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Negotiating Cognitive Dissonance

If you were listening to a spoken tape recording which had some interference on it but was still comprehensible, how hard would you try to make it clearer? The answer probably depends on whether you agreed with what you were hearing! In 1967, the experimental psychologists Timothy Brock and Joe Balloun played for their subjects a tape-recorded message attacking Christianity.[1] Some of their subjects were steady churchgoers, whereas others seldom if ever went to church. But Brock and Balloun deliberately added static to the recordings. They found that the non-churchgoers tended to make a concerted effort to clarify the message by removing the static. The churchgoers, on the other hand, were more likely to live with the static and let the message remain hard to hear.

Brock and Balloun did another study where they put static in a tape-recorded message that linked smoking to cancer. Again, it was the non-smokers who made the effort to remove the static and clarify the message. Smokers tended not to make the effort and to leave the static alone.

These psychological studies show that people want, all other things being equal, to get outside inputs consistent with their own previous beliefs and actions. That is, they try to avoid conditions that lead to *cognitive dissonance*, a term originated by Leon Festinger.[2] Cognitive dissonance means the ability of a person to simultaneously hold at least two opinions or beliefs that are logically or psychologically inconsistent. In some cases the believer is aware of the contradiction. In other cases she or he is only conscious of the two beliefs separately, in different contexts.

Academic research on cognitive dissonance was popular in the 1950s and 1960s but then went out of fashion for many years. The attention of both cognitive and social psychologists turned in that period to "cold cognition," that is, cognitive tasks that don't evoke strong emotional responses. This type of experiment was, in general, easier to perform than "hot cognition" where strong emotions are involved.

That is because "cold" experiments require less elaborate telling of cover stories to the subjects and pose fewer ethical dilemmas. Gradually, though, social psychologists returned to a strong interest in emotional aspects of motivation, starting in the mid-1980s. This included a revival of research into the factors influencing cognitive dissonance.[3] In addition to the academic interest in the subject, cognitive dissonance has remained a useful concept in folk psychology as well as some forms of psychotherapy.

Festinger described some typical reactions to cognitive dissonance as follows:

> 1. The existence of dissonance, being psychologically uncomfortable, will motivate the person to try to reduce the dissonance and achieve consonance.
> 2. When dissonance is present, in addition to trying to reduce it, the person will actively avoid situations and information which would likely increase the dissonance.[4]

But *how* do they try to reduce it? There's the rub. Some people resolve dissonance by "tuning out" information that threatens their biases or preconceptions. This is one reason why many people are attracted to "total systems" of beliefs, whether in religion, politics, or psychotherapy. But other people use more imaginative and complex methods of resolving dissonance, and these tend to be more self-actualized.[5] Specifically, self-actualized people are more likely to synthesize conflicting elements rather than decide between them. Self-actualized people are also less likely to resolve conflicts by repressing information about their environments. This will lead me to construct a series of brain- and neural network-based hypotheses about how self-actualized cognition might be organized biologically, and how it differs from cognition in people who aren't self-actualized.

The situations that Festinger describes refer to subjects who have already made decisions but may receive information that is inconsistent with a previously made decision. For example, a person may have become a heavy cigarette smoker because s/he likes the taste of a particular brand of cigarettes or finds they reduce tension. If the same person receives new information that smoking is likely to have worse effects on health than s/he previously thought, s/he could react in many possible ways. S/he could change her or his behavior, by quitting smoking. Or s/he could change his or her cognition, by denying the new information about the health risks of smoking. Or s/he could integrate the new information but still decide that the benefits of smoking outweigh the risks.

The smoking example shows that the effort to reduce dissonance often can lead to selective repression of information that argues against previously made decisions. The tendency to repress is greater when there is heavy personal investment in the decisions. For example, Festinger discusses data on people who have just purchased new automobiles, a decision that looms fairly large on the investment scale. After purchase, these people tended to look at advertisements for the brand of car they had just bought more than they did at advertisements for other types of cars.[6]

Since Festinger's seminal research, there has been some dispute among psychologists about the importance of dissonance. There has been evidence suggesting that people are most likely to feel bad about performing actions that conflict with their professed attitude when their actions are likely to have been harmful or unpleasant to others, and when they perceive they have personal responsibility for those bad consequences.[7] More recently, though, it was found that dissonance in and of itself, apart from its anticipated consequences, can lead to physiological discomfort. For example, Eddie Harmon-Jones and his colleagues gave some experimental subjects a choice to write on a piece of paper that a bad-tasting drink in fact tasted pleasant. Then the subjects were asked to throw that piece of paper away so nobody would be influenced by it. In spite of the lack of consequences of their acts, the subjects who pretended the drink tasted pleasant still showed an increase in their skin's electrical conductance, which is a typical physiological measure of emotional discomfort.[8]

That a *cognitive* mismatch can be *emotionally* uncomfortable is hard for many people (researchers as well as lay people) to accept. This is because those people believe the common nonsense that the cognitive and emotional spheres are separate. But the emotional effects of cognitive dissonance make sense in a dynamic neural network in which cognition and emotion are deeply intertwined. And there is much evidence of emotion and cognition being intertwined in the actual brain. The frontal lobes, which are involved in high-level cognitive processing, are also connected heavily with the limbic system and hypothalamus, which are areas involved in drive and emotion.* The hypothalamus exerts regulatory control over the autonomic nervous system, which influences skin conductance and other physiological responses to environmental events.

Moreover, the emotional distress resulting from cognitive dissonance makes sense for the purposes of adaptation. This is because accurate information processing increases the predictability of our interactions with a complex environment. If the information we receive is contradictory or lacks coherence, this provokes anxiety about our ability to cope with the environment's demands.

Levels of Mental Conflict Resolution

Festinger's definition of cognitive dissonance mainly emphasized mental conflicts that occur *after* a decision is made. But other psychologists have used a similar theoretical perspective to understand conflicts that occur *before* decisions are made. For example, Daniel Wegner and Robin Vallacher discussed different ways that people handle what they call *evaluative inconsistencies*, that is, combinations of different pieces of information that could lead to positive and negative evaluations of the same person or the same course of action.[9] We turn now to these different strategies for resolving inconsistencies. That should provide clues for neural organization of high-level cognitive information processing and how it differs between individuals.

A 1954 study of evaluative inconsistency by Eugene Gollin, largely confirmed by later studies, is discussed in Wegner and Vallacher's book.[10] In Gollin's work, subjects were shown a film of the same young woman engaged in a range of behaviors. The first two scenes suggested that she was sexually promiscuous, which would be likely to lead to a negative evaluation (more so in the 1950s than it would have more recently!) After a neutral middle scene, the last two scenes suggested that she was kind and

* While different parts of the frontal lobes seem to be specialized for cognitive and emotional functions (see Fuster, 1997), these two parts are heavily interconnected and most neuroscientists consider them part of a unified system.

considerate, which would be likely to lead to a positive evaluation. Then the subjects were asked to describe this woman in writing.

Gollin found that subjects tended to fall in one of three categories of description, which were called *univalent*, *aggregative*, and *integrative*. Univalent descriptions focused on either the woman's promiscuity or her kindness, ignoring the other entirely. Aggregative descriptions mentioned both the promiscuity and the kindness, but separately, without trying to form a unified impression. Integrative descriptions included an effort to form a unified explanation encompassing both sets of behaviors, such as "she's happy-go-lucky" or "she's easygoing."

