Interview with Johan Lundstrom

[JL] Main aim of the lab is to understand how psychology and biology interact. Biology affects psychology a lot, but now we know that psychology modulates our biology. I want to know where the reciprocal connection is and how that interacts and forms the final percept. The best way to study this is by looking at the brain. Contrary to what was traditionally believed, the brain is actually very plastic. The sense of smell is particularly nice to look at because it's also 'plastic'; for example, if you measure how well you can smell something in the morning, it will be different to how you perceive it in the afternoon. So, if you tested yourself against the same percept over ten time periods, each time it would vary. However, if you do the same thing with visual or auditory stimuli, it's very stable. Since there's huge flexibility on olfaction then we're able to 'push' it in certain direction, which you cannot do with vision. For example, if we pair odour stimulus with a shock then we make the odour 'negative', just as a result of the pairing. In this way, we can make a subject up to 20% sensitive to that odour. In terms of vision, we cannot make people 20% better at seeing by pairing it with additional stimulus.

[RB] **So, this is all by stimulating neural processes rather than by altering the percept?**

[JL] Yes. Figuring out this sensory and multi-sensory relationship is like pulling on the strings of a spider's web – as we pull we can see how the centre moves.

[RB] **You explain in your paper that special environmental properties are translated and stored as images in the brain; is vision our default sense?**

[JL] I think that this is because vision is a much easier sense to work with; It is less flexible and more linear, and also, in a sense, it is what we are exploring the 'finer' aspects of life with. I always use olfaction as 'painting with a very broad brush', whereas with vision we can assess fine, minute details. With vision, we can determine the difference between a pen and a pencil. If we try to do the same thing with odours then a person will probably perform very poorly. With olfaction, a person likely will not even be able to identify the differing fragrances of orange or pineapple, etc. With vision we determine very specific details, with olfaction we get large, broad information.

[RB] **Is part of that because we have been training ourselves to interpret the world through our visual sense, and we haven't done that in the same capacity through our chemical senses?**

[JL] I think that there are two factors: 1) When we are young we are trained to connect words to the things that we see; however, we rarely do this with our chemical senses. 2) More importantly, our brains are not wired to pay attention to such details. Olfaction is wired to the brain differently than all of the other senses. All of the other senses are coming from their respective receptors. Visual, tactile and auditory stimuli all comes to the thalamus; from there it projects outwards to the primary visual cortex, or the primary auditory cortex, or the primary motor cortex. With olfaction, signals arrive at the olfactory bulb where it then proceeds along a separation of paths. It goes to the pyriform cortex, or it goes to the amygdala, or it goes to the hypothalamus, or hippocampus, or then also the thalamus. So there is significant signalling throughout the brain before arriving at the thalamus. The thalamus is important because there is a saying in neuroscience that states, "Unless something crosses the thalamus then it doesn't reach into consciousness."

[RB] **Is it fair to say that we are ultimately working on a visual system and that all sensory stimuli eventually becomes an image?**

[JL] No. but all stimuli become objects. Whether it's a visual object or an olfactory object, it has to at some stage become an object; and it can become a very ill-defined object, but to 'grasp' it you have to link it to an object. [note: interesting use of conceptual tactility in the use of the term 'grasp'.] And that's why it's so hard to remember non-descriptive odours. So, we can create a molecule in a lab that nobody has ever smelled before; people are able to rate it on intensity, pleasantness, but they might not be able to tell you what it smells like. If you return to the subject a few days later and say, "Have you smelled this before?" and they will say, "I don't know." Unless you teach them, "This is Mumbapa" and you show them some sort of abstract figure. If you do this, then there can be odour recognition because now there is a mental object that they can link the odour to. Some people think that there cannot be a functioning memory for odours unless there is an object to link the odour to.

[RB] **So, have any monosynaptic connections between the Orbitofrontal Cortex (OFC) [cognitive processing] and the visual cortex been found?**

[JL] We don't suggest that there will be one. It's rather an old way thinking that we are trying to address, that suggests that only monosynaptic signals matter. In fact, the brain is an interconnected network and there are many ways to arrive at point 'B' from point 'A' [paraphrase]. If we fire electro stimulus into any part of the brain, we will be able to measure the response from any other part of the brain.

