Consciousness in Animals and People with Autism

Temple Grandin, PH.D. - October 1998 Department of Animal Science Colorado State University Fort Collins, CO 80523 USA

Some scientists and philosophers believe that animals are not conscious and do not lead internal mental lives. They think animals are like robots which just respond to changes in the environment in mechanical ways. Others believe that animals have a form of "animal consciousness" which is totally different from human consciousness. This debate between philosophers and scientists has raged for decades. As a person with autism, my "autistic like" consciousness is different from normal people. I think in pictures and language is not used to form thoughts or make decisions. In this paper, I discuss my views of animal consciousness using comparisons from my experience with autism, and examples from a large body of scientific evidence on other neurological disorders which affect consciousness.

Selective Attention

Although people who are familiar with cats, dogs, horses, even cattle have no problem with the question of consciousness, scientific evidence indicates that there may be many different levels of consciousness in animals. In 1890, William James, the founder of modern psychology wrote; "consciousness grows more complex and intense the higher we rise in the animal kingdom." According to James, a relevant property of consciousness is the capacity of an animal to compare and selectively attend to experiences. As a visual thinker my ability to consciously compare experiences and make choices is less complex compared to people who use both visual knowledge and internal verbal dialog to make choices. In the following description of how I avoided a car accident, I explain how I use thinking in pictures to make conscious decisions. This example illustrates a level of consciousness that may be in some ways similar to consciousness in higher mammals. The near-accident occurred in fairly light traffic on a sunny day while I was driving to the airport on Interstate highway 25. Cruising along at 70 miles per hour in the southbound lane, I suddenly saw a huge bull elk running full speed across the northbound lanes. I knew I had to react quickly to avoid hitting him. Instantly, three pictures appeared in my mind. Each picture represented the end result of an option available to me. The first picture was of a car rear ending my car. I knew from experience that slamming on the brakes could cause this. The next picture was the elk smashing through my windshield. From my understanding of animal behavior, I knew that swerving or any sudden movement of my car might cause the elk to stop or slow down. The third picture was of the elk passing harmlessly in front of my car. In this picture I saw what would happen if I gently applied the brakes to slow

down. These pictures were like the picture menus one can click on an Internet web page. They appeared in my mind one at a time, but all within one second. This was enough time for me to selectively compare the options and chose the slow down gradually picture. I immediately calculated the elk's trajectory and speed coming across the highway, and my speed and position in the southbound lane, and began to slowly apply the brakes. This choice prevented me from being rear ended, or having the elk crash through my windshield. The conscious choice was a visual process without the use of internal verbal dialog.

At the moment I became aware of the elk crossing the northbound lane, I resisted the urge to make a panic response and slam on the brakes. In just seconds, I evaluated the three pictures in my mind. To use computer jargon, I conducted a basic cost-benefit analysis of the options. After running a quick video like simulation of the elk passing harmlessly in front of my car, I simply clicked a mental mouse on the "slowing down gradually" picture. I made a conscious choice from visual simulations played in my mind In another mishap on the highway, my ability to make a conscious choice was overridden by sudden panic. I was driving along a section of straight level highway on an icy night when a sudden gust of wind caused the car to skid. In this situation, I did not have time to make a conscious decision. It seems that conscious behavior can only occur when there is time to think, whereas instincts, reflexes, and simple conditioned responses take over when there is no time to think. For example, a grazing animal suddenly being attacked or chased by a lion relies on instincts and reflexes. These behaviors may not be completely consciousness. However, when an approaching predator is far away, an animal has time to decide on the best evasive action. When I hit the patch of ice, reflexes took over and I lost the ability to make an appropriate response. No option pictures appeared in my mind which could be used for making a decision. Reflexively, I began swearing uncontrollably and jerking the wheel in the wrong direction as I was skidding off the highway. I had no time to recall what I had learned about steering into a skid. My car ended up on the median strip, and fortunately, neither of us were hurt.

Some people question why I had three visual choices instead of just one. This is due to my visual associative way of thinking. In everything I do I see different choices as pictures on a computer monitor in my imagination. My thinking is not linear. I have learned by interviewing highly verbal thinkers that their thoughts are in language and they do not consciously see choices. Language may be another layer of thinking which covers up the visual pictures. I have no purely abstract thoughts. I only have pictures.

