "neural static."[11]

When everything functions appropriately, however, precognitive feelings point us in the right direction by tapping the emotional learning of past experience and assisting the neocortex in its ability to make rational decisions. Although we may prefer to believe that we are basically rational beings, it is more accurate to say that reason and emotion play crucial and inseparable roles in our lives, and that at various times, one functions perceptually at the expense of the other.

LeDoux's findings that there are two ways of responding to visual stimuli in the environment—one, through an unconscious nonspecific, emotionally laden reaction (along a thalamo-amygdala pathway), and another, in a detailed perceptual analysis (through a cortical pathway)—also support earlier subliminal research on how we can receive and emotionally respond to messages below the threshold of conscious awareness. Without our realizing it, emotional response can then influence attitudes, thinking, and behavior, allowing us to cognitively congratulate ourselves on our perceptive thinking, while all the while we are in fact being guided by emotionally laden perceptual judgments beneath the level of our awareness.

This emotional response is vital to our well-being, however. Researchers have found, for example, that when damage is caused to the amygdala, although people may not lose the ability to recognize personal identity from faces, they may lose their ability to recognize fear in facial expressions and multiple emotions in a single facial expression.[12] Because personal, social, and economic decisions often rely on such cues, both emotional and cognitive functioning are vital in making effective judgments. Neurologist Oliver Sacks tells the story of a judge who after receiving frontal lobe damage found himself without emotion. To the rationalist, this might seem ideal, but the judge himself realized that without the ability to enter sympathetically into the motives and circumstances of the people who appeared before him, he could not render a just verdict, and he subsequently resigned from the bench.[13] The "Star Trek" characters of Mr. Spock and Data speak directly to just this issue.

Although the traditional assumption had generally been that awareness must mediate between stimulus and response, and therefore that emotion was a postcognitive phenomenon, these newer research findings have shown clearly that emotional response can and does bypass cognitive processing, conscious or unconscious, and that both rational and emotional processing are essential for our perceptual health. In turn, this realization has caused a renewed interest in subliminal research, which is primarily concerned with how we register messages from the environment before, or without, becoming consciously aware of it.

Subliminal researchers have found it perennially difficult to gain credibility for their findings, primarily because they have been unable to replicate certain studies or convince skeptics that test subjects could not be briefly aware of the stimulus when presented, although they might not later recall being aware. It has also been difficult to define exactly what separates *subliminal* perception (or *unconscious, nonconscious, implicit* perception, or *subception* as it has been variously defined) from consciousness and to qualitatively measure the differences between them.

Further problems with subliminal communication derive from apparently divergent results between studies which have utilized pictures (which are holistically processed in the right brain), and those using words (which are analytically processed in the left brain). As Erdelyi has stated, "different kinds of materials (such as images opposed to words) obey different psychological laws, irrespective of their relationship to consciousness."[14] Even though structure is perceived before meaning, and it is probably easier to derive partial meaning from pictures than from words, most of the research done in subliminal perception per se has been with verbal stimuli—primarily because it had been assumed that cognition always preceded affect. Exceptions to this include studies by Erdelyi and other earlier researchers that showed positive results using visual stimuli alone.[15] When subjects are not required to perform the additional task of converting images into words, research results become more pronounced.

LeDoux's neurological research also supports these findings. Because the pathway between the thalamus and the amygdala is designed to initiate a quick defense response, it is not geared for refined analysis. This means that a signal may be sufficient to cause an emotional response, but still not strong enough to reach conscious thought processes. Crude, rapid, and weak, the signal mobilizes defenses independently of the analytical cortex. This neural "shortcut" may be at least part of what makes the emotional response to subliminal stimuli possible.[16]

As early as 1971, and later in 1984, British researcher in preconscious process Norman Dixon argued for the presence of a dual system—one that was associated with involuntary primary process and emotional thinking, and an evolutionary later one that involved logical, rational, and verbal cognitive operations. Although he speculated that it would be surprising to find two discriminators at work in the nervous system, "one selecting information for the autonomic system, and the other for conscious and verbal report,"[17] Dixon nevertheless anticipated that "the brain's capacity to register, process, and transmit information is by no means synonymous with that for providing conscious perceptual experience [and that] manifestations of either capacity may occur without the other, and each may be independent of the other."[18] R. B. Zajonc also argued that "affect and cognition are separate and partially independent systems and . . . although they ordinarily function conjointly, affect could be generated without a prior cognitive process."[19] Zajonc also implicated the amygdala as the possible site for the emotional processing of sensory information.[20]

This neural independence also explains the internal emotional response that is derived from such simple stimuli as color alone, and how the emotional "coloring" of a situation—as in light and shadow in photographs, for example—can create emotional bias before conscious judgment is formed. Perceptual processing of color and movement appear to be neurologically preprogrammed and therefore particularly susceptible to subliminal affect. For millions of people raised on the black-and-white Cold War photos of the Soviet Union in *Life* magazine in the late 1940s and 1950s, for example, the image of the Soviet Union as a drab and colorless place very likely influenced the way they envisioned the people and the politics of that country.

The autonomy of primal emotions may also account for the fact that when internal needs remain unsatisfied, they continue to assert themselves, finding a way into consciousness despite our subconscious or conscious refusal to deal with them. At moments of low resistance, they invade our conscious reveries and dreams in the form of related or symbolic images.[21] We may thus already be emotionally "primed" toward accepting or rejecting certain ideas or people through influences of which we never become aware.

