THE HUMAN THINKING PROCESS

--- A HYPOTHESIS in EVOLUTIONARY NEUROPSYCHOLOGY

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INTRODUCTION

What can I contribute to a field that already has thousands of practitioners with much better education, experience, and equipment?

1. I try to examine “the big picture.” What is thinking? Why did it originate? How does it work? If my answers are not completely satisfactory, they might at least point the way to research that would help others to answer these questions.

2, To understand any subject completely and correctly it is necessary to take into account all the elements in its system. Even a holistic study of the entire brain is not sufficient because the human thinking process is only one element in the still broader system for survival.

3. The human brain did not arise in its present form but evolved from the survival mechanism of simpler creatures. Tracing the evolution of the thinking process provides important clues as to why it started and how it works.

4. Certain types of errors in the way people think occur so frequently, even in educated people, that they must be inherent in the mechanism. Tracing the evolution of the thinking process shows why and where these errors occur.

5. While it is not possible to offer proof for all assumptions, I test them where possible against the behavior of real people.

Although this is a new hypothesis of the human thinking process, it is based on a solid foundation built by others. The same old neurons and their synapses operate in the same old way in humans as they do in primitive creatures. I've connected the basic discoveries made by others in some new ways.

My approach might be called reductionism, or even simplistic. Nevertheless, I think Nature always starts with a simple system. Then, instead of designing a more efficient mechanism when more capacity is needed, Nature just adds more modules. At some point, the huge number of modules makes it difficult to identify the basic system. For example, only four bases make up the DNA in all creatures, but assembled over a billion times, they form a very complex molecule. I think the mechanism for the human thinking process also started off simply. It's now complex because billions of neurons are doing what only a few neurons did originally.

Of course I am concerned as to how this material will be received. The hypothesis itself shows why it is difficult for anyone to accept new ideas. Unless you guard against it, you will automatically reject as incorrect any new material that is contradictory to the information already present in your brain, even when the new information is correct. So, please try to let this material enter your brain uncritically, perhaps tagged as a strange new hypothesis. After that, you can, and should, be as critical about it as you like.

This material is, of course, a hypothesis. This disclaimer isn't mentioned at every point in the text in order not to weaken the presentation. Nevertheless, this hypothesis seems to provide interconnected mechanisms that account for most activities of the human thinking process, including associations, memory, the response to stimuli, and feelings.

This material is a successor to “Think Better, Feel Better,” published in 1990 by Libra Publishers. That book started with my identification of eight common errors in the human thinking process. These observations led me to try to find a mechanism that could account for them. The objective of that book was to show the reader how to avoid these errors in thinking in order to feel better. The present effort concentrates instead on identifying the mechanisms underlying the thinking process.

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Section 1

THE UNIVERSAL SURVIVAL SYSTEM

There are innumerable different kinds of creatures on earth. They range in size from microscopic to gigantic. They have a kaleidoscope of body shapes and appendages, have different habitats, eat different foods in different way, etc., etc., and yet they all have one important behavior in common. They all respond to stimuli by moving toward their necessities for life and they all move away from threats to their existence. This behavior exists in creatures so primitive that they have no equipment to let them know why they are moving, where they are going, or what they will do when they get there. In short, all creatures have a similar universal survival system.

The more appropriately a creature responds to the stimuli it detects, the better its chances of survival. Primitive creatures have no choice; they always respond to the same stimulus in the same way, which is sometimes fatally inappropriate, as in moving toward a camouflaged predator. More advanced creatures sometimes respond to the same stimulus in different ways, even when the external conditions are the same. The process by which an advanced creature arrives at its response to a stimulus will be called "thinking."

We would like to know what is going on in the human thinking process. However, thinking is only one part of the survival system. To identify any part of a system completely and correctly, it is first necessary to identify the overall system completely and correctly, so this study starts with an examination of the universal survival system.

1. THE BASIC SURVIVAL SYSTEM

Single-celled creatures first appeared on Earth about 3.5 billion years ago. Although these creatures are microscopic in size, each one is a complex factory of interrelated reactions involving thousands of different kinds of molecules. All these reactions are in accord with the same chemical and physical laws that apply to all materials in the world. The behavior that results from these reactions is what we call "life." This property of life is lost when the creature's internal reactions are not functioning properly.

This chemical factory continues to operate as a unit only as long as its reactants are present in the required quantities and under tolerable external conditions of temperature, salinity, etc. To keep its reactions in working condition, each creature must obtain the reactants (i.e., "food") it needs by manufacturing them internally, by absorbing them from its environment, or by ingesting other creatures that contain them. It also must obtain sufficient energy from an external source, such as the sun or hydrothermal vents, or from the metabolism of the molecules it ingests.

In addition, it must avoid anything that interferes with its reactions, such as unsuitable external conditions of temperature, pH, or salinity and physical objects that interrupt its reactions, as by piercing the membrane that contains them. And, the world being what it is, it must also avoid being engulfed by another creature.

Despite its fundamental need to keep these reactions in working order, single-celled creatures are not able to make a conscious choice of any kind. They are unable to seek out the reactants and the conditions they need and they are unable to purposely avoid threats to their existence. All their movements are simply the external result of their internal reactions.

The Basic Survival System

Occasionally, an external factor causes a significant change in the reactions within a single-celled creature, as when an external molecule (i.e., a "stimulus") connects with a molecule within the creature or on the membrane that surrounds it. From the creature's point of view, this connection "detects" the stimulus. This detection starts a series of internal reactions that result in a change in the shape of a protein embedded in the membrane, causing the creature to move. Dr. Du Duve won the Nobel Prize for identifying this mechanism.

A similar effect occurs when light strikes a pigment within the cell, increasing its energy. This increased energy is passed on to a small molecule when it bumps into the pigment. This "messenger" molecule moves randomly around the cell until it encounters a protein embedded in the membrane, causing the protein to change its shape and so move the creature.

In either case, the creature's movement can be toward the stimulus, away from it, or in any other direction. There is no purpose in this movement and no conscious objective.

Detection of the same stimulus always causes the creature to move and always causes it to move in the same way. It has no choice of moving or not moving; it always moves. Detection is like a one-way switch that is always in the "on" position.

All primordial creatures that, by chance, responded to stimuli by moving toward predators or unsuitable external conditions died off. So did those that failed to move toward their physical needs. After this dramatic evolutionary shakeout, the only creatures that lived to reproduce were those that always moved toward their needs and always moved away from threats. As shown by their continued existence, this basic survival system has operated successfully in many types of primitive creatures for billions of years.

These earliest creatures did not come into the world with the objective of survival. Nor were they pre-designed for survival. There might have been innumerable proto-creatures with other combinations of reactions that disappeared without trace. Only those creatures that responded appropriately to the stimuli in their environment survived. But once achieved, survival became the most important heritage of every creature. Today, all creatures, from the most primitive to the most sophisticated, respond to stimuli by moving toward benefits and away from threats to their existence.

This mechanism will be called the "basic survival system." The steps in the basic survival system are:

- Detection of a stimulus causes a change in the creature's internal reactions.
- Information of this detection is transferred by a series of internal reactions or by a messenger molecule (a "hormone").
- This additional energy reaches and changes the shape of a motor molecule embedded in the creature's membrane, causing the creature to move.

There are several systems within the cell so that each different stimulus causes a different movement. Its elements will be described in the next chapter.

Although it might not be obvious at this point, the basic survival system is the beginning of the human thinking process.

2. ELEMENTS OF THE BASIC SURVIVAL SYSTEM

The basic survival system consists of only three elements:

- A receptor that reacts with (i.e., detects) something (i.e., a stimulus) in the environment.
- A connection between the detector (also called a "receptor" or "sensor") and a motor molecule.
- A motor molecule that moves the creature.

The Stimulus

A stimulus is any external item that causes some change in a creature's survival mechanism.

A wide variety of items can serve as a stimulus. Some are individual chemical molecules that react with a receptor molecule that is embedded in a creature's membrane, as with the taste buds and odor detectors in humans. Some stimuli are intangible items, such as the electromagnetic radiation that reacts with the light-sensitive pigment in human eyes or the concentrations of heat detected by snakes. Some creatures detect changes in air pressure (i.e., "hearing") or physical pressure on the body (i.e., "touch").

It is important to recognize that a stimulus is the item that directly influences the reactions in the cell. It is not the source of these stimuli. For example, a stimulus is the odor molecule emitted by a rose, not the rose. It is the pattern of light reflected by a tree and not the tree itself. It is the temperature and not the sun that increased the temperature.

Primitive creatures have no equipment to identify either the stimuli they detect or their source. They always respond directly to the stimuli they detect. People occasionally respond directly to the stimuli detected, as in withdrawing from a hot object. Usually, however, humans respond not to the stimulus but to its source. As the same stimulus might have originated in several different stimulators, people need to know its origin in order to respond to it appropriately.

This topic will be explored in more detail in a later chapter.

The Detector

The receptor with which a stimulus reacts is a "detector" or "sensor." When more complex creatures evolved, the detector molecule evolved into a sensory cell and then into a sensory organ. The interaction between the stimulus and the receptor is "detection."

All creatures have more than one type of detector and so are able to detect more one type of stimulus. Each detection system is separate. That is, each sensory system has its own detector, its connection from the detector to the motor, and its motor molecule or motor organ. As a result, detection of one type of stimulus might cause the creature to move toward that stimulus while detection of another type of stimulus might cause the creature to move in some other direction. Moreover, the same stimulus might cause one type of creature to respond in one way and a different creature to respond in some other way. For example, detection of light might attract one type of creature (e.g., a moth) and repel a different type (e.g., a cockroach).

Even single-celled creatures have multiple receptors for the same type of stimulus. This mechanism provides a rough measure of the number of stimuli present. For example, single-celled creatures can detect the point of greatest concentration of some stimuli, such as a food source. In humans, the multiple detection of the same stimulus makes it possible to detect the loudness of a sound, the intensity of an odor, or the brightness of light.

The Messenger Molecule

In some single-celled creatures, the information that a stimulus has been detected is conveyed from the detector to the motor molecule by a messenger molecule. In other creatures, this information is transferred through a chain of chemical reactions. In either case, this transfer of sensory information can be considered the first “sensory signal.” Arrival of the sensory signal causes the motor molecule to change its shape and so move the creature.

The survival of all creatures is affected by the time it takes to respond to a stimulus. When simple multi-celled creatures first evolved, their larger size increased the time required for the messenger molecule or the chain of reactions to reach the motor cell. As this increase in response time could be fatal, a better way to transfer sensory information was needed. How this was done will be described in a later chapter.

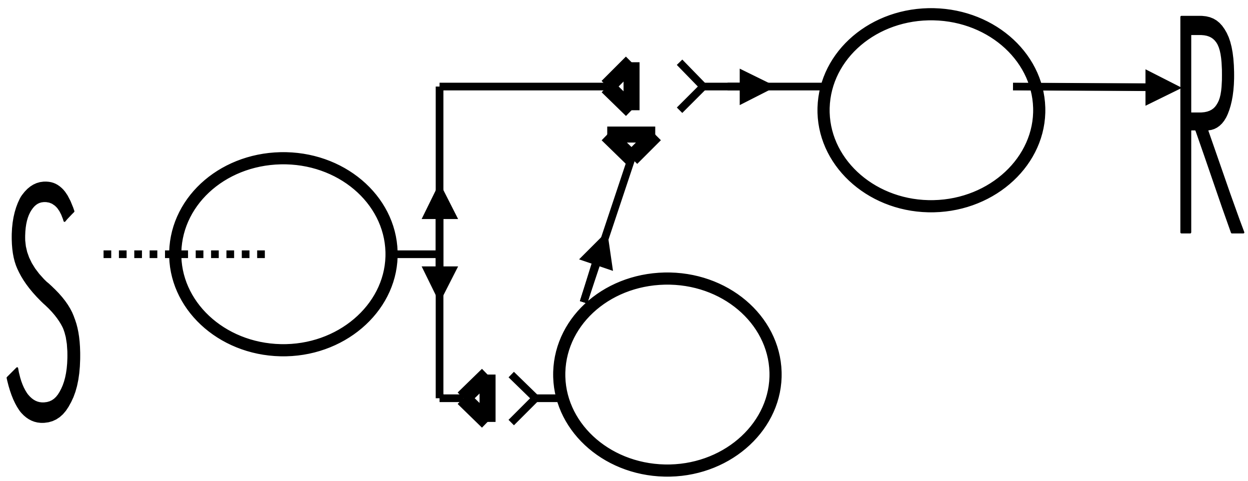
The Motor

The earliest motors were proteins embedded in the membrane of single-celled creatures. Contact with the messenger molecule (or later with neurotransmitters) increased the energy level of the motor molecule, which caused it to change shape, moving the creature in a given direction. Different proteins received their energy from different messenger molecules and so moved the cell in different ways. Eventually, this function was taken over by motor cells and still later by motor organs which could more precisely control the movement of all or only a part of the creature's body.

3. THE ADVANCED SURVIVAL SYSTEM

Some species of creatures with the basic survival system have survived for hundreds of millions of years. Nevertheless, this system has a serious shortcoming. The same stimulus might originate in more than one source. For example, a shadow might have originated in a prey creature, in a predator, or in an inanimate rock. The basic survival system cannot identify either the stimulus it detects or its source. It always responds to the same stimulus in the same way. As a result, the creature's response to the same stimulus sometimes achieves its objective, sometimes is a waste of valuable energy, and sometimes is fatally inappropriate.

To reduce this source of error, some of the early multi-celled creatures evolved another cell in parallel with the connection from the detector to the motor, as shown below:



Stimulus Sensory Cell Proto-Brain Motor Cell Response

DIAGRAM OF THE ADVANCED SURVVIAL SYSTEM

Overview of the Advanced Survival System

This overview introduces the next key step in the evolution of the human thinking process.

As shown in the diagram, a sensory cell detects a stimulus. This sensory cell discharges an impulse that is sent to both a motor cell and to the protobrain cell. This impulse increases the voltage of the motor cell, causing it to start to move the creature.

The protobrain cell extracts more information from the sensory signal before it discharges an impulse. This impulse is “inhibitory;” that is, it reduces the voltage to the motor cell. This reduction in voltage inhibits the motor response to the stimulus.

This simple process distinguishes among stimuli from different sources under some conditions. To continue the earlier example, a detector cell in an early multi-celled creature detects a shadow. This stimulus causes the detector to send a signal to both the motor cell and the protobrain cell. This signal causes the motor to start to move the creature toward or away from the shadow.

The protobrain cell requires additional input to reach its discharge level. If it does not receive additional signals from the detector, it remains inactive, so the creature moves.

When the detector continues to detect the shadow, it continues to send a signal to protobrain cell. At some level of repetition, this signal causes this cell to reach its discharge voltage. This inhibitory impulse to the motor stops it from firing and so stops the creature from moving. That is, the protobrain neuron gathers additional information from the sensory signal and uses it to modify the response started by sensory cell. In effect, the protobrain cell distinguishes between the intermittent shadow of a moving predator and the unchanged shadow of a rock.

This new cell is the beginning of the modern brain. Its basic function is that of inhibiting the creature's response to stimuli under certain conditions. It does not identify either the stimulus or its source. It does not choose a response to the stimulus. It simply discharges an impulse that modifies the creature's automatic response to the stimulus.

Elements of the Advanced Survival System

The "advanced survival system" consists of:

- A detector
- A direct connection from the detector to both a motor and to the protobrain

- A protobrain
- A motor
- A connection from the protobrain to the motor

Separate systems exist for each type of detector.

Overview of the Operation of the Advanced Survival System

The advanced survival system did not replace the basic survival system but incorporated it intact. Its response to a stimulus always starts with the automatic emotional response of the basic survival system.

- A sensory organ detects a stimulus.
- Detection of the stimulus causes the sensory organ to discharge one or more impulses (i.e., a "sensory signal").
- The sensory signal goes to the motor organ directly or through a short series of inter-neurons and so arrives almost instantly. As soon as the sensory signal arrives, the motor organ begins its automatic "emotional" (i.e., "survival") response to the stimulus.
- The same sensory signal is sent to the brain. The brain processes this signal by assembling all the information is has about the stimulus and how to deal with it to come up with the response most likely to increase the creature's chances of survival. The brain then sends an "intellectual signal" to the motor organ.
- The intellectual signal arrives at the motor a fraction of a second after the emotional signal.

- The motor organ responds in a way that is some combination of its automatic, emotional response to the stimulus and the intellectual instructions from the brain.

When survival is involved, the motor organ responds to the stimulus before it receives the intellectual signal from the brain. In less urgent situations, the intellectual signal modifies the emotional response (and sometimes suppresses it) in a way that increases the creature's chances of survival.

Selecting a Response to a Stimulus

As creatures increased in size and complexity, more neurons were added to the protobrain. Each new neuron modified the creature's response to stimuli in a way that increased its chances of survival under an additional set of conditions.

At some level of increased size and complexity of its brain, a creature sometimes responds to the same stimulus in different ways. This raises an important question. If it were possible to take into account all external and internal conditions, do all creatures, including humans, always automatically respond to the same stimulus in the same way? Or do advanced creatures consciously select their response to these stimuli? A conscious selection of a response to the stimuli detected is "thinking." The rest of this book attempts to identify what is going on in the billions of neurons in the human brain when it selects a response to a stimulus.

4. NEURONS AND THEIR SYNAPSES

In single-celled creatures, information that a stimulus has been detected is transferred from the detector molecule to the motor molecule by means of a messenger molecule. In later multi-celled creatures, this information is transferred from a sensory cell to a motor cell through a chain of nerve cells. These neurons are connected to each other at specialized locations called "synapses." These synapses are gaps in the membranes between the connected neurons. Chemical molecules, called "neurotransmitters," migrate across this gap from the transmitting neuron to the receptor neuron.

These three elements, the neuron, the synapse, and the neurotransmitters, are the basis for the human thinking process. It might seem unbelievable that the complex human thinking process could be based on only three simple elements, but it brings to mind that only four bases are the mechanism for heredity. In both cases, the complexity is not in the elements, which are simple, but in the increasing complex interconnections among these elements as more sophisticated creatures evolved.

Neurons

Structure of Neurons - Each neuron has a cell body that handles the metabolic reactions required for the cell's existence. There are many small filaments, known as "dendrites," leading into the cell body. A single long, thick extension, called an "axon," leaves the cell body.

In most cases, the axon of a transmitting neuron is connected to the dendrites of receiving neurons. Some neurons, however, are connected axon-to-axon, dendrite-to-dendrite, or axon-to-cell body. Energy is transferred from one neuron to others through these connections. About 5% of the connections are electrical. The others physically transfer chemical molecules.

Operation of Neurons - All neurons operate through a change in their voltage. All neurons at rest have the same voltage of -70 millivolts. Reception of each batch of excitatory neurotransmitters at its receptor sites increases the voltage, while reception of inhibitory neurotransmitters decreases it.

All neurons have the same critical voltage. When a neuron receives sufficient net excitation to reach this level within a given time period, it discharges an impulse along its axon and returns to its resting voltage. Since all neurons have the same firing and resting voltage, the voltage of an impulse is the same for all neurons.

In the absence of an external signal, neurons routinely discharge an impulse at a constant rate. This rate varies for different types of neurons from 7-15 times a second.

External signals change the discharge rate of a neuron dramatically. The time required to generate an impulse depends on the rate at which energy reaches the neuron through all its synapses. The faster its voltage is increased, the sooner it discharges an impulse. In transferring a signal, a neuron generates impulses at a rate that can vary from less than once to thousands of times a second.

There are two factors affecting the voltage of a neuron. One is the net change in its voltage by the reception of excitatory and inhibitory neurotransmitters received at its synapses. The other is "leakage" that slowly but steadily reduces its voltage. To reach its critical voltage, the neuron must receive excitatory neurotransmitters at a rate faster than it loses voltage through the reception of inhibitory neurotransmitters plus leakage. At any slower rate, the neuron does not discharge an impulse. The transfer of a signal stops at any neuron that does not receive sufficient energy to reach its critical voltage.

A neuron receives neurotransmitters from many different transmitting neurons. At any instant of time, some transmitting neurons are discharging neurotransmitters while others are quiescent, so that energy reaching a receptor neuron it is constantly changing. As a result, the interval between the impulses it discharges also changes frequently. This irregular discharge of a series of impulse will be referred to as a neuron's "impulse pattern." The impulse pattern is the means by which information is transferred from neuron to neuron and therefore is of great importance in the thinking process.

Organization of neurons - The human brain contains at least a hundred billion neurons of several different types together with many support cells. Neurons of the same type are grouped together in specific areas to perform specific functions.

There appears to be no fundamental difference in the structure, chemistry, function, or connections of neurons in humans and those in other creatures. Despite differences in size, connections, and functions, all neurons generate impulses in the same way.

Some neurons receive energy from a few to hundreds of different transmitting neurons and deliver their output up to hundreds of receptor neurons. Some transmitting neurons have multiple synapses with the same receptor neuron.

Neurons that connect only with other nerve cells are sometimes referred to as "inter-neurons."

Most neurons in the human brain are present at birth. Unlike other cells, neurons are seldom replaced when they die.

The Synapse

There is a narrow slit between the transmitting and the receiving neuron known as the “synaptic gap.” The area near the synaptic gap in the transmitting neuron has numerous small containers (“vesicles”), each filled with several thousand molecules of neurotransmitter. An impulse moving along the axon discharges these packets of neurotransmitters into the synaptic gap. The neurotransmitter molecules migrate across the gap to receptor sites on the receiving neuron. Reception of a neurotransmitter changes the voltage on the receiving neuron. As noted, excitatory neurotransmitters increase its voltage; inhibitory neurotransmitters decrease it.

In general, the reception of 10-20 packets of net excitatory neurotransmitters within a given period of time causes the receptor neuron to reach its discharge voltage.

Enhancing the synapses - The passage of an impulse over a synapse increases its surface area by forming spines, which provides space for a greater number of vesicles. This increases the number of neurotransmitters that will be released by a subsequent signal. An impulse also increases the number of receptor sites on the receiving neurons. This increase in the discharge and reception of neurotransmitters will be referred to as "enhancing" the synapse. The more frequently the synapse is used, the greater its enhancement up to some maximum amount.

Immediately after the passage of an impulse, the synapse begins to lose its enhancement. The enhancement caused by a single use is lost within a few minutes, at most. The more often a synapse is used, the slower it loses its enhancement. A synapse that has been used frequently retains its enhancement for days or weeks.

Reuse of a synapse before it has completely lost its enhancement restores it to its recent maximum level of enhancement. However, if the enhancement is completely lost, the next impulse has the same effect as a first one.

Neurotransmitters

Neurotransmitters are the chemical molecules that transfer energy from one neuron to other neurons or to muscle cells. The neurotransmitters are manufactured within the axon of a neuron. Over fifty different neurotransmitters have been identified. They can be grouped into two broad types, "excitatory" and "inhibitory." Excitatory neurotransmitters increase the voltage of the receiving neuron while inhibitory neurotransmitters reduce it. Each type is used in specific tracts within the brain. No neurotransmitter unique to humans has yet been found.

Most neurons transmit only one type of neurotransmitter. A few neurons transmit more than one type but at different synapses.

Section 2

ELEMENTS OF THE SURVIVAL SYSTEM

In deciding to buy a new automobile, most people consider its appearance, safety, and performance. They have little interest in its spark plugs, compression ratio, or brake pads. They don’t care what makes the engine turn or what makes the car stop. If you are one of these people, you can skim or skip this section and begin reading seriously at Chapter 10.

However, you will miss a fascinating part of our journey. The human brain is not like an automobile, a computer, or anything else. No one designed the human brain. No one selected its elements. No one decided how to put them together. In fact, the brain has no grand objective. It simply evolved to help improve a creature’s response to the stimuli detected.

The brain didn’t pick and choose its elements. The evolution of the brain worked the other way around. The elements invented the brain! The brain evolved from the properties of its elements. It wasn’t designed either externally or externally.

When a single-celled creature responds appropriately to a stimulus, it lives. When it responds inappropriately, it dies. The evolution of the human thinking process can be viewed as a way for a succession of creatures over billions of years to obtain additional information about their environment in order to increase their chances of survival.

This section starts with a very brief introduction of some basic facts about the brain that will help later in understanding how it works.