The "autistic type" of consciousness I used in both near accidents may be in some ways similar to conscious processes some animals use when they encounter danger. In both animals and people, conscious processes may have evolved as mechanisms for both avoiding danger and finding food. In other words, consciousness evolved as a means of allowing higher mammals to perform intelligent, adaptive responses to challenges in their environment. Rather than always relying on reflexes, simple conditioned responses, or hard wired instinctual behavior patterns, consciousness allows animals to make choices between several different options. Although consciousness is important, in most animals both instinctive and reflexive behaviors are also important. The instinctive killing bite to the throat that most predators do, the reflexive response

of a horse kicking at a predator on its heels, or the conditioned response of learning to avoid places that are full of predators, all evolved as mechanisms used for survival and may not require consciousness to perform. The questions of whether non-human animals have consciousness depends on what we mean by consciousness.

Orienting Response

On Thursdays, the garbage truck picks up trash in the neighborhood next to where Mark stables his horses. The moment the back up alarm sounds, all the horses turn and orient towards the sound. Like soldiers at attention, all the horses aligned their eyes, ears, head and body in the same direction. The orienting response is accompanied by increased heart rate, respiration, and blood pressure. The orienting response is also the point when animals switch from unconscious behavior to consciousness. Both animals and people orient towards novel sounds. In the wild, animals orient and freeze when they hear or see something that might be dangerous. A deer that hears the rustling sound in the bushes instantly freezes and turns both it's eyes and ears towards the sound. A deer will turn and face the noise before it flees. The orienting response provides time for the animal brain to make a conscious decision instead of just acting on reflexes and instinct. During the orienting response, the deer can decide to either flee or continue grazing. When I avoided the elk on the highway, I had time to make a conscious choice. But, when I skidded on the ice, there was not enough time to make a conscious choice.

Research has shown that the brain takes longer to process conscious awareness of a stimulus compared to an unconscious reaction to it. Up to half a second is required for full conscious awareness to occur after a stimulus is applied to the brain. For example, if you touch a hot stove, an unconscious reflex controlled by your spinal cord has already pulled your hand away before you feel the pain. Conscious processing of incoming information takes more time than a simple response governed by a reflex. A zebra kicking at a lion is probably relying on reflexes, but a zebra that hears a far away sound which may signal danger has time to weigh his escape options.

From my own experience, I have felt the difference between an orienting response and a fear flight response. For twenty years I have taken anti-depressants to calm constant anxiety attacks. Before taking the medicine I would wake up at 3:00 in the morning with my heart pounding. I was ready to flee from non-existent danger. This occurs because my nervous system has defects that put in a flight or fight stage for no reason. The medication blocks the massive fear response, but it has no effect on my tendency to orient towards intermittent high pitched noise. If I hear a garbage truck backing up in the middle of the night I still orient towards it.

Simple Consciousness

Worker bees communicate the location of food sources by performing dances when they return to the hive. When the colony gets ready to swarm, the workers go out and scout for suitable cavities in trees or buildings to build a new hive. Is this conscious behavior? Scientists have successfully built robot insects which mimic many of the behaviors of insects such as crickets and roaches. Although social insects such as bees and ants perform more complex behaviors than crickets and roaches, electronic circuits have been designed which can learn to walk by using a hierarchy of simple circuits. Scientists have also designed computer circuits that evolve and design themselves, or do amazing things such as compose Mozart like music. These circuits will often behave in ways that look intelligent, but they are definitely not conscious. None of the electronic components are conscious. They are based on physical principles. Although the animal brain is not the same as an electronic computer, I agree with writers such as Roger Penrose, and Daniel Dennett, that if improvements in computing continue at the present rate for a few for decades, it will possible to build a machine that simulates the way a human brain works.

For me, it is difficult to accept that individual bees are conscious. Could it possible that bees are more like elements in a biological computer? Perhaps the entire colony has a kind of collective consciousness where individual bees are like clusters of neurons in the brain, or electronic components in a computer. The creators of Star Trek came up with a scenario where humans loose their individual consciousness and become like bees in a hive. Called the Borg, their mission was to assimilate all life into the collective consciousness. By implanting electrodes in the brains of captured prisoners, everyone's thoughts are transmitted into everybody else's brain. Bach brain becomes like a component in a biological computer. A biological computer with a single collective consciousness is created and all individual self awareness is lost. An individual on patrol does not react as an individual, he only reacts after the Borg collective has processed the information.