Most of us are univalent, aggregative, and integrative at different times. Which strategy we adopt depends in part on how compelling the two "sides" of the information conflict are. For example, if we see a person being kind over several years, one short period of promiscuity may have little effect on our impressions of the person. Wegner and Vallacher reported other studies in which univalence can be disguised as integration.[11] Some subjects exposed to information that a person was loyal but also sarcastic and stubborn formed a global negative impression of the person, and then explained away the loyalty as blind faith in authority.

But the strategy a person uses to resolve inconsistency also depends on internal personality factors of the decision maker's. One of these is how much he or she relies on his or her own creativity as opposed to accepting outside judgments.

Not only is the amount of integration widely different among individuals, it varies a great deal in the lifetime of the same individual. Typically, children are most prone to using univalent strategies. Aggregative strategies first emerge just before adolescence and integrative strategies during adolescence.

Now let's return to the Festinger-style, post-decisional form of cognitive dissonance. Psychological experiments on cognitive dissonance have only begun to address different types or levels of conflict resolution.[12] The most common method of resolution is changing an attitude after one has acted in a manner contrary to the attitude. But the psychologists R. A. Elkin and Michael Leippe showed that in some cases, such attitude change doesn't relieve the physiological discomfort (such as skin response) caused by the dissonance![13] My unconfirmed speculation is that this experimental result reflects old folk sayings like "the body doesn't lie" and "one convinced against their will is of the same opinion still."

Would a "higher level" of resolution reduce physiological measures of discomfort? There don't seem to be any results on this. But recent work of Leippe and his colleagues suggests that people adopt more elaborate methods of dissonance reduction, rather than simple attitude change, when they have greater emotional investment in the attitude involved.[14] For example, Margo Monteith induced white subjects who showed little anti-black prejudice to discriminate against a black person.[15] These subjects had a great investment in seeing themselves as egalitarian and fair-minded, so were hurt deeply when made aware they had acted contrary to this self-image. As a result, most of them engaged in some elaborate cognitive restructuring[16] by reading an essay about how easily people can fall into discriminating behavior and thinking about how that might be avoided. The long-term effect may be to enable these people to live more fully by their egalitarian beliefs. This kind of cognitive restructuring is less common when the issue involved is more trivial (e.g., imposing a small parking fee at a university). In the latter case, either the attitude may change or the dissonance may simply be forgotten.

But high levels of dissonance on important issues don't always lead to cognitive restructuring. They sometimes lead instead to emotional paralysis.[17] The factors which make people resolve dissonance in one way or another haven't been studied much, but would seem to involve personality differences as well as social contexts. It seems likely, for example, that "higher levels" of resolution and more elaborate restructuring are associated with greater creativity. For example, Albert Einstein arrived at his theory of relativity through a lengthy process of cognitive restructuring. This occurred after he noted dissonances between the existing Newtonian theory and recent observations of other physicists, both of which he had strong investment in.

Higher levels of resolving dissonance also seem likely to associated with greater self-actualization. Abraham Maslow noted that self-actualized people bridge dichotomies between important elements in their mental makeup (e.g., emotion and reason), rather simply living with the dichotomies or suppressing one side of them.[18] So far, little has been done to integrate these three seemingly related areas of psychological study — cognitive dissonance resolution, creativity,[19] and self-actualization. But in the current integrative climate of psychology, I expect there will soon be experiments that bridge two or more of these three areas. The "systems approach" provided by neural network theory should aid in seeing the relationships between these concepts and providing testable hypotheses about them.

The next section begins the exploration of cognitive strategies in model neural networks. The network model will provide a metaphorical description of some of the interacting psychological processes involved in self-actualizing tendencies, which may be stronger or weaker in different people or at different times within the same person. Some of these processes I interpret tentatively as analogous to amounts of certain brain chemicals or electrical activities of certain brain regions.

Self-actualization as Optimal Cognition

Self-actualized people tend toward what Wegner and Vallacher called integrative strategies of absorbing conflicting information. Whenever possible, they resolve ambiguities in a way that synthesizes conflicting interests within the mind rather than choosing between them. This allows them to bridge typical dichotomies such as serious versus playful, masculine versus feminine, strong versus generous, rational versus emotional, by innovative solutions to complex problems.

Maslow was among those who believe that human behavior is not necessarily, or even much of the time, optimal. He believed that only about one in a hundred people are fully self-actualized, but most of the rest of us achieve that level of function in fleeting, rare states that he called *peak experiences*. This suggests that our brains are all capable of being in optimal states but are not there all or most of the time. I will attempt to use brain science and neural networks to get a mechanistic description of what constitutes optimal mental function (including behaviors, concepts, and beliefs) and how a system can move from less optimal to more optimal function. This will in turn suggest some scientific hypotheses about the "imp of the perverse": why don't all people, all the time, move toward optimal performance? Why do we only improve our mental states some of the time, and at other times get mired in states that we know are unsatisfying or unpleasant?

To attempt to answer these questions, we need to look for variables that differ between people, or within the same person as a function of mood, and that influence how likely we are to achieve optimal cognition. It will turn out that a key variable is one that measures a person's willingness to accept and live with partial satisfactions.

To describe a hypothesis about self-actualization, I will employ the mathematical language of *dynamical systems* (the same field that is more popularly known as *chaos theory*; see Chapter 4). A dynamical system can be defined roughly as a description of the changes over time in some set of interacting variables. In a neural network, some of the interacting variables are activities of nodes, which may correspond to average frequencies of electrical impulses among thousands of neurons. These activities could relate either to brain region electrical or metabolic activity, or else to strength of a particular emotion, memory, percept or behavioral plan. Other variables are connection weights, which may correspond to average amounts of some chemical transmitter substances at synapses. These connection weights correspond to associations between brain areas or between concepts.

In neural network theory and in economic decision theory, there is often a mathematical function of all the interacting variables that in some way roughly describes the system's goals (in a negative manner, that is, what the system is trying to avoid or minimize). An optimal state is where this mathematical function reaches its smallest possible value. In some systems arising from physics, the function being minimized is an energy expenditure, so the minimum energy denotes the least effort or least resistance. In a psychological or social system, the function is more abstract, but the terminology of "energy" is still often used since the mathematical theory is the same as for a physical system. In economics, this function might represent a cost, but for generality I will still use the term *energy*. This abstract function is also sometimes called a *Lyapunov function* after the early Twentieth Century Russian mathematician A. M. Lyapunov* who was a pioneer in dynamical systems theory.

A variety of system algorithms have been derived for achieving such a minimum energy. I will propose another such algorithm and conjecture that it approximates some process occurring in actual brains. The database about self-actualization is extremely wide and diverse, so our discussion must be fairly abstract at this stage. However, mathematical description can help us see analogies across diverse fields. In addition, my proposed model will lead to some very tentative suggestions about possible involvement of specific brain areas and chemical neurotransmitters in the processes discussed.

Global Versus Local and Part Versus Whole

The idea of an energy minimum is shown symbolically in Figure 7.1. The system's state at any given time is represented abstractly as a point in space ("where you're at," metaphorically), which allows one to visualize the changes over time in a dynamical system.[20] In this picture, the point in space is occupied by a "ball bearing." The coordinates of the point in space represent a pattern of activity levels of different network nodes (see Chapter 2) or different mental subsystems. The curves in that figure represent some of the possible paths (*trajectories*) for that system as it moves through time. The height represents the system energy or Lyapunov function, and it can be shown mathematically that the trajectories always move from higher to lower energy. So if lowest energy represents optimal functioning, the system is guaranteed to move toward an optimal state, right?