[RB] **Given that a stimulant is universal (i.e. synthetic chemical that can be reproduced identically), will the 'olfactory image' of the percept be the same across test subjects? Will the fMRI display the same image maps?**

[JL] Yes and no. In the big areas, yes - but, within the areas, no. It seems to be that not everyone is working with the same 'blueprint'. There are individual variations on how the neurons are connected within brain areas. But, we know that these areas will be activated, but exactly where in the area, we don't know.

[RB] And how does that compare to vision?

[JL] It's the same, but it's a more narrowly defined area.

[Note: this would suggest that there is subjective interpretation of visual data, as well as olfactory date; although, with a lesser degree of deviation.

[RB] You discuss the 'stimulus problem' in olfaction – any theories how odour quality perception is encoded in its molecular properties?

[JL] No. There's no known theory. 'Pleasantness' [13:17], some people claim, are encoded in the molecular properties; but that is controversial. Quality – the only thing that we know is some sort of combinatorial code where, if receptor A, D and P comes together then it creates 'banana'. But we also know that certain monomolecular compounds are able to give you some kind of hint of quality. For example, if you take the single molecule phenylethyl alcohol and smelled it then it would give you some notion of a 'rose' odour. It would be described by subjects as 'rose-like' because the actual compound in a rose is comprised of hundreds of molecules, where most of them smell nothing like a rose; however, when combined, then they smell like a rose.

That's why we only work with mixtures. We are waiting for single-molecular compounds, but for the time-being we need to wait. This area remains a 'big unknown'.

[RB] "The carbon chain-length does not equal the physical continuum within homologous series of substances that correspond to the single qualitative dimension, as with wavelength." Using this comparison, are there similarities between odour perception and visual perception? Can we compare something like wavelength to anything in olfactory perception? I understand that there is 'functional group', chain length, molecular size and molecular shape, the four pillars of odour.

[JL] To the best of my knowledge, there is nothing that we have found that has the same function, such as 'pitch' or 'wavelength'. We haven't found that continuance yet.

[RB] Olfaction is incredibly complex when compared to vision. Does that mean that there is the potential for more information to be absorbed through the senses of taste and smell than through vision? There's more data, more receptors, there are more variations – in vision we see in only three bands of light.

[JL] Yes and no. We seem to be able to communicate more biological information through odours, however, more semantic or cognitive information by way of vision. It seems as though our consciousness system is better at processing visual data, but the non-conscious is better at processing odour. This could be because, and this is pure speculation, odour was the first sense to develop in evolution. And that's why all living organisms have some sort of chemical detection system (including trees). But, it could be that odour remained in this stage where there are a lot of automatic processes but it is on a non-conscious level. Perhaps that's why a lot of olfactory processes are in the lower part of the brain, related to the limbic system; where vision and audition are in the neo-cortex, in this big outer shell where we don't have many odour processes going on.

[RB] You reference the work of R. Khan and pleasantness as a primary axis, does that mean that odour is similar to taste, in that pleasantness and putrid might be similar to something like sweet and sour. Are we wired to have hedonic response to chemical input? Perhaps that's why we have a problem with abstract thought when it comes to odour?

[JL] I think that the main functions of the chemical sciences are approach/avoidance. For instance, we habituate very quickly; particularly with odours but also with taste. For instance, once we have been warned about something then it doesn't make a lot of sense to repeat the warning. So, we are warned, then we habituate, then we continue to explore other odours. We also have a very rapid adverse reaction to odour and taste. If you've ever been sick from food in a restaurant, it actually only takes one negative pairing with a situation and a bad taste/odour and you will remember that odour for the rest of your life.

[RB] Yes. Nausea is an amazing reaction. I understand that nausea is being used to alter behaviour for diet change, breaking smoking habits, etc.

[JL] For treatment you have to repeat this exposure more often. And that, we think, is due to the close link between the olfactory system and the amygdala (saliency and fear detection) and the hippocampus (memory). But we also have a very strong approach. For instance, anyone who has smelled their baby attests that it's the most beautiful odour that they have known – the odour of a mother's child is highly linked to reward – so, the dopamine system. So, it seems as though we have this avoidance/approach function built into us, and when you have that system then there is no need to be detailed. You don't need to know if you're running away from a tiger or a lion; as long as you know that there's a dangerous cat trying to kill you then you're going to run away. So, you don't have that need in olfaction.

So, that's why we have this debate about whether the primary factor in olfaction is quality or pleasantness. I tend to think that it's pleasantness, but the qualitative is very important for the final perception. A new paper came out recently that suggests that we're faster at making a qualitative judgement than a pleasantness judgement (probably a bit biased in favour of their research).

