

PAIN IN BIRDS

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Abstract

For the detection and assessment of pain in animals both behavioural and physiological measurements are necessary. Cutaneous receptors which responded to noxious stimulation (nociceptors) have been identified in birds and have been characterized physiologically in the chicken. Following cutaneous nociceptive stimulation the chicken showed cardiovascular and characteristic behavioural changes consistent with those seen in mammals and indicative of pain perception. Following major burn trauma (partial beak amputation) there was behavioural and electrophysiological evidence for a pain-free period lasting several hours. This pain-free period was followed by pain-related behaviour with both anatomical and physiological evidence for long-term chronic pain.

While pain has been assessed following nociceptive stimulation and following trauma the painful consequences of chronic disease have not been investigated. Spontaneous degenerative joint disease is widespread in certain strains of intensively reared poultry, and while we do not know what effect joint degeneration has on the joint capsule receptors, recent work has shown in the joint capsule of birds there are similar receptor types to those found in mammals and it seems likely that joint degeneration in birds may be accompanied by painful sensations.

Experimental work has clearly detected painful conditions in birds but the alleviation of pain with analgesic drugs is not possible at present because analgesic agents have not been systematically investigated in birds.

Comparing pain in birds with mammals it is clear that, with regard to the anatomical, physiological and behavioural parameters measured, there are no major differences and therefore the ethical considerations normally afforded to mammals should be extended to birds.

Keywords: *animal welfare, beak amputation, birds, chickens, nociception, pain, trauma*

Animal welfare implications

Freedom from pain is essential for the welfare of an animal and this brief review summarizes the current state of knowledge on the detection and assessment of pain in birds. As such it provides information for the scientific evaluation of the painful consequences of current husbandry procedures and could have a predictive function for future developments.

Introduction

In birds, with the exception of a few isolated reports in the pigeon (Necker 1983, Necker & Reiner 1980, Szolcsanyi *et al* 1986), pain has been investigated almost entirely in the domestic hen (*Gallus gallus var domesticus*). Freedom from pain is essential for the welfare of an animal but the detection and assessment of pain in a bird presents a number of difficulties. Animals cannot be asked directly about the pain or suffering they may be enduring and even in humans verbal assessment of pain is difficult, especially in children. The problem is further complicated by the fact that there is no reliable or universal indicator of pain. What can be done, however, is to compare a range of physiological and behavioural measures with those changes which are associated with pain in humans, and thereby arrive at an estimate of the probability of pain in a given situation. Using a combination of physiology and behaviour, Zimmermann (1986 p30) has proposed a working definition of pain in animals:

Pain in animals is an aversive sensory experience caused by actual or potential injury that elicits protective motor and vegetative reactions, results in learned avoidance, and may modify species specific behaviour, including social behaviour.

This is not a comprehensive definition as it does not help to unambiguously determine whether or not an animal is in pain but it does provide a framework for experimental studies with which to detect pain. The results of such studies can be used to assess the painful consequences of current agricultural husbandry practices.

Pain is usually divided into acute pain and chronic pain. The former lasts for seconds to days and follows nociceptive stimulation or minor trauma, while the latter lasts for weeks or even years and is seen in chronic disease states or after major trauma. As part of this framework for detecting acutely painful experiences it is important to determine firstly that the animal has the necessary sensory receptors (nociceptors) to detect actual or potential injury and secondly that activation of these nociceptors results in both behavioural and autonomic cardiovascular changes. Chronic pain is not simply a continuation of acute pain; with prolonged pain new factors emerge following pathological changes in the peripheral nervous system and physiological changes occurring at the spinal cord and at higher levels in the nervous system. The behavioural changes seen in chronic pain are often more global in nature with not only guarding of the injured structure but reductions in a variety of behaviour patterns including overall activity, exploratory and grooming behaviour.

Nociceptors

A nociceptor has been defined by the International Association for the Study of Pain (IASP 1979) as: *A receptor preferentially sensitive to a noxious or potentially noxious stimulus*. A noxious stimulus being defined as a tissue damaging stimulus. Three different types of nociceptors have been identified in birds. Mechano-thermal (polymodal) nociceptors which responded to thermal and mechanical stimulation were

identified in the feathered skin of pigeons (Necker & Reiner 1980) and have been extensively investigated in chicken beaks (Gentle 1989). Thermal nociceptors without mechanical sensitivity have been reported in chickens (Beward 1985) and pigeons (Necker & Reiner 1980). Finally, a group of high threshold mechanical nociceptors have been reported in the chicken (Holloway *et al* 1980, Roumy & Leitner 1973) and other birds (Gottschaldt *et al* 1982, Gregory 1973) which have been investigated quantitatively in the chicken (Gentle 1989).

