UNLOCKING
CONSCIOUSNESS

BRIAN MIND FORUM

Appendix 041

CRADLE OF INTELLIGENCE
Evolution of the Five Sensory Organs

Evolution of the Sensory Organs

One thing we know s that the brain mind and the whole neural information processing system is entirely driven by the flow of information from the sensory and other organs. There is no central processor executing a program, as there is in our computers.

This is true from deep in our ancestral evolution. It is still true even in today's much more sophisticated world. Internal organs can generate neural signals, but the only other driving force might be the possible ability of advanced humans to be able to consciously initiate neural activities. This conjecture is one of the most hotly debated topics of cognitive neuroscience. Discussed in appendix 19.

So, if the sensory organs drive the whole system, we need to study them and our best guesses of how they evolved and operate.

One: Skin

To the best of our current knowledge the first sensory organ to evolve was the skin. Eric Kandell's research into '*Aplysia'* suggests that this, the oldest organism that survives as far as we can tell in much the form it has remained for many millennia, had just the ability to differentiate between a benign and an aggressive touch, and, incidentally, learn to respond differently to each. It seems a relatively simple process for a neuron under the skin to transmit a signal if impacted.

Two & Three: Taste & Smell

We do not know which evolved next, taste or smell. Both are near to the entrance to the gut which suggests they developed to monitor food supplies.

Taste buds in the tongue have the shortest lifetime of all cells, and are regularly replaced between weekly and monthly. Taste buds can differentiate principally between salt, sour, bitter and sweet. Even at this simple level neurons monitoring taste were an order of magnitude more complex than simple 'touch' in identifying different chemical signatures, and transmitting more complex messages to the brain. Saliva carries chemical signatures and presumably cannibal species are able to recognise the tastes of others in their species.

Smell involves the recognition of air born chemical compounds – *pheromones*, of which there are a variety. The *Olfactory* neurons have to identifying ephemeral chemical signatures as they pass by on the wind, and transmit identifying messages to the brain

Most organisms can also *output* pheromones, partly through the sweat glands. The ability to both send and receive signals, suggests that the neural patterns that recognise incoming patterns of signals must have some reciprocal facility to stimulate the output of saliva containing particular taste combinations and cocktails of pheromones.

Taken together the neurons began to be able to process a widening cocktail of touch, taste and smell signals, of type, strength and frequency. As a result, the brain mind developed the processing capability to select and reject good and bad food; and also to send 'warning orders' to an ever widening range of internal digestive organs and glands to output appropriate chemicals to provide an appropriate reception for what was about to come down the oesophagus. Similarly, the machinery was being put in place to activate the muscles to escape from predators or chase food.

Beginnings of the background 'autonomic' operating system

Building on the simple response to touch, the burgeoning neural signalling system evolved to accommodate the sensory organs of taste and smell, followed by the control of the glands, this encompassed the cardiovascular and endocrine signalling system of hormones. Operating together, this enabled a nascent background operating system to begin to evolve to control muscles and organs like the liver, pancreas, kidneys and heart; and in addition to begin to generate basic sensations like hunger and thirst, fear, anger and arousal.

Even at this very early stage of evolution the rudimentary elements were being evolved which would develop into the *autonomic* neural system that was increasingly capable of processing the signals from monitoring the outside world, then generate a selection of simple sensations and react accordingly.

Emergence

It is interesting to note that at this early stage of evolution, long before the mammals, the important concept of 'emergence' was already having a powerful effect. Namely: One element of taste or smell had one effect, however, two, and soon many more, had exponential effects. The concept that '*the whole is greater than the sum of the constituent parts*' was already making its presence felt and the burgeoning neural system was having to adjust and evolve to cope and react.

Thus, we can observe that the ability of the brain mind to process increasingly complex patterns of reactions even in response to just the first three sensory organs laid the foundation of the autonomic system which in due course has led to what we recognise as intelligence.

Four: Sound.

