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Effect of supplementary ultraviolet lighting on the behaviour and corticosterone levels of Japanese quail chicks

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Abstract

*Most birds have visual sensitivity to ultraviolet (UV) wavelengths, and this sensitivity appears to play a role in their colour vision. Artificial lighting is normally deficient in UV wavelengths. Hence, there may be welfare implications for captive birds kept under such lighting. We investigated whether the absence of UV wavelengths during rearing adversely affects Japanese quail (*Coturnix coturnix japonica*). We also investigated the short-term effect of switching from UV-containing to UV-deficient lighting, and vice versa. Stress was assessed by monitoring behaviour and plasma corticosterone levels. We did not detect any significant difference in these variables between birds reared either with or without UV. We conclude that rearing quail in an absence of UV does not appear to have a significant impact on their welfare, as measured using these indicators.*

Keywords: *animal welfare, behaviour, corticosterone, Japanese quail, ultraviolet, UV*

Introduction

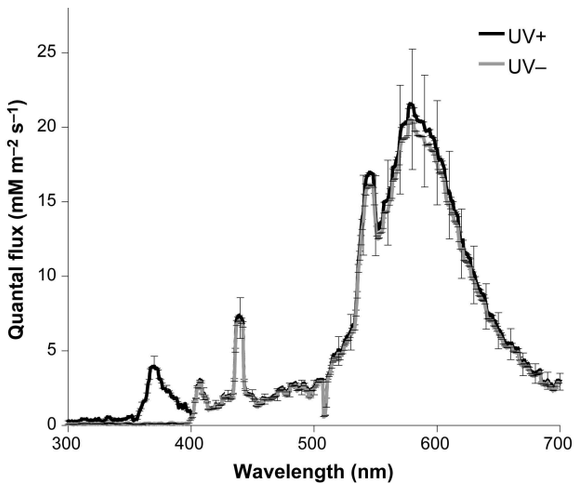
Many species of bird are kept under artificial lighting, which typically emits mostly medium to long wavelengths and has minimal ultraviolet (UV) emission (Lewis & Morris 1998). As well as utilising the human-visible spectrum, all diurnal birds studied to date have been found to perceive the near UV range (UVA 315–400 nm) (Bowmaker *et al* 1997; Prescott & Wathes 1999a; Hart 2001). Birds use UV cues in a range of ecologically relevant tasks, such as mate choice and foraging (Bennett & Cuthill 1994; Cuthill *et al* 2000), and UV sensitivity forms part of their colour vision system (Osorio *et al* 1999; Smith *et al* 2002). Consequently, it has been suggested that housing birds under standard, UV-deficient artificial lighting may deleteriously influence their behaviour and physiology (Moinard & Sherwin 1999; Sherwin & Devereux 1999; Maddocks *et al* 2001, 2002).

There has been relatively little research into how the absence of UV may affect welfare in poultry. UV reflections could potentially provide useful visual information, such as the quality of feed and various substrates (Prescott & Wathes 1999b). Also, parts of the plumage of certain breeds vary in their UV reflectance (Prescott & Wathes 1999b; Sherwin & Devereux 1999), a cue that may be used in mate choice decisions (Jones & Prescott 2000; Jones *et al* 2001). Turkeys (*Meleagris gallopavo*) have been found to prefer artificial lighting with supplementary UV (Moinard & Sherwin 1999), and a lack of environmental enrichment, including UV cues, has been associated with an increase in welfare-reducing behaviour such as feather pecking in this species (Sherwin & Devereux 1999).

As supplementary UV light is likely to increase the perceived brightness of the illumination as well as changing the spectral composition of the light, any apparent effects of supplemental UV may result purely from a preference for brighter lighting conditions (Greenwood *et al* 2002). This is noteworthy, as turkeys have been shown to have a preference for higher light intensities (Sherwin 1998). It is difficult to control precisely for perceived changes in brightness when manipulating the spectral composition of a light source, as it is not known how the avian visual system weights information from UV-receptive and other cones in the perception of brightness. In the absence of such knowledge, equalising the overall quantal flux in an attempt to equalise perceived brightness between the UV-containing (UV+) and UV-deficient (UV–) environments is a logical control. Maddocks *et al* (2001) found that domestic chicks (*Gallus gallus domesticus*) kept in UV– conditions had significantly higher basal plasma corticosterone levels than their counterparts kept in UV+ conditions when the quantal flux was balanced. As prolonged high levels of corticosterone are thought to be harmful (Beuving *et al* 1989; Wingfield 1994), it follows that provision of 'full spectrum' lighting may benefit poultry.