Perhaps we will never know if bees are truly conscious, or if they're like a biological computer with a collective consciousness, or maybe something else. Barbara Shiffman, a mathematician at the University of Rochester has discovered that bee dances follow the same pattern as a theoretical mathematical shape called a flag manifold. Changes in the bee's dance can be predicted and explained by mathematical formulas. The flag manifold also explains the geometry of subatomic particles called quarks. Shiffman theorizes that bees may be sensitive to movements of subatomic particles which follow the principles of quantum mechanics which govern the movement of subatomic particles. I prefer to think of a bee colony as a biological computer because much of this is over my head.

Moving up the evolutionary ladder from insects, many biological scientists agree that mammals and birds have primary consciousness because they can process simultaneous stimuli and they have an internal representation of their experiences. Svene Sjolander states that a snake may not be conscious because it does not have a centralized representation of its prey. It seems to live in a world where a mouse is many different things. Sjolander explains that striking the mouse is controlled by vision; following the mouse after striking is controlled by smell; and swallowing the mouse is controlled strictly by touch. There is no integration of information from all the senses. Each sensory channel operates independently of the others. When a snake has a mouse held in its coils, it may still search for the mouse as if "the information from its body which is holding the prey did not exist." It appears that the snake has no ability to transfer information between sensory channels. Sjolander further explains that a snake has no ability to anticipate that a mouse running behind a rock will reappear. Cats and other predatory mammals are able to anticipate that the prey will reappear. According to Sjolander, snakes are not conscious. Using this definition of consciousness, than an autistic person experiencing severe sensory overload is not conscious. Sensory overload causes them to loose the ability to integrate input from all the senses.

Higher Consciousness

Since I do not think in language, there is a whole layer of abstract language consciousness that I do not have. Some of the papers I have read are so abstract and verbal that I simply do not understand them. So I have to study things that are understandable to me such as neuroscience experiments and research on animal behavior. I can visualize how the brain works and understand a brain scan study, but a linguistic concept such as "linguistic referants" in the mind is incomprehensible. Brain research has concrete data that I can understand. Many scientists believe that there are different levels, or degrees of consciousness. The different levels are determined by the complexity of the brain. Humans with the most complex brains have a higher level of consciousness than dogs which have smaller, less complex brains. As an autistic person, I believe I have a unique perspective. In some highly verbal people, they have forms of higher consciousness that I do not have. Some philosophers believe that language is required for the highest form of consciousness. In this view, I would not be fully conscious because I do not think in language.

After reading several books and scientific papers on consciousness, I concluded that the biological theories which correlated the level of consciousness directly to the level of brain complexity are the most appealing. Animals with more complex brains have a higher form of consciousness than animals with a simpler brain. It is particularly interesting that warm blooded animals such as dogs or birds have more complex brains than cold blooded animals such as reptiles. Maintaining a high internal body temperature requires huge quantities of food compared to a reptile. The ability to make flexible choices improves an animal's ability to both find food and avoid predators. Perhaps the degree of consciousness shown by most mammals avoiding predators is similar to the degree of consciousness I used to avoid hitting the elk. It was a deliberate, conscious decision. Why did consciousness evolve ? If my response was based on simple reflexes, I may have caused an accident. I avoided the elk because there was sufficient time to bring the pictures into consciousness and make a decision. However, the ability to make a conscious decision was lost when I found myself suddenly skidding out of control on an icy road. As the car skidded out of control, I began screamed like an animal being attacked by a predator. My screams came out as an uncontrollable, panic induced string of swear words. Screaming and fish-tailing on the highway, my conscious self was thinking I can't believe this was happening. Reflexes had taken over. My conscious self did not regain control until my car stopped on the median strip. Even when I was screeching swear words during the swerving, my conscious self was observing but could not override the reflexive movements my body was making. I remained calm in the elk incident because I had the time to make a conscious choice in how best to avoid danger.