This, according to John Bargh, is where the greatest significance of subliminal effects lies—in our lack of critical awareness of the ways in which we may be affected unconsciously by biases, whether subliminally induced or not. When people are aware of a possible bias, his research shows, they can rationally counteract it, but they still may be unable to stop their biases from being activated when their conscious control lets down its guard. Thus people who are aware of the possibility of sex-stereotyping may give "politically correct" adjusted responses when their attitudes are directed to the "average person," but they may nevertheless project unconscious stereotypes when making behavioral judgments about individuals within other less direct circumstances.[22] Worse, when we make such unfounded judgments, we then rationalize and misattribute the source of our attitudes to the person or thing itself rather than to our own feelings. In the process we further justify our subconscious prejudices as if they were trustworthy judgments, and these judgments in turn affect subsequent perceptual processing.[23]

Research by Krosnik and others has also shown that paired associations can condition long-term attitudes that in turn influence beliefs. They suggest, for example, that an entire childhood spent hearing certain groups of people referred to negatively or seeing them continually associated with negative situations may not only generate a negative attitude but also render that attitude unresponsive to logical argument or to contradictory factual information.[24] The complementary "halo effect," in which the presence of a single positive quality seems to suggest more positive qualities is another such example of a single trait which, when activated, seems to suggest a whole image.[25] A rich tradition of social psychological research also confirms the power of priming effects, our lack of introspective access to behavioral and attitude motivation, and the ability of associative logic to prejudice perceptions.

Thus, although subliminal research has been met with some resistance from the general scientific community, what is uncontested about subliminal processing is that a great deal of perception can and does take place outside of conscious awareness, even though subjects themselves may be unaware of the exact source of thoughts or feelings stemming from unconscious stimuli. There is evidence, for example, for the existence of a perceptual defense—of what Freud called the "censor" and Bruner has called the "Judas eye" (a peephole in speakeasies used for quick identification before allowing someone in).[26] As early as 1949, for example, subliminal exposure to taboo words was shown to have caused elevated galvanic skin response (GSR) in subjects even though the subjects report not seeing the words.[27] Before defensiveness can be exhibited, of course, some mechanism in the subject must appraise the situation for its emotional connotation in order to determine whether to suppress it or not.

In 1917, Poetzl, a Viennese neuropsychologist for whom the "Poetzl procedure" is named, devised a subliminal procedure involving flashing a picture at about 1/100 of a second. Afterward he asked subjects to describe verbally what they had just seen, and then instructed them to dream about the picture that night. Results showed that previously unreported parts of the pictures had indeed found their way into subjects' dreams. Poetzl's studies of subliminal stimulation and repression have been replicated many times since, although the results have been methodologically challenged.[28]

A number of other studies have keyed in to the power of familiarity to raise preference, revealing that repeated exposure to an object will result in a more positive attitude toward it, even without integrated awareness.[29] Research by Zajonc, for example, suggests that emotional preferences can be developed faster than people can consciously recognize the objects that themselves produce those preferences. After repeated subliminal exposure to certain geometrical shapes, for example, people began to prefer those shapes over others.[30] Garcia and Rusiniak used unconscious noxious stimuli to condition animals away from certain kinds of food.[31]

This particular phenomenon has major consumer attitude implications for large advertising budgets: the larger the company and budget, the more often a message can be sent. The more familiar it becomes, the more likable the product becomes. Practical recognition of this phenomena was seen in the "payola" scandals in the 1950s in which certain radio disk jockeys accepted bribes for repeatedly playing designated records, thus boosting their popularity. We didn't listen to the records because we liked them, we liked them because we listened.

Fallacies of Rationality

Descartes, who saw conscious rationality as the essence of the self, believed we first comprehend an idea and then accept or reject it, with acceptance and rejection being equal choice alternatives. Rational people, in this theory, weigh things equally and then consciously decide on truth or falsity. Spinoza, however, offered a different philosophical viewpoint more consistent with recent neurological research, particularly by neurologist Antonio Damasio. Both have concluded that Descartes erred and that reason is founded on feeling.[32] Spinoza believed that when we comprehend something, we automatically accept it as well. The only choice we have, he thought, is to reject an idea deliberately or not.[33] Rather than a two-stage process of interpreting and then accepting or rejecting an idea, he believed that acceptance was part of interpretation. If the "off switch," which signals "no" to an idea is not activated, processed information—possibly emotionally laden via the thalamo-amygdala pathway—is simply accepted as true.[34]

Communication researcher Daniel Gilbert, who also believes that Spinoza was right, points to our tendency to trust first perceptions as the ironic result of evolutionary efficiency. Because our perceptual system is geared toward gathering information that is optimal for potentially urgent action, we are innately programmed to act first, think later in times of crisis. As LeDoux explains, we are programmed to respond even to false cues because the risk is too great not to,[35] and it is these apparently instinctual responses which move rapidly through the limbic system.

Because our cognitive system developed from our perceptual system, it, too, may be similarly geared to accept first and to ask questions later. The result, Gilbert feels, is an evolutionary cognitive bias toward initially accepting what we see or hear as real.[36] He suggests, in fact, that perceptual process is so intimately linked with comprehension that "people believe the ideas they comprehend as quickly and automatically as they believe in the objects they see."[37] Only subsequently and with conscious effort do we rationally *counteract* initial acceptance of ideas. This is consistent with LeDoux's findings that our quick emotional reflex to danger occurs first, but that it then can be consciously checked by rational perceptual analysis that quickly catches up to the first crisis-oriented response.[38]

Part of the reason for this rapid acceptance response may be that the conscious mind is not the initiator of action, but is more like a separate computer program or even a network of relationships that receives subliminal data from other relatively independent processing areas of the brain and only afterward makes conscious sense of it. In the process of vision, for example, a unified image is achieved out of the work of the specialized areas in the visual cortex by linking the four parallel systems of vision at every level into a vast network. In this network, reentrant connections allow information to flow both ways in different areas to resolve conflicts between cells, the end result of which is a visual image. These visual cells, Semir Zeki speculates, resolve the problem of information processed in different places by firing in synchrony, yielding perception and comprehension simultaneously.[39]

Experiments by Benjamin Libet, a neurophysiologist at the School of Medicine at University of California in San Francisco show a time gap between action and consciousness of action, with the conscious will to act coming only *after* action is initiated, not *before*. A period of delay in the sensation of movement fools the conscious mind into believing that it has decreed the motion, but in reality, the mind only receives the news. In experiments relating conscious finger reflex to brain activity, Libet has shown that the brain begins to prepare for movement a third of a second earlier than the mind decides to act, and that the only real option the mind has is a last-minute "veto."[40] This is consistent with neurological research findings and with Gilbert's view that comprehension includes automatic acceptance. Negative critical function—such as deciding that a statement is not true, or that one's first impression is faulty or inadequate—is secondary and must be deliberately invoked.