As the thinking process starts with detection of a stimulus, the second chapter introduces the human senses. The key point here is that our senses detect is the stimulus itself (say a loud noise) and not the source of the noise.

The senses make no contribution to identifying the stimuli they detect. They send this information to the cortex for analysis. And herein lies a problem. The human sensory cells detect so much information in each instant of time that there is no way to connect all these cells with their target neurons in the cortex. So the information is first condensed into a sensory signal, which is a unique pattern of impulses.

Well, this reduces the volume by about 90% but now there is a problem of delivering each compressed impulse to its target in the cortex. So the sensory signal is conducted along a specific pathway through a vast transmission system of interconnected neurons to reach the cortex.

What happens in the cortex will be described in a later section. However, a partially processed signal leaves the cortex and is recirculated back to earlier locations in the sensory pathway to do some amazing things.

Come join our expedition to learn how the human thinking process evolved. You might enjoy it

5. A PREVIEW OF THE EQUIPMENT

The objective of every living creature is survival. When a creature's senses detect a stimulus in its environment, the creature's brain processes this information and sends a signal to its motor organs to move the creature in the way most likely to promote its survival.

Before exploring how this might be done, it will be helpful to examine, albeit rather superficially, some aspects of the human brain that affect its response to stimuli.

Origin of the Human Brain

Nature did not design a new brain when humans evolved. As with all advanced creatures, humans came into existence as a modification of an earlier creature. Humans inherited sensory organs to detect stimuli in their environment and a brain that processed this sensory information to direct its motor organs to move its body toward benefits and away from threats. In short, the human survival system works in the same way as the survival system of all other advanced creatures.

Composition of the Human Brain

The brain of every living creature, including humans, consists almost entirely of two types of cells. It contains more than ten billion neurons and a large number of support cells. Most neurons are organized into "subunits," such as the thalamus, the hippocampus, and the cortex, which perform specialized functions. The neurons in these brain structures are interconnected in three dimensions by innumerable synapses. In addition, nerve fibers go through these structures in all directions as well as from one structure to another. Although the functions of some areas of the brain have been identified, most of their specific activities in the thinking process are still unknown.

The Neurons

There are several types of neurons in the human brain but they all generate their impulses in the same way. There are no neurons in the human brain that are not present in other creatures. In fact, all materials and processes in the human brain are similar to those in the brains of simpler creatures.

The neurons in the human fetus move to a specific location, even when obstacles are put in their way. This implies that each neuron has an assigned location. Most neurons that reach an incorrect location later withdraw their connections or die off.

The addition of neurons to increase sensory capability in a species is accompanied by an increase in cortical neurons to process this information.

The human brain is “organized” and all human brains are organized in the same way.

These observations indicate that the human brain does not perform its functions in some way that is beyond eventual human understanding.

Evolution of the Protobrain

Primitive creatures with a simple protobrain have all the brainpower they need for survival, as shown by the continued existence of their species over millions of years. So why and how were more neurons added?

Mutations are constantly occurring in creatures in all species but nature seldom keeps a change that does not benefit the creature in some way. So the size and capability of the protobrain would not have increased unless these additional neurons served some useful purpose. One obvious benefit is extracting more information from the sensory signal. However, there is no point in developing additional sensory capability if the brain is not able to use this information to improve the creature's chances of survival.

So each increase in sensory capability through random mutations must have been accompanied by, or soon followed by, the brain's ability to use it. Although it might seem unlikely that related mutations would develop in two different parts of the survival system, simultaneous changes are rather common in evolution, as with different parts of the human body increasing in size in the right proportion at the same time. The increase in sensory capacity and the ability to use it might have occurred simultaneously in the fetal neural tube. If so, this increase in the number of neurons in both the human sensory organs and the cortex implies that each sensory neuron has a specific target neuron or combination of neurons in the cortex to receive its information.

The Cortex

The cortex is a thin layer of neurons that covers the subunits of the brain. It is the region of the brain that arrives at the response to the stimuli detected. This remarkable process is described in considerable detail in later chapters. At this stage in the analysis, only a superficial introduction to the equipment and is functions is presented.

The human cerebral cortex is made up of at least ten billion neurons, interconnected by a hundred to a thousand trillion synapses. This huge number of synapses far exceeds the number of genes, so some other process must form these connections.

Although the regions of the cortex have different functions, the neurons in all regions are organized in the same way. The interconnections among the various types of neurons are now known, though not their specific functions. The cortex grew by adding more of the same structure and not by developing new types of neurons or changing its organizational structure.

The sensory signals from all the human senses, except smell, pass first through the thalamus. Axons from the thalamus enter the sensory cortex. Neurons in the olfactory system go directly to five separate regions of the cortex.

The sensory cortex has separate regions for each of the senses. These regions are further subdivided in proportion to the sensory signals that originate in each area. For example, there is more area for pressure signals from the lips and fingers than from the hands and feet. There is also a motor cortex that controls the movements of each part of the body.

The neurons in the cortex are arranged to obtain progressively more abstract information from the sensory signal as it passes through the cortex. For example, the information about individual visual stimuli is first combined into an image of the physical structure of their source. Still further along, the neurons identify movement, such as learning that an airplane is moving away from the observer instead of toward him. These "association areas" of the brain are larger than the primary sensory and motor areas.

There is a constant interchange of signals in all areas of the cortex but there is no "central controller" of this flow of information.

6. THE HUMAN SENSES

In order to survive, every creature must respond appropriately to the other objects in its environment. All the information any creature ever has about the external world is brought to it by its senses. It cannot respond appropriately if an object is not detected or if it is detected incompletely or incorrectly. So detection of stimuli by the senses is the indispensable first step in survival.

Each person obtains some of his or her information about the world by the direct detection of stimuli in the environment. Most information, however, is detected in communications from others. Nevertheless, somewhere in antiquity, some human obtained every item of sensory information by direct detection of external stimuli and passed this information on to others.

Some inappropriate responses to stimuli occur because one or more of the senses is not operating properly, as with blindness, deafness, etc. Some people die because they do not detect the odorant from an unlit gas range.

A more common error of the senses occurs when detection is incomplete, as when someone fails to hear all of a message warning of danger. Less common, but still important, are incorrect detections of external stimuli, as in the case of color blindness and dyslexia.

In short, failure to detect all the stimuli present in the environment completely and correctly always results in a response that is inappropriate at best and fatal at worst.

The Human Senses

Internal senses - Our internal senses are seldom considered, as they don't work in quite the same way as the external senses. Nevertheless, they have an important effect on the thinking process.

Detector systems within the body are triggered when its internal operations are not working properly. Whereas external senses detect the presence of something, some internal senses detect the absence of something in that person's body. For example, an insufficient amount of food is detected as "hunger" and an insufficient amount of water is "thirst." We "feel tired" when deleterious materials are present in our reactions.

Since nature seldom wastes the energy to develop unnecessary or ineffective systems, it did not develop senses to detect threats that occur only rarely or threats that the person could not do something about. For example, we have no way to detect the absence of oxygen, though we cannot survive more than a few minutes without it.

Also, there are no internal senses to warn us that an artery is clogging, a tumor is growing, or the immune system is functioning improperly until there is an immediate threat to survival, when we feel pain. Pain tells us that something is wrong within the body but not what is causing it.

Information from a person's internal senses joins other sensory signals entering the brain and has a major effect in the selection of a response to stimuli detected. For example, a person responds differently to the same stimulus when he is tired than when his is energetic.

External senses - To gather the information a person needs for his or her survival, the external senses evolved to detect stimuli that represent threats and opportunities. Each of the human senses detects a different type of external stimulus:

- The eye detects a pattern of form and color formed by light.
- The ear detects variations in the compression of air.
- Receptors on the surface of the body detect pressure.
- The nose detects several kinds of individual molecules.
- The mouth detects the properties of some molecules, such as sweet, salty, etc.

Some other creatures have senses that detect other types of stimuli, such as a concentration of heat or the earth's magnetic field.

Limitations of the Senses

Our senses might not detect a change in the environment for any of the following reasons:

1. We do not have a sensory organ capable of detecting certain items, such as radio waves or the earth's magnetic field, even though these items are all around us. We detect such stimuli only when we are able to convert them to a form we can detect, such as a sound or a visual pattern on an oscilloscope.

2. Our senses have a limited range in which they can detect a stimulus. For example, there is a minimum and maximum frequency of vibrations of the air that can be detected by the ear. The human eye was unable to detect microbes until the invention of the microscope brought then into our visual range.

3. There is some threshold level below which a stimulus is not detected. The ear cannot detect sounds that are within its frequency range when they have insufficient pressure to cause the sensory cells to discharge an impulse. Similarly, our sensory cells for pressure are not sensitive enough to detect the bacteria on our skin.

4. The sensory organ might become inoperative under some conditions, as in being unable to detect an odor when the nose is clogged.

5. The detector might be temporarily inoperative. Neurons cannot detect stimuli from the time they begin to discharge their impulse until they return to their resting voltage. This interval, of about 0.1 milliseconds, is its “refractory period.” This seems to be the reason the eye cannot follow the path of a bullet fired from a gun.

6. Some stimuli overwhelm the sensory organ so that other stimuli are not detected. For example, a bright light can overwhelm the sensory cells in the eye so that they are unable to detect other stimuli present. This also occurs with loud noises, strong odors, etc.

If our senses do not detect a stimulus for any reason, we have no way to know that it is present in our environment.

Simultaneous Detection of Multiple Stimuli

The senses detect stimuli and nothing else. The eye detects form and color, not the object that has this form and color. The ear hears sounds but not what caused the sound. No interpretation of any kind about the stimulus or its source occurs in the senses. The senses simply send a signal to the brain that the detector cells have discharged an impulse.

At any instant, the human senses might detect:

- Similar stimuli from the same source
- Similar stimuli from different sources
- Different stimuli from the same source
- Different stimuli from different sources

Similar stimuli from the same source - The simultaneous detection of multiple stimuli from a single source is common in nature. Through detection of the number of stimuli present at a location, a single-celled creature moves toward the highest concentration of a beneficial stimulus, such as food, and away from the area of greatest threat, such as acidity. This capability has been retained in the evolution of advanced sensory organs. For example, the human ear can locate the most desirable level of a sound. The nose can detect the optimum concentration of the odor molecules from a flower.

Similar stimuli from different sources - Similar stimuli from different sources might be present in an area at the same time, such as odor molecules from different flowers or the sounds made by different instruments in an orchestra. The senses detect all the stimuli present within the limits of their capability. They have no equipment to determine if the stimuli came from different sources or to identify these sources. They simply pass on information about all the stimuli they detect simultaneously to the brain.

Different stimuli from the same source - Simple creatures have only a few different types of detectors so that they are able to detect only a few types of stimuli. As a result, the stimuli they detect simultaneously usually originate in a single source. As will be shown later, this has an important effect on the human thinking process. In contrast, advanced creatures have several senses so that they can detect different types of stimuli simultaneously. For example, a person might detect the form and color of an dog, the sounds it makes, and its odor through different senses at the same time.

Different stimuli from different sources - The ability of advanced creatures to detect multiple stimuli simultaneously introduces an important source of error into the thinking process. The different stimuli detected might all have originated in a single source or they might have originated in different sources. In a visit to a zoo, a person might see a tiger just as an unseen lion roars. Or he might see one flower at the same time he smells the odor from a different flower. Each of his senses sends a single composite report on all the information it detects from all sources in each instant of time. The brain then must decipher this information to determine what is going on out there and the best way to respond to it.

7. THE SENSORY SIGNAL

The function of the sensory signal is to report the detection of a stimulus to the motor organs. In advanced creatures, the sensory information reaches the motor organs through two different routes. One is the direct connection that originated in the basic survival system from the sensory organ to the motor organ. The other signal goes first to the brain, which processes the sensory information before sending the processed signal on to the motor organ.

Detecting a Stimulus

In a single detector cell – Each detection of a stimulus increases the voltage of the detector cell. Several such increases are usually required to reach the cell's discharge voltage. When the stimulus is not detected for at least this length of time within a certain period, the detector cell does not discharge an impulse. Throughout this analysis, detection of a stimulus will mean detection for a period long enough for the detector cell to discharge an impulse. This period is measured in milliseconds.

When a stimulus is detected, the detector cell reaches its critical voltage, discharges an impulse, and returns to its resting voltage. When the stimulus is still present, this process is repeated. As a result, the continuous detection of a stimulus causes a detector cell to discharge a series of identical impulses. As both the resting and the discharge voltage are the same for all neurons, the amplitude of each impulse is always the same, regardless of the stimulus detected.

After discharging an impulse, a detector cell returns to its resting voltage. If the stimulus is still present, the voltage rises again to its discharge level, releasing an impulse. The time between these impulses is the “refractive interval,” which lasts about 0.1 milliseconds. Continuous detection of a stimulus forms a series of impulse spikes of constant amplitude with an interval of equal time between the impulses.

When a stimulus is detected irregularly, the signal leaving the detector cell is still a series of impulses of constant voltage but the intervals between the spikes are irregular. The less often a stimulus is detected, the longer the time interval between impulses. This irregular series of impulses being discharged by a sensory neuron will be referred to as its “impulse pattern.”

All detections of all types of stimuli detected by all types of detector cells, regardless of the nature of the stimulus or its source, are sent to the cortex as a pattern of impulses.

In a sensory organ - The sensory organs of advanced creatures are made up of millions of individual detector cells. The human eye will be used as an example of how a sensory signal is formed from multiple detector cells.

Each detector cell in the eye evolved to detect a specific stimulus. Some detect lines, some curves, some the edge of an object, etc. Each cell detects the presence of its target stimulus and nothing else. But since each of the millions of detector cells in the human sensory organs discharges the same type of impulse, how can all this information about the many different stimuli detected in each instant of time be conveyed to the cortex?

Obstacles to Transmitting the Sensory Signal

One possible way to transfer all the information detected by a sensory organ is to have a direct connection from each detector cell to a corresponding neuron in the cortex. However, the retina of each eye has about 125 million detector cells. All senses together probably have more than a billion such cells. It would be difficult, if not impossible, to have so many direct connections from all sensory organs to specific neurons in the cortex.

Another possibility is that of first gathering the information from all the detector cells into a single neuron and then sending it to the brain. This might work in a sensory organ that has relatively few detector cells but it can't handle the huge number of detector cells in a human sensory organ. To understand why this is so, consider each unit of time to be 1 millisecond. In each unit of time, the detector cells in an eye might discharge more than 100 million impulses. The neuron that gathered and passed on all this information would have to generate impulses at the rate of more than a billion a second before the information detected in the next unit of time arrives. This is far beyond the capability of any neuron.

Since any information that cannot be transferred in each time period would be lost, nature evolved a solution that combines these alternatives.

Condensing the sensory signal - The sensory information gathered by the eye is first condensed by a factor of about 100. There are three layers of cells in the human retina. The detector cells are in the bottom layer. The axons of about ten of these cells synapse with a single inter-neuron in the next layer. The axons of about ten inter-neurons in this second layer synapse with a single neuron (a “ganglion cell”) in the third level. Thus there are about 100 detector cells for each ganglion cell. The axons of the ganglion cells are the optic nerve.

This condensation makes the information transfer manageable, though it still requires over a million direct connections from each eye to carry its information. Condensing the sensory information greatly reduces the number of transmission lines required, but introduces the problem of encoding and then decoding this information.

Describing the stimuli detected – As all the impulses are identical, how do they describe the stimuli they detect? The short answer to this rhetorical question is, “They don’t.” Any description of even the simplest stimulus would increase the volume of information to be transferred many times, which is beyond the capacity of this mechanism. So the first step in solving this problem is both brilliant and unexpected. The sensory signal contains absolutely no information about the stimuli detected. It reports only which detector cells detected a stimulus in that instant of time.

Identifying the detector cells that detect a stimulus - The information about which detector cell discharged an impulse is encoded in the way the detector cells are connected to the inter-neurons and in the way the inter-neurons are connected to a ganglion cell.

Although all detector cells discharge identical impulses, these cells are connected to the inter-neuron in different ways. These are not random connections of neighboring cells but cells in different locations detecting different types of stimuli. In addition, each detector cell can have a different number of synapses with the inter-neuron so that the impulse from each detector cell would change the voltage on the inter-neuron to a different degree. Also, some connections are excitatory while others are inhibitory. As a result, information about which cells released an impulse is contained in the impulse pattern from the ganglion cell. Each different set of detector cells discharging an impulse results in a different impulse pattern.

For the brain to select an appropriate response to the stimuli detected, it needs to identify the stimulus or its source. Since this information is not in the sensory signal, it must be supplied in the cortex. This means that the information as to which detector cell was energized must be delivered to a specific target neuron in the cortex. How this might be achieved will be deferred to later chapters while the method of encoding the sensory signal is examined.

Forming an Impulse Pattern

The discharge pattern of an inter-neuron is determined by the impulses it receives from the ten or so detector cells that feed into it. This is not simple addition of the impulses discharged by the detector cells as the inter-neuron has more synapses with some detector cells than others. Also, some of the impulses increase its voltage while others decrease it. As a result, its discharge pattern is influenced both by the number of stimuli detected at that time and by which neurons did the detecting. Thus the pattern of discharges from the inter-neuron is constantly changing as the stimuli detected change.

This process is repeated in each ganglion cell as it gathers the impulses from about ten or so inter-neurons. As a result, the impulse pattern leaving the ganglion cell describes, in code, which detector cells were energized by a stimulus in that instant of time.

The impulses discharged by a ganglion cell pass along its axon, which is a fiber in the optic nerve, into the brain.

Visualizing the impulse pattern – The impulse pattern of each ganglion cell is a unique representation of all the information gathered by its set of detector cells at that period of time. To visualize an impulse pattern, consider a vertical line to show the presence of an impulse in that instant of time. If there is no impulse, there is a blank space instead of a line. As a result, the impulse pattern from a ganglion cell is a series of lines at irregular intervals, which is similar to the bar code on a grocery product.

It is not yet known how the detector cells, inter-neurons, and ganglion cells are connected to encode this information. Nevertheless, we know it occurs because the brain interprets the impulses it receives from the eye to “see” the stimuli detected. Some clues to how this occurs will be explored in later chapters.

Transmitting the Sensory Signal

The axon of each ganglion cell transmits the impulse pattern formed by its detector cells. Taken together, the impulse patterns of the million or so ganglion cells contain all the information about all the stimuli obtained by this sensory organ. This collection of individual impulse patterns from the ganglion cells is the visual sensory signal. Each eye sends the brain millions of sensory impulses each instant it is operating.

A sensory organ does not detect motion or any other change in the environment. It simply detects all the stimuli within its capability at each instant of time. When there is a change in the stimuli present, different detector cells discharge an impulse, resulting in a different impulse pattern leaving the ganglion cell. All changes in the impulse pattern are interpreted in the association area of the cortex. As a result, the first sensory signal does not provide an image of motion or other change. This information is conveyed by changes in successive signals, which energize different sets of cortical neurons. The brain then uses these changes to identify motion.

Despite this encoding of the information detected, the sensory organs do not interpret the information they obtain in any way. The eye does not see individual objects but detects only some pattern of form and color. The nose detects some combination of aroma molecules originating in a flower or in a glass of wine but does not identify these molecules or their source. All interpretation of the stimuli detected occurs later in the brain.

Stimuli from Multiple Sources

The detectors in a sensory organ detect all the stimuli present within their range at the time, whether they originated in a single source or in multiple sources. The impulses from all the detectors feeding into a ganglion cell form a single impulse pattern. This sensory signal is not a separate collection of stimuli from different sources but a single pattern formed by combining all the impulses formed by all the detector cells stimulated simultaneously.

Sensory Signals from Different Senses

Stimuli from the same or different sources can be detected by different human senses at the same time. For example, the eye might detect the form of an object while the ear records a sound and the nose detects an odor from the same or some other source. Each sensory organ first forms a composite sensory signal for all the stimuli it detects, as described above. The composite signals from all the senses, except smell, merge in the thalamus before they are sent to the target region for that sense in the sensory cortex. The sensory signal for olfactory information goes to the cortex directly. The brain then has the modest task of interpreting what all these impulses represent.

8. THE SENSORY PATHWAY

Detection of a stimulus by a sensory organ initiates a sensory signal consisting of some pattern of neuronal impulses. This sensory signal reaches the cortex where it causes some response to the stimulus. However, as there are billions of neurons and trillions of synapses along the way, it's unlikely that the neuron-to-neuron route of a sensory signal will ever be identified. Nevertheless, known information about the operation of neurons and their synapses provides some insight into what happens from the time the sensory signal leaves the sensory organ until it arrives at the cortex.

Connections

The impulse pattern of a sensory signal is conveyed from one location to another in three ways; along nerves, by direct connections between neurons, and through pathways.

Nerves - Nerves are bundles of individual nerve fibers, each of which is an axon of a neuron. The optic nerve, for example, is a bundle of axons of the ganglion cells in the retina of the eye.

As each axon in the optic nerve collects the impulses from a different set of detector cells, its impulse pattern is almost always different from that of other axons in the same nerve. As there are no connections within an axon, the impulse pattern travels through it rapidly and without change.

Direct connections - An example of a direct connection is that between a sensory cell and a motor cell. In some cases there are some inter-neurons in series between the sensory cell and the motor cell. However, as each interneuron in a series receives its impulses from a single transmitting cell, the information in the impulse pattern is transferred rapidly and without change.

Pathways - Most of the information transfer in the brain occurs through signals going along pathways. A pathway is the route taken by a sensory signal through the inter-connected neurons in the substructures of the brain.

Evolution of the Sensory Pathway

The sensory signal originated in single-celled creatures. A messenger molecule carries the energy from a sensory molecule to a motor molecule in some random route through the cell. This route can be considered the first sensory pathway.

Some of the earliest multi-celled creatures transferred neurotransmitters directly from a sensory cell through a few inter-neurons to a motor cell. This direct connection of neurons still exists in all living creatures, as when a person automatically withdraws after touching a hot object.

When sensory organs evolved, they detected a set of stimuli instead of an individual stimulus. Because of the large number of detector cells in a sensory organ, it is not possible to have direct connections from all these detector cells to their target neurons is the cortex. The mechanism that evolved to handle this task seems to be roughly similar to a telephone network.

The impulses from the detector cells are collected in a way that reduces their volume. This encoded series of impulses becomes the sensory signal. This signal is sent over lines (i.e., nerve fibers) to a central location (the thalamus). The information in the sensory signal is then decoded by conducting it over a vast switching mechanism (i.e., the interconnected neurons in the substructures of the brain) whose connections bring each impulse in the sensory signal to its target neuron in the cortex.

For example, when a newborn chick of some bird species detects a specific pattern of marks (i.e., a set of stimuli) on the face of its parent, it responds by pecking at the marks. As this behavior occurs immediately after birth, it is not learned by observing other chicks. Moreover, the chick does not peck at somewhat similar marks on the faces of other species of birds. So there must be an existing pathway, established by genetics, which conveys this sensory signal to specific neurons in the cortex, initiating the motor response of pecking.

This indicates that:

- The routes for sensory signals are established by genetics.
- That the sensory signals for different stimuli reach a different set of cortical neurons, presumably because they are conducted over different pathways.
- That the substructures are a complex switching mechanism whose function is that of delivering sensory information from the sensory organs to specific neurons in the cortex.

As noted elsewhere, Nature never evolved a complex mechanism where a simple one would do the job. Direct delivery of all sensory signals to the same neurons in the cortex could be done through nerves and direct connections of neurons, which would dramatically reduce the size and complexity of the brain. So this enormous investment in a switching mechanism must be needed to deliver a sensory impulse signal to a specific target neuron in the cortex.

Formation of Sensory Pathways

Entering a subunit - Each subunit in the brain consists of several types of neurons interconnected in three dimensions. Some of these connections are excitatory and some are inhibitory. There are many connections back to earlier locations through small local circuits made up of a few to several inter-neurons. There is also a major recirculation of the sensory signal to earlier locations that will be examined later.

The impulses in a sensory signal start a cascade of impulses through the interconnected neurons in the subunit. Each different sensory signal triggers a different cascade of impulses. The discharge pattern of each receiving neurons is affected by:

- The number of its excitatory and inhibitory connections it has with transmitting neurons.
- The rate at which it receives net positive impulses from all its connections.
- Feedback loops.