We report on an experiment similar to that which Maddocks *et al* (2001) carried out using domestic chicks, in which Japanese quail (*Coturnix coturnix japonica*) were reared under either UV+ or UV– conditions balanced for quantal flux. We assessed welfare using behaviour and plasma corticosterone measures. We assessed the basal level of corticosterone and its rise in response to capture, handling and restraint (Wingfield 1994; Wingfield *et al* 1995).

Figure 1



Mean irradiance (quantal flux) in the UV+ and UV– pens. Standard errors are plotted in one direction only (upwards for UV+ and downwards for UV–) and represent spatial variation, as measurements were taken from different parts of each pen. It is difficult to discern the difference between the two treatments except at 300–400 nm, where the UV+ pens have higher irradiance.

We predicted that even if UV does not have major welfare implications in the long term, a change of lighting conditions might induce stress in the short term. We therefore also investigated the short-term stress effects of switching the lighting from UV– to UV+, and vice versa.

Methods

Quail chicks were reared under either UV-containing (UV+) or UV-deficient (UV–) light from the age of 1 day until 21 days. The lighting treatment in half of the pens within each treatment was changed when the birds were 19 days old to assess the short-term response to a change in lighting conditions. The lighting in the other half of the pens remained unchanged. The stress response to rearing under each lighting condition prior to the light environment change on the evening of day 18, and the immediate short-term stress response to a change in lighting after day 19, were assessed by measuring behaviour and plasma corticosterone levels.

We randomly allocated 96 one-day-old mixed-sex quail chicks (obtained from Fayre Game, Liverpool, UK) to 16 pens (each 1.2 × 0.85 × 2.0 m, length × width × height, six chicks per pen). Each pen was light-proofed using hardboard and black cloth. The young chicks were maintained at 31 ± 5°C and the temperature gradually reduced by about 1°C per day to 19 ± 5°C. We provided a heat lamp (250 W, Pandorel radiant heat brooder: Bellsouth PTY Ltd, Australia) in each pen. These lamps did not emit any visible light.

Eight of the pens were assigned to have UV+ lighting and eight were assigned UV– lighting. The treatment allocated to each pen was counterbalanced for position within the building. In each pen there was a standard 0.6 m, 35 W fluorescent lamp (General Electric, UK) and a 0.6 m, 18 W, UV blue/black lamp (Sylvania Lighting International, Lisarow, NSW, Australia), both of which were fitted to 240 V, 100 Hz ballasts (Ring Lighting, Leeds, UK). The lights were horizontally mounted on the wall at a height of 1.2 m above the floor. The light sources were identical in both treatments except that UV-blocking filters (Lee 226 UV-blocking filter: Lee Filters, Andover, UK) were placed over both of the lights in the UV– pens to render the lighting conditions UV-deficient. The design of the experiment was similar to that of Maddocks *et al* (2001) except that, for the visible-spectrum illumination, we used fluorescent lamps to illuminate the pens, whereas Maddocks *et al* used halogen lamps (both studies used the same model of UV blue/black lamp and UV-blocking filter).

We aimed to vary spectral composition but not overall light intensity between light treatments. We used a calibrated Ocean Optics SD1000 spectroradiometer with a UV-transparent cosine-correcting detector to quantify the average reduction in quantal flux over the avian-visible spectrum (approximately 320–700 nm) that occurred when a UV-blocking filter was placed over the lights in a pen. This created an average decrease of 15% in quantal flux, measured using the spectroradiometer. We therefore partially covered the lamps in the UV+ condition with strips of black cloth so that the overall avian visible quantal flux was also reduced by around 15% (Figure 1).