Wrong!

As Figure 7.1 indicates, our abstract ball bearing can get stuck in a "well" around an attractor that is not the lowest ("optimal") point on the curve, such as the point *"A"* in the figure. Analogously, a neural

* Alternative spellings include Liapunov, Liapounov, and Lyapunoff.

dynamical system can get “stuck” in a state that is lower in energy than the surrounding states, but not the lowest for the entire system. In mathematical terminology, such a state is called a *local minimum* of the energy or *local attractor* for the system, as opposed to the *global minimum* which is the very lowest point on the curve. What does this mean for psychological and cognitive functioning? A local minimum is a model of, or at least a metaphor for, a psychological state that is not the best imaginable but may seem to be the best that is currently available. (In

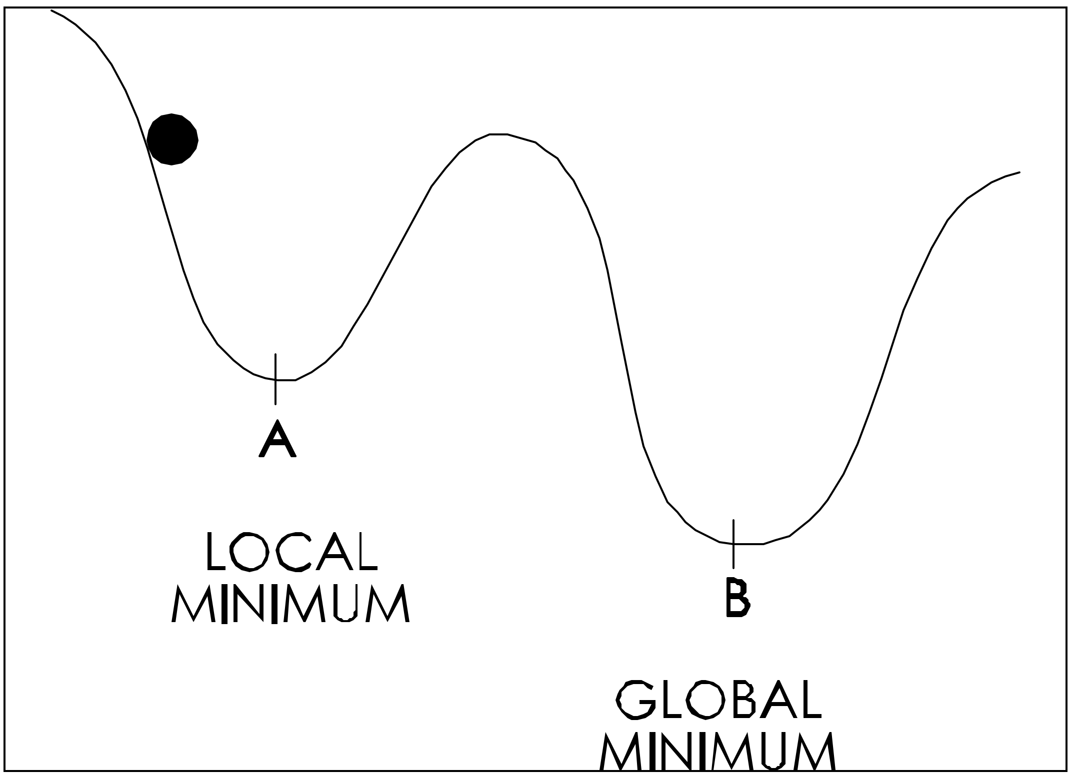

Figure 7.1. The path of the variables in many neural dynamical systems is analogous to the path of a ball bearing along a curve (representing the system “energy function”). Like the ball bearing, the system eventually reaches a local minimum state of the energy (either A or B in this figure). (Adapted from Rumelhart and McClelland, 1986, Volume I, with the permission of MIT Press.[21])

decision theory and economics, Herbert Simon coined the term *satisficing* for the act of seeking such an imperfect but partially fulfilling state.[22]) This could include, say, a decision to accept a job or relationship that doesn't fulfill all of your previous desires or expectations, but is adequate and meets some of your needs.

Many computer algorithms have been devised to move a system out of a nonoptimal local minimum of an energy function, and closer to an optimal global minimum. One of the most popular of such algorithms is called *simulated annealing*.[23] I won't go into a technical description of simulated annealing, but the basic idea is embodied in the name. Annealing is a process in metallurgy, in which a metal is heated to increase flexibility when a change in shape is desired, and then cooled when the desired shape has been achieved. In a neural network, "heating" and "cooling" are not actual but metaphorical processes. "Heating" means an increase in random "feverish" activity. If the network "heats up," the probability of random fluctuation out of the current state is increased. If the network decreases its random activity or "cools down," this fluctuation probability is decreased. Specifically, when the "ball bearing" of Figure 7.1 is trapped in one of the local attractors, random noise is added to the network (it is "heated") to "shake the bearing loose" until it gets to a state where it is drawn to the global energy minimum (point "B" of that figure). When it is heading in the desired direction, the noise is removed (the network is "cooled").

Figure 7.2 depicts my neural network theory that applies simulated annealing to human decision making. The basic needs of the organism are encoded by a network of nodes (represented by light or dark circles) that compete with each other for satisfaction (competition indicated by the minus signs on the pathways between nodes). Each need node represents fulfillment of a different drive such as hunger, sex, safety, esteem, or meaning. In a widely read paper, the neural network theorists Michael Cohen and Stephen Grossberg mathematically analyzed a neural network made of such competing nodes.[24] Cohen and Grossberg proved that their network has an energy or Lyapunov function and that every trajectory of their system moves toward an attracting state that is at least a local minimum of that function. The model of Figure 7.2 connects this network of needs to other networks that do other things. One of these networks is a "world modeler" that compares the current level of satisfaction with potential satisfaction.

The world modeler "imagines" various possible states of the need subsystem and calculates the mathematical energy function (see Figure 7.1) for each. This world modeler may be analogous to part of the brain's frontal lobes, which are believed to encode representations of projected future states.[25]