These factors cause the sensory signal to fan out through the substructure. However, when an impulse encounters a neuron that, because of its connections, does not reach its discharge voltage, it is extinguished at that point. As a result, each sensory signal proceeds only along the routes in which the connections of the neurons accommodate its impulse pattern.

The sidewise conduction of the signal is also limited. The receptor neurons at the fringe of the signal have fewer inter-connections with transmitting neurons and so do not reach their discharge voltage, causing the signal to be extinguished at that point.

Redundancy - It seems likely that there are several alternative routes for most impulse patterns. This redundancy is needed to handle the natural death of neurons as well as lesions and injuries to the brain. As a result, the sensory signal fans out through the substructures of the brain in several pathways, some of which are longer or shorter routes to the cortex. If the optimum pathway no longer exists for any reason, the sensory signal might still reach its target neurons in the cortex through these alternative routes.

Branching of the sensory signal - As the sensory signal proceeds along its route, it sometimes encounters one or more regions where the arrangement of the neurons propagates part of its impulse pattern. The signal "branches" at this point and continues along both pathways. For example, a sensory signal made up of the impulse patterns of several sets of stimuli detected simultaneously might encounter a region that accommodates the impulse pattern for one of these sets. This initiates a duplicate impulse pattern for that part of the sensory signal. This part of the complete sensory signal "branches off" as it enters its pathway.

The branching of signals in the brain structures is quite different from that of an electric current in a wire. An electric current subdivides when it branches so that the total current in the branches is equal to that of the original signal. Branching in neurons is similar to that of rope-like fuses sometimes used to ignite dynamite. The signal in the fuse (i.e., its burning) goes along each branch it encounters at its full strength. Each additional sensory signal formed by branching is conducted along any number of additional pathways at full strength.

The voltage of an electric current in a wire gradually decreases due to internal resistance. This does not occur in a chain of neurons, as each one is a small battery, getting its energy from the metabolic processes in its cell body. As a result, there is no decrease in the voltage of the impulses no matter how many neurons the signal passes through or how many times it branches.

Through this process of branching, the sensory signal reaches the cortical neurons as a "front" of many different signals rather than as a single linear signal.

Extinguishing the Sensory Signal

All or part of a sensory signal is extinguished when it encounters a region where the connections of the neurons do not propagate its impulse pattern.

A sensory signal is also extinguished temporarily through over-use. The same stimulus is sometimes detected almost continuously within a short period of time. At some frequency of detection, the materials required for the transfer of impulses at the synapses are used up faster than they can be regenerated. As the neurotransmitters are not released, the signal dies out at the over-used synapse. The stimulus is still detected, but this information is lost before it reaches the cortex. This process is known as "habituation." After some period in which the stimulus is not detected, the supply of required chemicals returns to normal so that the sensory signal can again reach the cortex.

9. THE RECIRCULATING SIGNAL

This chapter introduces one of the most important mechanisms in the human thinking process, the recirculating signals. Their principal activities will be described in more detail in later sections.

Formation of the Recirculating Signal

When a sensory organ detects a set of stimuli, it forms a sensory signal whose impulse pattern represents all the stimuli detected in that instant of time. This signal is conducted over a pathway determined by its impulse pattern to reach some set of neurons in the sensory cortex. The set of neurons triggered simultaneously in the cortex will be called a “brain pattern.”

The sensory cortex begins to process the brain pattern in some way. The partially processed sensory signal leaves the cortex. Some of this signal is sent to the motor cortex. Some is returned directly to the sensory cortex. Some is sent back to earlier locations in the sensory pathway as a “recirculating signal.”

Shortly after the detection of a first set of stimuli A, a different set of stimuli B is detected, and so on with the detection of C, D, and E. Each new sensory signal is recirculated in the same way. As a result, some of the recirculating signal for B merges with the recirculating signal for A. This process continues as the sensory signals for C, D, E, etc. arrive. As the sensory signals for the stimuli detected earliest fade out, those for the most recently detected stimuli are added to the composite. As a result, the composition of the current recirculating signal is constantly changing.

As noted earlier, nature seldom, if ever, retains a development that has no useful purpose. But what benefit can be obtained by sending a partially processed sensory signal back to earlier locations in a sensory pathway?

This recirculation performs a number of useful functions, ranging from minor to indispensable, not only in the human thinking process, but for survival itself. What these recirculating signals do will be described briefly here, but how they do it will be deferred until some new mechanisms have been introduced.

Some Functions of Recirculating Signals

Increased enhancement of the sensory pathway - As the signal recirculated is derived from the sensory signal, it is conducted back to the cortex over that sensory pathway.

When a set of stimuli is detected for the first time, the synapses in its sensory pathway are enhanced only minimally by the sensory signal. As this minor enhancement is soon lost, the information learned is also quickly forgotten. In contrast, recirculation sends a signal over these synapses several times and so retains the memory for a longer period of time.

This recirculation continues for some unknown number of cycles. However, as each additional cycle delays the response to the stimulus, recirculation probably continues for a few seconds, at most. As a result, the degree of enhancement provided by the recirculating signals is lost within a few minutes.

Retention of memories - Recirculating signals serve to enhance the synapses in many different pathways, keeping them intact even when the stimuli that formed them are not detected again. This makes a major contribution to the retention of memories that are brought to mind infrequently.

Smoother transition between sets of stimuli - If it were not recirculated, a sensory signal would be conducted to the cortex only once. The next sensory signal would trigger some other set of cortical neurons, which might be completely different from the previous set. The cortex would have to deal with the stimuli in each sensory signal separately, shifting from one set of stimuli to the next. Recirculating signals bring all the items associated with successive events into the same composite brain pattern. This permits the cortex to deal with a gradually changing succession of stimuli instead of responding to each one individually. For example, recirculating signals permit a person to respond to all the words in a sentence as a unit instead of responding to each word individually.

Recirculating signals appear to be the mechanism that associates all activities that succeed each other in time, such as the notes in a song, the words in a poem, the steps in a dance, etc.

Increased recovery of associated information – The sensory signal brings into the cortex only the information detected at that time. As a result, the brain would not have available for its response any of the information learned in previous encounters with this set of stimuli. Each response would be as naïve as the first one.

Some objects in the environment become connected with other objects in a person's brain through "association" (to be described). When this person detects one of the objects later, the associated item is also brought to mind.

As the recirculating signal is conducted along the sensory pathway, it sometimes encounters a pathway that is a connection between an item in the sensory signal and an associated item. Through a mechanism to be described later, the recirculating signal brings this associated item into the brain pattern.

This is one of the most important mechanisms in the human thinking process. It brings all the information in that brain associated with the stimuli detected into the cortex. The cortex then processes this information to arrive at the response to the stimuli most likely to promote survival. This elegant mechanism in the human thinking process will be described more technically in the section on Memory.

Associating items that occur at different times - In order for two or more stimuli to be associated (to be described later), their impulse patterns must be part of the same sensory signal. In the absence of recirculating signals, this occurs only when the stimuli are detected simultaneously. As a result, there would be no way to associate stimuli detected at different times or in different places. So an important function of recirculating signals is the formation of associations among stimuli detected at different times. This appears to be the mechanism for the formation of all intangible items, such as imagination, creative thinking, and anticipation of future events. It is essential for the identification of causes and their effects, which occur at different times.

Limitation of Recirculating Signals.

As all impulse patterns present in a recirculating signal were formed originally by the detection of external stimuli, they are always conducted over established pathways for sensory signals. As a result, they sometimes combine different items of information already present in a person's brain into new forms. However, they cannot introduce new sensory material, which occurs only through the detection of external stimuli. As a result, recirculating signals can combine existing information in new ways but cannot form completely new items.

This combination of items present in a brain can cause serious errors. All stimuli detected by the senses represent items that exist in the real world. The recirculating signals sometimes combine items in new ways that might or might not represent objects in the real world, as with flying elephants, tree spirits, and cold fusion.

Section 3

BRAIN PATTERNS

This section examines the transfer of information from the sensory signal to the cortex. The cortex processes this information to select a response to the source of the stimuli detected.

The set of cortical neurons stimulated simultaneously will be called a "brain pattern." This pattern is constantly changing. New Information about the stimuli being detected is brought into the cortex by a succession of sensory signals. Recirculating signals contribute items of information associated with the stimuli detected. All this information is constantly being processed by the way the cortical neurons are interconnected.

It is impossible to describe, let alone analyze, this constantly changing activity. Nevertheless, an attempt will be made to follow the presumed activity of a single sensory signal as its information is processed in the cortex to get some idea of what is going on.

Although the processing of the brain pattern is continuous, it will be subdivided for convenience into three phases:

- **The Proto-Pattern** – The first, incomplete information in the cortex is examined to determine if the stimuli detected represent an opportunity or a threat.
- **The Sensory Pattern** – This additional level of information, which is brought to consciousness, is processed to identify the source of the stimuli detected.
- **The Thought Pattern** – This final pattern, which has the most information about the stimuli detected, is processed to select a response to the stimuli.

The first chapter examines the proto-pattern for clues as to how the energized cortical neurons processes the sensory signal to determine whether its impulse pattern represents a benefit or a threat. This results in an immediate, emotional response to the stimuli detected.

The second chapter examines the sensory pattern. It presents an analogy that might be helpful in understanding how the source of the stimuli detected is identified.

The third chapter examines the thought pattern to learn how the recirculating signals bring additional information about the stimulus into the cortex. Processing the thought pattern results in an intellectual signal that merges with the emotional signal to form a composite response to the stimuli detected.

10. THE PROTO-PATTERN

It is not yet known how the cortex processes the sensory information it receives. Nevertheless, some insight is obtained by examining the objectives of cortical processing and from the information present in the signals that reach the cortex.

The primary objective of the thinking process is that of responding to the stimuli detected or to their source in a way that promotes that creature's survival. This objective, however, is not achieved all-at-once but in a series of steps as information about the stimuli detected is brought into the cortex.

Although cortical processing is a continuous process, it will be subdivided into three phases, each with a different type of information in the brain pattern and with a different objective. These phases will be summarized briefly here and then described in more detail throughout this section.

Cortical processing begins with the arrival of the sensory signal. This is followed by some number of trips of a recirculated signal, each delivering a number of items associated with the stimuli detected. Each successive recirculating signal penetrates deeper into that individual's memories to bring additional items less directly associated to the stimuli detected into the cortex.

Phases of Cortical Processing

The Proto-Pattern – A new brain pattern begins when a sensory signal enters the cortex. The principle information this signal contains is which detector cells discharged an impulse. It also brings with it a few items directly associated with the set of stimuli detected, such as its label (to be described later). Soon thereafter, the recirculating signal brings some items directly associated with the stimuli detected into the proto-pattern.

The objective of the human proto-pattern is the same as it is in single-celled creatures; to learn if the stimuli detected is a benefit or a threat. Although there is little information in the proto-pattern to identify the source of the stimuli detected, it informs the brain that something is out there that must be dealt with. Even a rough identification that initiates a correct immediate response is usually more helpful for survival than a more detailed identification that delays the response.

The Sensory Pattern – Although primitive creatures respond directly to the stimuli they detect, advanced creatures usually respond to their source. So the next objective of cortical processing is that of identifying the source of the stimuli detected.

The recirculating signals continue to add items directly associated with the stimuli detected to the brain pattern, converting it to a sensory pattern. The cortex begins to associate the items in the sensory pattern, forming images of objects in nature.

The Thought Pattern – The recirculating signal now brings items indirectly associated with the stimuli detected into the brain pattern. This includes not only specific items but also connections among items, and then connections among connections of items, such as “You can’t fight city hall” or “Never let them see you sweat.” When sufficient time is available, the recirculating signals bring into the thought pattern all information in that brain on how to deal with the stimuli detected.

The final objective of cortical processing is selecting the response to the stimuli or their source that is most likely to promote survival.

Identifying a Benefit or a Threat

Modern humans learn to identify most proto-patterns as a benefit or a threat through instruction from others or by observing how others respond to a given proto-pattern. Nevertheless, each proto-pattern had to be identified originally by some ancestor, who did it in the same way a modern human interprets an unknown proto-pattern.

The only information in the proto-pattern is that brought in by the sensory signal, together with a few directly associated items it picked up along it route. So this is the only information available for identifying the source of the stimuli detected as a benefit or a threat.

As noted earlier, primitive creatures have no equipment to identify a benefit or a threat. Surprisingly, humans do not have much more. Our senses deliver to the proto-pattern only a series of sounds, a smell, a taste, a pressure, etc. It is almost impossible to identify the nature of the source of the stimuli from this information. The crack of branch indicates that something is there, but what is it?

The eyes make some contribution by providing a vague form of the source of the stimuli detected. Nevertheless, even seeing the form of a new object does not identify it or its intention. At best there are a few clues based on the size of the object, on how fast it moves, or on the intensity of an odor or a pressure, but little else.

Some information is obtained from "commonality" of brain patterns, which will be described in the next section. Briefly, experience with one big cat, such as identifying a leopard as a threat, is carried over to the pattern for other big cats, even if this one is a cheetah.

So an identification of a previously unknown brain pattern as a benefit or a threat is an assumption that might be correct or incorrect. Creatures that make incorrect assumptions do not survive for long.

This identification of the stimuli detected as a benefit or a threat is sent to the motor cortex as the "emotional response" to the stimuli detected. As the emotional signal has very little intellectual content, it serves primarily to start to move the creature toward or away from the stimuli detected.

11. THE SENSORY PATTERN

As the cortex begins to process the associated items brought into it by the recirculating signals, the proto-pattern becomes the sensory pattern. The sensory pattern represents the stimuli detected in the real world. It's what we see, hear, smell, feel, and taste. It's the part of the brain pattern that reaches consciousness, rather like the monitor screen on a computer. It tells us something about the stimuli detected while the serious work of selecting the response to the stimuli is going on unconsciously in processing the thought pattern.

Reaching Consciousness

The most distinctive feature of the sensory pattern is that it reaches consciousness. We immediately become aware of the stimuli our senses detect, even when we don't know what they represent. Eventually, In a visual sensory pattern, we see individual objects. We hear the sounds in an auditory sensory pattern, and feel the pressure of a tactile sensory pattern.

Conscious information makes an important contribution to the thinking process, as this is the only information that a person can do something about. For example, when circumstances permit, he or she can obtain more information about the stimuli detected or can check the validity of his or her information about the stimuli before acting on them.

Interpreting the Sensory Pattern

We now interpret most of our sensory patterns so easily that we don't recognize how difficult this task really is. Try to identify what is going on around you when your eyes are closed. What made that noise? Where did that odor come from? The task seems easy only because we have learned the interpretation of almost all of our frequently formed sensory patterns from others. Nevertheless, the sensory pattern for every known item in the external world had to be identified by some human. The informal library of correct interpretation of sensory patterns is one of our most important cultural heritages.

Very little is known about how the brain interprets a sensory pattern. Quite a bit of work is being done on artificial pattern recognition, but although this process sometimes recognizes a known pattern, it makes little, if any, contribution to interpreting an unknown pattern. Nevertheless, we can get some insight into the process from what is known about how the equipment in the thinking process works.

Analogy with a Bank of Electric Light Bulbs

Some clue as to how sensory patterns are interpreted can be gained by an analogy with a bank of electric bulbs, such as those used for advertisements in Times Square or in some baseball stadiums. When a bulb is energized, it always lights up and always lights up to the same extent. The combination of lit and unlit bulbs forms some visual pattern. In some cases, this pattern is a meaningless jumble to the viewer. In other cases, detection of this pattern initiates an impulse pattern in the viewer's brain that is similar to the impulse pattern of a real object detected earlier. As will be described in the chapter on Similarity, this new sensory signal is conducted over the pathway established by the impulse pattern for that object, reaches the same set of cortical neurons, and so is interpreted as being that object.

Of course the pattern of lit and unlit bulbs is not that object. In fact, the pattern is nothing more than the image formed by some set of energized light bulbs. Nevertheless, this viewer interprets this pattern as representing an object in the real world.

A single, static image - In this pattern, all the energized electric bulbs are contiguous and so form a single image. Even when this pattern is meaningless to the viewer, he or she automatically assumes that the pattern represents a single object.

This assumption appears to be inherent in the thinking process inherited from less advanced creatures. These creatures usually detect a single type of stimulus from a single source. Although humans almost always detect multiple stimuli from multiple sources, every interpretation of a sensory pattern starts with the assumption that it represents a set of stimuli from a single source.

Subdividing the pattern – When the viewer cannot interpret the pattern as a single object, he or she examines some part of the pattern. When this part is sufficiently similar to one detected many times before, the impulse pattern for this information goes over that pathway, reaches its set of cortical neurons, and is interpreted as that object, say, as a person.

The viewer mentally separates out this part of the pattern and tries to interpret the remainder. As he or she focuses on a contiguous part of the remaining pattern, its impulse pattern goes over the pathway in his or her brain for an animal. The same process occurs with the rest of the pattern, which is interpreted as a stick. Of course the pattern could be subdivided into many other things instead.

Changes in the pattern - As the viewer watches, the pattern of lit and unlit bulbs changes. What does this new pattern represent?

- The new pattern might represent a different object or objects.
- The original object might have changed in some way.
- The object itself has not changed, but it might now be in a different position or location.

From the change in the pattern alone, the viewer cannot know which of these interpretations, if any, is correct. He or she *assumes* what the change represents. This interpretation might or might not be correct.

Labeling a Sensory Pattern

Perhaps someone uttered a sound when he or she detected a familiar sensory pattern. However it occurred, sounds became associated with specific sensory patterns. These sounds are not part of the sensory pattern itself but are associated with it. The sound (and later symbol) associated with a sensory pattern is its "label" or "name." Through their association, detection of a sensory pattern recalls its label, and detecting the label recalls its sensory pattern. (This important mechanism is described in the chapter on Associative Memory.)

The viewer also assigns a label to changes in a succession of sensory patterns. He or she might interpret these patterns as a change within the original object; it has "grown," "elongated," etc. Or it's the same object but it has changed its position; it has "moved," "walked," or "sat down."

The use of labels made a major contribution to the thinking process as it is much easier to manipulate labels than sensory patterns. Eventually, the labels became language, making communication possible.

The label assigned to the interpretation of a sensory pattern might be correct or incorrect. Mythology and superstition are good examples both of the difficulty of interpreting the sensory pattern correctly and the widespread acceptance of incorrect interpretations communicated by others.

As there is only one correct interpretation and many incorrect ones, the first interpretation of a sensory pattern was usually wrong. Well, no, that's not the chariot of a god going across the heavens; it must be a ball of burning coal. This process of assumption, recognition of error, and new assumption, sometimes repeated several times, is still going on in interpreting thought patterns in subject areas from astronomy to zoology.

Connections Among Objects

After the viewer has identified the objects in the pattern, correctly or incorrectly, he or she tries to identify how they are connected in the real world. Although the viewer now knows that the pattern does not represent a single object, he or she still assumes that all the items in the pattern are connected to each other in some way. For example, if the viewer interprets the pattern as consisting of a person and a dog, he or she might assume that the dog belongs to the person, even if the dog is simply walking by.

The viewer tries to find a connection among all objects in the pattern, including the stick. For example, he or she might interpret the pattern as a person and a dog playing with a stick. Well, no, maybe the person is beating the dog with the stick.

Although it might seem that any interpretation of the objects and their connections can be assumed, this is not the case. All interpretations are based on that person's information, right or wrong, in the thought pattern. Because of prior experience, the viewer would not interpret the scene as an animal beating a person with a stick. A new sensory pattern is interpreted in terms of information, correct or incorrect, already present in that brain.

Incorrect Interpretations of a Sensory Pattern

The brain has no equipment to know whether or not its interpretation of a sensory pattern is correct. There is no applause for a correct interpretation and no raucous buzzer to report an error. Misinterpretations can occur for a number of reasons, including:

Incomplete detection of the stimuli - Very often the stimuli detected are an incomplete representation of their source. For example, a sensory pattern might have enough information to be interpreted as a large cat, but not be enough to determine if it's a leopard or a cheetah, let alone whether the creature is young or old, hungry or sated, all of which might affect the response.

Incorrect connections of the neurons - There are so many connections between the detector cells in a sensory organ and their target neurons in the cortex that it is not unusual for some of them to be incorrect. As a result, the sensory pattern might not represent the sensory signal correctly, as in dyslexia.

Incomplete thought pattern - If a person's thought pattern does not contain all the information needed to interpret the sensory pattern correctly, his interpretation will be at least incomplete and more often incorrect. For example, since our ancestors' brains did not have any information about neurology, their sensory pattern of a person writhing on the ground could not be interpreted as a case of epilepsy. Based on the information available, the sensory pattern might be interpreted as possession by a spirit.

Incorrect items in the thought pattern - At the time the mechanism for the interpretation of sensory patterns evolved, all the material in the thought patterns of an ancestral creature originated in its detection of external stimuli and therefore was an accurate representation of the external world. This changed with the advent of communication. Now others communicate most of our information to us. This information often contains misinterpretations of the objects in the world and their connections. Nevertheless, we continue to interpret our sensory patterns as though all our information is correct,

Internally generated signals are another source of incorrect information. Although these signals do not introduce new sensory information into the thought pattern, they sometimes combine items already present into new forms that do not exist in nature, such as UFOs or witches consorting with devils.

Errors inherent in the method of interpretation – As noted, we continue the ancient process of interpreting a complex sensory pattern as though it originated in a single source. For example, when the ancient Greeks first saw men on horses, they interpreted this sensory pattern as a “centaur,” that is, as a single creature with aspects of both a person and a horse.

12. THE THOUGHT PATTERN

A thought pattern is the third and final phase of a brain pattern. Theoretically, it contains all information in that brain directly or indirectly connected with the stimuli detected.

Some of this information was obtained through direct detection of stimuli in nature, most was obtained by detection of stimuli in communications from others, and a bit was formed by recirculating signals that combined the sensory items present in new ways.

The thought pattern also contains that person's information about to deal with the stimuli detected, including his overall strategy for survival. For example, one person might want to achieve fame by his or her or her responses while another wants to reduce his or her risks. One person might want to avoid confrontations while another might welcome them. As a result, the information in a thought pattern varies widely both in quantity and quality. In short, except for what has been forgotten, the thought pattern contains all the information obtained over that person's life about the stimuli detected and how to deal with them.

Nevertheless, despite this huge volume of information, the thought pattern might not contain all items needed to respond appropriately to the stimuli detected. That is, the information available might be incomplete.

In addition, some of the information present might be incorrect. Each person has no way to know which items are correct and which are not. A person might recognize that a small part of the items in the thought pattern are assumptions, but most assumptions present are mistakenly accepted as facts. The brain considers all the information in a thought pattern to be correct, whether it is or not.

The interpretation of a thought pattern is strongly effected by the emotional signal. When the proto-pattern is interpreted as a benefit, the information in the thought pattern is given a favorable interpretation. Interpretation of the same stimuli as a threat causes the same information to be interpreted negatively.

Processing the Thought Pattern

Because of the huge quantity and complexity of the information in a thought pattern, there is no way it can all be represented in a sensory pattern, let alone processed consciously. Nevertheless, fragments of the thought pattern come to consciousness as intangible
"thoughts."

Conscious interpretation of a thought pattern is not necessary. The brain processes the thought pattern to select the optimum response to the stimuli detected whether or not the person participates in formulating the response or approves of it.

Responding to the Stimuli Detected

Timing the response - The more information in the thought pattern, the more appropriate the response to the stimuli detected can be. However, the time used to obtain and analyze additional information increases the response time and so reduces the chances of obtaining a benefit or escaping a threat. At some point, the brain responds without waiting for additional information. This decision occurs automatically, usually without any conscious input.

`We do not yet know the mechanism that triggers the timing of the response. The mechanism seems to sense the optimum point for a response that will achieve its objective. For example, a predator might defer its attack until it moves closer to its prey, where its chances of success are better. On the other hand, if it senses that the prey might move away, it might attack immediately.

Response to a real threat or opportunity - Survival sometimes requires an immediate response to a real threat or a real opportunity. These responses occur before a conscious choice can be made, as in ducking to escape a flying object or in fleeing a cry of "Fire!" In most cases, the person is not aware of these survival responses until after they occur.

Sometimes the benefit or threat is less immediate; indeed, the individual might not even be aware of it. A common example occurs in detecting an obstacle while driving an automobile. The driver sometimes steps on the brake before he or she is conscious of doing so; indeed, his or her conscious thoughts might be elsewhere.

