By ZOË SMITH

Professor Andrew Hemmings started researching the equine brain 22 years ago with his colleagues at the Royal Agricultural University

Photo courtesy of Royal Agricultural University

> “I developed a passion for horse behaviour and... the relation between brain function and behavioural output.”

THE **BIG** INTERVIEW

Andrew Hemmings

IH Magazine Editor ZOË SMITH talks to equine neuroscientist and Royal Agricultural University Associate Professor Andrew Hemmings about how horses learn, genetic testing for stereotypical behaviours, and why understanding the brain is essential to understanding horse behaviour.

“One of the most surprising things for me is how *similar* they are,” Dr Andrew Hemmings reveals when I ask him about the main differences between the horse and human brain. “When we started researching the horse’s brain about 22 years ago, we weren’t even sure that the striatum of the horse – the group of structures in the brain that includes the putamen, the caudatus, and the nucleus accumbens – even existed,” he recalls, “and very early on, we took thin microscope slides through what we thought was the striatum and we sent them off to a neuro-anatomist, Professor Paul Bolam at Oxford University, to see what he thought. About two weeks later, I received a call from him saying: ‘Are you taking the mickey? You’ve sent us *human* brain material!’ He could hardly distinguish the equine striatum from the human equivalent – that’s how similar they are!” Andrew laughs, agreeing: “if you look at both in diagrammatic form, they *are* exceptionally similar.”

Some of the biggest similarities lie in how horses learn, a process that, Andrew explains, is all related to the part of the striatum called the nucleus accumbens. “Horses learn in a very similar way to all mammalian species, and it always links back to the nucleus accumbens, the primary reward or pleasure centre of the brain.

“It starts with the cerebral cortex, which is that walnut-shaped, vastly folded outer covering of the brain. Essentially, this is the part of the brain that receives stimuli from the external environment. For example, there’s an area called the occipital lobe, which receives the sight-related information and the temporal lobe, which receives the sound-related information. The cerebral cortex is connected to the striatum via weak neural links.”

When the nucleus accumbens is activated, Andrew tells me, dopamine (that “happy hormone” or “molecule of more” that you’ve probably all heard of) is released, issuing a “reward” for the connected behaviour. That reward provides the motivation for repeating the learnt behaviour and, over time, with correct timing, it can strengthen the neural pathways leading to learning.

Andrew uses the easy-to-envision example of food training, with a clicker as a marker: “You’ve got a clearly audible click, which to an untrained horse means virtually nothing. But when we pair the click with the arrival of a food reward. Click: reward, click: reward, click reward.*

“The reward brings about activity in the nucleus accumbens, and when this fires, it strengthens the connection between the nucleus accumbens and the area of the cerebral cortex that fired immediately before the arrival of the reward. So, in this case, the click will bring about activation of the temporal lobe. After several pairings of the click and the reward, the neural circuitry between these two will strengthen over time. Such that, in a clicker-trained horse, the click alone has the power to bring about reward or activity within the NA. We call this strengthening process ‘long-term potentiation’.”

What about with negative reinforcement, I ask, the pressure-release formula that has long formed the basis of traditional riding and modern horsemanship protocols? “You are still activating the same circuitry in the brain. With negative reinforcement, you are applying what might be considered a mildly adverse stimulus, such as right-leg pressure, and continually applying that pressure, then removing it when the horse does the correct thing. At the end of the day, we’ll still see the same kind of brain activity as providing a reward or a treat.” Andrew assures me, although he admits that while “studies have looked at the difference in learning *efficiency* between the two types of training, it hasn’t been studied in the horse at the level of the brain.”

> **“Whenever we’re teaching a horse a new skill or new behaviour, we need to remember what is going on in the brain...”**

Photo courtesy of Royal Agricultural University

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Top: Andrew’s career in education aligns perfectly with his primary motivations as a scientist. Bottom: Zebra are far more difficult to domesticate because they have a larger amygdala or ‘flight centre’ than horses.

? DID YOU KNOW?

The amygdala or ‘flight centre’ of the zebra is significantly larger than that of a horse, which gives us some clues as to why some equids, such as Equus caballus, the domestic horse, have been domesticated and co-exist very happily with humans, while others such as the zebra are far more difficult to domesticate.