We do not know which evolved first, sound or sight. However, for a long period sound was far less significant than sight in the survival stakes. Only in the recent one hundred thousand years or so has sound equalled sight in sophistication and importance, with the arrival of language. Sound is both an input and output sense. Smell is also an input and output sense, but with the arrival of language sound became the premier communication system and completely eclipsed smell, although there is a strong argument that smell is still important in that aspect of communication we recognise as attraction.

Hearing

The ear mechanism solves a similar problem to smell, in that pheromones flowing over the olfactory neurons may be fleeting as air is drawn into the nose. It is often possible to suck air up the nose a number of times to identify a smell. Not so with hearing. The patterns of vibrations transmitted through the air with frequencies in the range of 20 to 20,000 hertz, capable of being detected by human organs of hearing are ephemeral. In a conversation someone can be asked to repeat some words, but that is a new unique sound pattern. Like smell with two nostrils, there are two ears in orifices in the head. The two ears, being slightly wider apart, enables the direction from which the sound is coming to be computed: rudimentary three-dimensional hearing.

The specialised ear organs can, therefore, convert passing waves of sound vibrations into neural signals and transmit them along dendrites to the brain in one continuous action. No processing appears to occur in the ears.

Five: Sight

The eyes are by far the most complex sensory organs and took up an order of magnitude more processing capacity in the brain mind than all the other sensory organs put together until the arrival of language, which appears to have appropriated some of the eye's original processing facilities at least as far as the development of meaning is concerned. Many different types of eyes have evolved, and human eyes are not necessarily the most complex.

There are particular reasons for eyelids, the shape of the lens, cornea and retina. In evolution there always are!

Eyelids

The muscles of the eyelids are distantly related to the operation of the synapses. When tension across the synaptic clefts is relaxed the tension in the eyelid muscles equally relaxes and the eyes close, cutting off the stream of stimulation. As tension across the synapses returns the eyelids open.

Retina

When the eyes are open a continuous stream of photons are focussed onto the retina at the back of the eye. There are many excellent publications of every sort about the operation of the eyes. We need only mention the key aspects that affect our study of information and intelligence.

Essentially, specialist nerves in the retina convert the streams of photons (the smallest measurable units of light – or energy) into a stream of infotons (the smallest measurable units of information) and transmit these patterns along the optic nerves to be processed in a wide range of areas of the brain.

Two groups of factors help us understand how visual images are processed, stored, recognised, subsequently recalled, and in particular how we perceive images. (1) We have discovered a lot about how a visual image is transmitted along the optic nerve and travels to various parts of the brain: one section recognises hard edges, another decodes colour, for instance.

(2) The stream of information 'fills up' the 'hole' left by the optic nerve almost immediately. The pattern of signals seeks to travel along neuron paths that offer the least resistance; those that are familiar – have 'seen this image before'; and so stimulate existing neural patterns that are to some degree familiar. Thus we can immediately recognise the image we are looking at, and all the information our experience has accumulated about this image.

If the image is not familiar – there is no existing neural patterns, then the brain grows a new tentative connection. The Hebbian effect appendix 10.

Seeing images with our eyes: *perceiving* images with our brain.

This highlights the first of the concepts about eyesight, and in due course language that are counter intuitive and therefore quite difficult to appreciate, or learn.

We are almost sure that most of the images we see with our eyes, especially the familiar ones, are not what we perceive with our brain minds. We *perceive the remembered image,* plus any obvious changes. If, for instance, we walk into our familiar kitchen we move around without any effort of concentration, reaching for implements automatically. If one day we walk and there is a mouse in the middle of the table we see it instantly. We take for granted what is familiar – we continue to use the stored image. We immediately perceive what has changed.

If we are looking at a familiar image, and close our eyes we continue to perceive that image. We can also zoom in and study quite intricate detail: all from memory. The remembered image is not as vibrant, but open our eyes and all the vibrancy returns. We can also recall – perceive - the image of the house we live in as it used to be, say, years ago before the garage and conservatory were built.

