ATTENTIONAL SHIFTS ALTER PAIN PERCEPTION IN THE CHICKEN

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In humans, psychological manipulations such as hypnosis, behavioural modifications, relaxation training and cognitive behaviour therapy have all been used to reduce pain intensity. One thing these treatments have in common is selective attention. Work on attention-based cognitive coping strategies has shown that they have potentially useful analgesic qualities in pain therapy. In animals, there have been few studies on the effects of attentional shifts on pain perception. There is extensive literature on stress-induced analgesia and it is likely that, in some of the experiments, attention could be an important variable. This paper will present some of our recent work on selective attention and pain perception using the sodium urate model of gouty arthritis. Birds are naturally prone to articular gout and the model we have developed mimics acute gouty attacks in a single joint. Experimental sodium urate arthritis produces a tonically painful inflammation lasting for at least 3h during which time the animals show pain-related behaviours. Changes in motivation can reduce these pain-related behaviours and it has been hypothesized that these motivational changes act by way of altering the attention of the animal away from pain. The motivational changes investigated included nesting, feeding, exploration and social interactions. The degree of pain suppression ranged from marked hypoalgesia to complete analgesia and as such demonstrates a remarkable ability to suppress tonic pain. These shifts in attention not only reduced pain but also significantly reduced peripheral inflammation. These results are discussed in terms of the limited capacity models of attention.

Keywords: *analgesia, animal welfare, articular gout, attention, chicken, pain*

Introduction

One of the major problems in evaluating animal welfare is the detection and assessment of pain. The acceptance that animals can feel pain, as opposed to simple nociception, depends to a large extent on being able to demonstrate a cognitive emotional response to noxious stimulation of the animal. Because of the absence of verbal communication, it is very difficult to demonstrate pain in animals and pain is generally identified on the basis of probability using a wide variety of behavioural and physiological measurements. A new approach we have been investigating is the effect of selective attention on pain-related behaviour, and this work on attention not only provides information about the cognitive perception of pain but is also evidence for consciousness in chickens.

In general, there are three major attentional functions: orienting to sensory stimuli; detecting target events; and maintaining the alert state. As such, attention is central to the issue of cognition (Posner 1995). In humans, psychological manipulations such as hypnosis (Spanos 1989), behaviour modification (Keefe & Lefebvre 1994), relaxation training (Jessup

& Gallegos 1994), and cognitive-behaviour therapy (Turk *et al* 1983) have all been used to reduce pain, but the mechanisms underlying these procedures have not been fully explained. One variable common to all of these procedures is selective attention (Miron *et al* 1989) and although attention-based cognitive coping strategies have potentially useful analgesic qualities, there are, however, contradictions in the literature (Eccleston 1995a). For example, McCaul and Haugtvedt (1982) have reported that a distraction strategy is inferior to an attention-focusing strategy in affecting pain; whereas Devine and Spanos (1990) used both distraction and attention-focusing paradigms, but found no strategy was superior to any other. Switching attention between competing inputs to the brain or between perceptual modulation is an important function in everyday attention and any object brought into attentional focus must be further processed or denied processing (Eccleston 1995b). Pain, however, is the ultimate controlled task: it is, by definition, a conscious process, which cannot become unconscious (Jaynes 1985; Cioffi 1991), and seems designed to capture the already-employed attention and to disrupt normal central attentional processing (Eccleston 1995b).

Attention is often viewed as a finite resource and many authors consider that there are only limited attentional resources available (Kahneman 1973; Logan 1985). High intensities of pain can interfere with the attentional processing of other tasks because they compete for attentional resources. Eccleston (1995b) found that when patients with chronic low-level pain were given an attentional task to perform they did not process pain at the same time. A study of acute pain showed that changes in directed attention could alter both the perceived intensity and the unpleasantness of a painful stimulus (Miron *et al* 1989). Recent work has shown that virtual reality is a medium capable of maximizing the attention drawn away from the 'real world' and has been used to provide pain relief during painful wound dressing (Hoffman *et al* 2000).

While attentional changes have been used for pain relief in humans, there have been few systematic studies in animals, especially non-mammalian vertebrates. In our laboratory, we have undertaken a series of experiments to investigate the effects of attention on tonic pain behaviour in the chicken utilizing different motivational states including environmental manipulation, nesting and feeding.