It’s one of many times during our interview when my questions are met with the admission that “it hasn’t been studied yet” or “we don’t know enough about this yet”, but Andrew sees this as an opportunity rather than an obstruction. In fact, it was the scarcity of answers in this field that piqued his interest in the first place. “The brain and how the brain generates consciousness, and behavioural output is one of the true research horizons for scientists,” he enthuses, “Whether you’re studying rodents, or humans, or horses, there is so much that we don’t currently understand about the brain. We’ve only really scratched the surface, so it’s possible for researchers to really make a difference, both for human health and welfare, and also equine health and welfare.”

Having grown up around horses “pretty much since the year dot”, Andrew caught the horse bug early. He progressed through a string of loan ponies before his parents finally bought him his first pony, a Welsh Section D called Fairy, at 11 years old, followed by several event horses through his teens. “My real love around horses was taking an unbroken horse and developing them and taking them up through the lower levels of eventing before selling them on.” By 21, his passion had evolved into career ambitions as he undertook a degree in equine science at Aberystwyth University and, he reveals, “very early on in my university life, I developed a passion for horse behaviour and, in particular, the relation between brain function and behavioural output.”

An MSc and a PhD in equine science followed, and he joined the Royal Agricultural University in 2000, where he is now an Associate Professor of Equine Science and the head of the Equine Management and Science department. His career in education aligns perfectly with his primary motivations as a scientist: “I think it’s safe to say that my true passion is taking the neuroscience that I’m learning in the lab and putting that into a usable format which can actually be taken on board by the average horse owner and applicable in the way in which we manage and own the domestic horse.”

True to form, as he talks me through the horse’s learning process, he’s keen that I don’t only understand the basic neurological functions but, far more importantly, that I grasp the practical takeaways. First up is the importance of giving our horses sufficient time to learn and consolidate that learning. “A really critical point to understand is that long-term potentiation involves a structural change in the brain – a strengthening of neural pathways – and that takes a bit of time to consolidate,” Andrew tells me. “Whenever we’re teaching a horse a new skill or new behaviour, we need to remember what is going on in the brain and that those structural changes take time.”

He gives me an example: “Let’s say you’re on a youngster and you’re applying right leg pressure and asking them for a left leg yield. Let’s imagine you’re trying this for the first time and not getting very far; you might get a couple of strides of leg yield, but not much. Then you leave it and come back the next day or in a couple of days, and very often, you apply the right leg, and you immediately get the leg yield. That’s because it takes a bit of time for the changes to occur in the brain; for the consolidation of learning. >>

i For more on clicker training & the use of food in training, read our Food for Thought article in the Winter 2017 issue of *IH Magazine*.

Andrew Hemmings

>> "When working with a youngster, or any horse for that matter," he concludes, "if you get something approximating the right answer, then it's probably a good time to end the session and come back the next day. "

The second point that Andrew wants to get across to riders – and it will come as no surprise to IH Members – is that: "Stress is the enemy to learning. Whenever we fire up the stress centres, such as the amygdala, it cancels out any useful changes that can occur in that animal's brain. It essentially *prevents* the long-term potentiation that we are seeking".

"The amygdala, which is Greek for almond, is the brain's 'fight or flight centre' [in humans, it's been shown to have a key role in processing amygdala emotional responses such as fear and aggression]," Andrew explains further, and it's one area in which the equine brain is different to the human equivalent, "If we look at the amygdala as a percentage of the brain's overall mass, it occupies a larger percentage in the horse than it does in the human, which speaks to the flighty nature of the species."

Combine this with the prefrontal cortex of the horse, the part of the brain that controls planning and decision making, which occupies a significantly *lower* percentage of the overall brain mass compared to the human equivalent. "This means that horses can't dampen down their impulsive nature; they are much more ruled by their instincts and impulses," he continues, "so just because a horse has wheeled around and galloped back up the farm lane because there's a fertiliser bag flapping in the hedge, that's not necessarily a cause for punishment. If the flight circuitry is activated, the horse might not actually have much choice in the matter. That's something that is quite valuable to bear in mind when we train horses."

