Animal consciousness and euthanasia: chicken euthanasia in the two-phase stunning system

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Summary

A form of consciousness cannot be excluded for animals and this has important ethical implications for acceptable slaughter methods, which should result in minimal signs of agitation and distress in the period before unconsciousness is reached. Simultaneous EEG, ECG and behavioural responses were recorded in birds exposed to either two-phase (40% CO_2, 30% O_2, 30% N_2 for 1 min followed by 80% CO_2, 5% O_2, 15% N_2) or single-phase (30% CO_2, 60% N_2 with <2% O_2) controlled atmosphere stunning in a pilot scale system. The EEG traces of birds in the carbon dioxide/nitrogen condition showed many more movement artefacts reflecting wing flaps and strong body movements such as convulsions, and this was confirmed by behavioural observations. These occurred during the period that consciousness could not be excluded; the time till unequivocal unconsciousness (expressed in an iso-electric EEG pattern) was estimated to be 20-50 seconds in the carbon dioxide/nitrogen atmosphere and 50-60 seconds in the carbon dioxide/oxygen/nitrogen condition. In addition, intense and long lasting artefacts in the ECG traces were visible in the carbon dioxide/nitrogen condition but were completely absent in the two-phase condition. These are thought to indicate strong isometric muscle contractions which may be painful and distressing. Time to death was established as heart rate under 180 beats per minute and was around 80 seconds in the carbon dioxide/nitrogen condition and 190 seconds in the carbon dioxide/oxygen/nitrogen condition. The chickens reached unconsciousness slower and died significantly later in the two-phase condition, as judged by the EEG, heart rate and behaviour. However, in the absence of oxygen leading to a faster death, the birds showed strong signs of agitation and distress. We are convinced that a milder death, which takes longer, is to be preferred to a quicker but more distressing death.

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Introduction

Consciousness in humans can be regarded as the complete set of mental facilities of an individual, expressed in awareness of what he is doing and what is happening around him. Consciousness is not a unitary condition, rather there is a variety of levels of consciousness related to vigilance which alternate over day and night. The level of consciousness indicates the degree of critical reactivity of a subject, analysing and evaluating incoming activity in the light of previous experiences and preparing reactions directed to certain goals. This implies that the state of wakefulness with a high vigilance, is associated with a high level of consciousness and that consciousness is reduced during the state of sleep and, furthermore, that consciousness is a gradual process related to the level of vigilance and the sleep-wake continuum. Moreover, this view leads to the assumption that during a deeply anaesthetised state consciousness is not longer present (Baars *et al.*, 2003). In the tradition of monism, conscious mental events are considered as arising from the neural matters of the brain and patterns of electrical brain activity produce vigilance and consciousness (Table 1) (Coenen, 1998). From this table it can be inferred that the basic neurophysiological correlate of consciousness are the membrane potentials of numerous thalamocortical neurons. During wakefulness the membrane potentials, which are near the firing threshold, lead to a tonic firing mode of these cells, explaining the high thalamic transfer ratio of information reaching the cortical centres. Ultimately, this results in a high EEG complexity as expressed in the correlation dimension.

Table 1 Neural characteristics and states of consciousness.

membrane potential mV	firing mode	transfer ratio	correlation dimension	EEG pattern	state of consciousness
< - 60	tonic	0.7 - 1.0	8 - 10	beta	wakefulness
- 60 - - 70	oscillatory	0.5 - 0.7	6 - 8	alpha or spindles	drowsiness
> - 70	burst	0. 3- 0.5	4 - 6	delta	slow wave sleep
< - 60	tonic	?	6 - 10	beta-like	REM sleep

Higher animal species are physically comparable to humans and brain processes involved in information processing in animals are reminiscent to human processes. Differences between humans and higher animals are gradual and unique features for humans have not yet been identified. Hence, the view that higher animals have some form of awareness and consciousness is inevitable, though caution is warranted to ascribe the same form of consciousness to animals as to humans. The central view that a form of consciousness cannot be excluded for animals has important ethical implications for the way in which we deal with them. This is particularly the case for such severe processes as the euthanasia of animals. The logic position is that a method of slaughter of animals is only acceptable when it results in minimal signs of agitation and distress in the period that some degree of consciousness cannot be excluded. This might imply that the first stage of the slaughter method should be a painless elimination of consciousness by the induction of an adequate anaesthesia, while in a second stage, when animals are deeply anaesthetised and totally unconscious, euthanasia can be accomplished.