The total quantal flux integrated over the avian visible spectrum (see Box 1, Equation 1) did not differ between treatments (Figure 1, repeated measures ANOVA on log-transformed quantal flux: $F_{1,6} = 1.27$, $P = 0.304$). The variation in total irradiance within pens of the same treatment was greater than the variation in total irradiance between pens within treatments and both greatly exceeded the between-treatment variance (76%, 21% and 3% respectively, of the total variance as determined by a fully nested ANOVA). The chicks could therefore vary the light intensity they experienced by moving around the pen, but

Box 1

Equation 1
Total quantal flux integrated over the avian visible spectrum

$$\int_{\lambda=320}^{700} Q\lambda$$

Equation 2
Quantal flux in the UV waveband

$$\int_{\lambda=320}^{400} Q\lambda$$

Equation 3
Quantal flux in the blue waveband

$$\int_{\lambda=400}^{500} Q\lambda$$

Equation 4
Quantal flux in the green waveband

$$\int_{\lambda=500}^{600} Q\lambda$$

Equation 5
Quantal flux in the red waveband

$$\int_{\lambda=600}^{700} Q\lambda$$

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Table 1 Description of all observed behaviours.

Behaviour	Description
Rest/sleep	Legs folded under body with body resting on substrate
Walk/run	Actively moving around the pen with body in contact with ground
Leap	Moving around pen out of contact with ground and flapping wings
Stasis	Mean duration of time spent in each quadrant of the pen, thus negatively related to overall activity
Feed	Frequency of pecks directed at food in the feeder
Drink	Frequency of 1 sec intervals in which bird spends drinking
Peck	Pecking directed at anything other than food, water or conspecifics
Scratch	Raking claws through substrate using vigorous leg movements
Preen	Running beak through feathers
Dust bath	Flapping wings in substrate whilst sitting, partially burying body in substrate
Stretch	Either wing or leg extended away from body as far as possible
Chirp	Audible vocalisation
Head shake	Shaking of head from side to side
Aggressive peck	Rapid pecks directed at other birds
Attacked	Receipt of aggressive pecks, often causing bird to run away or cower in submission

were, however, always exposed to the appropriate spectral composition of light. The quantal flux in the UV waveband (see Equation 2) was significantly higher in the UV+ than in the UV– pens (repeated measures ANOVA on log [x+1] transformed values: $F_{1,6} = 829.7$, $P < 0.001$; as a percentage of the total quantal flux this equates to 4.6% in the UV+ and 0.5% in the UV–), whereas the quantal fluxes in the 'blue', 'green' and 'red' wavebands did not differ between treatments (Equation 3, $F_{1,6} = 0.365$, $P = 0.568$; Equation 4, $F_{1,6} = 0.339$, $P = 0.582$; Equation 5, $F_{1,6} = 0.338$, $P = 0.582$; log-transformed values analysed as above). For the first two days, the lights were left on continuously to encourage feeding. The photoperiod was subsequently set at 18h:6h light:dark for the remainder of the experiment. To establish the short-term stress effects of a change in lighting condition, on the evening of day 18 we switched the lighting in half of the pens from UV+ to UV– and vice versa. The lighting in the remainder of the pens remained unchanged.

Turkey starter crumb (BOCM Pauls, Ipswich, UK) and water were provided *ad libitum* in tower feeders. Wood shavings were used as a substrate. Each bird was uniquely identifiable by use of numbered leg rings. In addition, we marked the birds dorsally with a temporary, non-toxic black marker pen the day before each observation session to facilitate observation of focal animals. Spectroradiometry confirmed that the ink had very little UV or human-visible reflectance and was truly 'bird-black' (IC Cuthill, unpublished data 2000) and therefore the appearance of these markings should not have differed between treatments.

Behaviour

On days 3, 6, 9 and 14, one bird from each pen was observed for a 20 min period in order to assess behaviour, with a different bird being the focal animal on each day. We selected focal animals randomly, with the constraint that no animal could be a focal animal twice. In each session, two pens were observed simultaneously by two different observers, which enabled a bird in each UV+ pen to be observed simultaneously with a bird in each UV– pen. We counterbalanced the order in which the pens were observed and observer with respect to treatment. Birds' behaviour was also assessed on day 19 after the lighting switch. We made observations from hides outside the pens and recorded the frequencies of 15 measures of behaviour (Table 1).