Mechano-thermal (polymodal) nociceptors

By recording the electrical activity in primary afferent nerve fibres from the trigeminal nerve the physiological characteristics of these receptors have been identified. These receptors showed no spontaneous activity and responded to heating of the receptive field with thresholds above 40°C and responded to mechanical stimulation with thresholds of 2g to over 50g. By measuring the conduction velocities of these afferent fibres it was determined that they conducted very slowly (from 0.4 to 1.86m/s) so that these fibres were unmyelinated C-fibres probably arising from cutaneous free-nerve endings. The discharge pattern of the majority of these polymodal fibres to sustained suprathreshold heat stimulation consisted of an irregular continuous discharge. Increasing the stimulus magnitude resulted in an increase in the number of responses up to a peak.

Thermal nociceptors

This group of nociceptors responded to thermal stimulation in terms of receptive fields, response threshold, and stimulus-response relationships in a similar manner to the polymodal nociceptors but did not show any mechanical sensitivity.

High threshold mechanical nociceptors

These receptors only responded to high threshold mechanical stimulation. Stimulation with hand held von Frey hairs, or by a 0.5mm diameter tungsten probe attached to a feedback-controlled mechanical stimulator, gave response thresholds of individual units ranging from 5g in some to over 50g in others. The conduction velocities of these fibres were measured and ranged from 1 to 5.5m/s which makes them small myelinated A-delta and unmyelinated C-fibres probably, like the polymodal nociceptors, originating from cutaneous free-nerve endings. Increasing stimulus strength over threshold produced an increase in response; in some fibres the stimulus-response curve was linear, whereas in others it was positively accelerating.

Comparing the physiological responses of the nociceptors found in the chicken with those found in mammals, it is clear that in terms of discharge patterns and receptive field size, they are very similar to those found in a variety of mammalian species (Beitel & Dubner 1976, Bessou & Perl 1969, Iggo 1959, Torebjork *et al* 1984). It has been held that the activation of cutaneous nociceptors is necessary for the conscious experience of pain in humans (Kruger & Rodin 1983, LaMotte 1984, Perl 1984, Zimmermann 1979) but this 'specificity' theory of pain has been subjected to criticism by Wall and his

co-workers (Wall & McMahon 1985) on the grounds that the specificity concept does not explain many clinical types of chronic pain. While specific nociceptive cells have been found in the spinal cord and in the somatosensory cortex (Kenshalo & Isensee 1983) the majority of cells in the spinal cords which respond to cutaneous nociceptive stimulation also respond to non-noxious stimulation (Iggo *et al* 1985). Therefore, while nociceptive stimulation cannot be equated with pain, it is, nevertheless, clear that activation of peripheral nociceptors is important in the detection of noxious stimulation and hence plays a crucial role in pain perception. The fact that birds like mammals have a well developed sensory system to monitor very precisely external noxious or potentially noxious stimuli means that the cutaneous sensory mechanisms for pain perception are present.

Behavioural and physiological responses to nociceptive stimulation

Having identified and characterized cutaneous nociceptors the next important step was to investigate the protective motor (behavioural) and vegetative (physiological) changes which follow nociceptive stimulation. A number of different nociceptive stimuli have been investigated and have included electric shock (Gentle & Richardson unpublished observations), comb pinch (Woolley & Gentle 1987), cutaneous thermal stimulation (Woolley & Gentle 1987) and the presentation of algogenic (pain producing) substances in the chicken (Gentle & Hill 1987) and pigeon (Szolcsanyi *et al* 1986). These nociceptive stimuli produced a rapid increase in both heart rate and blood-pressure. The magnitude and duration of the response depended on the strength of the stimulus. For example, a simple comb pinch produced a 23 per cent increase in heart rate which returned to normal within 35s, whereas following a 1s, 0.25mA electric shock the heart rate increased by 37 per cent and it took 2 minutes to return to normal. While heart rate usually increased following painful stimulation this did not invariably occur in response to each stimulus in any one animal and was a less reliable measure than blood-pressure. In an experiment where feathers were removed from birds (Gentle & Hunter 1990) individual feathers removed could produce as much as a 12 per cent increase in heart rate but of the 12 feathers removed from nine birds only 62 per cent of the removals gave a sustained increase in heart rate, whereas feather removal resulted in an increase in blood-pressure with each feather removed in all birds.