This study describes a two-phase stunning method meeting these starting-points, previously tested in the laboratory in chickens (Coenen *et al.*, 2000), and now examined in a realistic plant situation. In this two-phase method chickens are firstly anaesthetised in an atmosphere containing sufficient amounts of carbon dioxide to anaesthetize an animal, while oxygen is supplemented to minimise signs of agitation and distress. Unconsciousness occurs rapidly with carbon dioxide concentrations of minimally 15 to 20% (Kohler *et al.*, 1999). In this experiment, a gas mixture with 40% carbon dioxide, 30% oxygen and 30% nitrogen was used in the first 'induction phase', lasting about one minute. Birds were subsequently introduced to an atmosphere with a low level of oxygen (5%), nitrogen (15%) and a high level of carbon dioxide (80%), quickly leading to the death of the birds: the second or 'finishing phase'. This method was compared to a one-phase method based on the creation of an anoxic condition using carbon dioxide and argon (30% carbon dioxide, 60% argon in air with 8% nitrogen and less than 2% oxygen) (Raj and Whittington, 1995), leading to rapid death of the birds by asphyxia. In this condition the time till death plays a decisive role, but in the short time till death signs of agitation and distress are obvious. Previously, the two methods have been tested in the laboratory with EEG, heart rate, and behavioural recordings indicating the induction of unconsciousness and death (Coenen *et al.*, 2000). Unconsciousness was defined as the point where the EEG shows a fully aberrant pattern, either with an iso-electric pattern or an 'anaesthetic' pattern; both patterns are associated with an correlation dimension lower than 5, comparable to a deep anaesthesia (van den Broek, 2003). Subjects were regarded as dead when they showed an iso-electric EEG pattern with non-reversible properties, and this was always so when heart rate was extremely low (in chickens less then 180 beats per minute).

In the laboratory (Coenen *et al.*, 2000), EEG recordings showed that the time point when unconsciousness was reached, expressed in an iso-electric EEG pattern (Fig. 1), was 22 ± 12 s in the argon/carbon dioxide condition and 62 ± 26 s in the oxygen/carbon dioxide/nitrogen condition. There was also a difference in the time to death: 135 ± 36 s in the argon/ carbon dioxide condition and 249 ± 5 s in the oxygen/carbon dioxide/nitrogen condition. Differences in the behaviour of the chickens were found in the occurrence of purposeful movements, gasps and intense muscle contractions. Before EEG iso-electricity, gasping was more frequent in the argon/dioxide condition as were non-purposeful and intense muscle contractions, which were seldom seen in the condition with oxygen.

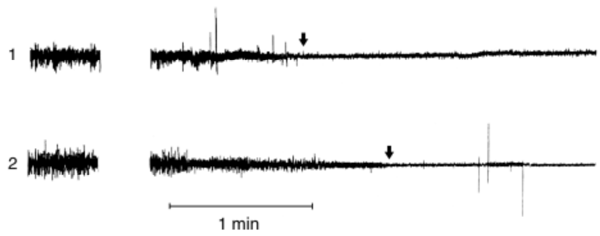

Figure 1 EEGs of a chicken in the anoxia condition (1), and in the oxygen/carbon dioxide/nitrogen condition (2). First, 30 sec of the baseline is shown, followed by a recording, starting when the chickens are placed in the gas mixtures. Arrows mark the iso-electric EEG.

These phenomena, regarded as strong signs of agitation and distress, occurred in a period when consciousness cannot fully be excluded, because they occurred when the EEG was not iso-electric. Because these unwanted signs were seen much less in the oxygen/carbon dioxide/nitrogen condition, it was concluded that the condition with oxygen is to be preferred above the condition without oxygen, despite faster induction of unconsciousness and death with anoxia.