We omitted the data for chirping and dust bathing from subsequent analyses as these behaviours were infrequent. We transformed the raw data (log [x+1]) to linearise the relationship between variables and then reduced the data using principal component analysis (PCA) (Chatfield & Collins 1995). This reduced 13 original variables into five orthogonal variables, the principal components (PCs), each of which was derived from reduction of the pooled observational data for the whole experiment. Each PC is a mathematical transformation of the raw data consisting of a weighted linear sum of the original data (Chatfield & Collins 1995). The raw data are transformed by multiplying by PC coefficients (weights), which can be either positive or negative. The resulting PC scores for each extracted PC were then analysed using repeated measures ANOVA or general linear model (GLM) in Minitab. 'Pen' was the unit of analysis, as the birds within a group are not independent. Therefore, although different birds were observed from each pen on different days, the data were treated as repeated measures. The data from the periods before and after the light environment change were analysed separately, with the additional factors 'day' (1–4) and 'day × treatment' in the pre-change analyses. We analysed post-change data with respect to the four conditions: UV+ changing to UV–, UV– changing to UV+, and UV+ or UV– unchanged, using non-parametric statistics where residuals could not be normalised.

Blood sampling and ethical note

Whenever the effects of a potential stressor are investigated, there is inevitably a moral concern that one may be applying a stressful and deleterious treatment. However, in this case

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Table 2 Coefficients relating the first five principal components to the log-transformed original behavioural variables.

Behaviour	PC1	PC2	PC3	PC4	PC5
Rest/sleep	–0.297	0.236	–0.278	–0.222	–0.222
Walk/run	**0.456**	0.285	–0.113	0.134	–0.076
Leap	0.111	0.112	**0.555**	–0.044	–0.159
Stasis	**–0.494**	–0.074	–0.123	0.211	0.012
Feed	0.147	–0.108	**0.398**	**0.382**	–0.225
Drink	0.279	–0.107	0.177	–0.351	**0.456**
Peck	**0.384**	0.028	–0.307	–0.174	0.119
Scratch	0.290	–0.296	–0.119	0.236	0.261
Preen	0.243	–0.155	–0.122	**–0.432**	**–0.488**
Stretch	0.045	**–0.495**	–0.283	–0.012	–0.000
Head shake	–0.140	**–0.311**	**0.433**	–0.319	0.382
Aggressive peck	0.189	0.105	–0.038	**0.459**	**0.417**
Attacked	0.014	**0.597**	0.070	–0.179	0.143

Numbers in bold show the three highest values for each PC, which correspond to the behaviours that correlate with that PC most strongly.

our stressor was UV-deficient lighting, a treatment that is applied to the vast majority of captive birds kept under artificial light. Blood sampling was the only experience within our experiment that is not a normal event in bird husbandry. We chose to use blood sampling because short-term changes in hormone levels cannot be monitored by the non-invasive method of faecal sampling.

Our blood sampling programme was designed to minimise the stress on any individual bird, and blood samples were not taken from any bird more than once. On days 15 and 20 we took blood samples from two birds in each pen to obtain, from the first, a measure of basal plasma corticosterone, and from the second, the level of corticosterone 30 min post-capture. We took a single blood sample from the bird that had been the focal bird of the previous days' observation less than 1 min from the time of capture to obtain a basal level of corticosterone. We then took a blood sample from the other bird at 30 min post-capture to gain a measurement of the rise in corticosterone in response to capture and restraint to assess the reactivity of the hypothalamic–pituitary–adrenal axis to stress. Birds that were blood-sampled after 30 min were moved from their pen to a procedure room and kept alone in cardboard boxes for 30 min. We caught two birds simultaneously in a design balanced for both treatment and sampler. We sampled UV+ and UV– pens alternately, ensuring that at any time-point we avoided sampling birds from a pen adjacent to that which had just been disturbed. We did not notice any change in behaviour of the birds in pens prior to sampling.

