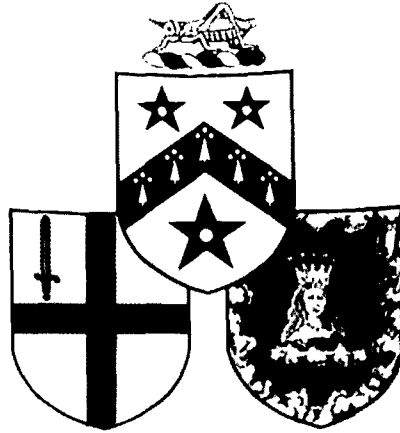


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EXPLORING THE BRAIN

Lecture 9

TOUCH, TASTE AND SMELL

by

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15 November 1996

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EXPLORING THE BRAIN: TOUCH, TASTE AND SMELL

Just as there are effective nerve motorways that leave the brain via the spinal cord to control muscles and hence movement, so there are incoming signals that are sent up via ascending nerves within the spinal cord, into the brain: these signals relate to touch and pain, and are referred to as the 'somatosensory' system. Triggered by the point of contact where, for example, a pin pierces the skin or a feather brushes the surface, local sensors within the skin trigger the relay of 'somatosensory' electrical signals. There are several different types of sensor: the largest and deepest are the 'Pacinian Corpuscles', which detect heavy pressure and fast vibrations. Another, smaller type of sensor are 'Meissner's endings', which are also sensitive to vibrations. By contrast, 'Krause' and 'Ruffini' endings respond to a steady state of pressure on the skin, rather than to changes in pressure. The sensors for pain however, are far simpler than these rather fancifully named and selective systems: pain is detected merely by free nerve endings within the skin, that are sensitive to chemicals that might be released when the local area surrounding the particular nerve ending, is damaged.

There are two major ways in which events occurring in remote parts of the body are reported to the brain: one, the evolutionary older, is chiefly related to pain and temperature, whilst the newer system carries precise signals relating to touch. This arrangement has an intuitive appeal in that it makes sense for the more basic, established system to be concerned with basic survival factors such as pain and temperature, whilst the more refined skills involving precision of touch would become only more important as the organism evolved. The two systems even take separate routes journey as they to the brain within the spinal cord.

In all cases however, painful or otherwise, the signals are relayed up from the spinal cord and finally arrive at the outermost reaches of the brain, in an area of cortex just behind the motor cortex known as the 'somatosensory cortex'. Different neurons in the somatosensory cortex correspond to touch in different parts of the body. One might expect that one's hand, which is a relatively small part of the body, would have

neurons that register impulses on the hand in a very small part of the cortex. However, there is no direct matching of an area of your body to an area of the somatosensory cortex. The hands and the mouth have an enormous, vastly disproportionate representation.

This biased allocation of neurons makes sense. Just as the hands and mouth claim a large allocation of neurons in the part of the cortex associated with movement, (the 'motor cortex') to enable, say, violin playing and speaking, so those same parts of the body lionize large proportions of neurons in the somatosensory cortex too. It is important for our mouths and our hands to be most sensitive to touch because eating and feeling things with our hands are among our most basic behaviours. Anyone who has had a local anaesthetic at the dentist will know how debilitated they feel at not being sensitive to movement or touch in even part of the mouth.

This difference in sensitivity to touch in different parts of our bodies can be demonstrated very easily on oneself or with a friend. If a pair of compass points are set relatively near each other and placed lightly on different parts of the body, they will be perceived either as one point or two according to where they are placed, even though the distance between them remains constant. In the small of the back for example, where the sensitivity is modest due to the modest allocation of cells in the cortex, two points relatively close will be felt as just one. By contrast, when the points are placed on the tips of the fingers, there are a sufficient number of corresponding neurons in the cortex to relay an adequately sensitive message that there are two points. The allocation of the brain to coordinating parts of the body will depend on the importance of that part of the body to the task in progress.

Have you ever stubbed your toe and felt two sorts of pain? First there is a quick and sharp sensation, followed a moment later by a dull throb. This is a phenomenon known as 'double pain', and it is caused by the fact that within the pain sensing system, we actually have two sets of nerves. One set of nerves is relatively thick, and therefore good at conducting the electrical signals from the nerve in the extremity, up into the brain: it is this nerve that is responsible for the initial, sharp

sensation. A second type of nerve however, will also conduct signals related to pain. However, because this second class of nerve is thinner and not covered with Nature's insulation, myelin, the signal it propagates will take longer to arrive in the brain. These two types of pain are called, not surprisingly, 'Fast Pain' and 'Slow Pain'. The staged sensation of first one pain then the next are only usually apparent in an extremity like the toe, where the distance from the brain is large enough for the difference in the conduction velocity within the two types of nerve, to be appreciated.