Two different behavioural patterns were observed following nociceptive stimulation. Following electric shock or comb pinch, active avoidance behaviour was observed; the birds showed vigorous escape attempts involving jumping, wing flapping and, occasionally, calling. Following cutaneous thermal stimulation or after the oral presentation of pain producing substances, however, the birds showed no escape attempts or vocalizations but remained passively immobile. This passive immobility was characterized by a crouched posture with the head drawn into the body and the eyes partially or fully closed. Either active or passive behavioural changes were observed following feather removal. In this experiment, feather pecking by other birds, a common

behaviour seen in intensively reared poultry, was simulated by the removal of a single feather from adult hens every three minutes. The animal was prevented from escape by being partially restrained. The behaviour of the bird and the electroencephalogram (EEG) were continuously recorded (Gentle & Hunter 1990). The first feathers removed resulted in the birds becoming agitated with wing flapping and/or vocalization. The continual removal of feathers did not produce an exaggerated escape response; instead they were observed shortly after feather removal to crouch in the restraint cradle with the tail feathers and head lowered in an immobile state. During this period of immobility following feather removal the EEG showed a characteristic high amplitude low frequency activity similar to that seen during sleep (Tobler & Borbely 1988, Van Luitelaar *et al* 1987) or catatonic states such as tonic immobility (Carli 1974, Gentle *et al* 1989, Klemm 1966, Ookawa 1972, Silva *et al* 1959). The functional significance of this change in behaviour from active escape to crouching immobility may be related to learned helplessness. Learned helplessness is a behavioural pattern which develops when an animal experiences traumatic events which are aversive and which continue to occur independently of any attempts by the animal to reduce or eliminate them. It is clear from work in mammals that learned helplessness can give rise to analgesia and a wide variety of repeated stressful or painful stimuli induce short-lasting reductions in responsiveness to noxious stimuli; a phenomenon referred to as stress-induced analgesia (Hutson *et al* 1984). During feather pecking it is commonly observed that the bird being pecked will show crouching immobility while feathers are removed with no outward sign of pain. Presumably this immobility is similar to tonic immobility, which is an anti-predator strategy to prevent further damage produced by struggling and to allow escape should the occasion arise. Hens kept under intensive agriculture conditions have no possibility of escape and the bird continues to be pecked. It is not known if the bird feels pain during this crouching immobility for although the bird still shows changes in blood-pressure and EEG arousal immediately after feather removal, the high amplitude slow wave EEG pattern is characteristic of catatonic states which in other species have been associated with analgesia (Bodnar 1984). The cardiovascular changes seen following feather removal could in this case reflect reflex activity and it is possible that the animal in the latter stages of feather pecking may not be experiencing pain even though it is subjected to considerable trauma.

It can be concluded that birds, like mammals, have two basic modes of response to external noxious stimulation: the flight-fight response and the conservation-withdrawal systems. The flight-fight system is seen typically after a comb pinch stimulus and the animal struggles to escape. Comb pinch would activate a variety of cutaneous mechanoreceptors including both the A-delta high threshold and the polymodal C-fibre nociceptors. The conservation-withdrawal system is typified in hens by the crouching immobility seen after noxious cutaneous thermal stimulation. Noxious thermal stimulation would produce activity primarily in the unmyelinated C-fibre polymodal nociceptors and it is activation of these receptors which is likely to initiate this type of behaviour.

The similarity between birds and mammals in their responses to pain raises the possibility of pain inhibitory mechanisms which are well developed in mammalian species. Little is known about pain inhibiting systems in birds but opioids have been identified in the central nervous system of the bird (Bayon *et al* 1980, Csillag *et al* 1989, Reiner *et al* 1984) and while in mammals not all pain inhibitory systems are opioid related, it seems probable that pain inhibiting mechanisms in birds are also well developed.