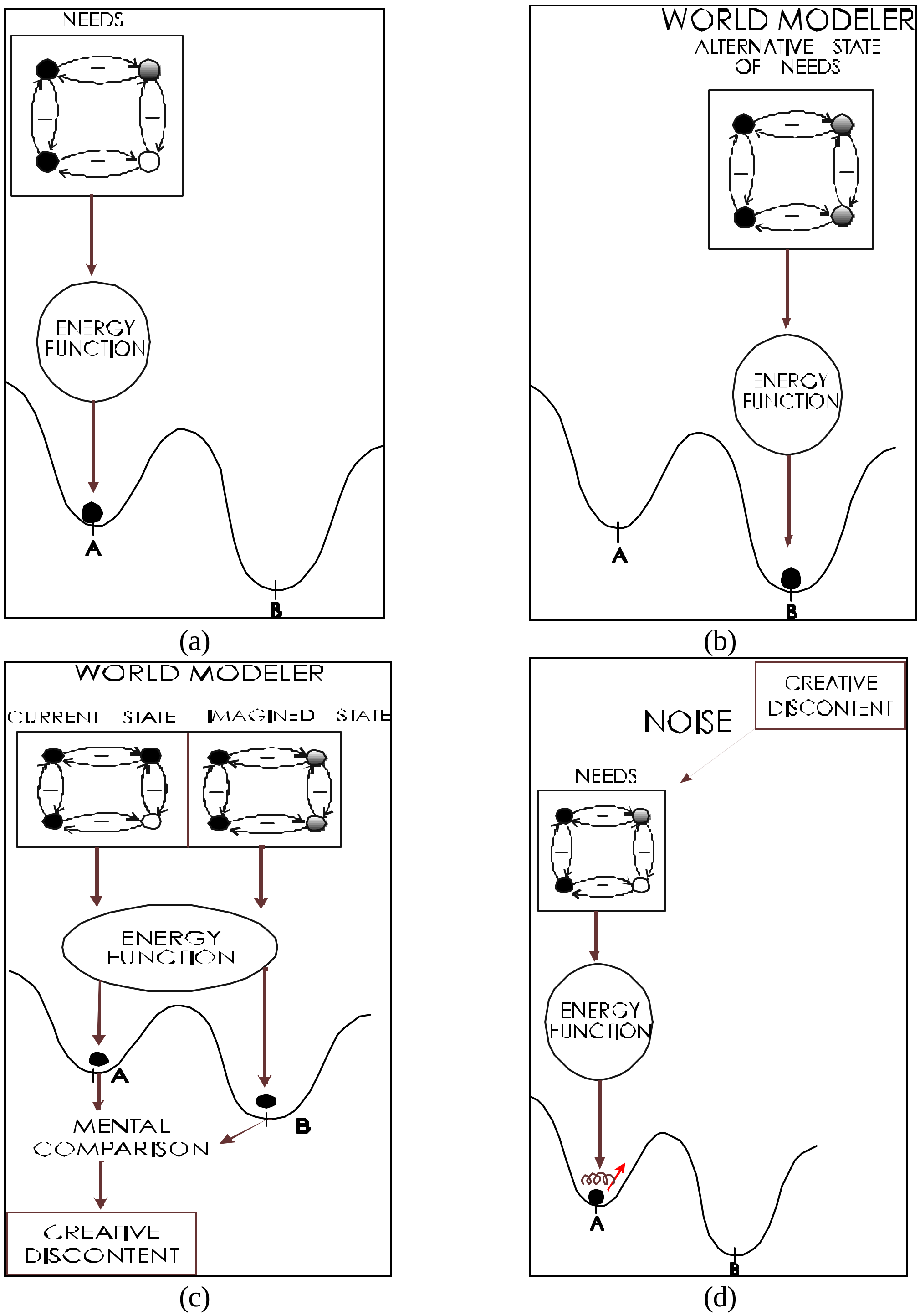

Figure 7.2. Neural network model of self-actualization. (a) Needs compete with one another (see minus signs inside the "Needs" box). (b) The world model imagines a "better" alternative state (mathematically, one with a smaller energy function than the present one). (c) Then a "mental comparison" takes place at the "creative discontent" node. (d) This in turn sends noise to perturb the balance between needs and "shake" the energy "ball bearing" out of the nonoptimal local minimum at A. (Adapted from Levine, 1994, with the permission of Lawrence Erlbaum Associates.)

If the (abstract) energy of some other projected state is less than the energy of the current state, the network gets into a state that is analogous to human discontent. That is, the network "wishes" to change its state because it "thinks" that another possible state is "better." In the network, this means that a signal is sent to a "discontent" node that in turn sends random noise back to the need subnetwork. This noise can move the needs subnetwork out of a less than optimal local minimum, as in the classical simulated annealing algorithm. The "discontent" may be analogous to the role described by the neuroscientist Antonio Damasio for the orbital part of the frontal lobes, which seems to rule out possible courses of action which would be too emotionally unpleasant or painful.[26] This can be the kind of discontent that fuels creativity and drives innovative approaches to life!

So if self-actualization means reaching the optimal state, what is meant by a "self-actualized" version of this network? Both the discontent signal and the response to it must be strong. If either the signal or response is too weak, the network never leaves its unsatisfying local minimum. By analogy, a person will never escape the "traps" of dead-end jobs, relationships, or activities unless she or he both feels conscious of discontent at this situation and motivated to act on this discontent.*

Now how might we define the optimal state of this mental-emotional network? It should be, on the average, a state that meets the greatest possible number of needs. Not only should it deal with basic survival needs like safety and food, and then "mid-level" needs like love and belonging, but also the needs for development of full potential, spiritual meaning, and a sense that one is benefitting society.

So far I have been discussing development of potential in individuals. But what about society as a whole? Think of society as an organism analogous to an individual, only more complex. In dynamical systems terminology, as long as society is stuck in an undesirable "local minimum" that meets the needs for order, safety, and coherence, but not the needs for meaning, richness, and loving closeness, no individual

* The reader who has seen the web site "www.disgruntled.com" for people dissatisfied with their jobs and seeking more creative work options may wonder if I am the Daniel S. Levine who tends that web site. I like what he's doing and we have the same name including middle initial, but we're not the same person!

can be fully "whole." A dominator society like present ones, partially successful but riddled with common nonsense that artificially limits human potential, can be thought of as a "local minimum." The more desirable "global minimum" is a partnership society built on common sense, love, and cooperation.[27]

But we can't wait around for society to "self-actualize" before we do. A partnership society can only be created by people moving in their own imperfect lives toward a partnership ethic. This means people must be willing to take risks by creating "noise" that challenges the comfortable, yet uncomfortable, "local minima" of a dominator society. So my neural network theory of self-actualization can also be used as a metaphor of society attempting to grow toward a partnership model. Now let's try to build on this network metaphor and speculate as to what influences might propel a person (or society) toward, or away from, self-actualization.

How Can Our Brains Meet More of Our Needs?

The theory that love and meaning are basic biological drives as much as food, sex, or safety fits into Abraham Maslow's idea of the hierarchy of needs.[28] This idea has generated much controversy among scholars, with the sociologist Geert Hofstede[29] and others showing apparent refutations of it in cross-cultural studies. But Maslow emphasized that he didn't imply by *hierarchy* a strict all-or-none progression, as it is often misunderstood, just a tendency for some needs when pressing to override others.[30]

Some personalities and cultures can more easily than others accept temporary dissatisfaction of a lower-level need in order to try to resolve the "whole picture" by meeting some of the higher-level needs. In his doctoral dissertation on the processes of choice, Sam Leven stated that there are three major styles of problem solvers: "Dantzig" or direct solvers who try simply to achieve an available solution by a repeatable method; "Bayesian" solvers who play the percentages and try to maximize a measurable criterion; and "Godelians"[*] who use both intuition and reason to arrive at innovative solutions.[31] Godelians are risk seekers: they are more likely than the other two solver types to accept temporary cognitive and emotional discomfort in order to achieve high-level understanding. But they are *more* sensitive than the other types to cognitive dissonance at high levels. A good example was Albert Einstein. Einstein

[*] These three names, based on those of famous mathematicians, are explained in the caption of Figure 6.1.

experienced cognitive dissonance between some new (relatively minor) results on light and radiation and the Newtonian paradigms for physics. Instead of glossing over the data (as many other top-level physicists did), he was motivated to make major changes in the paradigms.

So my neural model of self-actualization and the hierarchy of needs is subject to immense variations of network connection parameters that represent personality differences. When there are variations in connection parameters in a neural network, the different variations can represent cognitive or behavioral profiles of different people (as they did earlier with the “normal” versus “frontal-lobe damaged” performance on card sorting). So in this case, different versions of the network could represent either a person “stuck” at lower-level needs, a person exploring high-level needs while lower-level ones aren’t fully met, or a person with all needs basically met.