Stable Images

Even if we try and keep as still as possible the stream of photons impacting the retina inevitably bounces around, yet the image we perceive stays completely stable. If we used a cine camera to record what we saw while riding on horseback, when we played it back the image recorded by the camera would be going from side to side and up and down, and more so as our horse started to gallop. Nevertheless, the image we perceived of the outside world remained stable

The counterintuitive hypothesis is that there are no visual images – pictures - in the brain mind. If it helps there are no pictures in any computer. The 'picture' we see on the computer screen is megabytes of pixels. The image on the memory stick is just a string of binary digits. The image in the brain mind is a complex pattern of electrochemical signals generated by complex patterns of neurons interlinked and cross referenced to similar patterns from the other sensory organs. We largely perceive a remembered image.

Computers perceive no visual image of any sort. However, the brain mind generates very clear detailed sensations of images because the pattern of neural signals either from the eyes or more usually modulated through previously stored images, stimulates the production of a complex cocktail of hormones and neurotransmitters.

The computer images with which we are all familiar are like language. They are successions of a series of components nested together in almost infinite hierarchies. A child, or an adult who has only just acquired sight, perhaps as a result of some medical condition, sees almost nothing to start with: often just patches of lighter and darker fuzziness. Gradually, images that are frequently seen produce recognisable sensations of visual images. Myriad pieces of a massive tapestry accumulate to be woven into ever more complex 'pictures'.

Thus, a stream of photons, infotons and neural signal patterns acquire 'meaningful' images of pictures for us.

We accumulate an apparently infinite number of discrete and related visual sensations cross referenced, connected, overlaid and interwoven that are forever being modified, edited and varied with different perspectives and sources of light and dark. In our mind's eye we can turn images around, zoom in and out and even have the sensation of moving around *within* these images, as we might walk in a garden.

Complexity

All down through recorded history mankind has marvelled at the sophisticated complexity of our eyes that we can see, touch and dissect. This is as nothing to the neural complexity that enables us to perceive and process an infinite pantheon of visual images within our brain minds.

[Similarly, there is not one single note of music in our computers, nor in our brains. There is not one single word either.]

What evidence do we have for this?

Professor Chantel Prat at the University of Washington and her team have used transcranial magnetic stimulation to modify a subject's brain waves so that they take the shape of the brain waves observed in a different person – in effect transmitting the contents from one mind into another. *Stimulating the visual cortex causes the recipient to see the donor's image*; or more accurately:- c*auses the recipient to stimulate production of a similar cocktail of hormones thus generating a replica of the donor's image.* As Prat says, "*you are seeing with your brain, not with your eyes*".

Professor R Douglas Fields at the University of Maryland, College Park, USA, argues that this breakthrough in our understanding of the way the brain codes visual images rates alongside Pavlov's experiments with his dogs.

If we stop and think from another perspective, this is not quite such a counterintuitive concept as we first believed. In fact, we recreate images in other people's brains all the time, through ever more sophisticated language. If I now describe a country scene and mention 'thatched cottages', you, our reader, are already seeing 'in your mind's eye' images of bucolic cottages, roses all over the porch. You are not seeing those images with your eyes, but perceiving recalled images in your brain recalled from your memory.

Observing moving objects

One of the key skills for survival has always been the ability to identify a potential predator quickly, but also be able to tell if it is stationary, or moving, and if so in which direction, and how fast and, if possible, if it is slowing down or accelerating.

One possibility is that our ancestors evolved a means of making 'snap shots' of images and storing them long enough to be able to compare a new image with the previous one. Comparing images over time indicated moving images, while more sophisticated algorithms could compute speed and direction. This hypothesis poses a very interesting problem. Electrical energy travels. It can only be stored in some form of battery. In the brain mind patterns of electrochemical signals flow from the eyes through the brain to the muscles, thus if a predator is identified the legs are running fast enough to escape and reproduce.

Thus very early animals learned to 'pause' these monitoring signals long enough to compare two together (this is usually called the *Zeno* effect). There is an interesting additional aspect of this function relevant to Intelligence. All down the long history of evolution natural selection favoured the fastest possible response on incomplete information.