The dawn of true consciousness would also be closely related to the ability of an animal to think in a flexible manner in a new situation. Marian Stamp Dawkins at the University of Oxford, defines thinking by discussing what it is not. True thinking is not instinctual behavior, and it is not a simple "rule of thumb", or a conditioned response. Instinctual behavior is governed by neurological circuits hard wired into an animals brain. Mating rituals in birds and egg retrieval behavior in geese are instincts. Modern scientists call them "fixed action patterns". These are patterns run like computer programs. Fixed action patterns are triggered by a "sign stimuli". Geese will retrieve any object that is the approximate size of an egg and roll it back into the nest. Even beer cans will be retrieved. The beer can is the sign stimuli. A basic principle is that higher mammals have less instinctual behaviors than reptiles.

Conscious behavior and true thinking does not necessarily occur after an animal learns a conditioned response. An example of a conditioned response is; when a red light comes on a rat must press a lever to get food. When a green light comes on, the rat must jump over a barrier to avoid a shock. Cows lining up at 4:00 for milking does not require thinking. The cows and mice learn a simple "rule of thumb". In a classic experiment, blind mice were trained to run a maze almost without error. This required that the mice make correct turns at about twenty junctions in the maze. The maze was cleaned after each trial to remove olfactory cues and the orientation of the maze was rotated to prevent sound orientation from the laboratory. Temporary regressions were produced after new orientations of the maze, however the mice soon overcame this and were performing hardly any mistakes at all. After three months, the mice were successfully trained to the maze and four different variations of the maze were introduced. In the first, the size of the maze was enlarged, in the second the angles of the turns were skewed from 90 degree turns to 45 and 135 degree turns, the third was a reverse of the second and the mouse had to turn through 134 and 45 degree turns and the fourth was a mirror image of the original maze. Before long, the mice had successfully mastered all the different mazes. The success of the experiment proved that the mice had transformed the information learned from the first maze which the mice then used to solve the problems of the novel mazes.

When ever animal thinking is being evaluated, the "Clever Hans Effect" must always be taken into account. Hans was a famous horse which had been trained to count by tapping his hoof Many people were very impressed and thought the horse really could count. Hans did not know how to count, but he was a very perceptive horse who picked up subtle cues from his trainer.

Experiments with pigeons have shown that birds are capable of real thinking because they can use previously learned knowledge to solve problems. Research done by Herb Terrace demonstrated thinking in pigeons. To determine whether or not animals are really thinking about what they are doing requires testing under novel conditions. Some very elegant research with birds has shown very clearly that even our feathered friends can think. Herb Terrace, the famous chimpanzee trainer, trained pigeons to peck at a series of lighted buttons to obtain food. The task was designed to make it impossible for the pigeon to use simple "rule of thumb" such as "red light equals food." All of the experiments were conducted in an enclosed box and controlled by a computer to insure that the pigeons did not receive cues from the trainer. After all the precautions necessary to rule out the Clever Hans Effect were taken, the pigeons were trained to peck four colored lighted buttons in the correct order. Pigeons who learned the correct order of the buttons were rewarded with food. When the positions of the buttons on the wall of their box were switched, the pigeons were still able to peck the colored buttons in the correct order.

To rule out the possibility that the pigeons accomplished this task as a great feat of memory without real thinking, Terrace did a second experiment to determine if the pigeons really had a concept of order that would hold up under several conditions. The birds were presented with one familiar colored button and three new buttons with patterns of lines or diamonds. For one group of birds, the familiar colored button was in the same order as the previous test. A second group of birds were presented with the colored buttons placed in a different order. Would having the colored in the previously learned orders help the birds to learn the correct sequence for pushing lines, diamonds and colors ? Pigeons that had the colored button in the old familiar order in the sequence learned the new sequence more quickly. The colored light and pattern buttons were randomly moved on the wall in the box to force the pigeons to learn the order concept and not to rely on the spatial cues such as button position on the wall. The ability of the pigeons to do this task satisfied Dawkins' criteria, who concluded that the birds were not responding to a "rule of thumb," but were, indeed, able to think.