And different moods or environments can radically change these connection strengths in the same person! This lends us hope that a person stuck in bigotry or helplessness, a family stuck in dysfunctional roles, or a society stuck in distrustful hierarchies is not doomed to those patterns forever. The same person, family, or society is capable of changing its network parameters and getting to a better state.

Often, a different context or mood can change the person’s or society’s state, as it did in the case of Old Coke and New Coke (see Chapter 6).[32] In a neural network, the influence of mood might be simulated by modulation from another signal that can strengthen some needs at the expense of other needs. This signal could be a biochemical one, mediated by one of the chemical neurotransmitter substances in the brain such as dopamine, norepinephrine, serotonin, or acetylcholine.[33] For example, neurotransmitters can respond to physiological signs like low blood sugar and stomach contractions by selectively strengthening the food need. An unsatisfying local minimum (see Figure 7.1) may be one that satisfies a few needs fully but others not at all. If some of the needs (say, the lower-level needs like food and safety) suppress the others too much, higher-level needs like spiritual value may be unmet, but the lack of satisfaction of these needs is ignored.

The system for modeling self-actualization (or the lack of it) can be regulated on many levels. One process to be regulated is competition among needs. Competition doesn’t necessarily mean one wins completely. It can be steered either toward either “winner-take-all” (a few needs dominating others) or “stable coexistence” (many needs satisfied to varying degrees). Another process is the strength of signals from the discontent node to the production of noise. Such regulation can be achieved by extending our network with additional connections that exert some modulatory effect.

We don't yet know enough to identify exactly the locations in the brain of the nodes and their modulators in this neural network. But we do know enough to make some provocative suggestions. Either the needs nodes or the error signal may be located in some part of the amygdala, an area of the brain's limbic system that is involved in calculating emotional values of sensory events.[34] The orbital part of the frontal cortex has extensive feedback connections with the amygdala. The effects of connections from frontal lobes to amygdala would include the functions of the "world modeler" in that figure, and would also include controlling the strength of the "noise" signal from the discontent node. I suggest this because Brenda Milner[35] and other clinical neuropsychologists have observed that many frontally damaged patients express frustration when they fail on a cognitive task. This frustration, however, doesn't make them change their behavior. This hints that the frontal lobes play a key role in translating emotional reactions into motor actions.

The amygdala is also heavily influenced by synapses, from a region of the midbrain (see Figure 1.1) called the *locus ceruleus*,[36] using the neurotransmitter norepinephrine (NE). In addition to enhancing novel or significant inputs,[37] norepinephrine plays a role in generating cognitive attributions and beliefs. People or animals deficient in norepinephrine tend toward learned helplessness and lack confidence in their ability to influence events.[38] A milder form of learned helplessness, with an intermediate NE level, could make people passive about satisfying higher-level needs if lower-level needs are already met. In other words, the person may feel confident about satisfying a limited set of needs, and so not be globally helpless, but still not feel confident about satisfying needs for meaning and self-expression. This is an emotional state characterized by effectiveness at basic survival but missing out on the richness of life. Henry David Thoreau called it "quiet desperation."

In the neural network described by Figure 7.2, I conjecture that norepinephrine signals could directly affect competition among all the different needs. Stephen Grossberg showed mathematically that in a neural network of mutually inhibiting nodes, the dynamics can either be winner-take-all (one or a few nodes suppressing the activity of all others) or coexistent (many nodes active over time).[39] In addition, he showed that uniform excitatory signals can have the effect of spreading electrical activity around the network, so that more nodes become active. Here, the NE signal could play the role of such an excitatory signal. Figure 7.3 shows how the dynamics of the needs network can become more winner-take-all with a low NE level, since fewer need nodes become active. The dynamics become more coexistent with a high NE level. So a larger norepinephrine level moves the network toward stable attracting states that satisfy a greater number of needs.

Self-actualization and Information Processing

Now that we've outlined a very tentative theory of interactions and choices between drives (Maslow's "hierarchy of needs"), let's look further at what constitutes satisfaction of a

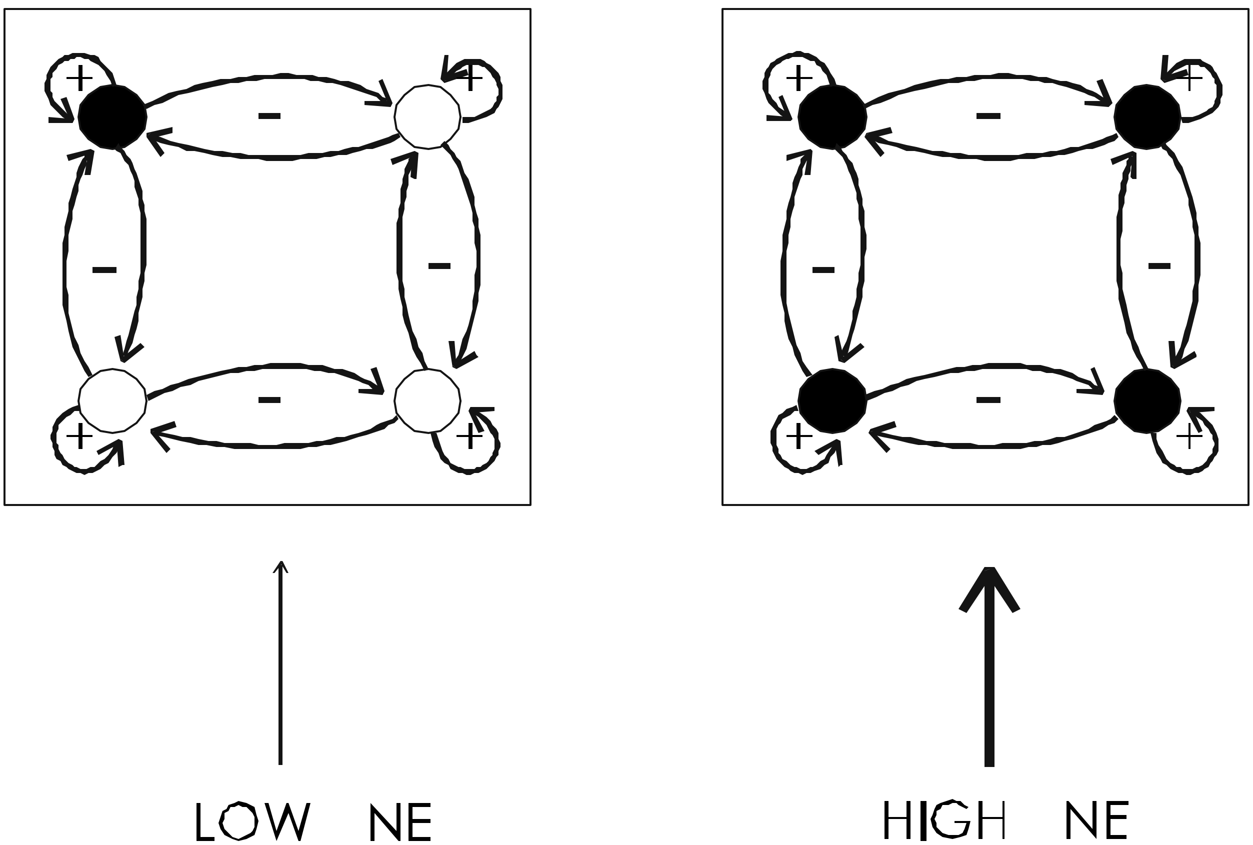

Figure 7.3. Effect of noradrenaline (NE) level on a network of competing nodes, such as the needs subnetwork of Figure 7.2. Dark circles indicate nodes with positive long-term activity.