Beginnings of Thinking

But the fastest response is not necessarily the best response. The first glimmerings of thinking may have been as a result of this ability to 'pause' a signal. To develop the ability to pause the system, evaluate alternatives and select a better response was a major step forward. Guy Claxton in '*Hare brain, Tortoise Mind'* outlined this theory in 1997. Daniel Kahneman explored this further in '*Thinking Fast and Slow'* published in 2011. (Appendix 23)

Aspect of conscious awareness.

Some people have taken this concept further. Professor *Gerald Edelman*, winner of a Nobel Prize for his work on the immune system, turned his mind to Artificial Intelligence and definitions of consciousness. He argued that one aspect of awareness was that this zeno effect could be extended to encompass everything going on at any particular time. He coined the phrase '*remembered present'* to explain conscious awareness in his book *'Bright Air, Brilliant Fire'*.

Imitation

Many mammals share with us a type of neuron, known as '*mirror neurons'* which are activated when we see someone carrying out some attractive feat. They assist in generating the same activity in our own neurons

Balance

One crucial part of the 'whole body system' is the ability to balance, orchestrated by the three concentric 'stirrup' bones in each ear. A string of signals is continually flowing from the ear to the brain by separate circuits to the sound system, indicating the state of balance, and quite automatically adjusts the muscles of our limbs to ensure we remain upright whether we are stationary, moving, walking or running.

When learning to ride a bicycle we learn to direct these correctional movements to our hands to move the handlebars.

Back to Sound.

We do not know when mankind began to learn to speak. Our best guess is between one and two hundred thousand years ago. A very short time ago in the evolutionary calendar.

There are many theories. Professor Steven Mithen argues persuasively in '*The Singing Neanderthals'* published in 2005 that specific music-like sounds – vocalisations – would have been accompanied by gestures and facial and body contortions. Put together these were Holistic, Multi-Model, Manipulative, and Musical: or '*Hmmmm*'. Speaking requires the manipulation of the lungs to generate and 'transmit' the sound patterns generated by the vocal chords and the tongue, cheeks and lips. Robin Dunbar from Oxford has suggested laughter was an early component of speech, drawing attention and squeezing the air out of the lungs to project an ever widening vocabulary of sounds.

It seems logical that the first words, or proto nouns, would have been labels to identify things and the first proto verbs to describe actions. Nowadays we attempt to describe sensations and feelings, qualia – beauty, the redness of a rose - in terms of words and phrases that we have developed over the millennia. It is just as likely that our ancestors 'invented' words to enable them to express their emotions, and the task is not complete yet.

Language

The arrival of language completely changed the balance of power in the animal world. We could absorb the fourth generation: time. Humans could reminisce about the past to influence decisions about the present, and even begin to predict the possible future course of events. Thus the community could work together as teams with all the benefits of specialisation and the division of labour. And the ability to imagine, debate and discuss what might happen enabled our ancestors to make provision for various eventualities. We are the only species capable of doing this, thus we have come to rule the world. This is so important we draw attention to it from different perspective: in particular in appendix 22.

Here we are more concerned with the impact of the sensory organs.

There has been much debate on whether speech is hereditary. There are two powerful arguments to suggest it is not. No child has even been able to say one single word at birth. The whole of language has to be learned word by word by every child from their parents or peerhood. If individual words had to evolve it would take centuries to create new words. As language is infinitely flexible we can, and do invent words continuously. We also invent one, or a few words, to represent whole concepts. Soundbites and 'slang' are very powerful thinking tools.

This ability to create words is another very powerful example of 'emergence'. A phrase can mean a very great deal more than the sum of the individual words.

Neural dictionaries

On the other hand, language has had a dynamic impact on the brain. Evolution did not lead to language. The opposite. Language has had a powerful influence on the evolution of the brain. A 21st century brain can remember one hundred thousand words or more, and that is just in one language. Pairs, triplets, phrases and paragraphs all have variant meanings. Add in where streams of words are linked together so that an actor can declaim his part: a politician make a speech, or someone recite a poem and the number of patterns of word forms and their meanings could easily be $100{,}000^3$. That is a lot to accommodate in one small brain. When people do research on mammal's brain, it might be useful to remember this.