Response to imaginary stimuli - Unless the brain has information that identifies an internally generated stimulus as imaginary, it responds to it in the same way it does to a real stimulus. These imaginary stimuli include UFOs, hell, unknown enemies, and various kinds of spirits. For example, someone with a life-threatening illness might respond by praying to a spirit instead of visiting a medical doctor.

Response to non-threatening stimuli - When the response to a real set of stimuli is not urgently required for survival, as in detecting a skin rash, the individual can seek new information about the nature of the stimuli and how to deal with them. He or she can also tinker with the thought pattern by combining its information in different ways to examine the response that would occur under those conditions. In short, a person can modify the thought pattern formed by adding information, but beyond that, the automatic processing of the information in the thought pattern selects the response.

The automatic response to stimuli occurs in many other common activities, from dressing to walking. This unconscious response to stimuli is often trivialized by brushing it off as a "habit."

Shortcomings of the Process

Despite its indispensable advantages, there are some shortcomings in the mechanism for processing a thought pattern:

Incomplete information

- The brain often does not know that it does not have all the information required to respond appropriately to the stimuli detected.
- The individual might respond before the recirculating signals have time to bring all pertinent memories into the thought pattern.
- Some pertinent memories might have been forgotten or changed.

Incorrect Information

- Some information might be incorrect.
- Information that was once correct has become incorrect because the external world has changed (i.e., "obsolescence").
- Some information represents items that might not exist in the real world.
- The sensory pattern might be interpreted incorrectly.

The human brain processes a thought pattern as though all its information is complete and correct. When the information is incomplete or incorrect, the response selected is usually inappropriate, sometimes fatally so.

Improving the Thought Pattern

The connections of the neurons in the cortex process the sensory information in the thought pattern but generate no new sensory information. So, the only way to improve the response to the stimuli detected, is to bring additional information into the brain pattern.

This information is of two principle types. One is additional experiences with the objects in the environment; that is, the formation of new memories. To do this, we need to know how memories are formed and how they are brought into the brain pattern.

It is also essential to know how the objects in nature are connected. However, perhaps because our ancestral creatures never needed to identify the connections among objects, very little equipment is available for this Herculean task. Nevertheless, examining this process will show the different ways in which the objects in nature are connected.

We'll leave the brain pattern at this point by delaying the intellectual signal while we examine how to improve it.

Section 4

IDENTIFYING CONNECTIONS AMONG OBJECTS

To respond appropriately to the stimuli we detect, we need to know how the objects in nature are connected to each other. A connection among objects that exists in nature will be called a "relationship." As primitive creatures had no need for this information, we have not inherited any equipment to identify these connections. So we are again forced to use a tool that evolved for other purposes for this task.

The first chapter in this section deals with one type of connection among objects; that of "commonality." This occurs when two or more objects have a significant part of their impulse patterns in common. These objects are considered to be part of the same group or class, such as trees, people, or books. The greater the percentage of their impulse pattern the members have in common, the more closely they are considered to be related in nature.

Objects that have most of their impulse patterns in common are considered to be identical, even when they are distinctly different. This type of connection is described in the chapter on Similarity. Commonality and similarity are identified automatically in the brain. Each individual must identify all other relationships consciously, either through detecting the relationship in nature or learning about it from others.

As noted earlier, the brain assumes that all objects detected simultaneously are connected in some way. The mechanism for this assumption is described in the chapter on Associations. Although these items are connected in the brain, they are not necessarily connected in nature. As a result, associations are both an indispensable tool and a major source of error in the human thinking process.

The relationships in nature can be grouped as static or dynamic. All the elements in a static relationship exist at the same time, as with the parts of a radio set or an automobile engine. In dynamic relationships, one set of items leads to some other set of items at some later time, as with the formation of a plant from a seed. These relationships are commonly known as "cause-and-effect." A chapter describes each of these types of relationships.

Our society is obsessed with measurements. However, the brain has no equipment to measure anything. So here again, we draft a tool to do the job. And here again, when this tool is used incorrectly, it causes errors in the thinking process.

13. COMMONALITY

A young boy is told that his sensory pattern for an object in his yard represents a "tree." When he sees another tree in his neighborhood, its sensory signal is conducted along the enhanced pathway for the earlier tree. As a result, it forms about the same sensory pattern as the earlier tree and so is interpreted as being identical with it, even though this tree is a maple and his tree is an oak.

One day he examines another tree more closely. He notices that its form and color are similar to the trees he has seen before. Now, however, he notices how the branches are formed and studies the shape of the leaves. As a result, the impulse pattern for this detection includes the form and color of the tree together with additional impulses for the newly detected items. So most of this impulse pattern is conducted over his enhanced pathway for "tree" but also forms some new pathways to conduct the impulses for the new items.

From time to time this boy examines several other trees, with similar results. As all these different objects have a significant part of their impulse patterns in common, they are all interpreted as the same object, but with some minor differences among them.

All objects that have a substantial part of their sensory patterns in common are considered to be members of the same group or class and so related to each other in some way. The term "commonality" will be used to describe the relationship among items that have similar portions of otherwise different impulse patterns.

Types of Commonality

As there are many different ways in which items can have part of an impulse pattern in common, there are many different types of groups. A familiar basis for grouping objects is their appearance, as with all types of cats, trains, and people. Some objects of dissimilar appearance are grouped by the commonality of their function, as with different kinds of fences, foods, and chairs. Some groups are based on the food they eat, such as carnivores, herbivores, and omnivores. Some people are grouped based on the region of their origin, as with Texans, Bostonians, and New Yorkers. Intangible items are also grouped, as with inventions, sciences, and religions.

Degree of Commonality

The higher the percentage of their impulse patterns, and therefore their sensory patterns, that are identical, the more closely the members of a group are considered to be related. For example, because of their common attributes, there is a group of “people.” Although all people have many aspects in common, they also have a number of differences. People who have the same skin color and the same type of eyelid are considered to be more closely related to each other than those who do not and so form a subgroup of “Oriental people.” Some members of this subgroup also have a common activity as “soldiers,” forming a smaller subgroup of “Oriental soldiers,” whose members are considered to be more closely related than the members of the larger group. Each additional item of commonality forms a smaller, more uniform group, as with “female Oriental soldiers,” “female Chinese soldiers,” “pregnant female Chinese soldiers,” etc.

Some types of commonality are considered to be more important than others in determining how closely the items are related. For example, creatures that have six legs are considered to be more closely related than those that are the same size.

Advantages of Commonality

Increased information - Commonality vastly expands our information about the world. Without it, it would be necessary to learn about each item in the environment individually. Commonality simplifies this process. For example, through encountering some of its members, we learn the common attributes of the group of "animals." After we learn that all members of this group must eat in order to survive, we do not have to learn this for each new type of animal we detect. When we learn that there are male and female dogs and cats, we can be reasonably sure that hyenas, lions, and chimpanzees also have male and female subgroups and that all mammals reproduce in about the same way.

Faster response time - If there were no commonality, every item detected would have its own unique sensory pattern. Each set of stimuli would trigger a different optimum response. However, additional time would be required to obtain this modest advantage. So, at some point, evolution traded off some improvement in the quality of the response for a faster response.

Disadvantages of Commonality

Including non-members in a group - Occasionally an otherwise distinctly different item has an attribute or two in common with the members of a group and so is mistaken as a member. For example, through having about the same physical form, koalas are often mistaken as bears. Someone who is not aware of the differences between these creatures will respond to a ferocious bear in the same way as to a harmless koala.

Failure to distinguish among members of a group - There are two principal ways in which some people fail to distinguish among members of a group. In fact, it is the same error arrived at from opposite directions:

Non-representative sample - Someone who has never met an Italian before, meets an Italian violinist, who introduces him to Italian friends who are also musicians. This person might then conclude that most, if not all, Italians are musicians. However, if he had met an Italian mobster instead, he might well conclude that they are all mobsters. In this type of error, the attributes of a few members of a group are assumed to apply to all members.

This error usually occurs when the number of members in the group is small. Since some politicians are dishonest, then all politicians are dishonest. In the extreme case, this error becomes, "If the members of a group are alike in some ways, they are alike in all ways." The ultimate example of this error due to commonality is "You men (or women) are all alike!"

Assumed uniformity of group members - In some cases, a person has more information about a group than he or she has about its members. For example, northerners might have some information about the Ku Klux Klan without ever having met a member.

The same is true of Russian communists, private detectives, and the chief executives of big companies. Whatever is known about the group, correctly or incorrectly, is assumed to apply to each of its members. All Frenchmen eat frog's legs, all Jews are acquisitive, and all blacks like watermelon. A familiar example of failing to distinguish among the members of a group is prejudice.

Effect of Commonality on the Response

Every advanced creature responds to a stimulus based on the information in the thought pattern formed by its detection. Detection of a member of a group brings to mind the group and its characteristics but does not bring to mind any other members unless they are connected to the stimulus in some other way. For example, detection of a Ford Thunderbird brings to mind "automobile" but seldom recalls a Buick or a Volkswagen.

A person's response to a specific member of a group is based on the ratio of his or her information about this member and his or her information about the group. For example, over the years this person might have known many engineers. He or she now meets another engineer for the first time. The sensory signal brings what little he or she knows about this person into a thought pattern. The recirculating signals bring in his or her extensive information about engineers as a group. As a result, this person responds primarily to the characteristics of the group with at best a slight modification for his or her limited information about this specific person.

In most situations, a "generic" response works reasonably well. People shoot in the same way at all ducks, compliment the mothers of all babies in the same way, and buy gasoline at any station. Nevertheless, the characteristics of an individual member often vary considerably from the generic characteristics of his or her group. The more you know about an individual, the more appropriate your response will be.

Effect of Commonality on Feelings

An important effect of commonality requires getting ahead of this analysis temporarily. As will be described in a later section, each response to the stimuli detected is accompanied by a feeling, such as affection, dislike, panic, and embarrassment. This feeling becomes associated with that thought pattern. When the same thought pattern is formed again, either by detection of the same set of stimuli or reformed by memory, the same feeling occurs, usually with somewhat reduced intensity.

Everyone forms many such associations between sensory patterns and feelings early in life. For example, eating a certain kind of "peasant food" a person had as a hungry child causes good feelings many years later. Most people also have a good feeling recalling the warmth of a mother's body and being comforted by her for minor injuries. Later in life, a boy might meet someone whose image is similar to that of his mother. Through commonality, this new image triggers the same feelings associated with the earlier image.

Of course the new image is not identical the one that initially formed the feeling. Indeed, even when the new image has several aspects in common with the original image, these aspects might not be the ones that triggered the strong feelings. As a result, a woman might "fall in love" with a man who has the same curly hair as the father she adored in her childhood but not the personality that triggered that love.

14. SIMILARITY

It was stated earlier that a sensory signal is conducted over the route determined by its impulse pattern. That statement is correct, but it's incomplete. There are a few "conditions" to consider.

Once formed, a sensory pathway has some flexibility in the impulse patterns it conducts. This occurs because each neuron in a pathway receives input from several different transmitting neurons, some with multiple synapses. Once a pathway is activated, the presence, absence, or change of some impulses in the sensory signal has little effect on the route. A major change in the impulse pattern of a sensory signal is required to extinguish the signal or divert it to some other pathway. As a result, a sensory signal with minor changes in its impulse pattern reaches the same cortical neurons as the sensory signal that formed the pathway and so is interpreted in the same way.

The enhancement of the synapses in a sensory pathway also affects the result. As the synapses in different routes are enhanced to different degrees, the same signal is conducted faster over some accommodating routes than others.

As a result of these factors, a sensory signal might be conducted over a somewhat different pathway and so reach a somewhat different set of cortical neurons. An example might clarify this process. Consider a sensory signal A that is conducted over sensory pathway A to reach a set of cortical neurons A where it is interpreted as Object A. Although this signal enhances all the synapses along its route, this minor enhancement is soon lost. This person then detects Object B, forming sensory signal B that is conducted over sensory pathway B to reach cortical neurons B where is it interpreted as Object B. The enhancement of this pathway is also soon lost.

This person detects Object A several times so that its sensory pathway is strongly enhanced. Soon after, this person detects Object B. Its sensory signal starts to be conducted over unenhanced sensory pathway B. However, when its impulse pattern in sufficiently similar to that for Object A, this sensory signal is also conducted over pathway A. Because of the enhancement of the synapses in sensory pathway A, sensory signal B reaches cortical neurons A before the signal in sensory pathway B reaches cortical neurons B. As a result, sensory signal B is interpreted as Object A.

This example implies that the information in the sensory signal is merely its routing address to its target neurons in the cortex. The interpretation of the sensory information is determined not by the information content of the sensory signal but by the set of neurons it reaches in the cortex. If, for any reason, a sensory signal reaches a different set of cortical neurons, its message is interpreted as the sensory signal that would normally reach that set of cortical neurons.

So, although Object B is really only similar to Object A, it is interpreted as being identical with Object A. That is, the brain interprets similar items as being identical. This is why, although we detect the difference, we do not "see" the difference in the appearance of people or objects we detect often.

Types of Difference in Sensory Signals

Sensory Signal B might differ from the Sensory Signal A in three ways:

- Although their impulse patterns are otherwise identical, Signal A has some impulses that are not present in Signal B. That is, Signal B is an incomplete version of the Signal A.
- The impulse pattern for Signal B is identical with that of Signal A but contains some additional impulses.
- The impulse pattern for Signal B contains some impulses that are different from those in the Signal A.

How Much Difference is "Significant?"

Incomplete impulse pattern – A similar but not identical impulse pattern occurs when the new pattern is an incomplete part of an earlier pattern. For example, someone has a reasonably complete sensory pathway for a horse. This person now catches only a glimpse of a horse. The impulse pattern for the stimuli detected is some part but not all the impulse pattern for "horse." What happens depends on how much of the complete impulse pattern for "horse" is present in the new signal. When the new impulse pattern is sufficiently similar to that for "horse," it is conducted over that pathway to reach the complete set of cortical neurons for "horse." So although the person detected an incomplete set of the stimuli for "horse," its incomplete impulse pattern reaches the complete set of cortical neurons and so is identified as all of "horse," just as if he or she had detected it all.

When detection of some aspect of a horse forms an impulse pattern that is an insufficient part of the total impulse pattern for "horse," it is extinguished in that pathway. However, it might be sufficiently similar to be conducted over the pathway for "animal."

A study attempted a quantitative analysis of this process by using stimuli of about equal significance (i.e., the letters) in a composite set of stimuli (i.e., a word). It was found that about 75% of the letters in the proper order were required to bring the target word to mind (Pacifico and Zillmer 1998).

Nevertheless, in some cases, even a small part of an impulse pattern is so distinctive that it triggers the complete impulse pattern, as with the roar of a lion or the neck of a giraffe.

This mechanism is the reason why, when you glance around a familiar room, you see all the objects completely, even when you detect them incompletely.

Extraneous impulses – The study mentioned above also explored the effect of extraneous letters in the impulse pattern. When the extraneous letters were a small part of the total, the impulse pattern was conducted over the pathway for the word. When they were a significant part of the total, the impulse pattern went over some other pathway and so did not bring the target word to mind.

Variations in the impulse pattern - There is fairly wide latitude in the impulse pattern that is conducted over an enhanced pathway. For example, the appearance of people varies considerably. Nevertheless, a glimpse of a someone in a supermarket might bring your neighbor to mind.

Advantages of Similarity

Similarity contributes to survival by speeding up the response to some stimuli. It usually isn't necessary for most creatures to know whether their prey or predator is young or old, male or female. An instantaneous response to a similar impulse pattern contributes more to their survival than the additional information present in a more complete pattern. In most cases, close enough is good enough.

Also, verbal communication would be impossible without this treatment of similar sensory signals. For example, different people make a wide variety of sounds for the same word. Nevertheless, when there is sufficient similarity in their impulse patterns, these different sounds are interpreted in the same way so that we understand each other. At some greater degree of difference, however, the sounds are interpreted differently. For example, it is difficult for most Americans to understand the sounds made for English words by a Scotsman and it's sometimes impossible to understand those made by a Jamaican. Similarly, we accept a wide variety of hand-written marks as representing the same letter. Nevertheless, beyond some degree of difference from standard, these stimuli become meaningless scratches.

There is, however, an important negative effect of this mechanism. It causes us to fail to distinguish among similar items. For example, it causes us to see all cats, clergymen, and wildebeests as being identical within their group. It also eliminates the differences among sets of stimuli we detect frequently so that we are not aware of the change in the appearance of friends, the maturation of our children, or the increased skill of old employees. And because the similarities of the members of a group result in somewhat similar impulse patterns, we conclude incorrectly that all its members are similar in all ways.

15. ASSOCIATIONS

To respond appropriately to the stimuli we detect, we need to know how the objects in our environment are connected to each other. Occasionally, it is enough to know that two or more objects are connected in some unknown way. In most cases, however, we need to know how they are connected; that is, the nature of the connection.

As primitive creatures respond directly to the stimuli they detect, they do not need to know their connections. In any case, no mechanism ever evolved to assist advanced creatures in identifying the nature of the connections among objects in their environment. So here again we are obliged to use a tool that was not designed for this purpose.

To identify a connection among two or more objects in nature, the images of these items must first be connected in a person's brain. If these images are not present in the same thought pattern, there is no way to know that they are connected in nature.

The images of objects can be connected in the brain by simultaneous detection or through connection by recirculating signals (to be described later in this chapter.) As noted earlier, in identifying the objects in a thought pattern, the brain assumes that all the objects presented are connected in some way, whether they are or not.

The connection of the images of two or more items in the brain will be called an "association" of the objects. A connection that exists among objects in nature will be called a "relationship." These relationships exists whether or not anyone is aware of them and whether or not anyone identifies them correctly. A relationship might be correctly known to some people but unknown or incorrectly known by other people.

Despite the connection of their images in the brain, these items might or might not be connected in nature. Moreover, this mental connection makes no contribution to learning how they are connected in nature. What's worse, it misleads us into assuming connections that do not exist in the real world and so causes frequent errors in the human thinking process.

Types of Connections

The many different ways in which items might be connected include the following:

- The connection might be tangible, such as those among the objects in nature, or intangible, as with money and education.
- The connection might be physical, as with a flower growing from a bush, or the state of Maryland abutting Virginia.
- The duration of the connection might be permanent, as between a parent and a child, or it might be intermittent, as with a bee feeding on a flower. It might be temporary, as with snow on a fir tree, or it might change erratically, as with the members of a group.
- The number of items in the relationship might be as few as two, or many, as in the components of a radio set or the citizens in a country.
- The connection might be direct, as with Ink and paper, or indirect, as with a seed and a flower.
- The connections might all exist at the same time or might be sequential, as with the words in a poem or the development of an embryo.

- The connection might be among the causes of an effect, such as the factors leading to a war.
- The connections might be among the effects of a cause, such as the effects of the discovery of a computer.

Forming an Association

The images of two or more items in the same thought pattern can occur in the following ways:

- The objects are detected simultaneously.
- The objects are detected together in a communication from others, as when a parent conveys a connection between behavior and social acceptance to a child. Almost all education consists of learning associations, such as the order of letters of the alphabet and the way to repair an automobile.
- Recirculating signals bring the images of objects that closely succeed each other in time into the same thought pattern. Examples include the notes in a musical composition, the words in a sentence, and the order of steps in knitting.
- Recirculating signals can also bring an image detected in the past (i.e., a memory) into the same thought pattern as the image of an object detected at that time. For example, you are sneezing and coughing with a cold. On your way to work, you meet a friend who is sneezing. That reminds you that someone at work had been sneezing and coughing, so you associate your cold with that person.

- Recirculating signals can also bring the images of objects detected at different times in different places into the same thought pattern. For example, the separate sensory pathways for two different objects might be present in your brain. However, you are not aware that these objects might be connected in nature until they are associated. For example, you never associated shaving lotion with romance until your girlfriend mentioned that she liked how you smelled after shaving.

While the presence of the objects in the same thought pattern is required for the formation of an association, it is not sufficient. These Items are seldom associated in a brain that already “knows,” correctly or incorrectly, that they are not connected in nature. For example, a person who has often eaten food and heard the sound of a buzzer will not associate the two items, no matter how often they are detected simultaneously. Nevertheless, the frequent detection of an advertisement connecting a commercial product with sexual success sometimes associates these items even though the person knows they are not connected in nature.

Incidentally, Pavlov’s monumental work on “conditioning” was actually a study of the conditions under which associations are formed.

Retaining an Association

As with all memories, an association is retained only through sufficient reuse of its sensory pathway to keep its synapses enhanced. For example, you are introduced to someone at your weekly dance. To be sure you’ll remember his name, you repeat “Joe

Jones" to yourself several times to form an association of his appearance with his name. You dance with him again over the next several weeks, addressing him as "Joe." But when a friend asks you who that man is, you realize you no longer know his last name. Nevertheless, you recognize him when he comes into the dance hall and you chat, without using his name, as you dance together in the following weeks. But when you try to introduce him to a friend, you're embarrassed to find that you have forgotten even his first name.

Obsolete Associations

Associations sometimes represent a connection among objects that no longer exists. This usually occurs when a change in the real world make an association obsolete. For example, Bob and Betty were married when you met them. They have been "a couple" in almost all your social contacts with them, further enhancing their composite pathway in your brain. Then Bob and Betty divorce. Nevertheless, until this sensory pathway deteriorates through disuse, you continue to identify them as being connected.

Disadvantages of Associations

As noted earlier, the brain considers all objects in the same sensory pattern to be connected, and therefore associated, whether they are connected in nature or not. Actually, relatively few of the objects associated through being in the same thought pattern are connected in nature. For example, our ancestors associated thunder with bowling balls, storks and babies, and formed innumerable associations of objects and intangible spirits.

In short, an association is required to identify a relationship, but most items connected in an association are not connected in nature.

16. STATIC RELATIONSHIPS

A young man is walking in the woods when he hears a vicious snarl. A moment later he sees a huge bear with two cubs. His automatic, emotional response is to run away as fast as he can.

The human thinking process evolved to modify the emotional response to stimuli in a way that improves survival. The information in this man's sensory pattern is recirculated to bring all items in his brain connected with bears, directly or indirectly, into a thought pattern. His thought pattern also contains information about the other stimuli detected, such as the location of the nearest tree. Nevertheless, identification of the individual items in his thought pattern is not enough for his survival; he needs to know how these objects are connected in the real world.

The man's brain compares his speed with that of the bear and concludes that he can't outrun the bear even to the nearest tree, so his incipient emotional response of flight is aborted. Comparison of their relative strengths shows that he would not survive a fight with a bear. So his brain directs him to fall down and remain perfectly still. After a few minutes, the puzzled bears move away. If his thought pattern had not contained these relationships between bears and other objects, his normal response of fight or flight would have resulted in his being injured or killed.

Identifying Relationships

This analysis of how to identify the connections of objects in the real world begins where the interpretation of a thought pattern left off. As noted earlier, these relationships can be identified only when the thought pattern contains the required information. Except for the modest internal help available for commonality and similarity, each person must learn each relationship. The only tool available for this Herculean task is the association, which results in about as many erroneous assumptions as correct identification of relationships.

A relationship among two or more objects in nature is identified in the same cumbersome, inelegant way as objects in a sensory pattern are identified. Some human assumes that they are connected in some way. Thunder is connected with lightning. Black cats are connected with evil spirits. No, that assumption is incorrect: black cats are connected with bad luck. This process of association, recognition of error, new association, etc. continues until no better connection of the items can be identified. The great difficulty of identifying relationships is shown by the number of incorrect assumptions about relatively simple relationships that still exist after thousands of generations of people. Incorrectly identified relationships are a major source of inappropriate responses to the stimuli detected and so are major reasons for our failure to achieve our objectives in life.

Relationships will first be subdivided into two types, static and dynamic. All the elements in a static relationship are present at the same time. In contrast, the elements in a dynamic relationship succeed each other in time, as in the growth of a child. This chapter describes static relationships, but most of these observations apply also to the dynamic relationships described in the next chapter.

Types of Static Relationships

An item can be connected with other items in the same instant of time in one or more of the following ways:

Direct relationships - In the simplest type of relationship, two or more items are connected directly with each other, as with a flower growing from a twig or a bird sitting on a tree. Despite their relative simplicity, direct relationships are not always easy to identify. For example, you notice that grape juice sometimes becomes wine and sometimes it doesn't. Eventually you learn that the grape juice becomes wine when yeast is present and never when it isn't present. So the presence of yeast is a "condition" for the relationship between grape juice and wine. However, if a bactericide is also present in the grape juice, this relationship does not exist. Thus the relationship between grape juice and wine exists under some conditions but not others. Unless all these conditions are known, the relationship between grape juice and wine is not known completely and correctly.