If stress is introduced into the process, the critical "off switch" may never be used at all, and what may be seen as patently false under other circumstances may come to be believed as true. Because survival situations are processed first subliminally through the thalamo-amygdala shortcut, stress is always emotionally loaded. Successful "brainwashing" propaganda efforts in prisoners of war, for example, show how the combination of physical stress, which results in what might be called "critical analysis fatigue," and emotional impact work together to condition thought. Prisoners weakened by torture, illness, or hunger may readily accept as true what under normal circumstances they would consciously reject. When we are under stress, we do not critically assess ideas presented to us. We simply accept them "as is."

Thus, although it may seem to us that our minds are in control and making consciously judicious decisions, and we would like to think that we always judge things in a relatively unbiased fashion or that emotion is only an "additive" to rational thought, exactly the reverse may be true. Even though we can and often do correct misperceptions cognitively if we become aware of inconsistencies, we must actively *choose* to do so. Otherwise, we just cruise along perceptually without critical examination.

Some researchers suggest that even when we know *beforehand* that information is false, we may still persist in believing it.[41] Witness, for example, how often, even without malicious intent, gossip can persist even after it is proven wrong. Procter and Gamble, for example, has for years been unable to squelch rumors that first appeared in the late 1970s that there is some kind of connection between their "man in the moon" corporate logo and the practice of Satanism, even though there is no foundation in reality for the suspicion.[42]

Perceptual Illusion

Given this inherent bias toward accepting what we see as true, it is not so surprising that we should also have developed a sense of play around it: we love optical illusions in magic shows, and we delight in perceptual riddles such as those seen in Escher engravings, where a waterfall can flow uphill, a staircase may never end, or a ladder can be seen as simultaneously in front of and in back of a pillar support. In *The Gold Rush* we laugh at the sight of Chaplin's "Tramp" turned into a giant chicken in the eyes of his starving cabin mate, despite our underlying knowledge of the historical occurrences of cannibalism that it reflects.[43] At the same time, however, we take it very seriously indeed when someone deliberately manipulates our *belief* if we depend on its honesty for our physical, economic, or social welfare.

When we are told that a respected doctor has falsified medical research, no matter in how relatively ineffectual a way, the result is national moral outrage. Media news and photography are good examples of this: when a newscaster is placed against a manufactured background, yet the story implies an on-the-scene presence, the public wonders what other information has also been manipulated. When we learn that a 1920 photograph of Lenin and Trotsky has been altered to erase the presence of Trotsky for political reasons, we begin to see just how insidious the maneuverings of Stalin were in his pursuit and retention of power. We must, we believe, be able to believe our eyes, for if we cannot, our very survival seems in jeopardy.

The truth about perceptual process, however, is that it is inherently heir to a number of distortions—like the way a straight stick seems to bend under water, or the moon seems so much larger on the horizon than it does overhead. One of the most convincing perceptual illusions we are heir to, for example, is related to the optic disk—the "blind spot" where the nerve receptors leave the retina to form the optic nerve. Because this area has no retinal receptors and therefore no way of receiving visual information, the area is "filled in" perceptually. We are never aware of its presence as a hole on our vision until we deliberately find it under specially enforced conditions, usually at an ophthamologist's office. We see in whole images only because we literally see things that are not there.

This filling-in is only one instance of what occurs generally in perception as well. The first data that the brain perceives, for example, is boundary contours. This allows us to distinguish one object from another and is key to our survival because recognition of boundaries is just what prevents us from walking into trees or over a cliff. Subsequent filling in by averaging occurs whenever other detailed information is absent. According to some vision theory, once the brain has perceived the edges, it fills in missing detail between them by averaging out sensory data, including color and brightness, and smearing the details.

This perceptual filling-in and smearing cognitively parallels how once a particular stereotype is activated, it defines both the shape of our judgment as well as the "filling-in" of missing details. Images formed consciously and unconsciously provide the perceptual borders, and as we then automatically assume the characteristics implied within the whole image, we average out the rough edges and fill in with what isn't really there. As Bargh has suggested, we must deliberately make continual rational adjustments to all of our thinking if we are to avoid the pitfalls of stereotypical, automatic thinking.

What perceptual process is mostly about, in fact, is hypothesis testing, and sometimes the hypotheses are wrong. We are, in fact, continually fooled by what we see—mostly by ourselves, as we incorporate our own cognitive distortions into our perception. Perceptual psychologist R. L. Gregory, who has conducted extensive research in the area of the "inner logic" of perception in visual problem-solving, has suggested that the way we think abstractly may be directly and developmentally related to the way we perceive.

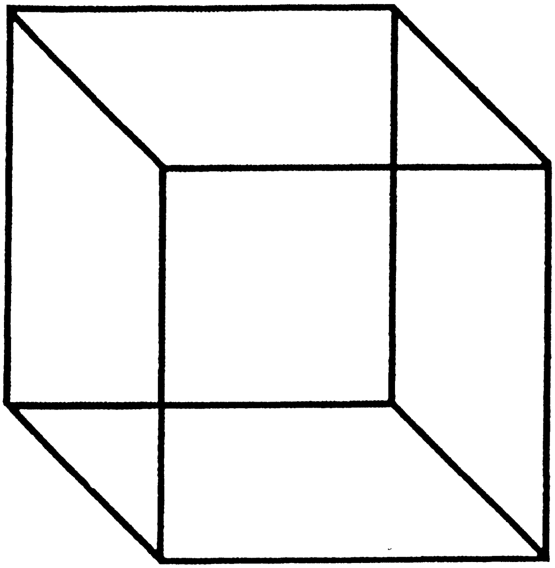
Our ability to see patterns in things, that is, to pull together parts into a meaningful whole is, he believes, the key both to perception and to abstract thinking. As we look at things in our environment, we are actually performing the enormously complex feat of deriving meaning out of essentially separate and disparate elements. Forming unified wholes—that is, *images* of things—in perception is not dissimilar in principle from forming whole and meaningful ideas out of various impressions. Both reflect a holistic logic that has its foundation in the evolution of perception.