We took a blood sample (0.1 ml) from each bird by puncture of the alar vein. We used a 25 gauge needle to prick the vein and collected a drop of blood using a heparinised capillary tube. The blood samples were centrifuged and the plasma stored in labelled vials at –20°C. Birds were inspected and returned to their pens after the procedure.

We monitored the birds regularly, and on day 14 removed two UV– pens from the experiment as some birds in these pens were starting to feather-peck the other birds. We removed and housed these animals separately for the sake of the birds' welfare, being careful to leave the feather-peckers in full sight of other members of their group so as to avoid socially isolating them. This reduced the number of UV– pens in the experiment from 8 to 6 at this stage. Following our experiments, all the birds were re-homed.

Radioimmunoassay

Corticosterone concentrations in the blood samples were obtained by radioimmunoassay using a similar procedure to that described by Wingfield *et al* (1992). Plasma samples (20 µl aliquots) were extracted in diethyl ether after adding 2000 counts per min of tritiated corticosterone ([1,2,6,7-^{3}H]-corticosterone label (Amersham Biosciences UK Ltd, Buckinghamshire, UK) so that the recovery efficiency of the extraction could be estimated. These evaporated extracts were reconstituted in 550 µl of assay diluents, 100 µl aliquots of which were subsequently added to 750 µl scintillant (UltimaGold: Packard, Groningen, The Netherlands). These were counted in a scintillation counter to calculate percent recovery. Duplicate 200 µl aliquots of each extract (each containing 7.3 µl of extracted plasma) were assayed using an anticorticosterone antiserum code B21-42 (Endocrine Sciences, Tarzana, California, USA) and [1,2,6,7-^{3}H]-corticosterone label (Amersham Biosciences UK Ltd, Buckinghamshire, UK). Corticosterone concentrations were corrected for recovery efficiency (percentage recoveries varied between 70% and 87%) and expressed in ng ml^{-1}. The assay was run with a bound:free ratio of 0.64, 50% binding was 1.03 ng ml^{-1} and the detection limit (for 7.3 µl aliquots of extracted plasma) was 0.95 ng ml^{-1}. Plasma corticosterone levels from before and after the light environment change on day 18 were analysed separately

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using non-parametric statistics. These data were analysed in a manner similar to the behavioural data: 'pen' was the unit of analysis, and, prior to the light environment change, measurements taken at different time-points from different birds within the same pen were treated as repeated measures. Data from before and after the light environment change were analysed separately.

Results

Behaviour

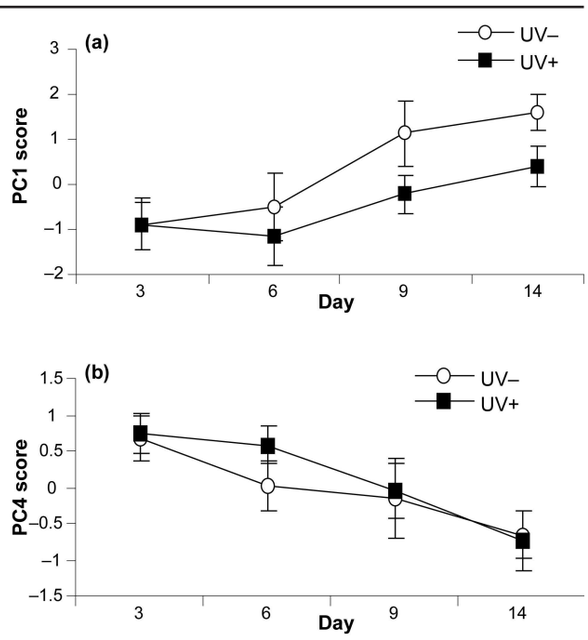
The first five components from PCA (Table 2) explained 68% of the variation in the 13 behaviours (Table 1). Further PCs were not analysed as they had eigen values less than 1.0.