"self-actualization drive."[40] Since self-actualization involves a feeling of completeness, let me conjecture (without hard evidence) that it's analogous to a somewhat simpler process of completion that takes place in vision. If much but not all of a familiar visual pattern, like the letter A, is in view, the eye and brain together reconstruct the rest of this pattern. This has been termed *pattern completion* in the neural network literature.[41] Some artificial neural network devices for computer vision have been able to replicate this reconstruction process. Neuroscientists and neural modelers often build hypotheses using the principle of *parsimony,* that is, the notion that general types of neural structures that appear in one brain area are likely to reappear, perhaps in different combinations, in other areas. So if we can understand how visual pattern completion works, we might be able to suggest, by analogy, some hypotheses for the many brain processes that go into the cognitive and emotional "completion" that constitutes self-actualization.

In humans, visual pattern completion depends on how familiar the context is. For example, once when living in Boston I was driving in the downtown area and saw a road sign in the distance. While the sign was far enough away that the letters looked blurry, I could immediately tell (correctly) that it pointed the way to Logan Airport. This was possible because of my familiarity with the city. I wouldn't be able to make sense out of a blurred road sign in, say, Kansas City, having only gone through there on the Interstate twice in a total of an hour.

The mechanism for pattern completion in the brain (or an artificial neural network) will not be discussed in detail, but relies on the existence of a stored representation in memory of what the complete pattern should be like. This is why it depends on some degree of familiarity. Can we say, speculatively, something analogous about the self-concepts comprised by self-actualization?

In the case of self-actualization, a "pattern" is harder to define, but it could be an entire environment as perceived by a person. This would include perceptions from the internal organs of the body (*interoception*) as well as from the traditional five senses of sight, hearing, touch, smell, and taste (*exteroception*). The frontal lobes of the brain would seem to play a critical role in self-actualization, since the frontal cortex has the special function of combining exteroceptive and interoceptive information.[42] In this function, it seems to be part of an integrated system including some brain areas below the cortex, such as the hippocampus and amygdala (see Figure 1.1). The frontal cortex exists in all mammals, but is most developed in humans and other primates, where it has six layers as opposed to two in other mammals.

In addition, the frontal cortex exhibits characteristic patterns of electrical activity while the mind pictures different possible actions. This led the neurophysiologist David Ingvar to coin, as a description of frontal lobe function, the fanciful expression “memory of the future.”[43]

Are there, somewhere in the brain, “superpatterns” of neural activity with varying degrees of completeness that include both actual and anticipated events? There is some fragmentary evidence that this is so, from electrical recordings of single neurons in the monkey frontal cortex and electroencephalographic (EEG) recordings from the human cortex. The neuroscientist Joaquin Fuster and his colleagues looked at cells in the frontal lobes of monkeys performing a behavioral task called *delayed matching to sample*.[44] This was a task where the monkeys first saw a particular object, then that object was taken away, then their scene changed to one that included a copy of the original object. In the new scene the monkeys were trained, using a food reward, to move toward the object that matched the original one. Fuster and his colleagues found some groups of cells in the frontal lobes were electrically active during the presentation of the first object; others were active while the monkey was being rewarded; still others were active while the monkey was responding to the matching object. They concluded that the frontal lobes included “representations” of all these different parts of the task.

Fuster’s idea was reinforced by some results on human subjects. Alan Gevins and his colleagues looked at EEG recordings from people before the performance of either an accurate or an inaccurate movement.[45] They found one EEG component in the *parietal lobes* of the cerebral cortex (see Figure 3.2) that occurred before either type of movement, and another component in the frontal lobes that occurred only before an accurate movement.

Now if such a “superpattern” is incomplete — say, if a person is in a situation but not currently achieving the satisfaction she or he would wish — how does he or she know the course of action that will complete the pattern? I mean “know” not in a purely rational sense but in a sense that combines reason and intuition. The work of the clinical neuroscientist Antonio Damasio suggests that this kind of combined “knowing” is deficient in patients with damage to the orbital part of the frontal lobes.[46] This is the part of the frontal lobes which has strong connections with the amygdala, the part of the brain’s limbic system that seems to measure the emotional value of sensory events.[47]

On a basic cognitive level, such as reading a blurred road sign in a familiar or unfamiliar city, perception of a potential complete pattern depends heavily on learning. Learned patterns, such as cultural beliefs and mores, also play a major role at the higher cognitive levels. But there is also a part of perceptual pattern completion that's inborn. Infants, for example, try to visually track a moving object after it has moved behind a screen.[48] This indicates that the infant has a neurally stored belief in the continuity of motion even when such continuity isn't directly observed.

The parsimony principle suggests that pattern completion at the higher cognitive and emotional levels includes a part that is inborn and genetic, just as it does at the perceptual levels. Both of the brain areas mentioned in this section — the orbital frontal cortex and amygdala — seem likely to be part of this hard-wired "emotional pattern completion" system.

Another aspect of self-actualization is creative synthesis of previously conflicting concepts or beliefs. This kind of synthesis can be present to varying degrees in different people. The clinical neuroscientists Lynn Grattan and Paul Eslinger, by observing cognitive effects of damage to different brain regions, found that generating new concepts involves somewhat different brain pathways than deciding among old concepts.[49] While decisions among old concepts involve connections between the frontal lobes and basal ganglia (the subcortical "decision area"), generation of new ones involves connections between the frontal lobes and other parts of the cerebral cortex where memories and associations may be stored.

Figure 7.4 suggests a continuum of possible human behavior types from the most "disintegrated" to the most "integrated." Behavior of people with frontal lobe damage is at the bottom, with obsessive-compulsive or stereotyped behavior just above it. The next stage of integration consists of behavior based on winner-take-all (univalent, in the terminology of the psychologists Daniel Wegner and Robin Vallacher[50]) choices to act strong *or* generous, playful *or* serious, and so forth. Entrenched neurotic patterns in individuals, or entrenched bureaucratic patterns in institutions — the typical stuff of society's common nonsense — are often like that. Still more integrated are choices based on rational judgment between a fixed set of alternatives, which are often analogous to Wegner and Vallacher's aggregative choices. Such rationally optimizing choices are often quite effective in moderately complex situations. But if the claims of two paradoxical ideas, such as "strength" and "generosity," are strong enough, still more effective, though often riskier, choices are available from syntheses of the two alternatives. These are part of self-actualizing synthesis, which is at the top of the continuum.

Synthesizing paradoxes leads to new, integrative ways of acting and thinking in many areas of life. One example is combining generosity and strength into being powerful so as to empower others. Another is combining playfulness and considerateness into "if it harm none, do as you will," a motto of the neo-Pagan religious movement.[51] And this helps people see the possibilities of similar creative synthesis in our social institutions. We can then aspire to jobs for everyone that provide meaning as well as pay, politics that nourishes our sense of community as well as providing equal rights, and religious faith that encourages the search for truth as well as providing spiritual comfort.

Such high-level syntheses involve a blend of rational, affective, and instinctive processes, that is, all of Paul MacLean's "three brains."[52] This suggests, as does Figure 7.4, that such syntheses require the frontal cortex which is the chief communicator between the three brains.