Pain following trauma

Acute pain following nociceptive stimulation or minor trauma is important to the animal, but it is chronic pain, which may last for weeks, months or even years, which presents the major welfare problem. Recently, work in this laboratory has been trying to evaluate the painful consequences of trauma using partial beak amputation (beak trimming) as a model system. Partial beak amputation is a common agricultural practice which involves the removal of part of the upper and/or lower beak in order to prevent or control feather pecking and cannibalism in poultry. The amputation is accomplished by a combination of cutting and cautery and results in full-thickness burns. When beak trimming was performed in birds 18 weeks old under commercial conditions, they remained immobile during the cutting and cautery although they struggled when being picked up and labelled. This immobility was similar to that seen following cutaneous thermal nociceptive stimulation.

The relationship between trauma and peripheral neural activity is complex but electrical recordings were made from sensory afferent fibres in dissected filaments of the trigeminal nerve innervating the lower beak before, during and after partial amputation (Gentle 1991). Amputation resulted in a massive injury discharge in the nerve fibres lasting from 2 to 48s which may be responsible for pain felt at amputation. Recordings from the nerve continued for 270 minutes after amputation and no abnormal pattern of response to cutaneous stimulation was detected in any of the sensory receptors in the stump of the beak. The absence of change in the peripheral neural input following beak amputation by this method would suggest an absence of pain during this period which was verified behaviourally. In this experiment the number of pecks delivered by birds to an attractive visual stimulus was measured before, and again 6, 26 and 32h after partial beak amputation (Gentle *et al* 1991). There was a significant reduction in the number of pecks by birds 26h after amputation but not at 6h after and this reduction was considered to be a quantitative measure of pain-related guarding behaviour. The results indicated the presence of a pain-free period immediately following amputation which may last in some birds for as long as 26h. A similar pain-free period has been observed in human patients following full-thickness burns (Robertson *et al* 1985, Stein & Stein 1983).

Behavioural changes which could be interpreted as indicative of pain were observed for at least six weeks after amputation. Twenty four hours after amputation the birds were not only unwilling to peck at the environment but they also showed reduced food

and water intake together with long periods of sitting and dozing (Duncan *et al* 1989). The behaviour of the bird changed over the next six weeks with food and water intakes returning to preoperative levels but preening and pecking were still significantly reduced. A more detailed study of beak usage after amputation (Gentle *et al* 1990) demonstrated significant reductions in environmental pecking, beak wiping and head shaking which persisted for six weeks after surgery and have been interpreted as instances of guarding behaviour and hyperalgesia. These results provide evidence for possible chronic pain in birds following amputation which is further strengthened by the results of Eskeland (1981) who showed that dozing and general inactivity were observed in partial beak amputated birds for as long as 56 weeks after surgery. Decreased activity is common in humans suffering from chronically painful conditions (Wall 1979).

In addition to this behavioural evidence there is anatomical and physiological evidence to support the possibility of chronic pain following partial beak amputation. In an anatomical study of the nerves in the beak of the chicken from 1h to 70 days after amputation (Gentle 1986) it was found that the beak had a limited ability to regenerate normal beak structure. By 15 to 30 days after amputation the stump had healed. The beak then continued to grow but the normal dermal structure did not regenerate. The healed stump contained a continuous layer of epithelium with outer keratin sheath overlaying an extensive area of scar tissue. Adjacent to the scar tissue the damaged and regenerating nerve fibres formed extensive neuromas. Electrophysiological recordings from the nerve fibres innervating these neuromas showed abnormal features not seen in normal trigeminal afferent fibres (Breward & Gentle 1985). The most characteristic abnormality encountered in the beak stump was the presence of large numbers of spontaneously active units with either regular, irregular or bursting discharge patterns. These abnormal units were recorded from the beak stump at 5 to 83 days after initial amputation and the receptive fields of these units were located on the distal tip of the stump and at varying distances (up to 12mm) proximal to it. This spontaneous activity seen in the amputated stump was similar to that observed in the experimental neuroma preparations developed initially by Devor, Wall and co-workers (Devor & Bernstein 1982, Govrin-Lippmann & Devor 1978, Wall & Gutnick 1974) in the rat and later extended to the mouse (Scadding 1981) and cat (Blumberg & Janig 1984). These studies on peripheral nerve injury and subsequent neuroma formation in mammals have suggested that abnormal activity arising from regenerating axons is implicated in post-amputation stump pain (Seltzer *et al* 1991, Wall 1981).