Two-phase chicken euthanasia in the plant

To further explore the carbon dioxide/oxygen/nitrogen gas mix in a realistic plant situation, an experiment with the Stork Multiphase Controlled Atmosphere Stunning pilot scale system (with a capacity of 10% of the industrial processing speed (Hoen and Lankhaar, 1999), was performed. This system consists of a conveyor belt within two compartments, connected with a transition compartment. In the first compartment a gas mixture of 30% oxygen, 40% carbon dioxide and 30% nitrogen is present. After placing the animals in the start box, they enter in the first compartment and move on the belt through this compartment for about 1 to 1.5 minutes, after which they move through the transition box to reach the second compartment. This second compartment contains a mix of 5% oxygen, 15% nitrogen and 80% carbon dioxide. Directly before being placed in the stunning system, birds already fitted with permanent EEG electrodes were also fitted with ECG electrodes. These were commercially available disposable self-adhesive ECG electrodes which were adhered to cleaned skin overlying the pectoralis muscle either side of the sternum. The birds were also fitted with a lycra harness containing a logging system allowing continuous, simultaneous EEG and ECG recordings to be made as the bird moved though the system. In addition, video recordings of behaviour in the stunning system were made for later behavioural analysis. The group of animals placed in the oxygen/carbon dioxide/nitrogen gas mixture was compared with a second group of animals in which both compartments were filled with 30% carbon dioxide and 70% nitrogen. The latter group was fully comparable to the carbon dioxide/argon condition used in the previously mentioned study.

In Figure 2 the EEG recordings of the chickens in the two conditions are shown. An immediately noticeable difference in these recordings between the two conditions is obvious. In the traces of the birds in the carbon dioxide/nitrogen condition there are many more movement artefacts, expressed in high amplitude deflexions in the EEG traces. Movement artefacts are caused by wing flaps and strong body movements, such as convulsions, and this was confirmed by the behavioural observations. The presence of numerous movement artefacts made the time till unconsciousness (expressed in an iso-electric pattern) difficult to accurately establish, but was estimated to be from 20 to 50 seconds in the carbon dioxide/nitrogen atmosphere and 50 to 60 seconds in the oxygen/carbon dioxide/nitrogen atmosphere.

In Figure 3 the ECG recordings of the birds in the two conditions are shown. The intense and long lasting artefacts visible in the carbon dioxide/nitrogen condition are striking. At the first sight these deflexions seem similar to movement artefacts, and, indeed, these are also contributed. However the ECG artefacts have a much longer duration than indicated by the movement artefacts on the EEG traces and did not always coincide, indicating that the animals were lying still during some of these disturbances. The preliminary interpretation of these long lasting artefacts is that they are caused by intense muscle cramps, the electrical activity of which (EMG) were recorded by the ECG electrodes. This suspicion was confirmed by behavioural observations showing the wings held rigidly forward at these times, suggesting tetanus in the pectoralis muscles. These muscle artefacts were not present in the ECG records of the oxygen/carbon dioxide/nitrogen birds; the artefacts present in these traces are purely movement artefacts which coinciding with the same artefacts in the EEG traces. The point of death of the birds as established by the point where the heart rate drops under 180 beats per minute was around 80 seconds in the carbon dioxide/nitrogen condition and 190 seconds in the oxygen/carbon dioxide/nitrogen condition.