[RB] Does speed necessarily mean importance?

[JL] For the brain it does. The shortest, most direct neural pathway is indicative of importance in the brain. We detect the image of a spider far faster than that of a mushroom.

[RB] So the avoidance/reward system exist quite strongly in vision as well as in olfaction?

[JL] Yes. It's throughout all of the senses. But it's much more attuned in the sense of olfaction.

[RB] Aristotle presents a hierarchy of the sense – is there validity to it?

[JL] People like to claim that the visual sense is the primary sense, but this may come down to the fact that 90% of perceptual work in the world has been done on vision because it's such an easy sense to work with. For example, with olfaction the odour object utilised in a test will change over time; so the odour that you begin a test with will not be the same as the one that you end with. With taste, you have to utilise physical objects – you have to carry them around, and deliver and retract that physical object. In the world of academic publications, vision is at the top. Lower down is audition, then tactile, then way lower down is olfaction, and hardly visible is taste. Taste, from a scientific point of view, is a more boring perceptual sense because you only have five qualities. We are only now beginning to do 'real multisensory research', where we explore three or four senses that are interacting. For example, they smell fish odour, they view a video of a flopping fish, they hear the sploshing of the fish flopping; we then try to see how the brain merges those three senses, and does it matter which sensory combination we have for the merger?

[RB] This is rather counter-intuitive to how research used to be done, as scientists used to try to make this research as simple as possible. I.e. researching a horseshoe crab and trying to understand basic black-white perception. At that time, it was almost impossible to comprehend the complexity of multisensory evaluation. So, in this regard, we've come a long way in a short amount of time.

[JL] Science has always been about reductionism; reduce the object of study to its most basic element possible and then explore that in absurdum, and then build from there. Many neuroscientists have a dream that we could 'plug in' to every neuron in the brain, and if we can record everything in the brain then we can understand the human mind. I don't think so. I think that there's a super-additive effect where the sum is more than that of its parts. So, even though we can record every single neuron, we still wouldn't know the neural code. What we're trying to do now is that we present multisensory stimuli and then adjust the levels of one to see how the others respond. So, if you study a single olfactory percept then we can begin to think we understand how that signal works. But if we pair that percept with a visual image, then the whole perceptual response changes. So, in that context, is it really true what we know about the olfactory system? Because, how often do we explore one odour in complete sensory isolation? Since that never happens then we should be studying that.

[RB] It seems as though, because we were very interested in vision, that we developed our knowledge about that sense over a long period of time, in increments determined by new tools and advances in our knowledge of biology; meanwhile, the senses of taste and olfaction were largely ignored. Now, even since the discoveries of the olfactory receptors by Buck & Axel (1991),

we've leaped forwards in our understanding of these senses, partly because we have both a desire to explore the senses and a huge array of tools available to do so.

[JL] When it comes to human perception, the big breakthrough for vision was the invention of the monitor, because then we could actually present stimuli on screen rather than having flashcards. Then, with speakers we could present artificial sounds, we can modulate it. But, with olfaction there has been a standstill for many years because for olfaction we need to have olfactometers. Olfactometers are very complex to build, it is dependent on a lot of technology, and the people who study perception are psychologists, not engineers.

[RB] I read your paper on how to build a cheap olfactometer…

[JL] What we would like to do, we can only do if we build these ourselves, because we cannot buy these devices. There's one that we can buy that delivers only four odours, but it will cost 190,000 euros. Since researchers can't spend that much money on one machine then we need to build our own.

[RB] I work with artists and would like to bring them some information that would help them to develop their ideas and projects that engage the chemical senses; do you have any favourite ways of manipulating taste perception? Looking at it as a sort of provocation for emotional responses from an audience.

[JL] Change the label. If you take parmesan cheese, put it in a jar and cover it with cotton, then say "Damn! Did someone vomit in this jar?" Then hold it out for them to smell. They will be repulsed by the smell. Then the next day you can try the same, or on some other person, and say "Don't you love this fromagio from Italy, this Parmegano?" And they'll be like, "Ahhh, with pasta, I love it!" So, while the odour is the same, the label will completely change its perception. We do this with isovaleric acid and either label it as 'stinky feet' or 'French cheesy' and people will believe it either way and rate it on either end of the pleasantness spectrum.

[RB] So, by providing varying emotional contexts for the interpretation then you can vastly alter the outcome.