Indirect relationships - The "end items" in an indirect relationship are connected through a chain of direct relationships. An example is the long chain of direct relationships, many of which are unknown, through which a seed becomes a flower. An indirect relationship exists only when all the links in its chain of direct relationships exist. Also, these direct relationships exist only when all the elements in their "conditions" and no others are present.

Steps in Identifying Relationships

Every object in the universe is connected to every other object, directly or indirectly. These relationships exist whether or not anyone knows them. So, to identify the relationship between any objects completely and correctly, it is necessary to know all their connections completely and correctly. The task of identifying most new relationships correctly and completely has been delegated to scientists. Nevertheless, everyone needs to identify some common relationships personally. Some of the more important steps are:

Identifying the level of precision required - The first step in identifying relationships is deciding how precisely the relationship needs to be known. The relationships involved in sending a rocket to Jupiter must be known more precisely than the time required to roast a turkey.

A relationship that is correct at a lower level of precision will be incorrect at a higher level. "Identifying a relationship completely and correctly" will mean identifying it completely and correctly at the desired level of precision.

Identifying all the elements - The correct identification of a relationship requires inclusion of all the objects that affect it at the desired level of precision. The assumed relationship will be incomplete and therefore incorrect If even one of its elements is unknown or not recognized as part of this system. For example, we could not identify all the relationships between microbes and infectious diseases correctly before antibiotics were discovered.

Identifying the elements correctly - Each element in the relationship must be identified completely and correctly. For example, some ancestors identified a flood as the wrath of the river god and so tried unsuccessfully to placate the spirit by making sacrifices of animals or people instead of building dams.

The correct identification of an element in a system is particularly difficult when it's a physical mixture of independent items, as in soil, coal, and food; that is, a composite of independent objects. For example, the fertility of a particular soil might be due to an undetected component.

Extraneous items – Just as the omission of an element in a system leads to an incomplete and/or incorrect relationship, the inclusion of extraneous items leads to a relationship that does not exist in the correct system. For thousands of years, most people included spirits in their system for survival. When someone was ill, his friends tried to drive the evil spirit from his body. As a spirit is not part of the correct system, the relationships they assumed resulted in responses did not achieve their objective.

Quantity of element present – In some systems the amount of an element is itself a factor in the system. For example, a certain piece of pine wood begins to burn a certain temperature but not at any lower temperature. A certain amount of burning kindling brings this piece of wood to that temperature, but no lesser amount.

This is "quantitative thinking." Not taking the correct quantity of an element into consideration can lead to a serious error. An example is the underestimation of the number of American troops required to control the population after the second war in Iraq.

Identifying the relationship correctly - Even when all the elements in a system have been identified completely and correctly, the relationship might be interpreted incorrectly. In his work on extra-sensory perception, Professor Rhine of Duke University found that some people could identify an unseen symbol (one of five) on a card at a rate well above chance. Some critics proposed that a computer generate the symbols randomly.

When Dr. Rhine put his best performers to this test, their frequency of a correct identification was reduced to the chance level of 20%. All the elements in this simple system presumably were identified completely and correctly. Nevertheless, Dr. Rhine interpreted the relationship as, "In the presence of computers, these subjects lose their extrasensory perception."

Checking an Assumed Relationship

The most important point in dealing with relationships is recognizing that they all start as an assumption and so might be correct or incorrect.

As with all assumptions, the brain has no way to know a relationship is incorrect unless it contradicts information believed to be correct. Some simple, direct relationships have been confirmed sufficiently to be accepted as facts. Nevertheless, we frequently encounter relationships that are unproved, as with rumors, political statements, and commercial advertisements.

Relationships that cannot be checked - There is no way to check some assumed relationships, such as the origin of the universe. However, while additional information can never prove this type of relationship, it can sometimes show that the assumed relationship is incorrect. For example, the invention of the telescope resulted in the discovery that the assumed relationship of the sun moving around the earth was incorrect, leading to the identification of the correct relationship.

Extent of proof - Except for the simplest relationships, it is seldom possible to prove a relationship beyond some possibility of being incorrect. There is always the chance that an unknown item will be found later that changes the relationship to some extent, even to disproving it. A recent example is discovery that a bacterium and not stress is a factor in the system for stomach ulcers.

Changing factors – You put your foot on the brake pedal in your car and it stops, as it has done hundreds of times before. There is no doubt that the relationship between the brake pedal and stopping the car is correct. Nevertheless, you push the brake pedal one day and your car keeps moving. This indirect relationship exists only when all the direct relationships exist, including the volume of brake fluid and thickness of the brake pads. So every relationship based on changing factors must be checked periodically to be sure all factors are present in the required quantity.

In the introductory example, the man's life was saved by his knowledge of relationships. Foremost was commonality. He had no knowledge about the behavior of this particular bear. Through commonality, he assumed its behavior was the same as that for most other bears. If this bear had behaved differently, his response might have been fatally inappropriate.

In addition, he knew the relationship between his speed of running and that of the bear. Otherwise, he might have tried unsuccessfully to flee.

Incidentally, he apparently didn’t know that bears climb trees, but fortunately this error was not a factor in his decision.

17. DYNAMIC RELATIONSHIPS

Our environment is constantly changing. Some changes occur suddenly. A river overflows. A new law is passed. An old barn collapses. Other changes occur so slowly they are hardly noticed. We don't detect the daily changes in a child. An employee becomes more experienced. Prices for groceries creep up.

Sometimes one change starts a succession of changes. The winter snow melts, increasing the flow of a stream, which washes away some rocks, causing a waterfall that forms a pool.

Early in human development, these changes probably seemed random and unpredictable. Perhaps someone noticed that the changes are always in the same direction. A person never gets younger. Old timbers do not assemble themselves into a barn. Zebras never eat lions.

Eventually, our ancestors recognized that one set of objects became a different set of objects. We now call the first set of objects the "causes" and the second set the "effects." These observed changes usually occur through a series of smaller changes, even if we do not recognize or cannot identify them all.

Dynamic Relationships

A dynamic relationship is an indirect relationship. However, it differs from the static relationships described earlier in that its beginning and ending objects are connected through a chain of direct relationships that succeed each other in time. The links in the chain might consist of only a few direct relationships or thousands of them. The time interval between the beginning and ending elements might be measured in milliseconds or in decades. Dynamic relationships are commonly known as “cause-and-effect.”

Dynamic relationships are either simple or complex. Although a simple relationship has only a single principle cause and a single principle effect, additional causes and additional effects are always part of the system, as in the growth of a plant from a seed. Although there is only one principle cause, the seed, and one principle effect, the plant, this dynamic relationship does not exist in the absence of other elements, such as soil, water, and insects.

A complex relationship has numerous causes connected to numerous effects, as with the set of causes and the set of effects for a war. So a more appropriate description of dynamic relationships is “causes-and-effects.”

These dynamic relationships exist whether or not anyone is aware of them and whether or not they are identified correctly. No doubt many important dynamic relationships have not yet been identified.

Importance of Dynamic Relationships

The importance of identifying dynamic relationships for human survival can hardly be exaggerated. Our ancestors used them to learn better ways to hunt animals, to grow food, and to build shelters. We use them for everything from preventing disease to making plastic film from petroleum.

There are innumerable important dynamic relationships, such as personal nutrition, education, job performance, etc. Indeed, dynamic relationships are involved in almost every aspect of our lives. The more we know about dynamic relationships, the more appropriately we can respond to the stimuli in our environment.

Identifying Dynamic Relationships

Many complex dynamic relationships are still unknown or incompletely known. Sometimes we don't know the beginning and ending elements and so have no idea that a relationship exists. An example is the dynamic relationship between microbes and disease that was unknown before microbes were detected.

Sometimes we know the beginning and ending items but don't know how they are connected. An example is the dynamic relationship between the poverty and crime. We know enough about some of their connections to modify the relationship but not enough to eliminate it.

The more we know about dynamic relationship, the better we can change it for our benefit. For example, in learning the chain of direct relationships between sexual intercourse and the birth of a baby, we can repair breaks in the chain to insure that the relationship exists. Conversely, we can break the chain when we want to eliminate the relationship. In short, the more we know about a dynamic relationship, the better we can use it to achieve our objectives.

Identifying the beginning and ending elements - A dynamic relationship cannot be identified if either its beginning or ending item is unknown. Even when the beginning and ending elements are known, they must be associated before the connection can be identified. As these elements in a dynamic relationship never occur simultaneously, they are never associated by being detected together. So the beginning and ending elements in a dynamic relationship have to be connected by recirculating signals, as with a detection being connected with a memory. For example, when you detect black spots on the peaches on your tree, you recall that you failed to spray the tree earlier in the year, thus associating spraying and the black spots. Or this association might be formed in the absence of any present detection by ruminating later on the source of the black spots you detected earlier.

As noted elsewhere, as association does not mean that these objects are connected in nature. An association sometimes leads to an imaginary dynamic relationship. These form when two or more items are associated by being detected together. A common assumption is that one of the associated items caused the other. Since a wolf howled just as a deformed child was born, the wolf howl caused the deformity.

Identifying the elements in the relationship – Associating the beginning and ending elements in a dynamic relationship shows only that they might be connected in some way. It is necessary to identify how they are connected before concluding that a dynamic relationship exists in nature. This is usually done by assuming a connection and then checking whether or not this results in a dynamic relationship.

Commonality sometimes assists in the discovery of the elements in a system. When we know the elements in the dynamic relationship for a tree, it is easier to identify the elements in the dynamic relationship for a shrub. Conversely, the difficulty of identifying the elements in a dynamic relationship completely and correctly increases exponentially as the number of elements and the links in the chain increase.

As with all relationships, it is necessary to exclude extraneous items that are not present in the true system.

Level of precision – Identifying the level of precision required simplifies the identification of the relationship as it eliminates elements that do not affect the relationship at a more precise level. As a simple example, estimating your annual expenditures within 10% eliminates many elements that would be present in the relationship if the level of precision were 1%.

Quantity of the elements – As with all relationships, it is necessary to identify the quantity of each element in the system. For example, how much detergent is required to clean a certain number of clothes with a certain amount of soil? Failure to identify the quantity of the elements in a system is a common error in trying to identify a dynamic relationship completely and correctly.

Dealing with Dynamic Relationships

We use dynamic relationships in several different ways:

Identifying all the effects of a cause - We try to identify all the effects of a proposed new cause to avoid an undesired result. A familiar example is identifying all the probable effects of a new pharmaceutical. Nevertheless, it is seldom possible to identify all the effects of a cause. Even if no adverse effects are discovered, it is still possible that they will occur at some later time.

The more elements in the system, the greater the possibility of "unforeseen consequences." An example is a war or the atom bomb. If a new pharmaceutical has adverse effects, the damage can be limited by removing it from use. Once a war is started, there is no way "to put the genie back in the bottle" in order to stop the cascade of effects.

Identifying the causes of an effect - We try to identify the causes needed to achieve a desired effect, as in making a new commercial product or to increase human longevity.

We also try to identify the causes needed to eliminate an unwanted effect, as in using a sanitizing agent to interrupt the dynamic relationship between bacteria and disease.

Although it is sometimes possible to identify the causes directly connected with the effects, as in the start of a war, it becomes progressively more difficult to identify the "causes of the causes" that occurs only a few links earlier in the chain.

Identifying the chain of direct relationships - We sometimes try to identify the causes for an undesired effect in order to eliminate it. A familiar example is finding the causes for the dynamic relationship that leads to AIDS. When this illness was first identified, its principle cause was unknown. After considerable scientific study, the HIV virus was identified as the principle cause. Nevertheless, despite extensive study, all the direct relationships in this system are not yet known. Although we have learned enough to modify this dynamic relationship, we do not yet know enough to eliminate it.

Changes in a Dynamic Relationship

Dynamic relationships do not change. The same set of causes always leads to the same set of effects. However, there might be changes in one or more of the causes so that the dynamic relationship no longer exists.

Recognized changes– As the same set of causes always leads to the same set of effects, any change in an effect shows that a change has occurred somewhere in the system. A common example occurs in manufacturing an industrial product. A company brings together all the necessary causes, such as raw materials, temperature, etc., that leads to a desired effect, say a specific product. Then, unexpectedly, the product changes in some unacceptable way. Why?

A study of the unwanted effect almost always shows that something in the system has changed. The composition of a raw material might be somewhat different or a temperature gage might now be incorrect. Once a dynamic relationship has been identified, any change in the set of causes, however minor it might seem, is suspect until proven otherwise.

Unrecognized changes – An unrecognized change in a dynamic relationship often causes serious errors. For example, an executive who has been successful in managing a company making a commodity product, such as steel or chlorine, uses the same relationships to manage a company that makes specialty product. This executive fails because he or she doesn’t recognize that the systems are different so that the relationships in the two systems are different. The set of causes that led to success in the previous system now result in a different set of effects.

The generals of a country that wins a war makes preparations for the next war based on the relationships in the previous war – and fail – because the systems are different.

Incomplete systems – Another important source of error is not recognizing that a system is incomplete. For example, almost everyone uses the same label for a certain dynamic system, such as child rearing or welfare for financially poor families. However, very few people first identify all the elements in the system and then derive relationships from them. Most people assume a relationship and then accept as elements (i.e., facts) the items that are compatible with the assumption and reject contradictory items, whether they are truly elements or not. As a result, each person has a different, incomplete system for the relationship. Nevertheless, because of the identical label, they think they are all dealing with the same system. A common example is disagreement between parents on how to raise their children. An even more dramatic example is the contrasting positions of the political parties on presumably identical national problems,

In short, it is very difficult to identify most dynamic relationships completely and correctly. The only way to deal with complex dynamic relationships is with extreme caution.

18. MEASUREMENTS

In our modern industrial society, it is necessary to know some relationships precisely. We need to know the size of drapes for a window, how long to make a pair of trousers, and how much brake power is required to stop a 200-horsepower auto traveling at 60 miles per hour. Indeed, our society reeks with measurements. We measure a person's weight at birth, intelligence, job performance, morals, net worth, and the length of his or her obituary.

There's an irony to all this. It seems our ancient ancestors didn't need to measure anything because the human brain never developed a mechanism to do so directly. So here again we are obliged to measure things indirectly, which introduces another major source of error into the human thinking process.

If two items that are identical in all other aspects are detected simultaneously, the brain can detect that one is longer, brighter, saltier, etc. than the other. But that's all it can do. It can compare, but it can't measure. It can't measure how much longer, brighter, or saltier one item is than the other.

So all measurements are based on a comparison. However, the comparison must be made correctly for the measurement to be valid.

A measurement is correct only when it is made under the following conditions:

1. The item being measured must be identified completely and correctly. Otherwise, for example, you might be measuring the effect of an impurity in a pharmaceutical.

2. The object must be compared against a known standard. This standard must be identical with the object being measured in all respects except for the one aspect being measured. For example, if the standard is made of a different metal, a measurement made at one temperature might be incorrect at every other temperature.
3. Some person must detect the difference between the object being measured and the standard. Even if a mechanical device is used to aid in this task, direct sensory perception by a person is required somewhere in this process.
4. The person making the comparison must be both accurate and objective. The comparison is meaningless if one person thinks the standard is longer and another person thinks it is shorter.
5. All extraneous factors in the system must be eliminated. If not, they must have a similar effect on both the standard and the item being measured. For example, you want to measure how fast grass will grow to a height of 3 inches from some new seeds. You use the present seeds as the standard for the comparison. The grass from the new seed reaches the target height in half the time. Wonderful, but would you accept this measurement if one seed was grown in loam and the other in clay? Of if one seed received more water than the other? So for any measurement to be valid, all factors that might influence the comparison, other than the one item being measured, must be absent or have a similar effect on both the standard and the item being measured.

Of course, this requirement cannot be met in most practical situations. You can't eliminate the soil and moisture from the measurement. Nevertheless, it really is the only way to get a correct measurement. If there are any other variables, known or unknown, in the system, you can never be absolutely sure that the measurement is correct.

Since you can't eliminate all other factors in this system, you'll make them identical. You'll use the same soil, the same amount of water, sunlight, etc. for both seeds. Will the measurement be correct now? Yes, but.... Yes, it will be correct but only for this specific set of conditions and no other. In a different soil, at a different moisture level, with some other degree of sunshine, etc., etc., the measurement will no longer be correct. So it is essential to specify the conditions for a measurement. A common error is considering a measurement that is correct under one set of conditions to be correct under some other set of conditions.

You cannot transfer the measurement of one aspect of an item to some other aspect of the same item. You measure the one aspect you compare and nothing else. Despite commercial advertisements, a food that contains more whole wheat is not necessarily more nutritious. Also, you cannot extend a measurement such as personal wealth into a value judgment. That is, the person who has more money is richer, not “better,” than the person he’s compared to.

Measuring Intangible Items

Standards - Are “the Joneses” really a suitable standard for measuring your income level, the pleasure of your vacation, or your success?

It's relatively easy to set up standards to measure physical properties of tangible objects, such as length, weight, speed, etc. However, it is impossible to measure intangible items, such as intelligence, success, and beauty because there is no universally accepted standard for these items.

What is beautiful by one person's standards might be unattractive by another person's. What's moral behavior at one time in one society might be immoral in the same society at a different time. As a result, every measure of an intangible item is based not on the item itself but on the standard used, and therefore is meaningless.

Nevertheless, almost everyone attempts to measure intangible items. The first obstacle is that we are unable define them completely and correctly so we don't know just what we are measuring. For example, different people have different definitions for "love," "morals," etc. As a result, the item being measured, say "behavior," can be satisfactory by one person's standard and unsatisfactory by other standards.

As a familiar example, we want to measure "intelligence," even if we can't define it. We use some set of questions as the measuring device, so what we are measuring is not "intelligence" but the ability to answer these questions. If there is a connection between the ability to answer these questions and, say, job performance, it will have to be established in some other way.

Expectations

The most frequently used standard for intangible items is "expectations." You set some expectations yourself, consciously or unconsciously, but your parents, peers, clergy, and teachers impose most expectations on you. Your performance is then measured against these expectations. Here again, performance that is “success” for one person’s expectations can be a dismal failure for some other person’s expectations.

Expectations are used to measure almost everything you do, such as your progress in school, your performance as an employee, and how often you cut your grass. Indeed, a common evaluation is that a person has not “measured up” to an expectation. But is this failure due to his or her performance or to an unreasonable expectation? The famous poet, Milton, said, “A man’s reach should exceed his grasp, or what’s a heaven for?” However, Milton obviously had his celestial directions wrong as it is hell to fail to meet expectations, whether your own or those imposed on you by others.

Setting expectations somewhat above what you think you can achieve sometimes helps improve performance, but an expectation beyond a person’s ability is destructive as it causes him or her to give up in frustration and despair.

As with your responses to all stimuli, you feel good when you achieve an expectation and feel bad when you fail to do so. So your expectations have more effect than your performance on your feeling of success and personal worth.

Cross-Comparisons

Like everyone else, you have some set of personal expectations, some of which you recognize and some of which influence your behavior even though you are not aware of them. Whether or not these standards are appropriate for you, they certainly are not suitable for measuring the behavior of anyone else. For example, Jackie Gleason, the famous comedian, was notorious for the amount of alcohol he drank. In a television interview, the interviewer said, “Some people say you drink too much.”

Gleason replied, “People who say that are measuring my drinking with their capacity.”

Most measurements of intangible items are incorrect, irrelevant, or meaningless. Nevertheless, as with assumptions, our society could not survive without expectations. They affect each person's occupation, income, social acceptance, and ego. Some expectations are unnecessary and others are too stringent. Check your expectations of yourself and of others to be sure they are realistic. By being aware of the source of this error in thinking, you can better handle the incorrect measurements others make of you and you can reduce to a minimum the unnecessary expectations you impose both on yourself and others.

Section 5

MEMORY

The mechanism for memory has eluded philosophers and scientists since humans first wondered about it. Nevertheless, this hypothesis of the human thinking process introduces a mechanism that seems to account for all the principal aspects of memory.

The first chapter in this section reviews the mechanism for the human thinking process to examine what happens when people re-detect a set of stimuli. This process will be called “recognition memory.”

Advanced creatures usually detect stimuli from several sources simultaneously. The second chapter shows how this simultaneous detection evolved into “associative memory,” in which the detection of one set of stimuli brings some other set of stimuli to consciousness.

The more memories a person has, the more likely that he or she will respond appropriately to the stimuli detected. Nevertheless, a large number of memories also has disadvantages. The time required to sort through all these memories delays the response, thus decreasing that person’s chances of survival. Moreover, it increases the chances of an incorrect memory being recalled. So evolution devised a clever way to retain significant memories while eliminating all others. A new memory is retained for only a few minutes, at most. Re- detection of the same stimuli increases retention for days or months. As a result, stimuli detected infrequently are soon forgotten while memories of frequently detected stimuli can be re-formed indefinitely.

Most memories change during retention. Some items in the memory are lost. Some items not in the original event are added. Some substitutions of associated items occur. As a result, a memory is seldom an accurate reproduction of the original event. Some memories are so erroneous as to be considered “false memories.”

The next chapter deals with how a memory is brought to mind. It also touches on the various factors that affect which memory will be re-formed.

The last chapter in this section describes how a memory is forgotten. This can occur naturally or unnaturally, temporarily or permanently, and can be intended or unintended. Forgetting serves the useful purpose of eliminating incorrect and painful memories.

19. RECOGNITION MEMORY

Memory is probably the most fascinating activity of the human thinking process. We humans could not survive for long without memory. But what is memory? Why and how did it originate?

“Memory” is the mechanism for bringing to present consciousness an event that was detected in the past. The term “memory” is also used to refer to a specific set of stimuli detected in the past that can be brought to mind in the present.

Memory has been subdivided in a variety of ways. This analysis will refer to “recognition memory” as the recall of a past event by redetection a similar set of stimuli. Recall of objects detected earlier by the present detection (or recollection) of other items will be called “associative memory.”

Requirements of a Mechanism for Memory

Innumerable mechanisms have been proposed for memory, but none has achieved widespread acceptance. Viewed as a separate entity, memory appears to be hopelessly complex because any mechanism for human memory must meet at least the following requirements:

- The mechanism must be constructed from materials available in the brain.
- The mechanism must be able to record the detection of stimuli instantly.
- The mechanism must be able to store all information detected in a creature’s lifetime. This number of items far exceeds the number of neurons in the brain.

- The mechanism must be able to bring sets of stimuli detected in the past to consciousness in the present.
- When a set of stimuli is detected again, the mechanism must be able to assemble instantly all information detected in previous encounters with it, even though these detections occurred at different times and in different places.
- The mechanism must be able to reform memories by the detection of associated items.
- The mechanism must provide for the changes that occur in memories during storage.
- There must be a way to eliminate (i.e., forget) all or part of some memories while retaining others indefinitely.
- The entire mechanism for human memory must fit into a volume of not more than 1500 cc.

This is indeed a formidable list of requirements for a mechanism for memory. It can be used at the end of this section to check the validity of the mechanism for memory proposed here.

Evolution of Memory

There is no mechanism for memory in the basic survival system. Also, there is no special provision for memory in the advanced system. So how and why did a mechanism for memory originate?

It seems that scientists and philosophers have been looking for memory in the wrong place. This analysis identifies it as an unexpected result of evolution's attempt to speed up the response to the stimuli detected.

Transferring sensory information - The principal function of the human thinking process is to respond immediately and appropriately to the stimuli detected. A brief review of how this sensory information is transferred might help explain the evolution of memory.

When a single-celled creature's detector molecule detects a stimulus in its environment. It transfers this information to a motor molecule for a response. Some single-celled creatures transfer this information through a series of chemical reactions. Others transfer it through a "messenger" molecule. The sooner this sensory information reaches the motor, the sooner the creature moves and the more likely that it will achieve its objective of obtaining a benefit or escaping a threat.