Analysis of the first five PCs showed that rearing condition with respect to UV had no significant effect on any PC before the light environment change (main effect of treatment: PC1, $F_{1,14} = 3.89$, $P = 0.069$; PC2, $F_{1,14} = 0.07$, $P = 0.790$; PC3, $F_{1,14} = 0.84$, $P = 0.375$; PC4, $F_{1,14} = 0.88$, $P = 0.363$; PC5, $F_{1,14} = 0.40$, $P = 0.538$). There was no significant short-term effect on behaviour resulting from a change in the light environment (GLM on the change between days 14 and 19, ie before and after the lighting changed: PC1, $F_{3,10} = 2.06$, $P = 0.169$; PC2, $F_{3,10} = 0.56$, $P = 0.651$; PC3, $F_{3,10} = 0.59$, $P = 0.636$; PC4, $F_{3,10} = 0.63$, $P = 0.612$; PC5, $F_{3,10} = 0.03$, $P = 0.993$).

As it has been suggested that a lack of UV may promote feather pecking because of loss of UV cues in the plumage (Sherwin & Devereux 1999; Maddocks *et al* 2001), we also separately analysed the number of pecks made by birds in each treatment towards other birds, as well as the number of pecks they received from others birds. These behaviours were quite rare (means of 1.87 and 3.19 occurrences per hour, respectively), and occurred at similar rates in both treatments, both before and after the light environment change occurred on day 18 (repeated measures ANOVA on log [1+x] transformed values: pre-light change — pecks given, $F_{3,14} = 0.87$, $P = 0.367$; pecks received, $F_{3,14} = 0.00$, $P = 0.993$; post-light change — pecks given, Kruskal-Wallis test: $H_3 = 1.29$, $P = 0.731$; pecks received, $H_3 = 3.77$, $P = 0.287$). However, it is notable that we had to remove two of the eight UV– pens from the experiment on day 18 for welfare reasons, as some birds in them had started to feather-peck each other. The removal of these two pens from the experiment will have affected the results post-light environment change but, even if we include these pens with a fictitious maximal level of pecking, treatment differences are far from significant ($P > 0.337$ for pecks given and received). This phenomenon was not completely exclusive to UV– pens, as feather pecking was starting to occur by day 21 in a UV+ pen as well, at which point the experiment had ended.

Although there was no significant effect of treatment, behaviour did change significantly with observation day prior to the light environment change. There was a significant change in PC1 and PC4 over time (PC1, $F_{3,42} = 5.30$, $P = 0.003$; PC2, $F_{3,42} = 1.21$, $P = 0.318$; PC3, $F_{3,42} = 0.75$, $P = 0.527$; PC4, $F_{3,42} = 5.11$, $P = 0.004$; PC5, $F_{3,42} = 1.26$, $P = 0.300$), with PC1 scores increasing and PC4 scores decreasing over time (Figures 2a and 2b, respectively). PC1 is mostly positively associated with walking or running, pecking the ground, and moving between different areas of the pen (Table 2). The amount of time spent performing these activities increased over time. PC4 is mostly positively associated with drinking and pecking other birds, but negatively correlated with preening (Table 2). Amount of time spent drinking and pecking others decreased, whilst preening increased over subsequent observation sessions. None of the time × treatment interactions were significant (PC1, $F_{3,42} = 0.66$, $P = 0.581$; PC2, $F_{3,42} = 0.63$, $P = 0.597$; PC3, $F_{3,42} = 0.80$, $P = 0.503$; PC4, $F_{3,42} = 0.69$, $P = 0.563$; PC5, $F_{3,42} = 2.57$, $P = 0.067$).

Figure 2



PC1 and PC4 are summary descriptors of various behaviours (derived from PCA; see Table 2). **(a)** PC1 scores increased significantly over subsequent observation sessions. **(b)** Mean PC4 scores decreased significantly over subsequent observation sessions. Neither PC1 nor PC4 differed significantly between treatments. Vertical bars show standard errors.

Plasma corticosterone

Many birds' basal corticosterone levels were so low that they were either below or only just above the assay detection limit. We therefore assigned the minimum corticosterone level that we considered our assay able to detect reliably (0.95 ng ml^{-1}) to these samples to enable further analysis.