Different degrees of self-actualization lead to different ways to resolve ambiguity. An example is Eugene Gollin's study of evaluating the person who was both promiscuous and kind.[53]

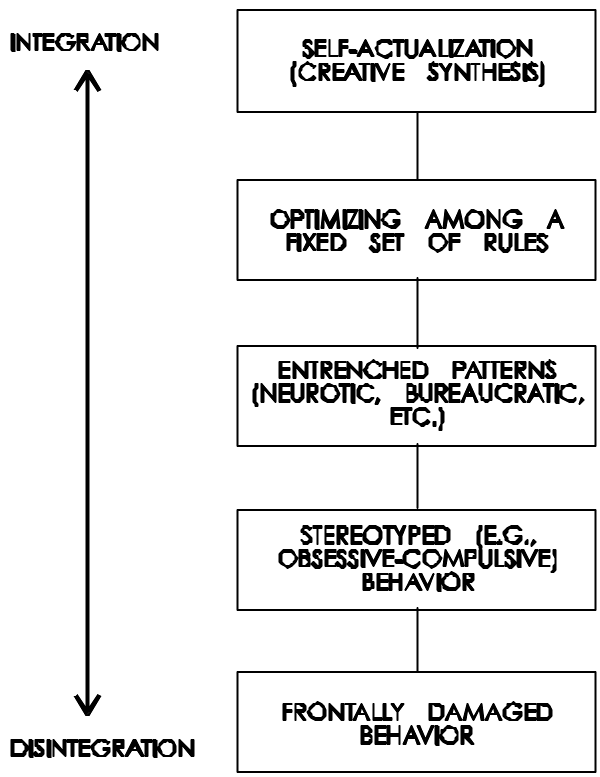

Figure 7.4. Continuum of behavioral patterns from frontally damaged to self-actualized, with stereotyped or entrenched behavior in between. (Adapted from Levine and Leven, 1995, with permission of Greenwood Publishing Group.[54])

The integrative strategy of conflict resolution involves an ability, and a decision, to transfer to a higher level in conceptual space if no decision made at a lower level is satisfactory.[55] Some existing artificial neural networks have this capacity to transfer levels of control. These networks contain more than one level of processing: a "lower level" that makes decisions in unambiguous cases, and a "higher level" that is called upon to decide if the lower level says "I don't know." They have been applied, for example, to simulating decisions by an insurance underwriter about whether to grant mortgage insurance based on personal profiles of applicants.[56]

Higher-level synthesizing resolution of conflicts is seen not only in people and machines but also in large social groups. One example is the community of scientific scholars. New resolutions of conflicts occur in paradigm shifts that accompany revolutions in scientific thought, as discussed by the philosopher Thomas Kuhn.[57] The ground-breaking insights of Copernicus, Newton, Lavoisier, Einstein, and others all resulted from recognition that (a) a few experimental observations couldn't be fit into a previously accepted theory and (b) a new theory was emerging that could synthesize these observations with other facts explicable by the old theory. When relativity theory supplanted Newtonian mechanics, for example, the first anomalous observations were seemingly minor ones, like an effect dealing with radiation from a black body. Before Einstein many other first-rate scientists, such as Max Planck, spent years trying vainly to explain these observations away. Kuhn stressed that scientists never simply reject the old paradigm; change doesn't occur unless they can think of another one to replace it.

A change of paradigm often depends on a shift in the level of explanation. The brain's frontal lobes seem to be involved in making such shifts. This conclusion is suggested by experimental data showing that frontally lesioned monkeys have difficulties on many cognitive tasks that are very different in detail, but have in common that getting food reward depends on learning to follow some abstract rule. Examples of rules that a monkey needs intact frontal lobes to learn are (a) choose whichever object is the most novel;[58] (b) alternate moving to the left and right;[59] and (c) press each one of several panels once, regardless of order.[60] In each case the monkey first tries a more concrete rule (e.g., go to a particular object or a particular color of object), and finds that following the simpler rule doesn't consistently yield food. So the animal then rejects the simpler rule and searches for a more abstract rule (e.g., go to the most novel object).

What might be the level-selection process mediated by the frontal lobes? By some dimly apparent mechanism, the brain networks seem to compute a mathematical parameter called *vigilance* that measures how much the brain will tolerate bad outcomes.* If the vigilance is small, lower-level rules will be accepted. If it is large, there will be significant dissatisfaction (analogous to the "creative discontent" of my model network) with low-level or univalent rules. This dissatisfaction leads to a search for more creative alternatives. The greater the degree of self-actualization, in general, the more such dissatisfaction is translated into action.

All people, whether rigid or creative, follow "rules" of behavior in the broadest sense of the word. That is, they form some sort of criteria that help determine what actions they will or won't perform. But the more self-actualized a person is, the greater the complexity, abstraction, flexibility, or subtlety of the rules she or he will tend to follow. This also relates self-actualization to Sam Leven's "Godelian" or risk-taking, innovative decision style described earlier. Since this process could involve many different dimensions of perceptual and cognitive experience at once, the cognitive scientist Douglas Hofstadter called it a *search of search spaces*.[61]

Besides the frontal lobes, what other brain regions might be involved in the search of search spaces? The neuroscientist Karl Pribram suggests the involvement of two areas of the limbic system, the hippocampus and amygdala (see Figure 3.1).[62] The evidence that Pribram reviewed suggests differentiated roles for the two regions; the amygdala is roughly associated with familiarity and the hippocampus with novelty. More specifically, lesions to the amygdala interfere with processing of parts of the environment that are currently being positively or negatively reinforced. Monkeys with amygdalar damage, for example, are less likely than normal monkeys to avoid locations in which punishment has previously occurred. Lesions to the hippocampus, by contrast, interfere with processing of parts of the environment that are currently *not* being reinforced. The hippocampus is therefore necessary for processing the currently irrelevant "background," which needs to be stored in case the context should change to the point where background information becomes necessary. An example of such a context change occurs when the experimenter rewards an animal's approach to a previously unrewarded object.

So the hippocampus is involved in orienting to novel events. Is it too fanciful to suggest that the hippocampus is involved not only in orientation within perceptual space, but also orientation within *belief*

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* Carpenter and Grossberg (1987) used "vigilance" in a neural network to mean the degree to which an input must match the stored prototype of a category to be considered a member of the category the prototype encodes. I am stretching Carpenter and Grossberg's usage but keeping within the spirit of their work.

space? The hippocampus has feedback connections with the parts of cortex that process all sensory modalities (vision, hearing, touch, smell); it deals not with raw sensory data but with storage of new associations in short-term and working memory.[63] The frontal lobes (the brain's "executive") are strongly connected to both the hippocampus and amygdala. If rules based on the dimensions that are currently emphasized don't lead to correct predictions, I conjecture that the frontal lobes suppress their signals to the amygdala ("familiarity locus") and increase their signals to the hippocampus ("novelty locus"). The hippocampus then somehow engages a search over attributes of the stimulus (e.g., the attribute of novelty) to which the person or monkey isn't currently paying attention. These dimensions could have been encoded at any of several brain levels. If a rule based on one of the newly relevant dimensions leads to accurate prediction of when the person or animal will get a reward, attention shifts to that new dimension.

Norepinephrine, Serotonin, and Pattern Classification

My account of the brain mechanisms that may be related to self-actualization, mood, and information processing is far from complete. There is also evidence that norepinephrine and other chemical neurotransmitters are involved somehow.