It is generally considered by the poultry industry that beak trimming results in acute pain to the birds, which quickly passes with the birds behaving normally within a few minutes after amputation. The prevention of cannibalism is seen as a positive contribution to animal welfare. The results from recent research (Gentle *et al* 1991) suggest that the acute pain from beak trimming is indeed short-lived and some of the birds are not in pain for 24h after amputation. Following this pain-free period the birds may experience chronic pain for long periods of time. Only a proportion of human patients experience chronic long-term pain following amputation (Wall 1981).

It seems likely, therefore, that not all birds subjected to partial beak amputation will suffer phantom and stump pain, but for those which do suffer it will be a welfare problem. In a survey of human amputees suffering chronic pain (Sherman *et al* 1980) a total of 68 different methods of pain treatment were described, none of which were 100 per cent successful. Given that a large proportion of post-amputated birds will suffer pain which cannot be satisfactorily treated in all cases and that feather pecking and cannibalism continue to be a major welfare problem, there are only two alternatives: either to develop husbandry conditions where feather pecking does not occur, or to breed birds which do not develop this behavioural vice.

Analgesia

In studies on the painful consequences of a procedure, analgesics provide a powerful experimental tool. In birds, analgesics have been largely confined to studies of the effects of the drug morphine (Bardo & Hughes 1978, Fan *et al* 1981, Schneider 1961). Because morphine produces both excitatory effects and sedation, with the degree of excitation depending on the species, as well as a number of side effects including anxiety, fear, nausea, apathy and reduced physical activity (Goodman & Gilman 1970), it is not surprising that the relatively unsystematic studies in birds have resulted in contradictory results. Schneider (1961) for example produced analgesia to a toe pinch test with very high dose levels of morphine (200mg/kg) whereas Bardo and Hughes (1978) produced analgesia at much lower doses (30mg/kg); these were both higher than the 5 to 20mg/kg customary dose given to human patients (Reynolds 1989). Hughes (1990) produced a strain-dependent analgesic (Rhode Island Red strain) and hyperalgesic (White Leghorn and Cal-White strains) effects using hot-plate tests of thermal nociception and concluded that the opposite effects of thermal nociception may reflect the effects of selective breeding on opioid receptor subtype. Unfortunately, this experiment is difficult to interpret because of the relatively high levels of morphine used (30mg/kg) and the long jump-latencies (50s) at an exceptionally high hot-plate temperature (61°C). This hot-plate temperature was at least 16°C above nociceptive threshold temperature and would rapidly produce thermal injury. Although other analgesics have not been systematically investigated, the effects of the anti-inflammatory steroid, betamethasone, have been studied on the pain associated with degenerative hip disorders in adult male turkeys (Duncan *et al* 1991). Turkeys develop degenerative joint disease, especially hip disorders, which result in reduction in spontaneous activity and sexual activity. Treatment with betamethasone resulted in increased sexual and spontaneous activity. This work is of particular importance because of the widespread nature of chronic orthopaedic disease in domestic poultry (Duff & Hocking 1986) the painful consequences of which are largely unknown. Recently, electrophysiological evidence has demonstrated the presence of a wide variety of receptors in the joint capsule of the chicken some of which have nociceptive functions (Gentle 1992). There is thus the likelihood that the degenerative joint changes are accompanied by chronically painful sensations.

Conclusions

The presence of nociceptors which signal actual or potential tissue damage, the behavioural and physiological changes resulting from nociceptive stimulation together with the physiological and behavioural changes following trauma would amply satisfy the definition proposed for pain in animals (Zimmermann 1986). The close similarity between birds and mammals in their physiological and behavioural responses to painful stimuli would argue for a comparable sensory and emotional experience, but is this inference valid? Pain is a subjective experience and the subjective experiences of a bird may be very different from humans. Birds do however, have the physiological, biochemical and anatomical mechanisms similar to those that in the human are known to be correlated with painful experiences.

With regard to animal welfare and pain in birds, it is clearly essential that the ethical considerations normally afforded to mammals should also be afforded to birds.

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