G.M. Edelman (cited by Lindahi) states that mammals have primary consciousness and have mental images in the present but they may not have higher-order consciousness with both the past and future represented. Terrace's pigeons did not solve the problems using primary consciousness alone. They had to use both information from memory and information in the present. When I first considered my experience of avoiding the elk, I thought the experience depended on primary consciousness alone. This is not the case. In order to create an image of the elk crashing through the windshield, I had to have knowledge in memory of what happens when a car hits a large animal. I knew from memory that it often goes through the windshield. Without this knowledge, I might have pictured that hitting the elk would only cause a minor dent. I had memories which contained pictures of large animals crashing through the windshield. These memories were used to construct an image of that particular elk prone on the hood of my car just as the windshield was shattering. I pictured him a fraction of a second before his antlers would have gored me. Information from my memory was also used to create the simulated picture of a car rear ending me.

Brain Damage

Research on people who have brain damage provide much insights into consciousness. When one part of the brain is damaged, a certain aspect of consciousness is lost. Damage to the visual cortex where visual memories are stored makes it impossible for a person to think visually the way I do. Damage to the prefrontal cortex destroys the ability to integrate information between the senses. Brain imaging studies have shown that the transfer of information between the senses occurs in the frontal cortex. If a person feels a key in their pocket and then tries to find one that looks like the one lying on the table, activity in the frontal cortex increases. The frontal cortex is the CEO of the brain. It receives input from all other systems. It enables both animals and people to have flexible behaviors. People who have severe injuries to the frontal cortex can do routine activities such as cooking breakfast, but they have great difficulty dealing with novel things.

Damaging the frontal cortex in mammals has profound effects on behavior. Higher forms of consciousness probably require a frontal cortex to integrate information coming from the senses and from the limbic system, the emotional part of the brain. Rats with frontal cortex damage can perform species typical behaviors, but the sequence and pattern of the behavior is disrupted. Many types of learning are also affected. A normal rat can quickly learn that it can reach a piece of food through a small hole in a barrier. It will quickly shift strategies an use it paw to get to the food. A rat with frontal cortex damage will continue to make futile attempts to get the food with its mouth.

Damage to the hippocampus will interfere with some types of learning and memory but not others. Hippocampus damage affects conscious learning but it has no effect on unconscious learning. This indicates that conscious learning and unconscious learning work via different brain systems. A person with damage in the hippocampus can easily learn classical conditioning. A blast of air in the face and a light occur at the same time. After a number of trials the light by itself will make the person blink and flinch. However, a person with hippocampus damage can not learn the task if there is a delay between the air blast and the light. Having a delay requires them to be consciously aware of the relationship between the light and the air blast. Normal subjects Who were given the test only learned to blink in response to a delayed light when they were consciously aware of the relationship. Robert Clark and Larry Squire at the University of California suggest that a conditioning task with a delay between the two stimuli could be used as a test of conscious awareness in animals. A review of the literature indicate that rabbits can easily learn the relationship between two events that are delayed.

In the most severe cases of autism, consciousness fragments when the subsystems in the brain fail to work together. People with very severe sensory processing problems loose their body boundary when they become overloaded with too much sensory stimulation. Called monochannel, these people are unable to determine where their body stops and a table or floor begins. They cannot attend to, or integrate both auditory stimulus and visual stimulus at the same time. What makes this even more complicated is the fact that in the visual system, separate subsystems of circuits process color, motion, and seeing edges. This was described to me in a conversation with Donna Williams, an autistic person with severe sensory processing problems. She related an experience she had while talking to a friend. A cat jumped up on her lap but she did not perceive it as a cat. All she saw was a vague black blob. The color circuits in her visual system perceived the black color of the cat, but the motion and edge detectors were shut down. She said; "Ongoing conscious awareness is a luxury that overload can not afford". In other words, when her nervous system is overloaded with too much stimulation, she looses conscious awareness of her actions. Her brain systems are no longer able to work together and she states that she has periods where she looses conscious awareness of her actions. She can go on sort of an auto pilot and not be fully aware.

It appears that the brain processes information in a compartmentalized manner. Seeing words, hearing words, thinking about a word and speaking a word activate different brain regions. Donna's experiences indicate that self awareness can become separated from the rest of the brain. When her sensory systems become jumbled, she looses some of the ability to extract meaning from sensory input. When she was a child, she described how she looked for meaning in the jumble of sensory input. Only a few sounds, such as the patterned sounds of the cat purring, the clock ticking, and the washing machine, had any meaning to her.