Fast pain is generally very well localised whilst slow pain is far more diffuse. Moreover it is slow pain that has far more 'emotional' overtones, and which is more effectively treated with morphine than fast pain. Morphine is one of the oldest and most effective drugs for alleviating pain. Only recently however was it discovered how it actually worked. In the early 1970s Kosterlitz, a pharmacologist working at the University of Aberdeen, isolated a substance that occurred naturally in the body, which he dubbed, 'enkephalin' (literally 'in the head'). It turned out that enkephalin was very similar in structure to morphine, and that it was a naturally occurring chemical messenger ('transmitter') within the brain. Because the brain usually used this substance for communication between brain cells, there were special, custom made chemical targets on which the enkephalin would act. It was on these targets that morphine too therefore, was able to work, fooling the brain into the idea that a natural transmitter was really at work.

The big difference however, between the brain's own enkephalin and morphine, is that the brain only uses very small amounts of its own transmitters, in highly specialised parts of the brain. By contrast when morphine gains access to the Central Nervous System, it is indiscriminate. The drug will be in far larger quantities than normally required for one neuron to communicate with another. Moreover, the drug will effectively marinate the brain, going to many different brain regions simultaneously and unnecessarily. Gradually the natural targets become habituated to the continual bombardment from these excessive levels of morphine molecules: they are less sensitive. Hence, in order to

produce the same effect as originally was possible within a target neuron, more morphine is needed. This is the biochemical basis of addiction.

No one knows why morphine should produce the euphoria that encourages repeated, illicit use. One possible, and highly speculative thought however comes from the actual way in which morphine causes relief from pain. Patients taking morphine often report that they are still aware of the pain: it just does not matter to them anymore, it is no longer of significance. Perhaps then, the 'pleasure' derived from morphine is in part that the everyday problems of life are no longer significant. Rather, the addict feels as though they are in a dream where nothing, not even their worries, are real.

Interestingly enough, another form of ancient pain relief may also involve our naturally occurring morphine, enkephalin. Among its many actions the ancient Chinese practice of acupuncture can cause relief from pain. Indeed it can even be used in some forms of surgery. An interesting feature of morphine analgesia is that it takes some twenty minutes to come to full strength, and can last for an appreciable time after the needles have been inserted into the relevant locations on the body. Moreover, the ensuing pain can be blocked by a drug, 'naloxone'. Naloxone blocks the targets for enkephalin without having any effect itself. Hence it is possible that when acupuncture needles are inserted, they cause the eventual release of naturally occurring morphine, enkephalin, which acts via its natural targets. Providing these natural targets are not blocked by naloxone, they will then enable the enkephalin released by stimulation of the acupuncture needles, to have an effect on pain relief. It is easy to imagine that the stimulation of the nerves and eventual release of enough of the natural transmitter would take some time, and by the same token, that the release of the transmitter might be sustained after the needles have been withdrawn.

Another way of alleviating pain is to exploit the fact that there are many different nerves all conveying signals regarding touch. When we hurt ourselves, a natural reaction is to rub the afflicted area. The reason that this action can cause some comfort is due to the fact that the nerves

carrying signals relating to ordinary touch, are in fact more efficient than those carrying signals relating to pain. Hence, by rubbing the skin, we are activating the more efficient nerves conveying signals relating to touch which, in a sense, trump the signals conveyed by the smaller diameter nerves, which relate to pain.

In any event the sensation of pain is far from straightforward. Although we know that local anaesthetics work, for example, by slowing down the propagation of the electrical signal, it is still largely a mystery as to how a general anaesthetic produces an abolition of consciousness. This problem arises because we do not know what causes consciousness in the first place. Another mystery concerning consciousness, and highlighted by the sensation of pain, is the extent to which we perceive something as painful. There is a particularly unpleasant experiment where volunteers agreed to have shocks and/or cold stimulus applied to their teeth, at different times of the day. The subjects then had to report how big the shock or degree of cold had to be, before it became unbearable. Interestingly enough this 'pain threshold' varied throughout the day. The time when the most pain could be tolerated for example, was mid-day. The nerves conveying the pain messages into the brain do not change at all in their characteristics and their efficiency or otherwise at conducting pain signals. Hence the real difference seen here in the subjective sensation of pain, must actually come from a much more subtle and elusive mechanism, as yet unidentified, within the brain itself.