This perceptual ability to holistically organize is, in fact, critical to the simplest perceptions. The grouping of various shapes of leaves, for example, allows us to discern a tree as separate from a telephone pole next to it. Sometimes, however, we can be fooled, and we resolve ambiguities into patterns which are not there. Shapes of both ideas and material things in the half-light of reason often seem to be what they are not, a phenomenon exploited in such apparently disparate things as military camouflage and Hollywood horror films. Film producer and director Steven Spielberg takes full advantage of this in *Poltergeist,* where in a twilight world a gnarled tree benign in daylight can turn into child-eating monster. Sinister shapes, he has shown us, come in the form of objects and ideas.

In exploring this problematic world, Gregory has identified a variety of illusions which illustrate how easily our judgment can be tricked perceptually into forming conceptions of wholes which do not in fact exist. These include resolution of ambiguities, which can be interpreted in more than one way; paradoxes which seem to show the impossible, pitting appearance against knowledge; and distortions, which rely on perceptual biases to confuse cognitive thinking. Classic examples of these include the Necker cube, an ambiguous image which seems to reverse its orientation continually (Figure 1.1); the "Devil's tuning fork" which is possible only when observed in parts, but not as a whole (Figure 1.2); and the Müller-Lyer illusion, in which the central line with spokes directed away from it continues to look longer even though we know it isn't (Figure 1.3). As Gregory puts the case: "Given the slenderest clues to the nature of surrounding objects we identify them and act not so much according to what is directly sensed, *but to what is believed.*"[44] Because *all* stimulus is ambiguous in nature, meaning can come only from the individual through the process of perceiving it.

FIGURE 1.1

Necker Cube. Because it is ambiguous which corner is closest to the viewer, the cube figure continues to reverse itself. First the top-left square seems closest, then the bottom right.



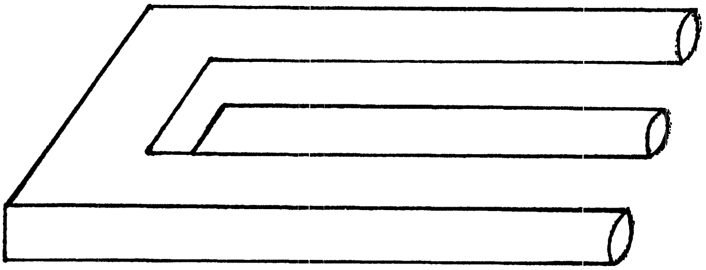
Yet only occasionally do we doubt that what we see is palpably real, even though it may be more accurate to say that we see what we believe to be there. In fact, it is only because humans as a group tend to have evolved the same kind of perceptual abilities that we can agree on any objective "reality" at all. Radical skeptics even insist that "it is not clear that you have the slightest reason to suppose that others have anything you could recognize as experience. When others see things, their visual experience may be something you could not even imagine."[45]

Remnants of Former Perceptual "Truths"

Many early theories on perception now look quaint, even comical, yet others persist into the present and continue to complicate our understanding. Aristotle, for example, championed the "emanation theory" of early Greece, which proposed that vision was the result of the viewer projecting out rays that were then sent back into the eye when they

FIGURE 1.2

Devil's Tuning Fork. An example of an "impossible" figure, the "Devil's tuning fork" seems to have three prongs but a base that can support only two. Only the parts make sense, not the figure as a whole.



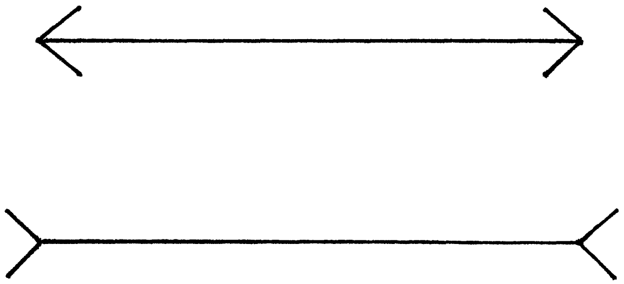
encountered objects. The glow of cat's eyes in the dark seemed to prove that the source of visual rays was from within; belief in the theory eventually gave rise to the myth of the "evil eye," which could send malignant rays outward toward a chosen victim. The emanation theory is also the basis for common expressions such as "the eye is the window of the soul" and "if looks could kill."[46] The converse of this theory, called "emission theory," postulated that objects gave off tiny luminous replicas of themselves.[47]

As proponent of emanation theory, Aristotle reasoned that we must all have a "common sense," that is, a faculty for unifying and synthesizing the data from all of the senses. He located this sense in the heart and believed its function was to give us a focused and meaningful interpretation of the outer world. Memories were formed by "phantasms," which remained after the stimuli were gone; these provided the basis of the imagination, and linked thought and perception.[48] Numerous other theories on sense perception followed, but these were essentially philosophical observations, and in the physiological studies of the seventeenth and eighteenth centuries, investigation for the most part stopped at the image on the retina.[49]

Johannes Kepler, in 1604, was the first to envision a model of the eye as a camera that accurately records what it sees, with the lens as optic and the retina as receptor. While this model seems to make sense, it nevertheless implies a one-to-one correspondence between external reality and perception that really does not exist. In 1637, however, Descartes published an experiment that seemed to "prove" Kepler's hypothesis. He scraped the sclera at the back of the excised eye of a slaughtered ox to

FIGURE 1.3

Müller-Lyer Illusion. Although both lines are of equal length, the bottom one is usually judged to be longer because of the context of the "spokes" or "wings" that lead the eye into the line or away from it.



make it translucent, placed it as if it were looking out his window, and on it observed a perfect upside-down, reversed image of the scene outside his window. The eye, it seemed, really was a "camera."