When early multi-creatures evolved, the distance between the senses and the motor increased, which increased the time needed to transfer the sensory signal from the detector to the motor. A faster means of transferring sensory information was required for survival. So instead of a detector cell transferring its information to a wandering messenger molecule, it released a neurotransmitter molecule directly to another neuron. This receptor neuron discharged its own neurotransmitter molecules to the next receptor neuron, and so on until the signal reached the motor. This new equipment for transferring sensory information decreased the response time dramatically and so had great survival value.

Nevertheless, new creatures continued to grow in both body and brain size. As a result, the sensory signal had to be conducted through innumerable connections of neurons in the brain structures to reach the cortex. Although the signal goes over a synapse in a fraction of a millisecond, there are so many synapses along the route that the total transit time is significant, especially when every millisecond affects survival. As the evolution of a larger brain increased the time required for an intellectual response, it jeopardized survival. So, another new way to speed the transfer of sensory information was needed.

Nature devised an elegant way to speed up the sensory signal in large brains. Each passage of a signal over a synapse causes it to discharge more neurotransmitter molecules the next time it is used. The more often it is used, the more the synapse is "enhanced." The more neurotransmitter molecules received by a receptor neuron, the sooner it reaches its critical voltage and discharges an impulse, and the sooner the sensory signal reaches the cortex. This enhancement of the synapses in a sensory pathway speeds up a creature's response to the stimuli detected and so contributes to survival.

The Effect of Enhanced Synapses on Memory

Although the enhancement of synapses clearly evolved to reduce the time required to respond to a stimulus, it also had an important effect on memory. The information in a sensory signal is retained only as long as the synapses in its sensory pathway are enhanced. When the enhancement is lost, a new sensory signal needs to re-form its pathway to the cortex. This is the same as detecting the stimuli for the first time; nothing would be gained from the earlier experience. So retaining the sensory pathway though enhancement of its synapses is a key element in the mechanism for learning and memory.

Enhancement of the synapses in a sensory pathway is similar to marking trees to find your way through a forest. Or perhaps a closer analogy is constructing a paved pathway through the forest. Any later signal with a similar impulse pattern is conducted over this enhanced pathway instead of expending the energy to form a new one. This later signal reaches the same set of cortical neurons as the signal that formed the enhanced pathway and so is interpreted in the same way. As a result, this individual is aware that he or she has detected this object before.

So memory is not something stored in the brain in some way that removes it from consciousness and then is somehow retrieved and brought to consciousness. It is the re-formation of a specific pattern of stimulated cortical neurons. This occurs when a later sensory signal is conducted over an enhanced sensory pathway formed by a similar sensory signal at some time in the past.

This formation of a memory through the re-detection of a set of stimuli will be called "recognition memory."

Forming a Memory

All memories are formed by a sensory signal that enhances the synapses in a sensory pathway to the cortex. This can occur in three ways:

- The sensory signal is formed by detection of stimuli representing real objects in the environment.

- The sensory signal is formed by the detection of stimuli in a communication from others.
- Recirculating signals bring the impulse patterns of many different stimuli into the cortex at the same time. These impulse patterns sometimes encounter a region of neurons that accommodates the impulse patterns for two or more sensory signals. These sensory signals enter this pathway, forming a composite sensory pathway for the stimuli they represent. As a result, the sensory signal for these items is recorded in a sensory pathway in the same way the simultaneous detection of external stimuli is recorded.

As the brain has no way to know the origin of its sensory pathways, internally generated memories are handled in the same way as those formed by detection of external stimuli.

Learning

Learning is simply the formation of a memory. Some learning occurs on the first detection of a set of stimuli. More often, however, repetition is required to enhance the synapses in the sensory pathway for the item.

Most learning occurs through an extension of information already present in that brain. For example, learning a list of new technical items usually requires numerous repetitions. However, a brain that already contains information in that subject area often readily learns a new item in that subject area.

An item is learned only as long as its sensory pathway remains enhanced.

Failure to Form a Memory

The human sensory organs do not always detect all the stimuli present in the environment because:

- No human sensory organ is capable of detecting some types of stimuli, such as gamma rays or bacteria.
- The senses might not be able to detect the stimuli present because of "sensory overload."
- The senses cannot detect stimuli that are changing above a certain frequency, as in the inability of the human eye to follow the flight of a bullet.
- There is some maximum number of new pathways that can be formed in a given period, probably because of the temporary exhaustion of the chemicals required to enhance their synapses. Stimuli that are detected but not recorded in the enhancement of the synapses in a sensory pathway are not learned and so cannot be recalled later. For example, at some point you no longer understand what you are reading.

Organization of Memories

It is known that the sensory signals originating in each sensory organ are conducted to the corresponding area of the sensory cortex, but is the information content of these signals organized in some additional way? As seeing one movie actress sometimes brings to mind the name or image of other actresses, are these images stored by subject matter in one place? Are all memories concerning Paris grouped in one location and all names starting with the letter C in some other location?

Any organization of memories by location, beyond that of the sensory organ that formed them, seems most unlikely. It has already been shown that memories are not stored in a location but in a route to the cortex. And it is not likely that the routes of the items in a specific group are located in one place because most items belong to many different groups. The recall of related items occurs through commonality and associations and not by physical location or any other organization of memories.

20. ASSOCIATIVE MEMORY

The mechanism for recognition memory will be used to lead into the mechanism for associative memory. It consists of:

- Detection of a set of stimuli.
- Formation of a sensory signal that is conducted along a sensory pathway to some set of cortical neurons.
- Enhancement of the synapses in this pathway
- Formation of an image in the cortex, whether or not it is interpreted.
- The continued existence of this sensory pathway.
- Redetection of the same set of stimuli.
- Re-formation of the same image in the cortex.
- Recognition that the same image was formed earlier.

This mechanism shows that a memory is not stored somewhere in the brain and then recalled to consciousness. Instead, the same image is re-formed. What is stored in the brain is an enhanced sensory pathway.

This analysis of recognition memory is helpful in understanding the basic mechanism for a memory. However, most memories are not formed this way because the human sensory organs seldom detect a set of stimuli for a single item and nothing else. Nevertheless, the detection of the stimuli for a single object is helpful in understanding the simultaneous detection of stimuli representing multiple objects.

Detection of a Single Object

You detect the complete set of stimuli for a person. A few days later, you detect the same set of stimuli. This sensory signal goes along the same sensory pathway as the earlier signal and so brings the same image to mind. You recognize that you have detected this person before. That is, you “remember” seeing this person.

Still later, you catch a glimpse of this person walking by, so you do not detect all of his body. What your senses do detect forms an impulse pattern that is identical with some but not all the impulse pattern for this person.

As described in the chapter on Similarity, the result of this detection is determined by how similar this incomplete impulse pattern is to the complete impulse pattern for that person. When it is quite similar, it is conducted over that sensory pathway, re-forms the earlier image, and is interpreted as that person. At some greater difference, the impulse pattern is conducted over some other pathway, so you are not aware that you saw this person before. That is, redetection of a sufficient part of an impulse pattern that has an enhanced pathway re-forms the image of the item that formed that pathway. A less similar impulse pattern does not.

Forming an Associative Memory

Advanced creatures almost always detect the stimuli from many different sources simultaneously. All stimuli detected at the same time form a single homogeneous impulse pattern. For convenience in description, an impulse pattern representing two or more different items will be referred to as a “composite impulse pattern.” This composite sensory signal is conducted over the route that best accommodates its impulse pattern to reach some set of neurons in the cortex, enhancing all the synapses along its route.

You interpret this set of stimuli as an old man and a large dog. After you have detected them together several times, you see the dog walking alone. If the impulse pattern for the dog is a sufficient part of the impulse pattern for the old man and dog together, it is conducted over the composite pathway to reach its set of cortical neurons and so brings the composite image of old man and dog to mind. That is, detection of the dog brings the image of the old man to mind, even though he was not detected at this time.

The conditions under which as associative memory does and does not form will be described later in this chapter. However, it might be helpful to pursue this example a bit further.

The impulse pattern formed by the detection of the old man might or might not be sufficiently similar to the composite impulse pattern to bring his dog to mind. However, for this analysis, let's assume it is sufficient. Now you detect a different old man. The impulse pattern formed is less similar to the composite of the other old man and his dog and so might or might not bring the dog to mind. A still greater difference, such as the impulse pattern for a young man or woman almost certainly would not bring the old man and dog to mind.

The presence of additional stimuli not present in the original detection also affects associative memory. For example, the old man might be detected with friends or in a different environment. This impulse pattern would be too different to be conducted over the composite pathway and so would not bring the dog to mind.

Obstacles to Forming an Associative Memory

Strongly enhanced pathways exist for the individual items - In his classic work on conditioning, Dr. Pavlov sounded a buzzer as he presented a dog with some food. The odor of this food caused the dog to salivate. After the dog detected the sound of the buzzer and the smell of the food enough times to enhance its composite pathway, Dr. Pavlov sounded the buzzer in the absence of the food. Nevertheless, the dog salivated, showing that detection of the sound had triggered the composite image and brought the food to mind.

Dr. Pavlov and his assistants also heard the buzzer and smelled the food simultaneously but there is no record that the sound of the buzzer alone caused any of them to salivate. Why not?

Most people already have a strongly enhanced pathway for the sound of a buzzer and another one for the odor of food. When these items are detected simultaneously, the impulse pattern for the sound goes over its pathway and that for the odor goes over its pathway. The composite pathway formed, if any, is weakly enhanced compared with the strongly enhanced pathways for the individual items. When one of these items is detected later, its sensory signal is conducted over its own strongly enhanced pathway instead of the weakly enhanced composite pathway and so does not recall the other item. As a result, we do not associate items that we already know are not connected in nature.

Effect of repetition – A composite pathway is sometimes formed even when strongly enhanced pathways for the individual items already exist. This occurs through frequent simultaneous re-detection of the items. A familiar example occurs in commercial advertisements that associate an expensive automobile (or toothpaste, etc) with sexual attraction so often that some people believe that these objects are connected in nature. A less familiar but more destructive association occurs in the "big lie," as in associating political dissent with treason.

Novelty – Occasionally the combination of stimuli detected is so unusual that the composite impulse pattern does not go over the pathways for the familiar items. For example, the ancient Greeks had strongly enhanced pathways for "horse" and for "man," but had never seen a man on a horse. They first detected Scythian horsemen in the heat of battle. This composite sensory signal formed a new pathway that was interpreted as a single object, a "centaur." (A centaur is an imaginary creature with the head of a man and the body of horse.)

Number of items in the association – As noted, the human sensory organs detect everything within their capability in each instant of time. As a result, every composite impulse pattern always contains a number of "background" items that alone or in total, affect the formation of an associative memory.

The impulse pattern for any one of many background items is seldom a sufficient part of the composite impulse pattern to be conducted over the composite sensory pathway and so re-form the memory. This is fortunate as otherwise our minds would be constantly filled with a jumble of associations.

Nevertheless, the background items, taken together, might be a large percentage of the composite impulse pattern. For example, you and a friend visit a pond in a snow-covered national park. Re-detecting that scene the following winter might be sufficient to bring your friend to mind, while revisiting it in the spring would not.

In some cases, neither a principle object alone nor a complete background alone is sufficient to re-form an associative memory. For example, detecting a crime suspect in a line-up might not re-form a memory. Revisiting the scene of the crime also does not re-form the memory. However, detecting the suspect at the scene of the crime might form an impulse pattern sufficiently similar to the original to re-form that memory.

Number of associations – Some items are associated with many different items while others have only a few associations. For example, there might be a composite pathway for horse-and-buggy. Because the sensory signal for “horse” has many enhanced composite pathways, it is unlikely to bring “buggy” to mind. Nevertheless, as “buggy” has few enhanced composite pathways, it is more likely to bring “horse” to mind.

Background items – To return to the example of the old man and the dog, you now see the same old man again. However, he is with a group of friends in a bar. These stimuli not present in the earlier detection make this impulse pattern too different from the original pattern. It is not conducted over the composite sensory pathway and so does not bring the dog to mind.

Changes in Associations

As associations are composite memories, they are subject to the same changes that occur in simple memories:

- The entire association is forgotten if the synapses in the composite sensory pathway lose their enhancement.
- Part of the association is forgotten through failure to use some of the composite sensory pathway. For example, there might be an association between the appearance of an acquaintance and his full name. Someone who uses only that person's first name will forget the association between that person's appearance and his last name.
- Substitution of associated items occurs rather frequently. For example, a little girl who was angry at a playmate named Tommy Rice, said, "I'm not going to play with you anymore, Tommy Krispies!"
- Some associations become obsolete in the sense that the connection among the objects that formed them no longer exists. For example, seeing Bob brings Betty to mind, even though they are no longer married.

Naming a Sensory Pattern

The most important type of associative memory is that between a sensory pattern and something that identifies it. The sensory pattern might be the image of an object that exists in nature or it might be an imaginary object that does not exist in the real world. It might be something intangible, such as an idea, a political philosophy, or a social custom.

It might be a series of movements, such as running, fighting, or dying. In short, any sensory pattern or series of sensory patterns can be associated with a label.

A wide variety of labels can be used. Even the most primitive human societies have developed a vocabulary of sounds (i.e., “language”) for some sensory patterns. Some but not all human societies also have a vocabulary of marks (i.e., “writing”) associated with sensory patterns. Almost anything can be used as a label, from a toot on an auto horn to a whistle by a sports official to a two-bid in a bridge game.

The association of a sensory pattern and a label is formed in the same way as all other associations. Some are formed by simultaneous detection. Some are received already formed in the communications from others. Recirculating signals forms some. These associations are forgotten in the same way as other associations – by disuse.

As it is much easier to deal with labels than with sensory patterns, these associations greatly facilitate human thinking. They are also the mechanism for communication, both verbal and nonverbal.

Nevertheless, as usual, labels introduce some common errors. One type occurs because the same label is used for two or more different sensory patterns.

A more serious error occurs because each person has a somewhat different thought pattern even for the same sensory pattern because of its associations. So even though two or more people might use the same label, it is associated with a more or less different thought pattern. This difference is especially important in communicating with others. One person associates his sensory pattern with the sound “love,” but this might bring a very different sensory pattern to the mind of the receiver.

21. RETENTION OF A MEMORY

As a memory is recorded in the enhancement of the synapses in the route of a sensory signal to the cortex, anything that enhances these synapses contributes to the retention of a memory. Anything that interferes with the neurons or the enhancement of the synapses in this pathway eliminates the memory.

Duration of Memories

A memory might be retained for a few seconds or for a lifetime. Although the boundaries are indefinite, the retention period is usually subdivided into short term, intermediate term, and long term.

Short-term memory - Short-term memory occurs only with newly formed memories. The sensory signal that forms a memory is usually recirculated for only a short time. As the first few uses of a synapse enhance it very little, the synapses in this new pathway soon lose their enhancement completely. As a result, it is not possible to recall this memory by association. The memory has been "forgotten."

The lost memory can be re-formed by redetection of the same set of stimuli. However, once a memory has been completely forgotten, re-forming it is similar to forming it for the first time. There is no recognition that these stimuli were detected before.

The example frequently used to illustrate short-term memory is looking up a telephone number and then forgetting it immediately after use. A very high percentage of all memories are retained only for a short time.

Intermediate-term memories – A short-term memory is retained by re-use of its sensory pathway before the synapses have lost their enhancement. Each use increases the enhancement of the synapses up to some maximum level. A strongly enhanced synapse also begins to lose its enhancement immediately after use, but as this enhancement starts at a higher level and is lost more slowly, the memory is retained for days or weeks.

The re-enhancement of the synapses can occur through frequent detection of the stimuli. Occasionally, through prolonged recirculation of the sensory signal, some memories move into intermediate term memory on a single detection, as with detection of events that affect survival. A similar result can be achieved by purposely recirculating the sensory signal for the memory a number of times; that is, by "concentrating on it."

Long-term memory - There really is no long-term memory as all memories are forgotten unless their synapses are re-enhanced. What appears to be long-term memory is nothing more than the periodic re-enhancement of the synapses in the sensory pathway of an intermediate-term memory before their enhancement is completely lost.

These standard categories for memory are misleading, however. They imply that the duration of a memory is from the date it was formed to the present. As will be shown, memories are constantly changing. Parts of the original memory might be forgotten through disuse. Items not in the original memory might be added by the way it is brought to mind. As a result, a present memory has existed only since its most recent formation.

Retention of a Memory

By re-forming the memory - Each re-formation of a memory enhances the synapses in its sensory pathway to the cortex and so retains it. This occurs in the following ways:

- Re-detection of the stimuli that formed the memory.
- Detection of an associated item that re-forms the memory.
- Intentionally recirculating signals for the items in the memory or for items associated with them. Examples include "thinking about it," reviewing your college notes, practicing a foreign language, etc.

Effect of other memories - The retention of a specific memory is also affected by your other memories:

An item in the brain can be part of many memories or only a few. The more associations an item has, the more likely that the synapses in its pathway will be re-enhanced through detection of one of its associated items.

The greater the number of memories in a brain, the larger the number of associations formed among them by recirculating signals. This makes it more likely that the synapses for any specific memory will be re-enhanced by detection of an associated stimulus.

Intersecting pathways - The ways to retain a memory described above occur through re-forming it. However, there seems to be another way to retain a memory even though it has not been re-formed in many years. As noted, there are billions of neurons and trillions of synapses in the substructures of the brain. Nevertheless, the number of synapses required to record all the memories in person's lifetime far exceeds even this enormous number. This implies that a synapse is usually part of many different pathways. As a result, the impulse pattern for one sensory signal crosses the pathway for many other sensory signals, enhancing the synapses where they intersect. The impulses at the crossing point start a cascade of impulses that enhance several other synapses in the pathways it crosses before being extinguished. This process sometimes repairs breaks due to disuse in the pathway for a memory.

Other factors affecting retention - A memory that is seldom used can be retained by associating it with a memory that is frequently used. For example, you probably would have forgotten where a certain tablecloth came from if it weren't associated with the dear friend who gave it to you. Each time you think of your friend, you also enhance the composite pathway for her and the tablecloth. As a result, the tablecloth is remembered even if it is seldom used.

The genetic makeup of individuals also seems to be a factor in the retention of a memory. Some people seem to retain memories for a longer period than others, indicating a difference in the rate at which different people lose the enhancement of their synapses.

Changes in a Memory During Retention

Not only are the synapses in a memory constantly gaining and losing enhancement, but recirculating signals sweep over them frequently, sometimes forming new associations. These factors can cause a change in a memory in any of the following ways:

Partial forgetting - You attend a company picnic. That night you relate all the important events to your wife, together with your interpretation of how they affect company politics. However, you don't tell her most of the memories you formed because you have already forgotten them.

Some people at the picnic were from the home office. You have occasional contact with them and hear about them from your co-workers. As a result, some portions of your earlier memories are re-formed. However, the synapses for some parts of these memories have lost their enhancement, so this part of your memories has been forgotten. You tell a friend about the picnic a month later, but because of the memories you have forgotten, your interpretation of the company politics involved is now quite different from what it was earlier.

Additions to a memory - Memories are often re-formed by the detection of an associated item. For example, seeing your friend Tom recalls the fun you had together at the picnic. Tom is married to Betty. Telling your wife about the picnic brings Tom to mind, which triggers his association with Betty. So, in telling your wife who was present at the picnic, you include Betty, even though she was not there.

Substitutions - A variation in the addition of an associated item to a memory is that of substitution by an associated item. For example, an address is remembered as being on Pine Street even though it is on Spruce Street. Or you remember that your brother made the winning goal when it was made by his teammate.

Sometimes, through checking with others, it is possible to know which items were part of the original memory and which items were added or substituted later. More often, however, there is no way to know that a present memory is an incorrect representation of the original event. As a result of these changes that occur during retention, few, if any, memories are an accurate representation of the event that formed them. In some cases, the changes that occur during retention change the memory so much that it becomes a “false memory.”

22. RE-FORMING A MEMORY

Bringing a memory to consciousness is usually described as “recalling” or “retrieving” it, implying that memories are stored somewhere in the brain. However, as shown earlier, a target memory is brought to mind by re-forming its sensory pattern.

Some material on re-forming a memory introduced in earlier chapters is incorporated here with additional material for a more comprehensive presentation.

Re-forming a Target Memory

A memory can be re-formed in any of the following ways:

- Through redetection of all the stimuli in the memory (i.e., recognition memory”).
- Through redetection of a sufficient percentage of the stimuli in the memory (i.e., similarity of its impulse pattern).
- Through detection of items associated with the target memory (i.e., “associative memory”).
- Through detection of two or more associated items, neither of which recalls the memory by itself (i.e., a form of associative memory).
- Through recirculating signals that contain the impulse pattern of an item associated with the target memory (i.e., another form of associative memory).

Redetection of all the stimuli in the memory - When all stimuli in an earlier event are again detected simultaneously, they initiate a sensory signal with the same impulse pattern as the signal that formed the memory. This signal is conducted over the pathway established by the earlier signal and so reaches the same set of cortical neurons to form the same sensory pattern, thus re-forming the memory.

Although redetection of the same set of stimuli re-forms the same sensory pattern, it does not necessarily re-form the same thought pattern. In the interim, some sensory pathways for items associated with the stimuli detected might have deteriorated through disuse while pathways for new associations might have been formed. As a result, the recirculating signals bring somewhat different information into the thought pattern, changing it to some extent. So, even though the sensory pattern for the memory is the same, it might be interpreted differently.

Redetection of some of the stimuli in the memory - Sometimes an incomplete set of stimuli in a memory is re-detected, as in catching only a glimpse of a person or hearing only part of a song.

When the impulse pattern for an incompletely detected set of stimuli is sufficiently similar to that in a memory, it is conducted over that pathway, reaches the earlier set of cortical neurons, and so re-forms the entire memory. This is why all zebras in a herd seem to be identical and the Oriental gentleman you passed on the street today seems to be the same person you saw yesterday, even though he is taller and thinner. It is also why familiar items always look the same, even when you detect them incompletely.

However, incomplete detections of stimuli can also lead to the re-formation of an incorrect memory. For example, your neighbor, Bob, has a beautiful dog, Tony, he keeps fenced up in his yard. You enjoy playing with the dog and he seems to like you. One day you see Tony alone near the supermarket. How did he get loose? Where's Bob?

Concerned, you approach the dog in your usual way. However, instead of the expected greeting, he snarls at you. After a few minutes of confusion, you recognize that this isn't Bob's dog. It's bigger, younger, and has somewhat different coloring. Its appearance was sufficiently similar to that of Tony that it was conducted over his pathway as so was interpreted as Tony.

Signals that are an insufficient part of the original impulse pattern are extinguished before they reach the cortical neurons and so do not recall any part of the memory.

Detection of an associated item - Recall by association refers to the re-formation of the image of Object A by the detection of the stimuli for Object B.

An enhanced sensory pathway for the associated items must be present in that brain to re-form a memory by detection of an associated item. For example, if the sensory signal for "Narcissus" did not bring "Echo" to your mind, these items were not associated in your brain.

Re-formation of a memory by association occurs when the image of Item A is associated with the image of Item B through a composite sensory pathway. When the impulse pattern of one of these items is a sufficient part of the composite impulse pattern, it is conducted over the composite pathway to re-form the composite sensory pattern that contains both images, and so re-forms the image of the other item.

A memory can also be re-formed by detection of an item with which it is indirectly associated. For example, you are idly thumbing through a book of puzzles when the image of your granddaughter's dog pops into your mind. Where in the world did that memory come from? Then you notice that you were looking at the solution for a game of tic-tactoe, with all its X’s and O’s. That was the way your young daughter ended her letters to you. The image of your daughter started a cascade of images; her graduation from high school, her marriage, the birth of her daughter, the puppy you gave the child on her fifth birthday, and the child playing with her dog.

Recall by detecting two or more independent stimuli - In some cases a target memory cannot be re-formed by the sensory signal of an item associated with it. A familiar example occurs in crossword puzzles where the clue (i.e., a set of stimuli) does not recall a target word (i.e., the memory). Also, in the absence of the clue, the target word sometimes cannot be re-formed by detecting some of its letters. Nevertheless, the simultaneous detection of the clue and these incomplete letters sometimes re-forms the memory.

The clue in a crossword puzzle is always associated with the target word in some way. When the clue and the memory are directly associated, the impulse pattern formed when the clue is detected is conducted over their composite sensory pathway and so brings the target word to mind. Some clues, however, are connected to the target memory through a series of associations. In some cases, the impulse pattern of the sensory signal is extinguished at one of the direct relationships and so does not reach the cortex. In other cases, the sensory signal does reach the composite pathway but is an insufficient part of the composite sensory signal and so does not re-form the memory. Detection of each letter in the target word adds its impulse pattern to that of the clue. At some point the impulse pattern for the combination of the letters and the clue becomes a sufficient part of the composite sensory signal and so re-forms the memory.