Tonic pain model

Orthopaedic disease is widespread in modern meat-type poultry and leads to a loss of locomotor function (Duff 1985; Duff & Thorp 1985; Duff & Hocking 1986). Articular gouty arthritis is common (Riddell 1991) and can be induced experimentally by the injection of microcrystals of sodium urate into the joint space. Intra-articular injection of sodium urate has been used as a pain model in both mammals (Okuda *et al* 1984; Coderre & Wall 1988) and birds (Floersheim *et al* 1973; Brune *et al* 1974; Gentle & Corr 1995). In the chicken, injection of sodium urate in the joint space was followed by a latent period lasting from 2–30 min, after which the bird lifted the injected leg and stood on the unaffected leg (Gentle & Corr 1995). Within 45–90 min after injection, the birds spent most of their time sitting and dozing. They appeared hypoaesthetic, with drooping head and tail, ruffled feathers, few head movements and eyes intermittently closed. In this condition they were unwilling to stand or walk, and if encouraged to do so, they staggered and were reluctant to put any weight on the injected leg. One-legged standing, limping and sitting were clear examples of pain-coping behaviour, which can be assessed quantitatively (Gentle & Corr 1995). In all of these experiments the birds were housed singly in cages and were returned to their cages after the urate injection.

Sodium urate injected into the joint space produced an inflammatory response which could be measured by the classic signs of inflammation: redness, swelling and pain. There was a significant increase in temperature in the injected joint as well as an increase in joint diameter (Gentle 1997). To provide underlying physiological evidence for the pain-related behaviours, the properties of the joint capsule receptors in the ankle were studied in the 3h period immediately after sodium urate injection. During the inflammatory period there was a sensitization of the C fibre nociceptors but not the A-delta fibres. This sensitization was observed as significantly increased receptive field size, decreased response thresholds, increased response to joint movement and a high level of spontaneous activity. In normal joints, the receptive fields of the nociceptors is usually circular or elliptical in shape and 2mm in diameter, whereas in the inflamed joints 53 per cent of the fibres had receptive fields significantly larger than 2mm. Thresholds to von Frey hairs were reduced from a mean of 11.5g in the normal joint to 1.29g in the inflamed one. Spontaneous activity in the normal joint usually consisted of 1–2 nerve impulses in a 10s period in about 21 per cent of the fibres. In the inflamed joint, 86 per cent were spontaneously active and this level of activity was several impulses per second. The level of neural activity in response to moving the joint was very low in the normal joint (28%) and this response was only to noxious movement, whereas inflammation resulted in neural responses to both normal and noxious activity in a large number of nerve fibres (70%). In humans, nociceptor sensitization results in increased pain, hyperalgesia which produces decreased pain thresholds (Torebjörk *et al* 1996), increased pain following stimulation and spontaneous pain. Hyperalgesia would explain the behaviours shown by the birds following urate injection when the animal is attempting to reduce any stimulation of the inflamed joint by standing on one leg or sitting quietly. The behavioural changes, and physiological and clinical evidence point to prolonged inflammatory pain lasting for at least 3h after sodium urate injection into the joint space (Gentle & Corr 1995; Gentle 1997).

Effects of environment on pain behaviour

In a second experiment, the effects of the environment on pain-related behaviour was tested (Gentle & Corr 1995). The birds had been reared in cages, and 3 days before testing they were placed in pairs into pens containing a deep layer of wood shavings. One bird in each pair received an injection of sodium urate into the left ankle joint and the other a control injection, and they were returned to the pen. The urate-treated birds showed significantly less pain-related behaviour than those birds tested in cages ($P < 0.01$). There are a number of factors in the pen environment which might provide an explanation for pain suppression, such as distraction, redirection or even motivation to explore the litter for possible food. If the hypoalgesia resulted from competing stimuli then it is likely that the introduction of a degree of novelty might be expected to produce a greater degree of pain suppression. This hypothesis was tested by injecting birds which had been reared in cages, and after injection placing them into a pen with a companion bird. The urate-injected birds either showed complete analgesia or significantly less pain-related behaviour than those in battery cages ($P < 0.01$). The reduced pain behaviour in the novel pen experiment cannot be described as 'stress-induced', as the birds showed none of the signs of fear or distress such as vocalization, immobility or escape behaviour. Instead, they behaved as normal, alert birds whose attention was being directed to exploring the novel physical and/or social environment.