Unlike our three senses of sight, hearing and touch/pain, the remaining two senses differ in that they have an important common factor: they rely on the detection of chemicals. If the chemicals in question are air-borne, we refer to the sensation of 'smell', whereas if they are contained within a liquid, we talk of 'taste'. In the case of taste the initial sensors, 'chemosensors', are aggregated into groups of 25-50 forming a 'taste bud'. An adult has approximately 10,000 taste buds, but the aging process can leave us finally with as few as 5,000. In any event each individual chemosensor lasts only for about ten days, but is normally replaced within twelve hours. These taste buds are distributed mainly around the sides of the tongue: 'bitter' is at the back, 'sour' at the sides

with 'salty' in front and then 'sweet' at the very tip. In addition it is important to remember however that the touch system we have already been discussing will play a part. The mouth, as we saw previously, is very sensitive to touch: signals relayed from this region regarding the temperature, moisture and texture of the food in our mouths, will also play an important part in determining the net 'taste', as will the contribution from the sense of smell.

Each taste bud has an outer layer with a hole in it. The chemicals dissolved in our food and drink seep through the hole and bathe the chemosensors, which actually detects the chemical in question by means of tiny hairs that are linked to the flux of ions into and out of the cell. This traffic in ions will cause a change in potential, and hence an electrical signal which can then be passed into the brain. The first relay station is in a primitive part of the brain, the medulla, which is very near the junction between spinal cord and brain proper. Thereafter signals are sent to a major brain region named after the Greek for room, the 'thalamus', and subsequently on up into a region of cortex very close to the 'somatosensory cortex', which we saw was responsible for processing the signals relating to touch and pain. On the other hand, the brain is not organised as a one way ladder, where the cortex acts as a 'brain' within the brain. Rather, by a process we still do not understand, the conscious sensation of taste is the net result of many brain regions working together. For example, we also know that the taste system extending initially from the tongue also has close connections with the 'hypothalamus', a tiny but vital region associated with our drives and hormonal state, as well as with another important series of brain regions, the limbic system, which is closely linked with emotions.

The sense of smell can also evoke emotions seemingly directly. In fact the limbic system has been referred to as the 'nose brain' because of its close anatomical connections with our sense of smell. Air-borne chemicals arrive in the nose, drawn in by an intake of breath. Once at the top of the nasal cavity, the chemicals will come into contact with a thumb sized area containing about ten million sensors. Each sensor is a cell with a tip containing, just as we saw for taste buds, tiny hairs. This tip floats in

the nasal mucus, and thus samples whatever chemicals are inhaled. By a process that is still controversial specific chemicals, each with a specific smell in some way interact with the hairs to activate electrical signals in the sensor-cells, and hence once again start a chain of electrical events up into the brain. One idea has been that the very shape of a certain molecule would determine its odour, because it would fit into target proteins (receptors) on the sensors, that would then set off certain electrical signals. This idea has now however been called into question since cyanide and almonds, for example, both smell very similar, but are of very different molecular shapes. Unlike the other senses, inputs from the smell system do not go to the cortex, but rather straight to the limbic system, the region mentioned earlier as associated with emotion. This primal brain region has also been linked to memory, and may explain why a certain smell can suddenly evoke a very vivid recollection.

Given this close link between smell and the less sophisticated areas of our brain, it is perhaps no surprise that the sensation of smell dominates the lifestyle of non-humans far more than it does our own. A sniffer dog, for example, has an area in the nose sensitive to smell that is thirty times larger than our own, and can detect odours at levels ten thousand times weaker than our own detection threshold. For many animals, smell can be vital for survival. Not only does it allow us to detect a meal left in the kitchen burning for example, but in non-human species, plays an important part in alerting an animal to either a predator or a mate. The chemicals secreted by one animal to signal to another, are known as 'pheromones'. 'Primer' pheromones trigger a series of reactions over a period of time. For example the 'Bruce Effect', so named after its discoverer Hilda Bruce, is when a just mated female mouse is exposed to the smell of another, but strange male mouse within twenty four hours. The smell of the strange mouse triggers 'danger', in that a strange male would kill another male's pups. Hence as a result, the female, though mated, does not become pregnant.

The other type of pheromones are 'releaser pheromones' which trigger an immediate reaction. For example, when a honeybee stings, an alarm pheromone, isopental acetate, is also released. This chemical has

the effect of attracting other bees so that they attack whatever threatening presence may have come within the vicinity of the hive. Although pheromones may play a conspicuous role in the lives of fairly simple animals, even we humans are not immune to their influence. For example, menstrual synchrony in women is now well established. In general, pheromones seem to play an important part in reproduction. As yet however, no one has yet been able to identify, and thus undoubtedly commercialise, a pheromone that could work as a sexual attractant between humans!

Our senses enable us to interact with the outside world. Although we now know much about the mechanisms of transduction, ie how physical properties are converted into electrical impulses, many big questions still remain. How might the senses interact to produce a unified conscious experience? Why do electrical signals arriving in one part of the brain give rise to sound, whilst another gives the sensation of sight? What are the bases of our sensations in the absence of external objects, such as in hallucinations and dreams? To what extent does this internal world colour the 'real world' in any case? These are the kind of questions that a consideration of the senses poses, and which represent some of the most enthralling and challenging issues in neuroscience.