At day 15, before the light environment change, quail chicks showed a typical corticosterone response to the capture–handling–restraint procedure, although the rise in corticosterone in response to this test was of a fairly small magnitude (from a mean of 0.95 to 0.96 ng ml^{-1} in the UV+ treatment, and from 0.95 to 1.01 ng ml^{-1} in the UV– treatment). Birds being sampled immediately post-capture

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had a lower level of corticosterone than those sampled 30 min post-capture (Wilcoxon signed-ranks test: $T = 45.0$, $n_{test} = 9$, $P = 0.009$). There was no measurable treatment effect on basal corticosterone levels, as all basal corticosterone levels were at or below the assay detection limit, with the exception of one bird reared in UV–. There was no effect of lighting condition on corticosterone levels taken 30 min post-capture (Mann-Whitney *U* test: $W = 69.0$, $n = 8$, $P = 0.956$).

At day 20, after the light environment change, corticosterone levels were even lower than at day 15. All birds had basal corticosterone below the detectable limit and only four had supra-limit levels after capture and restraint (two from pens switched from UV+ to UV–, one from a pen switched from UV– to UV+, and one from an unchanged UV+ pen). This precluded statistical analysis, but no trends were apparent.

Discussion

Absence of UV wavelengths during rearing had no significant effect on any of our indicators of stress in Japanese quail chicks. Behaviour was not significantly affected by treatment, and it is clear that rearing in, or switching to, UV– conditions does not cause a significant rise in the level of plasma corticosterone in quail, or elevate their corticosterone above the normal baseline level for this species.

Behaviour did, however, vary significantly with day of observation. Chicks became increasingly active and spent more time pecking at the ground and preening over subsequent observation sessions, and correspondingly spent less time pecking at other birds and drinking (see Figure 2 in conjunction with Table 2).

Many of the blood samples had baseline corticosterone levels so low as to be effectively undetectable by our assay, which reduced the power of our statistical analysis. Whilst it could be argued that treatment differences might have been detected by using a more sensitive radioimmunoassay procedure, we used a standard capture and restraint test, and followed a standard procedure that has been used successfully to measure corticosterone in a range of species (Wingfield *et al* 1982, 1992, 1995; Wingfield 1994; Wingfield & Ramenofsky 1997; Maddocks *et al* 2001). Indeed, corticosterone has previously been measured successfully in quail using a similar paradigm and exactly the same antiserum (see Satterlee & Johnson 1988 in conjunction with the methods outlined in Satterlee *et al* 1980). Satterlee and Johnson (1988) found that quail have a baseline corticosterone level of just over 1 ng ml^{-1}. The assay we used would have been sensitive enough to measure corticosterone in the quail studied by Satterlee and Johnson, as our reliable assay detection limit was 0.95 ng ml^{-1}. It appears that the quail in the present experiment were simply less aroused than the quail studied by Satterlee and Johnson, and also that they had lower levels of corticosterone (approximately 10%) than the chickens studied by Maddocks *et al* (2001) when housed and treated under similar conditions. It is clear that absence of UV does not elevate corticosterone above the normal baseline level for this species.

It should be noted that different species may have differing levels of need for UV cues. Maddocks *et al* (2001) found that chickens have higher baseline corticosterone levels in the absence of UV wavelengths. Chickens are known to have UV-reflecting plumage (Prescott & Wathes 1999b; Sherwin & Devereux 1999), to prefer to preen under daylight (Nuboer 1993) and to use UV cues in mate choice (Jones & Prescott 2000; Jones *et al* 2001), and hence may find UV+ conditions beneficial. No comparable information exists for quail. However, as quail can discriminate UV cues from the rest of the spectrum and use UV cues when foraging (Smith *et al* 2002), it seems likely that quail use UV sensitivity in a manner similar to chickens. Also, the types of light source we used differed from those of Maddocks *et al* (2001). We manipulated the spectral distribution of fluorescent lamps plus black-lights, whereas Maddocks *et al* manipulated the spectral distribution of incandescent halogen lamps plus black-lights. Poultry are known to prefer fluorescent to incandescent light sources (Widowski *et al* 1992), perhaps because the spectral distribution of fluorescent lamps more closely resembles daylight than does that of incandescent lamps (Lewis & Morris 1998). Our light sources would have been richer in short wavelengths of the 'blue' waveband than those of Maddocks *et al* (compare Figure 1 with Figure 1 of Maddocks *et al* 2001), and consequently our supplemental UV light may have had a less dramatic effect on the availability of visual cues in the shorter wavelengths, especially as the violet-sensitive cones of poultry would be stimulated by these short blue wavelengths. Plausibly, Maddocks *et al* (2001) may have found basal corticosterone levels elevated in conjunction with UV– conditions in chickens because of the general lack of short wavelengths in the light environment, rather than because there was a specific absence of UV.