Some recent work has shown that not only can pain be reduced by changes in attention but also clinical signs of inflammation can be reduced. In humans there is evidence that placebos not only influence pain but also reduce inflammation (Hashish *et al* 1988). Although it would be very difficult to design an experiment to investigate placebo effects on inflammation in animals, the effects of attentional changes on inflammation has been investigated (Gentle & Tilston 1998). In this experiment, a similar protocol to the novel pen experiment was used and the skin temperature over the injected joint was used as a measure of inflammation. These results showed that reduced inflammation accompanied reduced pain when the birds were placed in the novel pen as opposed to the familiar cage. At present, we can only speculate as to the possible mechanisms for this reduced inflammation. Studies on the neural activity in the medullary dorsal horn of the monkey (Hayes *et al* 1981; Bushnell *et al* 1984) would indicate that attention-dependent changes in sensory discrimination and affective components of pain are mediated at an early stage in sensory processing. Bushnell *et al* (1984) recorded the neural activity from trigeminal nociceptive neurones in the medullary dorsal horn and showed that the magnitude of the response to thermal stimulation was modulated by its behavioural significance to the animal. Behaviourally-relevant thermal stimuli presented during a thermal discrimination task resulted in a greater response than an equivalent irrelevant thermal stimulus. The mechanisms for these effects have not been fully investigated but there are numerous descending modulating pathways which influence processing of nociceptive information in the spinal cord. Descending inhibitory mechanisms, for example, would reduce neural activity in the dorsal horn in response to afferent nociceptive inputs and alter the activity of the peripheral nervous system. The peripheral nervous system plays a significant role in inflammation (Levine & Taiwo 1994), and similar neural components (neurogenic inflammation) have been demonstrated in birds (Gentle & Hunter 1993). There is evidence that dorsal root reflexes in the spinal cord contribute to the acute inflammatory response by means of neurogenic mechanisms (Rees *et al* 1994; Sluka *et al* 1995). In the chicken, if the shift in attention affects pain processing in the dorsal horn of the spinal cord then this could attenuate the dorsal root reflexes. The inflammatory response to sodium urate has two components: a general tissue reaction, and an additional neurogenic effect. Changes in attention will not affect the tissue reaction, but by attenuating the dorsal root reflex could reduce the neurogenic component. This would explain the fact that the joint is still inflamed but to a significantly lesser extent than in birds where they are attending only to the painful nature of the stimulus.

Nesting behaviour

Pre-laying behaviour has been well documented in the domestic hen (Mills 1983) and can occur several hours before the egg is laid. In this experiment, the birds were injected with sodium urate into the ankle 1–2 h before oviposition (Gentle & Corr 1995). All of the birds were tested in cages where they showed pre-laying behaviour such as pacing along the sides of the cage, attempts to escape and rotating movements in the corner of the cage. None of the birds showed any lameness, one-legged standing or sitting during this pre-laying period which lasted up to 2h after injection. During this period, the birds' attention seemed to be fully occupied with finding a suitable nest site, and they seemed to be totally unaware of the pain coming from the ankle. Following oviposition, the birds would briefly feed and would then show pain-related behaviours, either one-legged standing or sitting.

Feeding behaviour

The relationship between feeding and pain is complicated and, although McGivern and Berntson (1980) have suggested the effects of food deprivation on pain sensitivity are related to the hunger state, in conditions where tonic pain follows trauma or disease reduced food intake is commonly observed (Morton & Griffiths 1985). When food-deprived birds are food deprived they show a prolonged period of feeding when given access to food. During this feeding period they show significantly less pain behaviour to intra-articular sodium urate injection immediately prior to being given access to food than those birds given no access (Wylie & Gentle 1998).