Today, even though we understand that there is no one-to-one correspondence between retinal image and mental image, that it is the mind that actively creates meaning through a process that only just begins with the stimulation of the retina by light, this comparison of eye to camera persists. Popular adages as "Seeing Is Believing" and our continuing trust in eyewitness testimony are based on the assumption that the eye accurately records the scene in little images that are then filed and stored in memory. For many, in fact, the accumulation of practical observation has superseded Aristotle's idea of "common sense." Yet history and the present are filled with examples of people whose eyewitness "common sense" has led them to believe such things as the earth is flat and that pictures do not lie. Yet the eye does not record an image, nor are images stored in memory as whole entities like photographs or slides.[50]

In an elementary way, however, the analogy of eye and camera seems to make perfect sense: the pupil of the eye does correspond in some ways to the aperture in a camera; the lens in each does focus the image onto a back wall—of film in a camera and onto the retina in humans; and in both mechanisms, images are inverted and reversed. But the analogy must stop there, for in many ways, the concept is a false and thoroughly misleading one: the lens of the eye is not a passive, but a dynamic apparatus. It focuses automatically without conscious manipulation, and it achieves clarity only in the retinal fovea—the small central area of the retina that focuses detail. Where a photograph will show with equal clarity everything at the same distance, the eye must jump in saccadic movements to focus clearly on parts of the scene and then construct the whole from the focal points that it has momentarily examined.

The eye also works in the reverse of the camera image: in a camera, the image is focused directly onto a film that contains the emulsion for capturing it; the receptors of the human retina, however, actually face backward so that it can be in contact with the pigment epithelium, which contains the chemicals necessary for the transformation of light into electrical energy.[51] Unlike a camera lens that must be deliberately selected according to a specific distance or desired effect well beyond the range of human capabilities—as in telephoto or fish-eye panoramic lenses, the eye has a flexible range, but is limited to about 140 degrees horizontally and 120 degrees vertically.

The human eye also is automatically "accommodating," where focus in a camera must be consciously and deliberately changed. Ciliary muscles at the front of the eye tighten to increase the curvature of the lens in order to focus at close range and then relax into normal position when we look away. When these ciliary muscles weaken at around age 45, accommodation ability decreases and our ability to focus on nearby objects becomes increasingly poorer. At this point reading glasses must substitute for what the ciliary muscles can no longer do.

In response to light, the rods and cones in the human retina also play different roles from the chemical emulsions used to capture images on film. Retinal cones determine visual acuity, and rods detect shape. In humans, the fovea is composed only of cones, which are geared to day vision, reaching their limited resolution in darkness within three to four minutes. The periphery, which is better at detecting movement than detail, has both rods and cones—but twenty times more rods. This gears it toward night vision; rods achieve maximum sensitivity in darkness in about twenty to thirty minutes.[52] During the day we can immediately focus on the details of our surroundings, but at night, we see only shapes and forms, and these we can see clearly only after a considerable period of adjustment. Humans have adapted to day vision, and this is why our eyes are very different from those of nocturnal animals, which often have large eyes to increase the size of the image on the retina, corneas that collect light, a retina that is dominated by rods rather than cones, and a back surface (the tapetum) that reflects light to improve night sight. Cats' eyes seem to emanate light because of the presence of a tapetum that reflects incoming light and thereby increases night visibility.

Also unlike the static camera lens, human eyes adjust automatically to light. They are also subject to a variety of problems such as astigmatism, a visual defect of unequal curvature, usually of the cornea. This prevents light rays from focusing clearly to a single point on the retina, and therefore results in blurred vision. The glasses or contact lenses worn to correct the problem are what most resemble the camera lens: both are rigid in nature and cannot adjust to light except by darkening the whole surface.

Additionally, the image on film is recorded as a fixed one. If we move while snapping the shutter, a blurred picture will result. The image on the retina, however, is in constant motion. Our eyes move in rapid short jerks ("saccades") because to achieve clarity of detail, we must continually redirect the fovea around the scene. The image that we perceive as a result is a mental one, which results from gleaning what remains constant while our eyes are moving. Even when we visually fixate on an object, our eyes are subject to "drift" and "flicker" movements and a superimposed tremor. If the eye is temporarily fixed under experimental conditions, as the eye of the ox in Descartes' experiment, the retinal image from it fades.

Movement is thus essential to vision because our eyes function by noticing and recording change. Without it, they simply record nothing at all. If, for example, the eye is covered completely by a plastic diffusing eye-cap (like half of a Ping-Pong ball) so that it can perceive no edges, perception stops because stimulus information is absent. In homogeneous darkness, when both stimulation and stimulus information are absent, there is also no perception.[53] Despite the eye's continuous motion, however, we do not perceive in a blur because perceptual process functions by detecting what remains invariant, even as our eyes move and we shift our point of view, or both. There is no fixed retinal image as in a photograph, but only a stable mental configuration subject to a variety of influences.

The camera image recorded on film must be also chemically fixed, in order to activate its latent picture. The visual system, however, actively explores the environment, captures and organizes information, and utilizes chemical-electrical processing to form the mental image. And although the photographic image clearly exists only within the camera before processing, the perceptual image is always interpreted as a reality outside of the person rather than as an internal process.

This is because the retinal image that Descartes mistook for the completed image of vision is only the beginning of the process. Our vision is not framed, as through a window, but unbounded. We do not use a separate consciousness to watch our images on an inner screen, but rather we sense that what we see is "out there" in an environment in which we have a presence. As we move through this environment, stimulation from the external world is clearly differentiated from our awareness of our bodies themselves. We use all of our senses to interpret the environment. Therefore, what ultimately sets the eye apart from a camera may be as simple as our direct awareness of the *externality* of the world.

This is why where the camera image is clearly bounded, as is the retinal image, what we perceive seems unbounded.[54] J. J. Gibson emphasizes that the analogy between the eye and a camera must be inherently false because the retinal image is merely the most elementary stage in the complex process called "seeing." The eye, Gibson states, is a biological device for sampling the information available outside in the ambient optic array. In Gibson's view, as we move our gaze or negotiate our bodies through the environment, ambient light within the "ambient optic array" is created by the diffused and multiple reflections of light from textured surfaces around us. This array surrounds us on all sides as a "reverberating flux"[55] and yields information on what Gibson called "invariants"—that is, attributes that do not change as we shift our point of view.