Research on people with autism shows that there are defects in the sensory processing and attention shifting mechanisms. The autistic brain takes longer to shift attention back and forth between a visual and an auditory task. A normal person can shift attention in microseconds, the autistic person can take a full second to shift attention. The cerebellum is underdeveloped and this may affect timing and coordination of all the different brain subsystems.

Self Awareness

Being able to solve problems in a flexible manner is necessary to have thought, but being able to think does not automatically make animals conscious. Thinking is not a necessary prerequisite for consciousness, but maybe intelligent behavior can occur without being self aware. LeDoux writes in his book *The Emotional Brain*, consciousness occurred when the brain expanded in mammals. Consciousness in animals enables them to relate several different things at once. This is a conception of the self as the experience. Chimpanzees have self awareness. When they look at themselves in a mirror, they do not react to the image as if it was another animal, and if paint is applied to the chimps face, it will try to wipe it off Because dogs are not able to do this, one should not jump to the conclusion that dogs are not self aware. Dogs may not be visually self aware, but are possibly smell self aware. A dog marking its territory is able to discriminate between its own urine and a strange dog's urine. It may be that self awareness can occur in one sensory modality and not in another. In *Animal Minds*, Donald Griffin writes how a bear must have a body self awareness to hide from hunters. I agree with LeDoux's and Griffins ideas about consciousness.

An ability to relate present experiences to memories is a critical component of consciousness. This agrees with both LeDoux's, and Griffins views on animal consciousness. In a natural environment, animals must learn about things in their environment, and learn to predict which of their actions are rewarding or aversive. This requires the integration of different sensory systems into coherent and meaningful memories. The brain receives input from the eyes, ears, skin, tongue, and nose, from which it learns and stores representations of valuable stimuli. Recall of these representations are used to control adaptive behaviors.

If you hold a peach, you need to be able to feel its shape and see its shape. Holding the peach to your nose can integrate smell into the representation of the peach. For adaptive behavior to

occur, animals have to have some ability to anticipate the future. Even simple invertebrates can learn a conditioned response and use information from past experience. For example, in humans with the highest levels of consciousness, we are able to look into the future and know that if we don't eat the peach soon it will rot. How far an animal can anticipate the future may depend on the complexity of the brain. Dogs can anticipate a trip to the vet's office when the car goes down a certain road. They can also anticipate a pleasurable event. A dog will come running and will jump up and down when it anticipates being petted. The difference between a dog and a person is understanding that the past and the future is a matter of degree. A dog can anticipate an event which will be coming up in the next five minutes but it is probably unable to think a year into the future. A person with frontal lobe damage loses the ability to anticipate the future. However, some animals that hunt may be able to know that the food will go bad if it is not eaten in a few days. I agree with the biologists view that there are degrees of consciousness and that the degree of consciousness is due to the ability of different subsystems within increasingly complex brains to integrate information and make associations.

Conclusions

As brains become more complex the complexity of consciousness increases. Maybe in some animals only one sense is fully conscious. It may be easier to define consciousness by saying what it is not. It is not a reflex, it is not simple conditioning, and it is not a hard wired instinct which works like a computer program. Conscious behavior is flexible. Conscious behavior allows animals to make choices between different options. It is difficult for some people to imagine a consciousness that is different from themselves. Language based thinkers often have difficulty imagining that animals can think. They can not imagine thinking without words. Collin Allen in the philosophy department at Texas A & M University states that many scientists can accept the idea that animals have internal representations of memories and events. Some people think animals are not conscious because they do not have beliefs and desires like humans. I do not have some of the higher abstract consciousness most people have, so I have to define "belief" and "desire." If I say I desire chocolate cake I immediately see a slice of cake. In fact I see it at a particular cafe'. Desire has no abstract meaning. I just see pictures of things I would want such as an ice cream cone. I use the word belief to describe things where there is a high probability that something may be true, but I am not 100% sure.

There are four basic levels of consciousness:

- 1. Consciousness within one sense
- 2. Consciousness where all the sensory systems are integrated.
- 3. Consciousness where all the sensory systems are integrated with emotions.
- 4. Consciousness where sensory systems and emotions are integrated and thoughts are in symbolic language.

The second level of consciousness is where I am at. My thoughts are not linked with emotions. I think a hierarchy of consciousness is reasonable because damage to the nervous system will

damage consciousness. The different brain subsystems no longer work together when the brain is damaged.