Keeping training stress-free is clearly key but, I wonder, surely we can't eliminate all stress from training? In fact, I'd read that in humans, some element of difficulty or challenge is actually required by the brain to promote learning and increase neuroplasticity. Andrew agrees that this is likely similar for the horse, but he draws a firm line at anything that engages a flight response through pain or fear. "A moderate level of arousal can promote learning," he tells me. "Awareness and alertness to the environment and incoming stimuli means that the horse will have a cerebral cortex which is primed for new stimuli and a striatum which is all fired up for forming these new connections. And although this has not actually been studied in the horse, looking at the studies in humans, I believe that would be the case.

"However, when you fire up the amygdala, the flight centre, you can pretty much cancel out any useful learning or structural changes in the brain," he cautions, "Eliciting a true stress response or flight response, through punishment, for example, that's rarely going to yield the results we need, and it's rarely going to set the scene for a successful horse-human bond."

This dopamine response and subsequent strengthening of neural pathways is all well and good when the horse is learning something we want them to learn, but what about when the horse learns a negative or unwanted behaviour? One of the major breakthroughs in equine neuroscience, and one that Andrew's studies have been pivotal in highlighting, concerns stereotypical behaviours such as crib-biting, wind-sucking, and weaving. Interestingly, it turns out that these behaviours, while self-taught, are actually 'learnt' by the horse in a similar manner to positive reinforcement.

"The results that we've obtained from quite a few of our brain studies suggest that a behaviour like crib-biting actually results in a low-level activation of the brain's pleasure circuitry. So, it actually brings small pulses of pleasure [i.e. dopamine] to the horse as they crib bite, and we believe that the horse uses these behaviours as an anti-stress coping strategy," he surmises, "in the same way that we might use pleasurable commodities like coffee, chocolate, alcohol, or nicotine to help us cope with the stress of modern living".

Generating data on this has seen a decisive shift in the ways in which these kinds of behaviours are handled within the horse industry. "Twenty years ago, when I was coming through the pony club and the BHS, if a horse started crib-biting, we were told to get a crib strap on immediately to prevent the behaviour. But [these studies have enabled] me to say, 'well, how would you feel if you were denied your [choice of coping mechanism] on a Friday night after a massively stressful day in the office?' It's a similar thing for a horse by putting a crib strap on."

That's not to say that these stereotypical behaviours are unavoidable or inconsequential, but Andrew insists that it's important to shift the focus to early prevention and management rather than cure. "We've found that as a horse develops crib-biting or weaving behaviours, widespread changes occur in that horse's brain and, based on information that we already have from rodents, undoing those changes at the level of the brain will be exceptionally difficult. So, for me, once these behaviours are developed, I don't think we can get rid of them altogether," he concludes.

"Several people have tried a drug-based approach, blocking certain receptors in the brain, but for me, physical prevention is definitely not the way to go. As these are stress-relieving behaviours, all we are going to succeed in doing is elevating the daily stress that we're inflicting on that horse. And we all know that when we're under stress, particularly chronic or long-lasting stress, our health is reduced, we become more prone to infections and illnesses, and our performance is reduced. It's exactly the same for horses."

"It is possible to reduce stereotypical behaviours significantly," Andrew assures me, if we focus on minimising stress and allowing the horse a lifestyle closer to that which it evolved to live (increased forage, plenty of turnout, cutting out concentrated

> **"There are still so many fundamental questions that remain unanswered."**

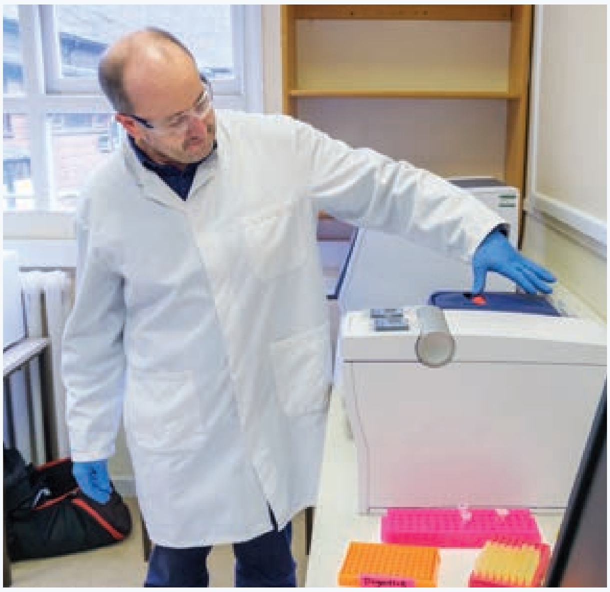

Photo courtesy of Royal Agricultural University

Andrews laments the lack of funding for equine neuroscience, but he is hopeful that this will change as the industry better understands the value of equine behavioural neuroscience

? DID YOU KNOW?