No other species has any facility even remotely capable.

Reading and writing

Reading and writing has redoubled these unique skills. Drawing the symbols of the alphabet and numbers, requires a degree of skill in manipulating the muscles of the hands and fingers far more accurately than any other species has ever had to come near to doing. Decoding sound patterns of words and phrases, recognising written letters and words: making the correct sounds, even with the right emphasis according to circumstances, is so intricately detailed that it makes the combination of sight, sound, reading and writing almost a candidate to be considered a separate sensory organ in their own right.

There is more.

Abstract.

It is not too difficult, at the conceptual level, to see how the neural profile of an image of mother could be linked to the neural representations of the smell and taste of mother and, therefore, the sound of the noun word 'mother'. Similarly with the verb words for actions. But we also developed adjectives and adverbs. No one has seen a 'big' tree or a 'fast' deer. One humble adjective can apply to many nouns. The combination of a noun and an adjective means a great deal more than the sum of the meaning of the two words separately.

Efficiency suggests that adjectives and adverbs are stored just once – just like nouns and verbs, otherwise every noun would need to be stored with every possible adjective. Linking them together as required is quite a feat of neural engineering design.

Thus we began to develop a whole language subset of words that are only anchored indirectly to words that have any physical presence. Thus we developed the ability to think entirely in the *abstract,* where the meaning was exclusively ephemeral and only had meaning to anyone else who knew that language and had discussed, or was familiar with that concept. A good example would be the entirely abstract concept of '*freedom*' that has exercised the world since the beginning of recorded history.

Thus we can create an entirely fantastical imaginary world entirely within our heads. Having imagined impossible futures people go and make them happen. Science fiction has played a valuable role in opening people's minds to the possible.

Sixth sense

There are many candidates for the accolade of sixth sense. Some are fantastical, some we suspect might have grain of truth. Educated people are careful not to write off even the most improbable new ideas. “Beam me up Scotty” surely was way out of court, yet Professor Anton Zeilinger and his team at Innsbruck demonstrated ‘teleportation’ of molecules back in the last days of the last century.

One candidate is worth exploring.

We all have a well-developed capacity to *speak silently*. We talk to ourselves. We speak without saying a word, we hear without a word being said [the first recorded example is between Ambrose and Augustine of Hippo].

Children learn to read out loud to start with. Soon they learn to read silently. Reading can be said to be the conversion of symbols (the alphabet) into speech, and writing the conversion of speech into written symbols. Note how we assemble a text in our heads before we speak it out loud, write it, or tap it onto keyboard.

This suggests some quite interesting possibilities.

When we prepare to say something, we assemble some words and send streams of neural signals to the lungs, throat, mouth, tongue and lips to say the words. Or we activate the muscles of the arms and fingers to write our message. Now we have added a third alternative: transmit that pattern of signals direct to the hearing system bypassing both the throat and the ears.

In all the research on the neurons no one has identified a nucleus that can select one of two or more outputs. The conventional neuron has one axon. Some axons branch near their destination, but all branches appear to receive the same signal. Significantly, we have made and executed a choice. So the question arises, who, or what has made that choice, and how?

We know how a computer makes this choice. The instructions in the program can be “output to screen”, “output to Printer”, “output to internet”.

But we know there is no program in the brain mind. Equally a program inputs information.

The second question, therefore, is who, or what makes the choice to silently hear, or input these signals as though they were input monitored from the external world similar to familiar inputs like visual images.

Have we uncovered a clue to a senior level of neural activity that a number of people have suggested, like the ‘spindle cells’ conjecture proposed by Francis Crick and Christof Koch in 1994 in the *Astonishing Hypothesis*?

If so then we have indeed identified a sixth sense, and possibly a great deal more.

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