The optic array—on the *outside*—is the stimulus to which the chambered eye responds, and the retinal image is merely a part of the internal mechanism, not its product.[56] "From the earliest stage of evolution," Gibson states, "vision has been a process of exploration in time, not a photographic process of image registration. We have been misled about this by the analogy between eye and camera . . . a camera is not a device with which one can directly perceive the whole environment by means of sampling, whereas an eye does perceive the environment by sampling it."[57]

Our visual image is therefore a good deal different from a photograph. The eye, unlike the camera, is not a mechanism for capturing images so much as it is a complex processing unit to detect change, form, and features, and which selectively prepares data that the brain must then interpret.[58] As we survey the three-dimensional ambient optical array of the environment, properties such as contour, texture, and regularity, which are invariant under perspective transformations, allow us to discriminate objects and to see them as constant and external to ourselves.

This is why two-dimensional information such as occurs in a photograph may be impossible for a person blind from birth to even imagine,[59] and it may even be difficult for sighted people to read, because we cannot move about in it both to observe invariant shapes, textures, and patterns, and to filter out irrelevant information. We are geared for seeing a world in which we are predators, and like other predators, our eyes, set in the front of our heads, are particularly good at judging depth and distance. Because binocular vision helps us to see in three dimensions by giving a slightly different viewpoint to each eye (separate images that are combined in the brain and interpreted as depth), we exist in a world of space and movement. Preyed-on species, however, exist in a different world. Because they must be eternally vigilant, their eyes are placed at the sides of their heads to allow for an almost total view of their surroundings. Where these nonpredatory species have limited depth vision as a result of this anatomy, we have limited peripheral vision and rely on our superior sense of depth to orient ourselves.

This may account for why people who have never seen photographs before may have to learn how to read them.[60] What makes reading traditional two-dimensional (2-D) X-rays so difficult for their readers, for example, is their lack of depth, a problem complicated by poor contrast resolution and visual "noise." Radiological training to read them effectively involves a finely tuned discrimination between the normal patterns and textures of the body and the typical patterns and textures of abnormal conditions, because the details—such as small nodules of diseases like emphysema—are easily lost and may not, or cannot, be seen. Even though digital imaging enhancement and subtraction techniques can improve detail and contrast, even though "smart machines" can read a safe Pap smear, identify a high-risk loan applicant, and interpret a handwritten zip code, it is unlikely that machine readings will ever fully supplant human diagnosis. Human vision is still the most powerful means of sifting out irrelevant information and detecting significant patterns.[61]

This human perceptual ability to recognize patterns and to select relevant data has proven, in fact, to be the most perplexing obstacle in creating Artificial Intelligence (AI), which sees the mind as a computer that processes strings of data in symbols of 0 or 1. After a series of early AI failures which did not attempt to repeat the human processing of information at all, but rather focused on achieving the same outcome, "connectionist" researchers in the 1970s turned to human models in mental processing of experience, that is, to neural net processing and to "fuzzy logic" as the key to understanding intelligence. Rather than the computer approach of storing data and searching through it all to make a match, neurocomputers work like brain networks, learning patterns by clustering data from a number of samples or examples. Researchers like Bart Kosko at the University of Southern California have developed networks that imitate the brain's ability to make connections in the performance of simple tasks.[62] Results have been successful but limited in scope, however, imitating the brain only in a small way by creating discrete neural patterns paralleling up to only a few hundred neurons.

In other words, neurocomputers can "learn," but only to a limited degree. What the brain does that machines cannot do is to utilize billions of synapses to access the whole of memory and to instantly recognize invariance, integrate it, generalize from it, and extend itself through analogy. Although neurocomputers can perform a variety of tasks that are beyond human capability because of speed, complexity, or dangerous environment, some of the simplest patterns immediately recognizable to the eye are still elusive to machines.

There is as yet nothing that can replace perceptual process on so grand and efficient a scale. Our automatic complex image processing allows not only for the detection of invariances within the ambient optical array, but also for the recognition of gray states where identities bleed into one another, outside of linear logic. Perception corrects judgments, reduces and compresses complex information, filters out irrelevant information, alters memory, recognizes patterns, extends learning through analogy, and does it all instantaneously. As R. L. Gregory has pointed out, "It is just those aspects of control and the selection of relevant from irrelevant data which are the most difficult to mechanize—though they were the first problems to be solved by organisms."[63] Whatever success "smart machines" have had is due to their mimicry of our own neural brain networks, but as physicist Roger Penrose has noted, the "quality of understanding and feeling possessed by human beings is not something that can be simulated computationally."[64]

Neurology of Perception

R. L. Gregory has posited that vision developed only after our sense of touch, taste, and temperature. In all probability, he suggests, visual perception developed out of the sense of touch "in response to moving shadows on the surface of the skin—which would have given warning of near-by danger—to recognition patterns when eyes developed optical systems."[65]

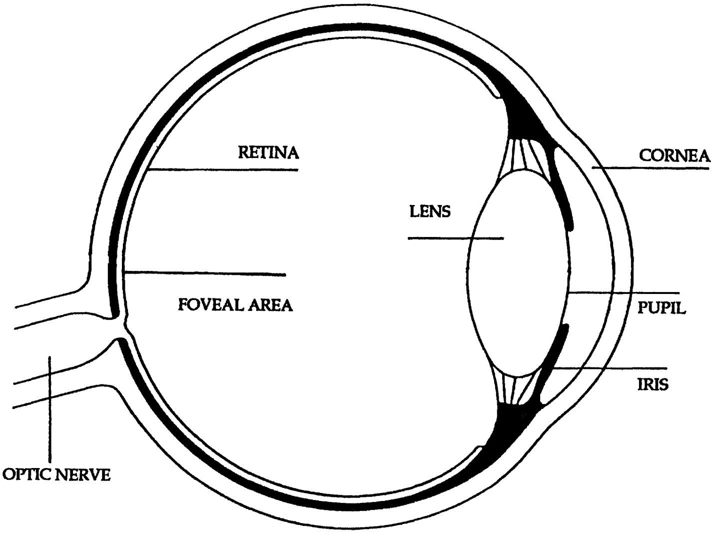
This optical system represents an interface between the brain and the environment. Characterized by cells responsive to minutely differentiated and specialized aspects of the environment, the optical system is a symphony of millions of nerve cells firing in particular patterns, responding to each of the component parts of the final image such as direction, degree of slant, shape, and color through the activation of specialized areas within the visual cortex. No neural response ever achieves its complete meaning alone, however. Within the visual system, cells work separately and in concert with one another to activate and to inhibit certain responses, and there is continual feedback among the parts. Perception is a dynamical system that utilizes the input from the body's sensory systems, synthesizes this with memory and understanding, and creates from both an integrated sense of self and mind.