The horse brain (around 750g) is about half the size of the human brain (around 1500g).

The amygdala occupies a larger percentage in the horse than it does in the human, which speaks to the flighty nature of the species

"Stress is the enemy of learning."

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PICKING OUR EXPERT'S BRAIN

CAN HORSES EXPERIENCE REMEMBERED PAIN?

"I haven't come across any aspects of remembered pain in the peer-reviewed science in horses, but given the similarities between the equine and the human brain, I wouldn't be surprised if some horses exhibited a degree of neuropathic pain, which is a pain response or lameness that persists way beyond the injury itself. In humans, this is related to a neurotransmitter called glutamate in an area of the brain called the anterior cingulate cortex, and there have been quite a lot of studies that show some people have a hypersensitive anterior cingulate cortex. Once that area has been activated during a significant injury like a limb break, for some reason, that area of the brain keeps buzzing away."

CAN A HORSE GET ALZHEIMER'S?

"No, not that it's been recorded. The only equine neurological condition we are aware of that's more associated with the veteran animal is PPID or Cushing's disease, which mirrors some of the behavioural aspects of Parkinson's in humans. Nerve cells containing dopamine actually dwindle or die off in horses with PPID, and because it's really important for learning, we often find that their cognitive skills are affected. Horses with Cushing's can be significantly slower in learning brand new cognitive tasks, and also more docile and less active.

feeds, etc.), but there is also a possible long-term strategy that he is particularly excited about. "One of the really interesting research frontiers for me is figuring out the relationships between breeding, genetics, and behaviours. For example, what aspects of brain structure and function is that animal born with? What aspects of temperament and behaviour can be related to nature, and what bits can we impact upon with training and management that are more open to nurture?

"We've already learnt quite a bit about the relationship between brain function and temperament, and I'm currently working on developing a genetic screening, where we can take a horse at birth or at weaning and make predictions about its future temperament and behavioural output. For example, I would love to have a genetic test for stereotypical behaviours; then we could put in place a series of management to reduce stress for that horse to prevent that horse from ever manifesting crib-biting behaviour. Or if we could create a set of environmental conditions that reduce stress and improve behaviour for, say, a 2-year-old racehorse, then we would reduce things like gastric ulcers, reduce the days that the horse takes off from training, *and* have a happier, healthier racehorse at the end of it.

"One caveat," he's quick to add, "is that we don't throw the baby out with the bathwater. Whenever we develop this genetic test, we need to be careful that we don't use it to select *against* genetic traits but instead to inform the management of that animal in light of its genetics.

"If we were to do that, we could select against really useful performance traits," he warns, "For example, I think there's a reason why many top-level event horses are also crib biters because they are quick thinkers and quick learners." It's been noticed by scientists, too: "When we take horses that crib bite and weave and ask them to perform relatively simple cognitive tests – for example, we train them to select a screen for a food reward – they seem to learn those tasks remarkably quickly; quicker than other horses".

While Andrew laments the lack of funding for equine neuroscience (despite there being "an almost unlimited pot of money for human neuroscience!") and admits that "there are still so many fundamental questions that remain unanswered", he is hopeful that this will change as the industry better understands the value of equine behavioural neuroscience. "If we think about what might be considered as the main trait of interest in the horse, to me, its temperament and behaviour, because an amenable temperament and an appropriate behavioural profile is absolutely essential to the horse-human relationship," he tells me, "And the primary organ of behavioural output is the brain. So, for me, if we are ever to properly understand behaviour and temperament, we've got to understand the brain."

• To find out more, sign up for the IH Webinar "Exploring the Horse Brain with Dr Andrew Hemmings" on Wednesday 12th October 2022 at 8pm on the IH website.