Inserting an incorrect letter in one of the spaces for a word in a crossword puzzle inhibits the re-formation of the target memory. This occurs because the impulse pattern for the incorrect letter makes the sensory signal more unlike the composite signal for the combination of the clue and the target word. As a result, its sensory signal is conducted over some other pathway to form some other thought pattern and so does not re-form the target memory.

This result occurs even when there are enough correct letters present to re-form the target memory when the incorrect letter isn't present. In this case, when the incorrect letter is removed, the remainder of the impulse pattern becomes sufficiently similar to that for the memory so that the target word immediately pops into consciousness.

Another example of using a combination of stimuli to re-form a memory occurs in trying to remember the name of a person you see again after a long absence. Although you see him clearly and know you once knew his name, you can't re-form it. So you go through the alphabet until you reach the first letter in his name, which immediately jumps into your mind. You could not re-form his name from his appearance alone and you would not be able to recall his name from its first letter alone, but together they serve to re-form that memory.

Recall by a Recirculating Signal

All the ways of re-forming a memory described to this point begin with the detection of an external stimulus. However, some types of memories seem to be re-formed in the absence of an external stimulus, including:

Memories of traumatic events - Memories of events that involve survival, such as past dangers, tragedies, and triumphs, frequently come to mind uninvited when there are few, if any, detections of external stimuli, notably in sleep.

As the sensory signal for a traumatic event is recirculated longer than usual, its pathway is highly enhanced. The recirculating signals also enhance the pathways for items directly and indirectly associated with those in the memory. As a result, detection of any of many different items re-forms the memory, keeping these pathways enhanced. This increases the possibility of triggering one of these pathways by a residual recirculating signal during periods when few external stimuli are being detected.

Random memories - Sometimes a miscellaneous memory pops into consciousness. This usually occurs when the person is not detecting any external stimuli. It seems likely that these memories are re-formed by residual signals that continue to circulate in his or her brain for some time after the stimuli are detected. The effect is random because the residual signal energizes any pathway where its impulse pattern is a sufficient part of the composite impulse pattern that formed it.

Specific memories - More puzzling is the process of purposely recalling specific memories, such as consciously deciding to think of ways to solve some personal problem. No external stimulus seems to be involved in beginning this process. Nevertheless, it is often possible to track the series of associations back to an unrecognized external stimulus.

Selection Among Memories

A set of stimuli is often a significant part of the impulse pattern for many composite memories. When this set of stimuli is detected, which of these memories does it re-form? Also, why does the same set of stimuli re-form a different memory at a different time? This seems to be a race measured in milliseconds. The memory that reaches consciousness is the one that gets to the cortex first. The factors that affect this selection are:

The percentage of the memory represented by the stimulus - The impulse pattern for a given set of stimuli is conducted fastest over the pathway in which it is most similar to the composite impulse pattern that formed that pathway. This favors the re-formation of a memory in which the set of stimuli is a significant rather than a minor part of the impulse pattern for the associated items.

The enhancement of the pathways for the memories - When more than one composite sensory pathway is intact, an impulse pattern is conducted fastest over the one whose synapses have the greatest enhancement. This favors memories that have been recalled recently and those that have been recalled frequently.

Length of the chain of associations - The set of stimuli detected might be directly related to some memories but only indirectly related to others. The sensory signal will first reach and recall the memory that has the shortest chain of associations with the stimuli detected.

Extraneous items in a sensory signal - The re-formation of a memory is inhibited by the simultaneous detection of stimuli extraneous to the original memory. For example, you are sufficiently familiar with a person so that seeing only part of his appearance readily brings his complete image to mind. Yet one day you see but do not recognize him. This occurs because he has grown a beard and is wearing a tuxedo. Your sensory signal still contains all the impulses necessary to re-form his memory but now it also includes impulses not present in your sensory pathway of his image, so it is conducted over a different route and so does not re-form his memory.

23. FORGETTING A MEMORY

As with “recall” and “retrieval,” this proposed mechanism for memory requires an adjustment in the meaning of “forgetting.” In this hypothesis, the sensory image exists only for the brief period of time when the stimuli are detected. This image is not stored anywhere; it is extinguished. As there is no image to be recalled, the memory must be reformed. The memory exists only in the sensory pathway to the cortex. A memory can be re-formed only as long as this pathway is intact.

A memory is forgotten by anything that interrupts its sensory pathway. This can occur naturally through the loss of enhancement of its synapses or by the death of its neurons. Its pathway can also be interrupted unnaturally through injuries, lesions, or drugs

Although forgetting is usually unintentional, some memories are forgotten intentionally.

Advantages and Disadvantages of Forgetting

Memories are essential to the survival of all advanced creatures. Nevertheless, there are some disadvantages to remembering all memories and advantages to forgetting some memories.

The more information a person has about the source of a set of stimuli, the more appropriately he or she can respond to it, so memories of past encounters contribute to survival. However, the longer a person takes to process his or her memories to arrive at an appropriate response, the less likely that he or she will respond in time to gain a benefit or to escape a threat.

Nature evolved a simple but drastic trade-off between these objectives. It developed a mechanism that retains a memory, but only for a short period of time. Any memory not used within this period is considered unnecessary and so is eliminated. Reuse of a memory during this period restarts the clock. As most memories that affect survival are used frequently, this mechanism retains useful memories while eliminating all others as being unnecessary.

Forgetting has another important benefit. Everyone has some incorrect information in his or her brain. Some sets of stimuli were interpreted incorrectly. Some incorrect information was accepted unknowingly from others. Some information that was correct when it was recorded has become incorrect through changes in the external world. Some correct memories, such as social errors, mistakes, and personal conflicts, are painful. Also, as will be described in a later section, an incorrect memory interferes with the acceptance of correct information in that subject area. If all memories were retained indefinitely, there would be no way to eliminate incorrect and painful memories.

Interrupted Memories

Suppression - Unwanted memories are sometime suppressed (or “blocked”) by the formation of strongly enhanced pathways that conduct away the signal that would otherwise re-form the memory. Although blocking prevents the unwanted memory from reaching consciousness, its sensory pathway is more or less intact and brings enough of its signal into the thought patterns to affect the response to stimuli. A suppressed memory is sometimes recovered by elimination of the blocking pathways by psychotherapy.

Sometimes the pathways blocking a memory deteriorate or are interrupted by other factors. For example, when the more strongly enhanced pathways in their recent memories are interrupted, older people sometimes re-form long suppressed memories of events in their youth.

Habituation - Habituation is a special form of interrupted memory, as it is followed by automatic remembering.

Prolonged detection of a stimulus exhausts a key material in the synapses. This interrupts the pathway for the sensory signal so that it cannot reach the cortex to bring its information to consciousness. This effect usually occurs in the gradual loss of awareness of a continuing stimulus, such as a sound or an odor, but it also occurs with some visual stimuli. It might also be the mechanism that eventually cuts off worry or the tune "you can't get out of your head." This process serves the useful function of temporarily interrupting memories that are not essential for survival.

When the stimuli causing habituation are not detected for some time, the materials in the synapse automatically return to their normal levels so that the sensory signal can again reach the cortex to re-form the memory.

Permanent Forgetting

Natural forgetting - A memory is forgotten naturally when the synapses in the pathway to the cortex lose their enhancement through disuse.

A specific memory can also be forgotten through the natural death of the neurons in its pathway. Neurons die in random locations at an accelerating rate as a person ages. The occasional loss of a neuron in a pathway has a negligible effect on the transmission of a sensory signal. Over time, however, enough neurons in a pathway die so that the sensory pathway is interrupted. As the sensory signal cannot reach the cortex to re-form its brain pattern, this memory cannot be re-formed, and so is “forgotten.”

Unnatural forgetting - A memory can be prevented from re-forming, permanently or temporarily, by external factors that interfere with its transmission, intentionally or unintentionally. These factors include:

- Drugs (e.g., alcohol, pharmaceuticals, street drugs)
- Electric and other form of therapeutic shock
- Growths or other injuries to the brain
- Surgical procedures
- Traumatic experiences

Growths, injuries, and surgical procedures physically interrupt the sensory pathway so that the sensory signal cannot be conducted over this route to a memory, though it might be able to go over some other route to re-form the same thought pattern.

Shocks seem to affect principally the recently formed pathways, probably by killing some of their neurons. As a result, recent memories are eliminated while older memories are retained, perhaps because they have more alternative or more enhanced routes to their thought patterns. Although the memories lost due to shock treatment cannot be recovered, similar memories can be formed later by redetection of the stimuli. As a result, shock treatment permanently eliminates recently formed memories but does not prevent formation of new memories.

Partial Forgetting

If a memory were like a photograph, it would be all present or all forgotten. There would never be a partial or a changed memory.

If a memory were stored in a linear sensory pathway, all its synapses would be enhanced to the same degree. The entire memory would be re-formed or the entire memory would be forgotten; there would be no partial memory.

Many memories consist of impulse patterns formed by simultaneous detection of several different sources of stimuli. This composite sensory signal branches into the sensory pathways for the principle components of the memory, often triggering "twigs" for the details of these principal items. As most pathways for the major components are also part of other associations, the synapses in some parts of the composite sensory pathway are enhanced more than others. As a result, the synapses in some parts of the sensory pattern while others have little or no enhancement, so this part of the memory is forgotten. The synapses in the twigs, which are the "details" of the memory are seldom enhanced and so are soon forgotten. As a result, a re-formed memory is seldom a complete replication of the original.

Purposive Forgetting

Although it is easy to forget some memories you would like to retain, it is very difficult to remove specific memories you would like to eliminate. This occurs because the very attempt to forget the memory enhances its pathway and so retains it.

Nevertheless, setting up conditions that permit the synapses to lose their enhancement can sometimes eliminate a memory.

If an unwanted memory is not re-formed for a few weeks, some or all of it will be forgotten through the natural loss of enhancement of the synapses in its pathway. However, any signal that uses this pathway during this period will start the time clock again, retaining the memory.

It isn't possible to stop all internally generated signals from using the highly enhanced pathway for the unwanted memory, but there are three things that will gradually reduce this enhancement:

1. Avoid detection of stimuli representing that item or stimuli associated with it. For example, to forget a lost relationship, avoid not only that person, but also pictures, places, etc. associated with him or her. Leaving the area also helps reduce detection of random reminders.
2. Although it is not possible to subtract anything from the brain purposely, adding negative items to the unwanted memory can help in forgetting it. Purposely decreasing the benefits of the lost item also reduces the pain of the loss.
3. Redirect the signals you cannot avoid, such as the recirculating signals, by preparing a new destination in your brain for them. This new target should be sufficiently similar to the unwanted memory so that the signals will go there instead. Examples are a new love interest, a new job, etc. You then strengthen this new pathway by frequent use so that any similar signal will more likely pass over this new pathway than the deteriorating old one.

TIME OUT

Let's take a time out to review where we've been and to get a broader view of what's going on.

Our investigation has been shifting back and forth between two inter-related streams of information. One stream consists of the information we need to know about our environment in order to respond to the stimuli we detect in a way that promotes our survival. The other stream consists of the mechanisms that evolved in the advanced survival system to obtain this information.

The only equipment we have to obtain information about our environment is our senses. By the time we humans made our appearance, all we could do was expand the range of our senses. So we had to extract more information from the stimuli we could detect.

There's a fascinating aspect of these two streams of information.

In most cases, the need to learn more about the environment drove evolution to develop a new mechanism to achieve each objective. However, in achieving two of these objectives, evolution produced a mechanism for achieving a different, much more important one.

The following list shows the connection between the objective and the mechanism. The list isn't complete, but it should show how these streams are related.

Single-Celled Creatures

Detection of a stimulus – Reaction with a detector molecule.

Identification of stimulus – No way to do this.

Response to stimulus - Automatic movement toward or away from the stimulus.

Transfer of information from detector molecule to motor – Achieved by a messenger molecule or series of chemical reactions.

Early Multi-celled Creatures

Speed up transfer of sensory information from detector cell to motor - Evolution of neurons that deliver neurotransmitter directly to motor or to other neurons.

Distinguish among possible sources of the stimulus detected – Evolution of a protobrain to extract additional information from the detection of the stimulus.

Increase chances of survival - Protobrain sends an intellectual signal that modifies the automatic emotional response.

Sensory Organs in Advanced Creatures

Detection of additional stimuli- Evolved additional detector cells in sensory organs.

Identification of stimuli detected – Usually not required. Response occurs before the stimulus is identified.

Detection of multiple stimuli in the same source– Different detector cells evolved in a sensory organ to detect different types of stimuli.

Handling large volume of information from numerous detector cells in a sensory organ – Cells in the sensory organ connected in a way that compresses the sensory information obtained.

Identification of the source of the stimuli – Not done in the sensory organ.

Identification of which detector cells detected a stimulus – Encoded in the irregular interval between impulses In the sensory signal.

Transfer of sensory information to the cortex – The sensory signal's unique impulse pattern causes it to be conducted along a route to reach a target set of neurons in the cortex.

Identifying Items in the Environment

Identifying stimuli detected as an opportunity or a threat – This is an assumption based on information in the sensory signal.

Identification of the source of the stimuli detected (i.e., interpretation of the sensory signal) – A pattern of stimulated neurons is formed in the cortex. The cortex processes this pattern to assume what it represents.

Identifying a connection between two or more objects in nature – Images of these objects are associated in the brain by simultaneous detection. It is assumed that associated items are related in nature, which might or might not be correct.

Associating items detected at different times or in different places – This occurs through the recirculating signals.

Identifying similar behavior in different objects – This occurs through identical impulses is a major part of the impulse pattern of the sensory signal for the objects (i.e., commonality), resulting in groups or classes of objects.

Identifying an object from an incomplete set of stimuli – When the impulse pattern for an incomplete set of stimuli is a sufficient part of the complete impulse pattern, it is conducted over the composite pathway to re-form the complete brain pattern and so is interpreted as the complete object (Similarity).

Interpretation of similar impulse patterns – Sufficiently similar impulse patterns are interpreted as being identical. (Similarity) This is essential for communication.

Identifying indirect connections among objects –This occurs through a series of direct associations.

Identifying changes in the environment – This occurs through identifying a set of causes and its set of effects (i.e., a dynamic relationship).

Identifying a dynamic relationship – This occurs through identifying a set of causes and a set of effects and the series of direct associations connecting them over a period of time.

Failure to identify changes in the environment - Unless the change is detected, the brain is not aware of changes in the environment. As a result, the brain interprets the world as it was when the most recent item detected in each subject area was detected and not as it is now (Obsolescence).

Memories

Information retention – This occurs through enhancement of the synapses in a sensory pathway to the cortex. This retention is temporary but can be extended through re-enhancement of the synapses by later sensory signals.

Memory – This occurs through enhancement of the synapses in a sensory pathway to the cortex.

Recognition memory – This occurs through formation of an enhanced sensory pathway to the cortex where this later sensory signal is interpreted in the same way. A later detection of the same stimuli is conducted over the same sensory pathway and so is interpreted in the same way.

Association memory – This occurs when the impulse pattern formed by detection of an associated item is sufficiently similar to the composite impulse pattern that formed an enhanced sensory pathway. This impulse pattern for the item is conducted over the composite pathway to re-form the composite sensory pattern, which includes the associated items.

Elimination of an unwanted memory – This occurs automatically when the synapses in its sensory pathway are not enhanced periodically.

Assembling memories to respond to stimuli detected – This occurs through recirculating signals that bring items associated with the stimuli detected into the thought pattern.

Impressed? There's more ahead. How the brain decides if an item of information is correct or not.

Section 6

THE COMPOSITE RESPONSE TO A SET OF STIMULI

To arrive at its response to the stimuli detected, the brain processes all information in its thought pattern. When all this information is complete and correct, the response is appropriate and so achieves its objective. When significant items in the thought pattern are incorrect, the response is inappropriate and so fails to achieve its objective. So an appropriate response depends on the correctness of the information in the thought pattern.

Only a small part of anyone's information has been checked for validity. Moreover, the brain has no internal way to know if an item of its information is a correct interpretation of the real world. The peculiar way the modern human brain decides if an item of its information is correct or not is derived from the way single-celled creatures made this decision billions of years ago. The correctness of an item to the brain is simply its compatibility with the bulk of the information already present in that subject area.

The second chapter deals with the combination of the emotional and intellectual signals. When an urgent response is required, the emotional response occurs before the intellectual signal arrives. Otherwise the signals merge to direct a composite response, which is a combination of the information in the two signals.

The strength of the emotional signal is determined by the effect the stimuli detected could have on survival, positively or negatively. The strength of the intellectual signal is based on how much the person knows about how to deal with the set of stimuli detected.

Detection of the stimuli also causes a “feeling.” These feelings evolved to inform the individual of his or her status for survival. Detection of stimuli that promote survival causes a good feeling. Detection of stimuli that threaten survival causes a bad feeling.

The feeling that occurs when a set of stimuli is detected has the same ratio of emotional and intellectual components as the composite response to stimuli. Since each feeling has two components, there is a matrix of possible feelings for each situation. The third chapter in this section shows how the ratio of emotional and intellectual signals determines the specific feeling that accompanies each response.

The feeling that occurs is determined not by the true nature of the stimuli detected but by each person’s interpretation of the stimuli. When a person’s interpretation is incorrect, the feeling that occurs is inappropriate. As a result, most bad feelings are due to errors in the thinking process and therefore are unnecessary.

24. INCOMPLETE INFORMATION

A common complaint after an inappropriate response to stimuli is, "I didn't know…" "I didn't know the gun was loaded." "I didn't know a girl could get pregnant the first time she did it."

When a primitive creature detects an unknown stimulus, it responds with whatever information it has at that time, usually by fleeing. It has no way to obtain additional information in order to respond more appropriately. As a result, no mechanism ever evolved to inform advanced creatures whether or not they had all the information required to respond appropriately to the stimuli detected, let alone what additional information was needed. It is only from previous experiences in other situations that a person can suspect that there might be more useful information about this one.

Types of Incomplete Information

Each person thinks that he or she has all the information required to respond appropriately to the stimuli detected. Even when this person might suspect that his or her information is incomplete, he or she usually doesn't know just what additional information is needed.

Information unknown to anyone – In some cases, the information required to respond appropriately to a set of stimuli is unknown to anyone. For example, when the plague reached Philadelphia during the Revolutionary War, the city fathers asked the medical community how to respond to the threat. They recommended firing cannons at sunrise and sunset. In these cases, the best anyone can do is imitate primitive creatures and flee the threat.

Information known to others – Although the information required to respond appropriately might not be known to a specific individual, it is usually known to others.

Primitive creatures always respond immediately to the stimuli they detect. Humans also respond immediately to some stimuli, such as a hot object, with whatever information we have about the stimulus or its source at that time.

More often, people have some leeway in when a response is required. In some cases, the response can be delayed for seconds, minutes, or even months. This time can be used to gather additional information. For example, a candidate might learn more about the policies of an employer before the deadline for deciding on whether or not to accept a job offer. And many a bride-to-be has decided in the last hour before a decision is required not to attend her wedding.

The time before a decision is required can be used to gather more information about the set of stimuli detected and how to deal with it. There are many such sources, including libraries, the Internet, and knowledgeable individuals. The true problem is not that the information is not available, but that the individual does not try to get it.

Information known to that person – In some cases, all the information needed is already present in that person's brain. Nevertheless, some people "shoot from the lip." That is, they respond to the stimuli before the recirculating signals can bring all the information associated with the stimuli detected into the thought pattern. It is only later that this person recognizes "what he should have done," based on this additional information.

Assumptions

As one wit put it, "It ain't what we don't know that hurts us, it's what we know that ain't so!"

At the present stage of human evolution, everyone has many gaps in his or her knowledge about the environment. We bridge these gaps with assumptions. That is, we guess at what information is missing. We guess that when we step on the brake, the auto will stop. We guess that the chest pain is due to indigestion and not a heart attack. We guess that the nice man wants to help us in our old age by allowing us to invest in his wonderful invention.

Nevertheless, despite the risk of error, we have so many gaps in our knowledge that we could not function without assumptions. So we need to learn how to deal with them.

Identified assumptions – Like ancient lepers, some assumptions carry a banner warning us of their dangerous nature, such as:

"Let's assume that …"

"In my opinion, …"

"In my considered judgment, …"

"Everybody knows that …"

We know that an assumption might be concealing a bomb, so we deal with it cautiously. We might avoid a response that involves an assumption or we might take the time to learn whether the assumption is correct or not.

Unidentified assumptions – Unless an assumption is carrying a tag that identifies it as an assumption, there is no easy way to distinguish it from a fact. Indeed, many assumptions have been accepted as facts for centuries. Some of these assumptions can be seen in what we now call superstitions, such as:

"A rain dance causes rain."

"Breaking a mirror causes seven years of bad luck. "

"You'll fall off the edge of the earth by sailing west. "

"The Aztec gods needed a supply of human hearts to keep the world going. V

"Virgins in heaven tend Scandinavians who die in battle. "

Checking the Validity of an Assumption

An assumptions becomes a fact only by verification of its validity, and not by any of the following:

- How logical it seems, as in believing the earth is flat.
- How long it has been accepted
- How widely it is accepted
- How intensely it is believed

25. INCORRECT INFORMATION

After our long journey through the senses to the cortex, we arrive at the last obstacle to understanding how the human brain responds to stimuli. How do we know which items of our information about the environment are correct and which are not?

We now know that the human thinking process is subject to numerous sources of error. All identifications of the objects in nature, as well as their connections, are assumptions, which might be incorrect. We bridge the many gaps in our information with assumptions, which also might be incorrect. Moreover, our identification of complex dynamic relationships is especially subject to error.

We can see that most people behave in ways that are counter-productive, which implies that at least some of their information must be incorrect. Nevertheless, everyone thinks that all of his or her information is correct. If asked to identify a single incorrect item, most people cannot do so. What's going on here? How can all of your information be correct and everyone else's be wrong? What mechanism could account for this weird contradiction?

On Being Correct

An item of information is considered to be correct (i.e., a "fact") if it correctly identifies an object or a relationship among objects in the real world. For example, "The sun is one of billions of stars in the Universe" is a correct item; "The sun is a ball of burning coal" is an incorrect item. "A bear can run faster than a man" is a fact; "Toads cause warts" is not a fact. "Make haste slowly" is correct in some situations and incorrect in others. In many cases, we don't know if an item is a fact or not, as in "Honesty is the best policy."

Evaluating Information for Correctness

A primitive multi-celled creature flees from a set of stimuli it interprets as a predator. These creatures have no mechanism for any kind of thinking. They cannot identify the stimuli, they do not choose a response, and they don't know if their response is appropriate. Nevertheless, let's assume they are sensate creatures that can do all of these things.

As this creature survived an encounter with the set of stimuli, it would consider its interpretation of the stimuli to be correct. When it encounters a similar set of stimuli, it responds in the same way and so survives. Therefore, it automatically considers its interpretation of this set of stimuli is also correct.

The way the human brain evaluates the correctness of an item of information appears to be a relic of the way primitive creatures made this decision billions of years ago. The human brain evaluates the correctness of each item of information when it detects it. Whether or not this items is a correct interpretation of the real world is not a factor in this evaluation. It is determined solely by the compatibility of the new item with the information already present in that subject area.

First information in a virgin subject area - A "virgin subject area" is one in which a person has no information. The entire brain of a newborn baby is a virgin subject area, but the brain of every adult is still virgin in many subject areas.

For example, an ancient ancestor is told that the orange object in the sky is a god. His recirculating signals bring all items in his brain associated with gods into his thought pattern. As there are no items that contradict this new information, his thought pattern consists only of information compatible with the stimuli detected.

As a result, his interpretation of his thought pattern is essentially identical with the information he has just received. The orange object in the sky is a god. So the first item in a virgin subject area is uncritically accepted as correct, whether it is or not.

Subsequent compatible items – A young child is told by an angry mother that he is a bad boy. As he has no other information in this subject area, he interprets his thought pattern as, "I am a bad boy."