Perceptual process begins first of all as light that bounces off objects in the environment. The process of vision (Figure 1.4) begins when the optic array is focused by the cornea and lens onto the 126 million receptors of the retina—120 million rods and 6 million cones—which line the back of the eye. As the visual system seeks and acts on information from the environment, retinal inputs lead to ocular adjustments and then to altered retinal inputs as the eyes actively engage the environment. Receptors in the retina transform and reduce information from light into electrical impulses ("transduction") that are then transmitted by neurons via the optic nerve, to the lateral geniculate nucleus (LGN) in the brain.

The LGN contains six layers of cells. Cells in the four uppermost, called the parvo-cellular layers, which branch again into two pathways,

FIGURE 1.4

The Eye. Information in light from the ambient optic array passes through the pupil, is focused by the lens onto the foveal area. It then passes along the optic nerve to the brain, first to the LGN and then to the visual cortex.



are responsible for perception of color, some contrast, and spatial resolution. The two lowest layers, called the magno-cellular layers, are responsible for perception of movement, depth, and some spatial resolution. Because the "parvo" layers most probably developed from the more primitive "magno" layers, they share some common functions despite their specialization. From the LGN, the two visual systems link to the striate or primary visual cortex, also known as area V1. V1 is separated from other specialized cortical areas by an area called V2. Together V1 and V2 act "as a kind of post office, parceling out different signals to appropriate areas."[66]

Researchers have delineated four parallel systems involved in the different attributes of vision—one for motion, one for color, and two for form.[67] Color is perceived when cells specialized to detect wavelength in "blob" regions of V1 signal two other specialized areas, V4 and the "thin stripes" of V2, which connect with V4. Form in association with color is detected by a circuit of connections between V1 "interblobs," V2 "interstripes," and V4. Perception of motion and dynamic form occur when cells in layer 4B of V1 send signals to areas V3 and V5 and through the "thick stripes" of V2.[68]

Thus, in the visual cortex, the electrical data sent from the retina is processed in thousands of specialized modules, each of which corresponds to a small area of the retina. In this process, data are reduced and compressed, so that the "image" that the cortical stimulus represents, although stimulated by the outside environment, nevertheless has no physical counterpart in external reality. What it contains, however, is a representative map of the entire visual field.

As Goldstein reminds us, "perception is based not on direct contact with the environment, but on the brain's contact with electrical signals that *represent the environment*. We can think of these electrical signals as forming a code that signals various properties of the environment to the brain."[69] In this process, vision is not a truthful recording sent in a one-way delivery of sensory data to the brain, but an active exploratory process that is cyclical and in which there is continual feedback and interaction throughout the visual system.[70] The visual system, in other words, has its own "intelligence." Because all external data is essentially chaotic and ambiguous, the eye—as an extension of the brain that interfaces directly with the environment—works to detect change and non-change, and to create meaningful sense out of the rush of stimuli from the external world.

What we see, then, is not a direct recording of what's out there, but a mental configuration that we interpret as an image—the end result of a highly exploratory and complex information-seeking system. In the visual system, parts interact synergistically in an instrumentalized arrangement that plays very much like a symphony, where neurons simultaneously fire in different areas to produce a stable mental image. In the production of this image, multiple structures become involved: after the visual cortex filters and codes information, it is then sent to as many as thirty-two different locations for further processing. As the brain continues to build on what it learns, these separate bits of information are broken down and efficiently stored in different places, ready to be reconstructed again. When we see, we not only utilize invariance in the ambient optical array but also call on our past experience to make it meaningful.

Perhaps nothing makes this interrelationship clearer than cases of newly sighted people, such as patients whose long-standing cataracts have been removed, who must learn how to interpret the new visual stimuli bombarding them but can draw only on experience rooted in a different sense mode, primarily of touch. As neurologist Oliver Sacks has observed, "When we open our eyes each morning, it is upon a world we have spent a lifetime *learning* to see. We are not given the world: we make our world through incessant experience, categorization, memory, reconnection."[71] Because of this, Virgil, one of Sacks's patients, blind for fifty years since early childhood, found himself more disabled after cataract surgery than before it. Because there is no automatic connection between sight and touch to translate one into a map that can be read by the other sense, Virgil's perceptual map was experientially blind. Without visual learning to establish the visual templates necessary to make visual impressions meaningful, his vision had no perceptual coherence, and everything ran together.

As a result, he lost his confidence and ease of movement, found walking "scary," and was unable to recognize objects without touching them. This extended into the abstract as well, so that to understand the orientation and layout of the house, which he could now see but not comprehend, he had to touch a model of the house. He had difficulty recognizing faces, yet could recognize letters fairly easily because he had learned the alphabet by touch in school. Space, which is an essential aspect of sight perception, was extremely confusing to him, and he could not grasp concepts of size or perspective. Because the sightless live in a linear world of sequence and time where sense impressions are built up in sequence, their perceptual maps give them no useful information in perceiving simultaneous space and depth.