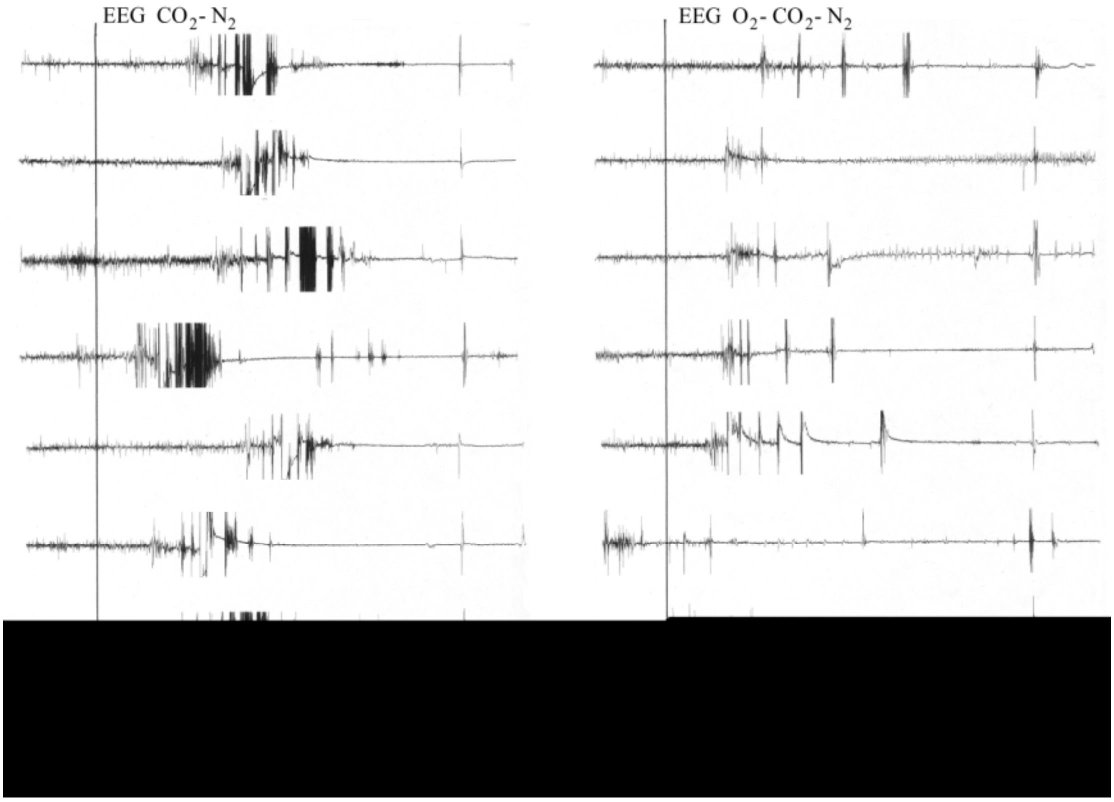

Figure 2 EEG records of chickens in the two conditions. The time-line (bottom right) is 10 seconds. The recordings are synchronised on the artefact at the end of each trace, caused by the transition of the birds from the first to the second compartment, at which the birds changed over to a following transport belt of the second compartment. 90 seconds before that point, indicated by the long vertical lines, the animals were placed in the stunning system. Animals were put in the start box and entered the first compartment after a variable time of 10 to 20 seconds (due to movement of the animals, e.g. walking). Then, they stayed for 60 seconds in the first controlled gas compartment, before moving in about 10 seconds through a transition box to the second controlled gas compartment. Note the differences in the quantity of movement artefacts and the transition from a normal (base line before the vertical lines) to an iso-electric EEG pattern in the two conditions. See the text for additional details.

Discussion

In the carbon dioxide/nitrogen condition strong signs of agitation and distress as judged by all parameters (EEG, ECG and behaviour) were observed, to a significantly greater extent than in the two-phase condition. Wing flaps, convulsions and strong muscle contractions occurred in the gas mix lacking oxygen, whereas wing flaps and convulsions are seen to a much lesser degree in the gas mix with oxygen. Moreover, no ECG activity indicative of strong muscle contractions was seen in the gas mix with oxygen. The time to reach unconsciousness was not very different for the two conditions, although the carbon dioxide/nitrogen condition tended to act more rapidly. The time till death was, as in the previous laboratory study, longer in the oxygen containing condition. As in the laboratory study, disturbed behaviour and signs of distress, such as convulsions and wing flaps, occurred during anoxia in a period that consciousness cannot fully be excluded. This includes ECG recordings of long-lasting artefacts indicating strong isometric muscle contractions which were completely absent in the two-phase condition with oxygen.