Discussion of the behavioural experiments

It is clear that significant analgesia can be produced in the chicken by a variety of different motivational states and the mechanism involved presumably involves attentional mechanisms. Although the absence of pain-related behaviour does not necessarily indicate the absence of pain, it does, however, seem the most likely explanation, given that changes in attention are known to be effective in attenuating pain perception in humans (Eccleston 1995b). When tested in the battery cage, the birds spent 93 per cent of their time showing pain-related behaviour following urate injection and many of the experimental manipulations produced partial pain relief, with pain-related behaviour occupying on average 59 per cent of time in the familiar pen and 46 per cent in the novel pen. It was also clear that some of the pain-related behaviours were not mutually exclusive, and birds were observed feeding while standing on one leg or even sitting. Although a range of different motivational states were effective in producing hypoalgesia, there was some indication that the degree of analgesia depended on the degree of motivation. Nest site selection in the battery cage and feeding behaviour can produce total analgesia in most birds tested. When tested in the battery cage, it would appear that the whole of the bird's attention was occupied in trying to reduce the pain as far as possible, and that the animal 'perceived' the pain as fully as it was capable of experiencing. When the animal's attention was drawn to another stimulus then the model of limited capacity of attention (McCaul & Malott 1984; Fernandez & Turk 1989), when the animal performed a variety of behavioural patterns sometimes interspersed with pain-related behaviours, was supported by the data.

Brain mechanisms

The brain mechanisms involved during attention-related modulation of pain have not been investigated in any detail, but a recent paper by Petrovic *et al* (2000) has shown that the lateral orbitofrontal region of the cortex shows an increase in neural activity in humans during pain combined with an attention-demanding task, as compared to only pain, indicating possible involvement of the frontal cortex in attentional modulation of regions processing pain. The homologue of the frontal cortex in the chicken has not been defined, but there is evidence in the pigeon that the caudolateral forebrain may have some of the functions of the prefrontal cortex (Mogensen & Divac 1982, 1993; Waldmann & Güntürkün 1993). Ablation of the caudolateral forebrain in the chicken has demonstrated that this area of the brain is necessary for the development of pain-related behaviour (Gentle *et al* 1997) and provides behavioural evidence for a possible homology between the mammalian prefrontal cortex (Freeman & Watts 1950; White & Sweet 1955, 1969; Hardy *et al* 1967) and the caudolateral forebrain of the chicken.

Conclusions

Although sodium urate arthritis produces a tonic pain, the dose used was the minimum necessary to produce a significant behavioural change in the battery cage (Hocking *et al*

1997), and the ease with which the birds could be distracted from the pain would indicate that the pain was not severe. The fact that changes in attention modulated pain behaviour, and hence probably the pain experience by the animal, has far-reaching consequences for our understanding of pain in birds. It means that there is likely to be a cognitive component of pain in birds (with all that this implies) and provides evidence for consciousness.

From these experiments on pain and attentional mechanisms in the chicken, there are clear similarities with observations in humans, which indicates some basic underlying mechanism. In humans, however, pain seems to be designed to gain access to consciousness by interrupting all other current processing, and it is these characteristics of pain which are important in capturing attention (Eccleston 1995a). The ability of pain to capture attention in humans is also influenced by previous experience and the ability to predict future consequences. In the chicken, we will never know how much pain they experience and, in the absence of competing attentional demands, the animal's behaviour indicates that it is fully occupied in dealing with pain processing. In the presence of competing attentional demands, this results in the bird partitioning its neural processing between them. Wall (1994) has proposed a hypothesis which fits well with these observations in the chicken. He considers that there are two sequential uses for the sensory input: the first is to assign priority, and the second to guide motor behaviour. Pain only appears as a conscious phenomenon in the second epoch of sensory analysis, after the first period during which priority was established and during which consciousness was not altered. In the case of a bird in a novel environment or nest building, the major priority is exploration or searching for an appropriate nest site and pain is assigned to a lesser priority.

Animal welfare implications

Freedom from pain is essential for the welfare of the animal. Lame birds are commonly seen in commercial poultry flocks and the extent to which the lame birds suffer pain will depend on the cause of the lameness. In general, inflammatory conditions are usually regarded as painful. The results from a series of experiments using sodium urate arthritis as a model of arthritic pain has shown that motivational changes can alter the birds' attention and significantly alter pain-related behaviours. These attentional shifts indicate a cognitive component of pain in the chicken and provide evidence of consciousness. The implications for the welfare of the bird is that the pain they experience may have some of the complex facets of pain normally only ascribed to pain in humans. On a practical level, because the motivational state can alter pain, environmental enrichment would promote attentional shifts and thereby potentially improve the welfare of birds suffering pain under commercial conditions. Because behavioural measures are probably the only practical methods which could be used to try to assess pain in these animals, considerable care must also be exercised when collecting behavioural data so as not to influence the birds' motivational state.

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