Richard Gregory tells a similar story of S.B., a patient who was blinded in his youth and whose sight was restored by a corneal transplant when he was fifty-two. He, too, understood that the blur he saw was a face only because he could recognize a voice and knew that voices come from faces. Having lived in the sequential and material world imposed by blindness, he could make no sense of a two-dimensional photograph, seeing only patches of color. Visually immature, he did not perceive the usual optical illusions which so interest Gregory, such as those associated with figure-ground reversal, ambiguous figures, apparently bending parallel lines or apparent movement. Without well-established visual experience, he could truly see only what he could first feel. As he discovered that some of the things he loved and found beautiful by touch were visually ugly, that he could not make up his deficit in visual learning, and that socially he could not fit in this new world, he became progressively more depressed and eventually died within two years of his corneal transplant.[72]

While both men had learned to become fully competent in perceiving the world through sound and touch, both their sense of wholeness and their competence were shattered in a perceptual transition they were powerless to make. Ill equipped to perceive the world visually without a developed visual cortex, they could see but not perceive in a visual mode. The difficulties experienced by both men point up both the essential perceptual wholeness sought and developed by the psyche, and the importance of the role played by visual learning and memory in visual perception.

Contemporary visual theories generally assume that the visual memory in sighted people holds a set of representative shapes that capture invariant properties of objects in their various orientations, and that it is these invariant patterns that were lacking in both men. As experience in the visual world grows, these patterns become templates that allow us to recognize basic shapes and to approximate the in-between shapes of various positions. In the process of visually recognizing something, it is fairly well agreed that the retinal image is checked against an experiential template held in long-term memory, and that the memory representation that provides the closest match is selected as the object seen.[73] Hand shadows on a wall, which can be made to imitate rabbits or any number of other characteristic animal profiles, provide simple yet clear examples of such template shapes.

Although it is tempting to assume generally that memories are true in the sense of constancy, however, like the rabbit profile cast on the wall, memory is probably never the exact same shape twice, but only a pattern which remains flexible despite fluctuations and changes over time. Gerald Edelman, for example, sees memory as something that is continually shifting and changing under the influence of new experience. He stresses an open, dynamic and reciprocal relationship between perception and experience, viewing memory not as fixed, but as ever-evolving and re-creating itself within an open system.[74]

Neuroscientist Bessell van der Kolk also postulates that cognitively processed thoughts and traumatic experiences are recorded and stored separately in different parts of the brain. When people consciously remember traumatic events, blood flow increases to the amygdala and the visual cortex may be stimulated at the same time, resulting in intense visual flashbacks. Routine thoughts, however, stimulate the Broca's area, which is involved in verbal language. Van der Kolk and others speculate that because the Broca's area is not stimulated when traumatic memories are recalled, traumatized people may have great difficulty in verbalizing what has happened to them.[75] This may indicate that when the brain represses the anxiety-provoking experience, it is stored differently from ordinary memories, and may therefore be less accessible to conscious thought and verbalization.[76]

In the process of normal perception, exactly how much preprocessing is done in the retina to match the memory-shape and how the retinal input and memory representations are transformed to bring them into correspondence for perceptual recognition is another area of speculation. Models for shape recognition vary widely and range from the whole shape to simple geometric feature detection such as vertical and horizontal lines, curves and angles; to Fourier models in which the optic array is decomposed into a trigonometric set of components sensitive to intensity, orientation, and spatial frequency; to structural descriptions in which shapes are represented symbolically.

Holistic versus Analytical Perceptual Views

Current schools of thought on perception generally fall into one of two groups. J. J. Gibson's view of perception, which has its roots in early Gestalt theory, supposes that perception is a holistic, direct interpretation of the environment, a natural mechanism for detecting ecologically significant information. The other is essentially analytical, following a computerlike model of information gathering and the build-up of meaning from pieces of separate information gleaned from scanning the environment.

From Newton up to the point of Gibson's publication of his ecological optics theory in 1960, it had been assumed that the essential stimulus properties of light lay in its content—that is, the energy manifested in wave-length and intensity—and that it was this content which resulted in vision. Gibson, however, placed the emphasis on relationship, positing that it was the *transitions* in the natural optic array, not the energy content of the light beam itself, which signal objects as "out there." It is primarily the *differences* "between spots or patches of light, not the spots or patches themselves"[77] which we see. It is therefore *change* that signals vision and *relationship* that carries meaning.

In this view, as we move about within the ambient optic array, those aspects of the environment which remain constant suggest the forms of objects and people as well as the scale of things. The visual system actively explores and detects information directly from the environment.[78] We can tell size and distance, for example, without elaborate mathematical calculations by sweeping the environment as if it were a grid, with the size of its squares diminishing proportionately into the distance. We recognize shapes by what stays constant, and we see movement by recognizing what aspects remain true while others change. It is not surprising that the impetus for Gibson's theory of Ecological Optics began in his work during World War II with pilots, particularly with the difficulty of landing airplanes on aircraft carriers.

What the brain does, then, is to extract the invariant features of objects from the ever-changing flood of information it receives from the environment, actively constructing a working image of the world. To do this, the brain utilizes an incredibly complex organization of interrelated specialized functions which continually send electrochemical messages back and forth, and which ultimately combine to give us a unified view of the world.

One of the foremost researchers working from a computerlike model of perception, David Marr, has suggested that perception is a three-stage process built in much the same way a computer program is structured and organized: First, a "primal sketch" is formed in which intensities and major features such as the location of edges, corners, bars, and blobs of different size and orientation are discerned. Next, the more subtle characteristics of surface texture and depth are referenced to the viewer in a "2$^1/_2$-D sketch" that is viewpoint-specific. Finally, a three-dimensional mental model emerges which is centered in the object itself.[79]

Irving Biederman has focused on component recognition of three-dimensional objects through analysis of basic volumetric components termed "geons." These geons are basic configurations—like cylinders, cubes, bricks, curved macaroni, flat topped pyramids, megaphones, and so on—which act like short-cut templates for perception. We recognize these as invariants within three-dimensional shapes, so that perceptual process is speeded up. Objects composed of two or three of these basic configurations can, he believes, be differentiated easily from others by the way the various geons are put together.

Other researchers have directed their attention to texture analysis, which involves the most basic lines and directions within perception.