This first memory is followed by numerous similar incidents. Each incident brings previous statements that he is a bad boy into his thought pattern. As the items in this latest incident are compatible with the information already present, they cause little or no change in his interpretation of the thought pattern. So a new item that is compatible with the bulk of the information in a given subject area is uncritically accepted as correct, whether it is or not. He is a bad boy.

Contrary information – One day, this boy, cleaned up for the occasion, meets and shakes hands with his aunt, whom he hasn't seen in recent years. She says, "What a good boy you've become!" These stimuli bring all his unforgotten memories about his behavior into his thought pattern. His brain must now find some interpretation that includes both his prior information and this new item. Depending on the other information present, he might interpret his thought pattern as, “She knows I’m a bad boy and is just being sarcastic.” Or his other information might lead to, “I’m a bad boy but she doesn’t know it yet.”

When the brain can find some interpretation that accounts for the both the old and the new information in the thought pattern, the new item modifies its interpretation to some degree but does not change it fundamentally. He is still a bad boy. The contrary new item is incorrect.

Contradictory information – In this example, a man has a fatal cancer. He reads in a magazine that a new drug is a cure for his cancer. However, when he checks with his doctor, he is told that this new drug is toxic. There is no way his brain can interpret a thought pattern in which the drug is both therapeutic and toxic. So at least one of these items must be incorrect. But how does his brain decide which is correct and which is incorrect?

At this point, a brief digression might help clarify the origin of this impasse. A primitive creature automatically moves toward a stimulus it interprets as a benefit. If it then learns that this stimulus is a threat, it would move away from it. So when it detects this stimulus again, the creature would try to move both toward it and away from it at the same time.

As this is impossible, this decision depends on how much of each type of information is present in the brain. For clarity, this analysis starts with a preponderance of one type of information and then considers lower ratios.

A substantial majority of compatible items – A person who has a lot of compatible information in a subject area detects a contradictory item. This new item is such a small part of the total information present that it does not noticeably affect the interpretation of the thought pattern. In effect, the brain uncritically rejects as incorrect a new item that is contradictory to the bulk of the information it already has, regardless of which is right and which is wrong.

Because almost everyone rejects and then forgets incompatible information, most adults accumulate a preponderance of compatible items, right or wrong, in most subject areas. As a result, their responses to stimuli in this subject area are essentially unchanged by any new item of information. This condition is an example of the sign that reads

> "My mind is made up;
> Do not try to confuse me with facts."

Several compatible items - A person who has several compatible items in a subject area detects a contradictory item. In processing all its information, the thought pattern might arrive at a slightly but not significantly different interpretation. In effect, this person retains his or interpretation, so here again the contradictory item is rejected as incorrect, whether it is or not.

Although detection of a contradictory item does not affect the response to the stimulus significantly, it does form a sensory pathway for this information. A contradictory item is usually soon forgotten through disuse, so that each later detection of a similar item has the same lack of effect on the response. Sometimes, however, similar contradictory items are detected frequently enough so that their pathways remain enhanced. Each additional detection in this subject area brings both the old information and the incompatible items into the same thought pattern. At some point, the newer items might outweigh the former majority and so change the response to the stimulus. This is the mechanism for changing anyone's mind, including your own.

When there are only a few compatible items, even a single contradictory item can modify the response. The more items in a thought pattern, the less effect each new item has on its interpretation.

About equally balanced – When contradictory blocks of information are about equally balanced, the thought pattern can be interpreted either way. This condition causes the person to shift back and forth from one alternative to another, unable to carry out any of them. This person "can't make up his mind."

This situation is vividly illustrated by Pavlov's experiment with a dog. He sounded a buzzer as he fed the dog so that it advanced when it heard this sound again. He made a sound of a different frequency when he gave the same dog an electric shock. The dog fled when it heard this sound again. Pavlov then gradually brought the two sounds closer together until they became indistinguishable. The same stimulus now caused the dog to try to approach and to flee at the same time until it had a dog's version of a nervous breakdown.

Conflicts of this type also occur in people, as in having a job that attracts you for the money but repels you because of your boss. Or a man is attracted to a woman for her beauty but is repelled by some aspect of her personality. The situation is easily resolved when the items associated with the stimulus overwhelmingly favor one response over the other, but it becomes life threatening when the alternatives are about equally matched. A conflict of this type in a minor subject area is “stress,” which is harmful enough. In subject areas affecting survival, this conflict can cause a physical illness, including a mental breakdown.

You can reduce this conflict by adding favorable associations to one alternative and unfavorable associations to the other so that they are no longer equally attractive or equally repelling.

Relative strength of contradictory items –A person who accepts completely the Biblical version of creation sees the skeletons of ancient creatures. If he or she believes his or her eyes, his or her information on Biblical creation would be incorrect. However, this is seldom the case. Because of the greater volume of Biblical information, the brain continues to consider its present information to be correct and so attempts to interpret the new item in that context. For example, the visual information might be interpreted as bones deposited during the Biblical flood or as fossils formed by God to test our faith.

Where the information present is less strong, however, even “one ugly fact can destroy the most beautiful assumption.”

The Effect of this Mechanism for Deciding Correctness of an Item

This bizarre way in which the human brain evaluates new items of information is responsible for the majority of all errors in the human thinking process. It causes everyone to think that his or her interpretation of the world is correct and that every different interpretation is incorrect.

This mechanism not only introduces errors, but also makes it difficult to correct them. The more erroneous information a person has in a subject area, the more difficult it becomes to correct it.

It is very difficult to prevent this source of error. Most incorrect initial items in a subject area occur when a child is unable to defend himself. Parents, who wouldn't think of putting bad food into a child's body, put incorrect information in his or her brain, which will make the child just as sick.

Even adults are not safe from this source of error. As there is only one correct and many incorrect interpretations of each item, most interpretations are incorrect. So based solely on chance, the first information received in any subject area is usually incorrect.

Well, what can you do about it?

- You can recognize that any item of your information might be incorrect.
- You can tag all the information you receive as unproved, which will help both in letting contradictory items into the brain and make it easier to remove incorrect items.
- You can avoid making a frontal attack on entrenched information, which only reinforces it. It's better to plant a seed of correct information and cultivate it.

In summary, the correctness of an item to the brain is simply its compatibility with the bulk of information already present. The brain uncritically accepts as correct the first item is receives in a virgin subject area. It then uncritically accepts all items that are compatible with the bulk of its information and rejects as incorrect all items contradictory to the bulk of its information. As a result, correct information inhibits the acceptance of incorrect items but incorrect information just as effectively inhibits the acceptance of correct items.

26. THE COMPOSITE RESPONSE

Timing of the signals – Detection of a set of stimuli initiates a sensory signal that is sent to both the motor organs and to the brain. As there is a direct connection from each sensory organ through the cortex to a motor organ, the emotional signal arrives almost instantly. A small but finite amount of time is required for the thinking mechanism to process the information detected by the senses, so the intellectual signal arrives at the motor organs a fraction of a second later.

As it arrives first, the emotional signal starts a movement toward or away from the stimulus, so there is always an incipient movement in every response, even to internally generated stimuli. The intellectual signal then arrives and merges with the emotional signal.

When an immediate response is required for survival, the emotional signal responds before the intellectual signal arrives, so the response is entirely emotional. An example is the immediate emotional response to flee from a threat before the thinking mechanism can process this information to arrive at a more appropriate response.

The Emotional Signal

As advanced creatures almost always respond to source of the stimuli detected, they first need to identify it. This identification occurs through their interpretation of the sensory pattern formed by detection of the stimuli. However, this identification might be correct or incorrect.

The intensity of the emotional signal is related to the effect that the source of the stimuli might have on survival. A stimulator that threatens inevitable death, such as an inescapable predator, generates an intensely negative emotional signal. A stimulator that would save a person's life when survival seems hopeless, such as someone who provides water when the person is dying of thirst, generates an intensely positive emotional signal. The less directly a stimulator affects survival, the weaker the emotional response it causes.

The intensity of the emotional signal is determined not by the true source of the stimuli but by what a person interprets it to be. Interpreting a sensory pattern as a rattlesnake causes an intense emotional signal, even if the object is really an old leather belt.

Imaginary sources - The brain does not distinguish between real sources of external stimuli and imaginary sources formed by internally generated signals. For example, the threat of eternal damnation can generate a stronger emotional signal in some people than encountering a drug addict with a loaded gun.

Unknown sources - Some sensory patterns are partially or completely unknown to the viewer so that he or she doesn't know how it might affect his or her survival. Nevertheless, he or she does get some indication of its effect by the commonality of its attributes with the sensory patterns in his or her memory. For example, large creatures are more threatening than small ones, those that move swiftly are more threatening than those that move slowly, those that have big teeth or sharp claws are more threatening than rabbits. The word “cancer” in a diagnosis is a life-threatening stimulator even though most people have no idea what it is.

In summary, the intensity of the emotional response depends on each person’s interpretation, correct or incorrect, of how much the source of the stimuli detected can affect his or her survival, positively or negatively.

The Intellectual Signal

The strength of the intellectual signal is determined by the amount of information in the thought pattern generated by detection of the stimuli. The more information a person has about the set of stimuli and how to deal with it, the more neurons in the thought pattern are energized and so the stronger the intellectual signal. The intensity of the intellectual response is based on the volume of information, right or wrong, in the thought pattern at that time.

The Composite Signal

A composite signal is a combination of an emotional and an intellectual signal. The combination can vary from a strong emotional signal with little or no intellectual content to a strong intellectual signal with a weak emotional content.

For example, a person identifies the source of the stimuli as one that affects survival, initiating a strong emotional signal. When this person has very little information on how to deal with the source of the stimuli, his or her intellectual signal is weak. As a result, the overall response to the stimulus is almost entirely emotional. An example is the response of most people to detection of a mugger. At the other extreme, some people have so much information in a subject area that their intellectual signal almost completely suppresses their emotional response to most sets of stimuli. An example is the “absent-minded professor.”

A gradual change in the relative strength of the emotional and intellectual signals is seen during the maturation of children. They start with a strong emotional and a weak intellectual signal, resulting in frequent aggression or tearful flight. The intensity of their emotional signals is reduced as they learn that most stimuli do not affect their survival while the intellectual signal is strengthened as they learn more about how to deal with the stimuli they encounter.

Nature of the Response

In single-celled creatures, the response is always a simple movement toward a benefit or away from a threat.

The response of a more advanced creature takes into account the conditions at the time. Its response can be a series of actions instead of a single movement. For example, a lion might not attack its prey directly but first move upwind to increase its chances of success.

The vast amount of information in a human thought pattern permits a wide variety of responses to the source of the stimuli detected. Sometimes the response is a simple movement, as in flicking away a fly. Or it might be a complex series of movements, as in outmaneuvering a threat. In some cases, the response is a planned pattern of actions over months or years.

Plasticity of the Response

Primitive creatures always respond to the same stimulus in the same way, but do advanced creatures really respond to the same stimulus in different ways?

Different people often respond differently to detection of the same set of stimuli. This occurs because the stimuli detected bring a different set of associated items into each person's thought pattern. So each person's response is almost always different from the response of anyone else.

But why does the same person respond very differently to the same stimulus at different times? There are two reasons why the same person responds differently to the same set of stimuli. One is that the associated items in his or her thought pattern has changed since he or she last detected these stimuli. He or she has might have added some associations and forgotten others.

The other reason is that, as noted, the human sensory organs detect all the stimuli within their capability. So, although the principle stimuli detected are the same, the other stimuli present might be quiet different. For example, a wife might respond differently to her husband in public than she would at home. A person responds differently to a greeting when he or she feels good than when he or she is ill. That is, the "conditions are different."

As the same thought pattern is always processed to the same response, these examples imply that the response would be the same if all the conditions were the same. In that case, people have no more choice in selecting their response to a stimulus than a single-celled creature does.

Response to Multiple Sources of Stimuli

A person usually detects stimuli from more than one source simultaneously. When one of the sources has much more effect on survival than the others, the mechanism finds the best response for these stimuli and ignores the others. When two or more sources of stimuli are significant, this process arrives at a compromise response; that is, a response that is not the best for any single source, but is the best balance among them.

Further insight into the effect of the emotional and intellectual signals is shown in the feelings they cause, which will be described in the next chapter.

27. FEELINGS

We experience life both through our thoughts and through our feelings. Although thoughts and feelings are commonly considered to be distinctly different, even diametrically opposite, they both occur through the detection of stimuli.

The thinking process evolved to improve a creature's response to stimuli in order to increase its chances of survival. Feelings evolved to report on the success or failure of that activity.

Occurrence of Feelings

A feeling occurs when the brain interprets the nature of the source of the stimuli detected. Identifying the source of the stimuli as something that promotes survival, such as food or a friend, causes a good feeling. An interpretation that threatens survival, such as a predator, causes a bad feeling.

Another feeling occurs when the result of the response to the source of the stimuli is detected. Obtaining a benefit or escaping a threat causes good feelings. Failing to obtain a benefit or failing to escape a threat causes bad feelings. As a result, we feel good when we achieve any objective and feel bad when we fail to achieve an objective.

The set of stimuli detected might be a real external object or an imaginary item. This imaginary item might be the memory of a past event, a non-existing creature, or something that might or might not happen in the future. The same feeling, positive or negative, occurs with an imaginary item as with a real object.

The feeling that occurs is not based on the actual effect of the stimuli detected on that person's survival, but on what he or she interprets that effect to be.

Feelings Association with Social Acceptance

Feelings evolved originally to inform an individual of his or her chances of physical survival. However, about 40,000 years ago our ancestors began to form cooperative groups. Acceptance by a group greatly improved a person's chances of survival, while rejection was a sentence to a short life and painful death. As a result, social acceptance became directly associated with survival. Through this association, most people now have about the same intensity of feelings for social acceptance as for their physical necessities for survival.

We feel good when our social acceptance is promoted, as with compliments, salary increases, and being invited to activities by those we consider socially superior. Conversely, we feel bad when our social acceptance is threatened by criticism, by exclusion from group activities, and by rejections.

Level of Feelings

Long-term - At every point in life, each person has had a different set of experiences, some of which are retained as memories. Some are memories of achievements, good health, and financial security. Some are memories of an unhappy childhood, of difficulties at school, of unpleasant employment, and of injury or illness. Most people, of course, have some combination of successes and failures.

These memories, accompanied by their feelings, are brought by association into many thought patterns. As a result, each person has some general, often unconscious, feeling of his or her chances of survival based on previous experiences. This general feeling is a person's "ego." A person's ego is some variation of "good" when he or she thinks his or her chances of survival are good, and feels some variation of "bad" when they are not. For example, "optimism" is a positive feeling about a person's chances of survival, while "pessimism" is a negative feeling.

Intermediate-term - Intermediate-term feelings are commonly known as "mood," which is a move up or down from a person's basic feelings about his or her chances for survival. It is based on the ratio of his or her major successes compared with failures in recent responses to stimuli. Frequent successes lead to a "good" mood, with feelings such as confidence and hope, while frequent failures cause a bad mood, with feelings such as frustration and dejection. Although a single new experience can change a person's mood from positive to negative or vice versa, most moods last for hours or weeks.

Short-term - These feelings occur in the detection and response to each set of stimuli. They modify a person's present mood, up or down. Short-term feelings change frequently as each new set of stimuli is detected and with the success or failure of each response.

Nature of Feelings

Each feeling has the same ratio of emotional and intellectual components as the composite physical response to the stimuli detected.

The emotional component - The emotional component of the feeling that occurs is determined by the effect the source of the stimuli has on that person's survival. Interpretation of the source of the stimuli as a benefit causes good feelings. Interpretation as a threat causes bad feelings.

The intensity of a feeling, good or bad, is determined by how much the source of the set of stimuli detected might affect that person's chances of survival. For example, detecting food when you are hungry causes a more intense positive feeling than when you are sated. Learning that you have liver cancer causes a more intense negative feeling than learning that you have skin cancer. A bigger raise in pay causes a more intense positive feeling than a smaller increase.

The intellectual component – The intellectual component modifies the feeling in two ways. As noted, the emotional component is formed by the preliminary identification of the stimuli detected as a potential benefit or a threat. As more information enters the brain pattern, its first interpretation might be modified. The source of the stimuli might now be seen as more or less threatening or more or less of a potential benefit. This intellectual change in interpretation modifies the intensity of the feeling, up or down.

The more information a person has about how to deal with the source of the stimuli detected, the stronger the intellectual component, which reduces the intensity of the feeling. For example, the more a person knows about how to deal with the source of a negative set of stimuli, such as a cancer or a crocodile, the less afraid of it he or she is. Conversely, increasing knowledge about the source of a positive set of stimuli dilutes the emotional component so that the good feeling becomes less intense. An example is the gradual loss of the good feeling about Santa Claus.

A Matrix of Feelings

A feeling can range from almost 100% emotion with little intellectual content to almost 100% intellectual with little emotional content. This combination of an emotional and an intellectual component forms a matrix of feelings. The matrix is subdivided imprecisely into segments, each of which is given a label. The matrix of the feelings that can occur when someone achieves his objective as shown in the following diagram:

FEELINGS ON ACHIEVING AN OBJECTIVE

Exultation	Triumph	Joy	
Elation	Happiness	Pleasure	
Delight	Gratification	Satisfaction	Contentment

Intellectual Component

As an example of this matrix of feelings that occur on achieving an objective, consider a schoolboy who is afraid of the classroom bully. Detecting the bully causes a moderately intense emotional component. As he has little knowledge of how to deal with the bully, his intellectual component is quite low. So if this boy defeats the bully, the moderate emotional component and the low intellectual component would result in a feeling of "elation."

Another classmate is wary but not afraid of the bully. As he has taken karate lessons, he is reasonably confident that he can defend himself. So his feeling on defeating the bully would be “satisfaction” on achieving the same objective.

A similar table can be prepared for the feelings that occur upon failing to achieve an objective, such as being rejected for a job or by a desirable mate:

FEELINGS ON FAILING TO ACHIEVE AN OBJECTIVE

Emotional Component				
	Anger			
	Despair	Depression	Disappointment	
	Displeasure	Frustration	Regret	
	Resentment	Pique	Chagrin	Annoyance
	Intellectual Component			

There is a matrix of feelings for each situation that affects a person’s chances of survival, including gaining or losing social approval. Some of these situations are shown in the following table:

Situation	Feeling
Continued failure to achieve an objective	Depression
Minor social error	Embarrassment
Unknown or incompletely known stimuli	Fear
Assistance in achieving an objective	Gratitude
Achieving an objective unfairly	Guilt
Unfairly causing others to fail to achieve their objectives	Guilt
Others interfere with achieving your objectives	Hostility
Social error that hurts others	Regret
Regaining social status (e.g., revenge)	Satisfaction

Of course different people might subdivide the feelings within a matrix in different ways or label them differently. The objective here is to show that feelings are not random but are related to the emotional and intellectual signals that occur in the response to a stimulus.

The Effect of Errors on Feelings

When you detect a set of stimuli, you have a feeling, good or bad. This feeling, however, is not determined by the true source of the stimuli, but by your interpretation of its source.

Your response to the stimuli also causes a feeling, good or bad. Here again, your feeling is not determined by the true result, but by your interpretation of the result. Your might think that your presentation to the committee was well received and so feel good, when, in fact, most members didn't like it.

There is only one situation in which the detection of the source of the stimuli or your response to it should cause a bad feeling. This occurs when you correctly identify a threat. This might be called an "appropriate bad feeling."

However, bad feelings also occur through errors in the thinking process:

- Incorrectly identifying a benefit as a threat.
- Incorrectly identifying one type of threat as some other type of threat.
- Responding inappropriately so that you fail to obtain a benefit.
- Responding inappropriately so that you fail to escape a threat.
- Responding correctly to a misinterpretation of a threat so that your response is inappropriate for the real threat.

As these bad feelings are caused by incorrect thoughts, they might be called "unnecessary bad feelings." They are unnecessary in the sense that they can be changed by correct thoughts. Just as physical pain is a signal that something is wrong in your body, unnecessary bad feelings are a signal that something is wrong in your thinking process. By thinking better, you can feel better.

ERRORS INHERENT IN THE HUMAN THINKING PROCESS

Nature did not design a new brain to suit the requirements of each new creature that evolved. The new creature inherited the brain of its ancestors but gradually modified it through chance mutations that increased its chances of survival. Sometimes, the evolving brain was unable to keep up with rapid changes in the creature's environment. A mental activity that was advantageous in an ancestral creature sometimes became disadvantageous in its more sophisticated descendants.

The human brain inherited a number of these shortcomings. In some ways, despite the addition of billions of neurons over billions of years, the human brain still performs in ways established by primitive creatures. Unless we know what these shortcomings are and how to avoid them, we tend to make the following errors:

1. The first information detected in any virgin subject area is uncritically accepted as correct, whether it is or not.
2. The brain automatically accepts as correct a subsequent item that is compatible with the information it already has, whether this item is correct or not. It automatically rejects contradictory information as incorrect, again whether or not it is incorrect. As a result, correct information impedes the acceptance of incorrect information, but incorrect information just as effectively blocks out correct information.

3. The brain has no internal way to distinguish a correct item of information from an incorrect item. To the brain, the correctness of an item is simply its compatibility with the majority of the information already present in that subject area.
4. The brain has no way to know if it has all the information necessary to respond appropriately to the source of a stimuli it detects.
5. The brain misinterprets similar items as being identical.
6. The brain is not aware of connections among items that are not present in the same thought pattern.
7. The brain has no internal way to know that a formerly correct item has become incorrect because of changes in the environment.
8. The brain has no way to measure anything. All measurements occur through comparisons, which are often made incorrectly, especially in intangible items.

Each of these errors due to shortcomings in the equipment, together with how to handle them, has been described in detail in my earlier writings and so will not be duplicated here.

I hope you enjoyed our journey!

POSTSCRIPT

A display of a human brain is not impressive. Physically, it's a gray blob of protoplasm, weighing about three pounds, and about the size of a small roasted chicken. It doesn't have eyes or ears or any visible moving parts. The only indications of internal activity are numerous gullies. So what does it do and how does it do it?

Nevertheless, this blob of protoplasm has had some almost unbelievable achievements:

- It transformed a weak creature into a super-species that now has the power of extinction over all creatures except some microbes and insects.
- It expanded the range of its senses to detect microscopic atoms as well as galaxies billions of light-years away.
- It has begun to explore the world beyond its environment by sending people to the moon, robots to sample the planets in the solar system, and it has looked back almost to the origin of the Universe.
- It created profound literature, exquisite music, great science.
- Perhaps most incredible of all, this brain that evolved to serve only the person of which it is a part, has learned that it helps itself by helping others.

These achievements are even more remarkable when the brain's limited capabilities are considered:

- The brain has no way to identify the source of the stimuli it detects in its environment. It can only assume what they are. The correct identification of even common items has taken millennia of trial and error and is not yet complete.

- The brain has no way identify how the objects in nature are connected. All connections of objects are assumptions that might or might not be correct.
- It has great difficulty identifying indirect relationships, especially those among causes and their effects.
- It has no way to know if it has all the information it needs to respond appropriately to the stimuli it detects or what additional information it needs.
- Its memories change during storage so that correct information often becomes incorrect.
- It is unaware when an item of information becomes incorrect because of a change in its environment.
- It misinterprets similar items as being identical.

We could cope, with some discomfort, with these shortcomings of the human brain. However, there is one cluster of serious errors that is beyond our present power to control:

- The brain uncritically accepts as correct the first information it receives in a virgin subject area, whether or not this item is a correct interpretation of the external world.
- The correctness of an item to the brain is determined only by its compatibility with the majority of information already present in that brain. Whether the item is a correct interpretation of nature is not a factor in this assumption.
- The brain rejects as incorrect any new item that is contradictory to the bulk of its information in a given subject area. As a result, correct information rejects incorrect items but incorrect information just as effectively rejects correct items.

As a result of accepting incorrect information about the world, this same brain has contributed to:

- Genocides, wars, aggressions, slavery, torture.
- The abuse of the weak by the strong, including abuse of women and children, taking resources from others, economic exploitation, etc.
- Intolerance, even to the death, over religious differences.
- Superstitions, spirits, and other erroneous assumptions.
- Unnecessary destruction of other species.

Nevertheless, I believe there has been some slow progress from the time when we burned heretics and enslaved defeated enemies. Perhaps, as more people understand how the human thinking process works, we will interpret our world, and ourselves, more correctly.