June Corwin and her co-workers studied classifications of words by subjects who were or were not taking some depression-inducing medication.[64] This medication mimics certain symptoms of depression by interfering with one type of cell membrane protein that takes up ambient norepinephrine. Corwin and her colleagues found that decreased available norepinephrine caused subjects to be more conservative in their criteria for admitting a new word to membership in a previously formed category.

From the viewpoint of understanding self-actualization, the finding of Corwin's group is a double-edged sword. Greater conservatism could mean excessive caution about making sense of the environment and therefore acting on it, which is bad for self-actualization. However, greater conservatism about category membership could also stimulate the innovative style that Sam Leven called Godelian, which favors forming novel categories when an input partly but imperfectly matches a previously formed category.[65] This promotes novel syntheses and possible paradigm changes, which are good for self-actualization.

Norepinephrine is closely related chemically to two other neurotransmitters, serotonin and dopamine; all three are produced in the midbrain.[66] The neurochemist Paul Willner gathered evidence that depression can involve abnormal levels of any one of these transmitters.[67]

The neural network theorist David Hestenes discussed evidence that serotonin tends to be low in bipolar (manic-depressive) illness.[68] This, he conjectured, relates to the function of serotonin in pattern categorization, which is to provide a "reality check" between inputs from the environment and categories of thought. The main evidence for this hypothesis is that the hallucinogenic drug LSD is known to interfere with transmission of serotonin (5-HT) from its main source in the midbrain. an area called the *raphé dorsalis*. Also, raphé dorsalis activity is decreased during REM sleep, the stage of sleep in which most dreams occur. Hestenes developed a tentative neural network theory for 5-HT action. Pattern processing in model networks typically involves a balance between excitation and inhibition among nodes representing different percepts, and he speculated that serotonin deficiency disrupts this balance and thereby distorts perceptions.

All this should make the reader appreciate the vastness and complexity of the brain network involved in regulating the satisfaction of our deepest yearnings. While we can be confident that midbrain-generated neurotransmitters are involved in pattern classification (and so in determining how we resolve ambiguous information), I won't yet hazard a guess about the exact nature of this involvement. Research in this area is still in its early stages: the modern techniques of mathematical computation are just starting to make contact with the rich literature on clinical biochemistry of mental function and dysfunction.[69]

I should add a caveat: understanding a mental function biochemically does *not* mean that difficulties with that function must be treated only by drugs! On the contrary, the neurochemist Paul Willner,[70] after an exhaustive analysis of what was then (in 1985) known about the biochemistry of depression, repeatedly said that the preferred treatment is usually a *combination* of drugs with a supportive environment. If that is true of clinical depression, it is even more true of more subtle forms of nonoptimal human performance, running the gamut from persistence in abusive relationships to mental blocks about learning mathematics.

So the reader shouldn't be afraid that biochemical understanding of mental function must lead to control of the population by psychoactive drugs, whether mediated by government control or by a free market.* For one thing, a drug that raises or lowers the level of a single neurotransmitter substance might be ineffective, or might have undesirable side effects. This is because the same transmitter is located in widely scattered brain areas and might have different effects in different locations. The clinical neuroscientist Daniel Weinberger and his collaborators, for example, have found evidence that dopamine in some parts of the limbic system may *oppose* the action of dopamine in the frontal cortex.[71]

Our current common nonsense about mental illness includes the false split of "biochemical versus functional disorder." This is a false split because every human interaction or decision profoundly affects our neurochemistry (later we will see physiological evidence of this). So an environmental change or a behavioral change is sometimes more effective in treating a biochemical disorder than any medication would be. And no matter how effective our psychoactive drugs become, they will never fully compensate for an emotionally hostile environment. There is no drug for an abusive family or a dominator society!

Promoting Global Thinking

Our neural analysis of self-actualization is in line with one of the buzzwords of our age, "global thinking" (in bumper sticker form, "Think Globally, Act Locally"). This is promoted on the large scale by many of our most optimistic popular writers about the future, such as Patricia Aburdene, John Naisbitt, and Alvin Toffler.[72] The neural network structures discussed here promote global, holistic thinking about all the different parts of our individual brains and minds.

Of course, global thinking can be misused. Currently, as global communications have increased and trade barriers between nations weakened, there is increasing global economic and social control by a few powerful multinational corporations.[73] But the only way to combat centralized power at the international level is to create global networks among workers, social change agents, and citizens as a whole. This can be facilitated by world-wide computer networks.

The self-actualized, integrative form of cognition can be described as effective "negotiation" between the disparate, sometimes conflicting, desires and needs within each of us. This process within the

* The lead article of the February 7, 1994, issue of *Newsweek* raises the specter of widespread chemical redesign of personalities, based on the enormous current American market for the antidepressant Prozac.

individual seems analogous to negotiation between people or groups, which has also been modeled in computer simulations of neural networks.[74]

Negotiation within a person and negotiation between people may follow analogous complex system principles.[75] Understanding this negotiation process, and how to manage it effectively, is vital for building a cooperative society. As our society becomes more complex and conflicts between disparate viewpoints become more overwhelming, interest in mediation is growing in many walks of life. The thrust of much of the legal profession to replace litigation with mediation whenever possible[76] is one of the more encouraging signs of the times. And this process might even be facilitated by artificial neural network technology! For instance, there have been preliminary suggestions on how to use artificial neural networks, and other computer techniques from artificial intelligence, in making legal "litigate or settle" decisions.[77]

Global thinking has metaphysical as well as practical implications. The emerging complexity of neural network studies will be one method for getting us closer to the common religious ideal of seeing all things as one, in spite of differences. For example, the motto of my own religion, Unitarian Universalism, is "Unity in Diversity." In the same vein, Hinduism sees the separateness of things as the ultimate illusion, known as Maya.[78] The Hindu outlook has been expressed poetically by the mythologist Joseph Campbell:

> The old Greek idea of Love as the eldest of the gods is matched in India by the ancient myth from the ... Upanishads ... of the Primal Being as a nameless, formless power that at first had no knowledge of itself but then thought, "I," aham, and immediately felt fear that the "me" it now had in mind might be slain. Then, reasoning, "Since I am all there is, what should I fear?" it thought, "I wish there were another!" and, swelling, splitting, became two, a male and a female; out of which primal couple there came into being all the creatures of this earth.
>
> ...
>
> For, according to the Indian view, our separateness from each in space and time here on earth — our multitude — is but a secondary, deluding aspect of the truth, which is that in essence we are of one being, one ground; and we know and experience that truth — going out of ourselves, outside the limits of ourselves — in the rapture of love.[79]

Self-actualized people, then, are people who can experience that "rapture of love" within the complexity of their own natures. That does *not* mean excessive self-involvement or avoidance of bonds with other people. On the contrary, it requires spiritual involvement with a cause or causes "outside one's skin," and an ability to appreciate all of life flowing from appreciation of self. It's not a grim asceticism but an outlook in which play, humor, sensuality, and spontaneity are valued as well as rationality and order.

This chapter hints that as we better understand the neural networks of our own minds, we can resolve much of the cognitive dissonance in our lives and our societies at high levels of integration. Some traditional conflicts of values, such as "reason versus emotion" or "idealism versus pragmatism," will increasingly seem like common nonsense. Synthetic and holistic ideas that bridge such conflicts will seem like common sense. Now let's explore further some of these traditional dichotomies and our best ways of negotiating between apparent opposites. The following chapter will now focus less on brain science, and instead deal with the implications of self-actualizing synthesis for other areas of life.

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