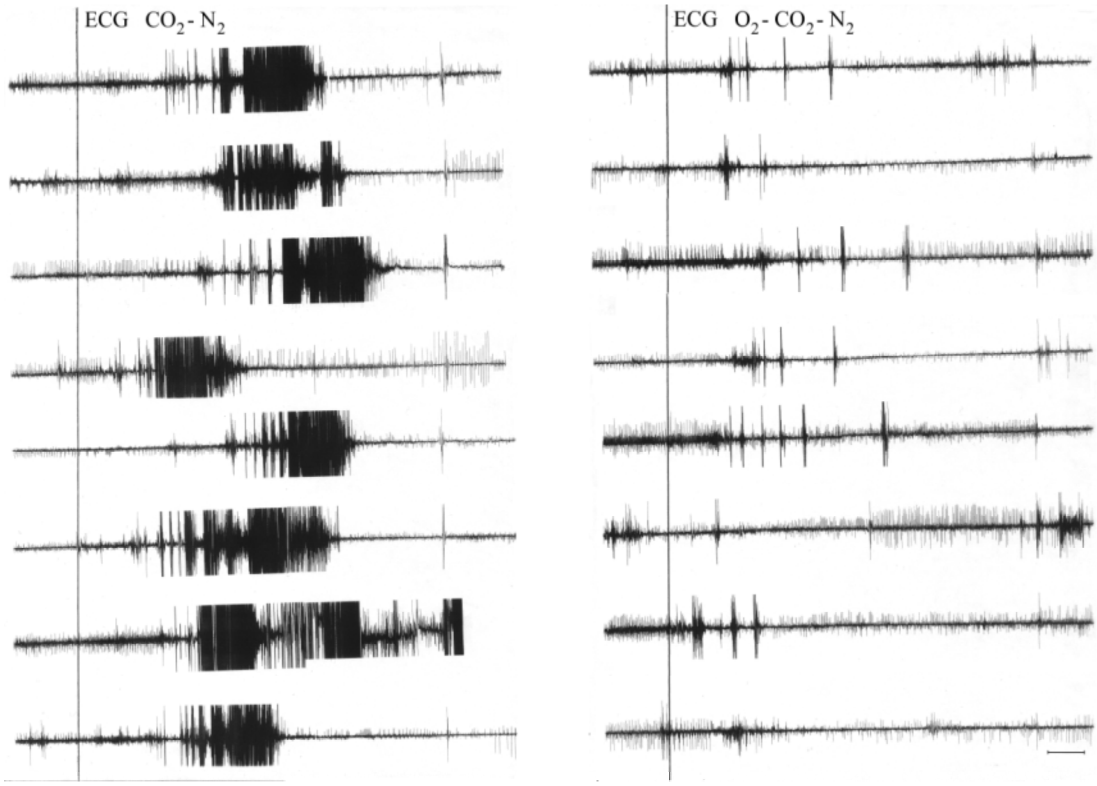

Figure 3 ECG records of the chickens in the two conditions. The time-line is 10 seconds. Note the large differences in artefacts between the two ECG recordings. See the legends of Figure 1 and the text for more details.

It is our opinion that the time that it takes for an animal to die is important, but the way it dies is even more important. Ethically, events during unconsciousness are less important that those occurring when the bird is conscious. Thus, knowledge of what is happening during the time that the EEG is not iso-electric or shows a complete ‘anaesthetic’ pattern (e.g. the EEGs of the birds presented in the oxygen/carbon dioxide/nitrogen condition on the third and six lines from above, at the end of the recording) is important. In the oxygen containing condition, chickens were conscious for longer and time to death was longer than in the oxygen lacking condition. However, in the latter condition there are many negative behavioural signs, such as intense gasps, wing flaps and convulsions while still not completely unconscious. In these circumstances, distress may arise from the agitation and flapping (‘convulsion’) itself, pain caused by injury during wing flapping or disturbance and/or injury resulting from nearby birds experiencing agitation. In addition, evidence of potentially painful and distressing intense isometric muscle contractions seen in all chickens subjected to the carbon dioxide/nitrogen condition are cause for concern.

Conclusions

It is concluded that chickens reach unconsciousness slower and die significantly later in an oxygen containing condition, as judged by the EEG, heart rate and behaviour. However, in an oxygen lacking condition leading to a faster death, the birds show strong signs of agitation and distress. The disturbed behaviour and the signs of distress occur in a period that consciousness cannot fully be excluded. Thus, it is proposed that a gas mix with oxygen is strongly preferable above a gas mix without oxygen. The presence of oxygen in the first stage of euthanasia is important in the reduction of distress. We are convinced that a milder death, which takes longer, is to be preferred to a quicker but more distressing death.

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