Although we found no significant measurable short-term response in behaviour or corticosterone level in response to a change from UV+ to UV– conditions, or vice versa, interpretation of these results is problematic. Two of the eight UV– pens were removed from the experiment before the light environment change occurred, as the birds within them had started to feather-peck each other. This reduced the sample size in the UV– treatment, and also excluded the two pens within that treatment in which welfare was presumably poorest. There is evidence that turkey poults receive less feather pecking in environments enriched by various materials and supplementary UV lighting (Sherwin *et al* 1999). Hence, it is plausible that the development of feather pecking in these pens was promoted by the absence of UV. However, as feather pecking had also developed in a UV+ pen by the end of the experiment, and as the sample size of pens was low (eight per treatment), it is difficult to tell whether the feather pecking in the two UV– pens was triggered by a lack of UV cues.

Animal welfare implications

We found no significant effect of the presence or absence of UV during rearing on the behaviour or plasma corticosterone level of Japanese quail. Consequently, we conclude

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that rearing quail in an absence of UV does not appear to have a significant impact on their welfare. Although our results are not consistent with previous work suggesting that UV+ conditions may be beneficial for poultry (Moinard & Sherwin 1999; Sherwin *et al* 1999; Lewis *et al* 2000; Maddocks *et al* 2001), it should be noted that the effects of providing supplemental UV light might vary with species and context. Species such as those in the order Galliformes, which possess violet-sensitive cones that are stimulated by short blue wavelengths as well as UV, may be less vulnerable to any deleterious effect of UV– conditions than species such as passerines and parrots, the UV sensitivity of which is conferred by cones that are maximally sensitive to UV (see Hart 2001 for details on species differences). Also, supplemental UV light may be of greater importance in conjunction with incandescent lamps which have long-wavelength-dominated emission spectra, than in conjunction with fluorescent lamps which are richer in short wavelengths.

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References

Bennett ATD and Cuthill IC 1994 Ultraviolet vision in birds: what is its function? *Vision Research 34*: 1471-1478

Beuving G, Jones RB and Blokhuis HJ 1989 Adrenocortical and heterophil/lymphocyte responses to challenge in hens showing short or long tonic immobility reactions. *British Poultry Science 30*: 175-184

Bowmaker JK, Heath LA, Wilkie SE and Hunt DM 1997 Visual pigments and oil droplets from six classes of photoreceptor in the retina of birds. *Vision Research 37*: 2183-2194

Chatfield C and Collins AJ 1995 *Introduction to Multivariate Analysis*. Chapman & Hall: London, UK

Cuthill IC, Partridge JC, Bennett ATD, Church SC, Hart NS and Hunt S 2000 Ultraviolet vision in birds. *Advances in the Study of Behavior 29*: 159-214

Greenwood VJ, Smith EL, Cuthill IC, Bennett ATD, Goldsmith AR and Griffiths R 2002 Do European starlings prefer light environments containing UV? *Animal Behaviour 64*: 921-926

Hart NS 2001 The visual ecology of avian photoreceptors. *Progress in Retinal and Eye Research 20*: 675-703

Jones EKM and Prescott NB 2000 Visual cues used in the choice of mate by fowl and their potential importance for the breeder industry. *World's Poultry Science Journal 56*: 129-138

Jones EKM, Prescott NB, Cook P, White RP and Wathes CM 2001 Ultraviolet light and mating behaviour in domestic broiler breeders. *British Poultry Science 42*: 23-32

Lewis PD and Morris TR 1998 Responses of domestic poultry to various light sources. *World's Poultry Science Journal 54*: 7-25

Lewis PD, Perry GC, Sherwin CM and Moinard C 2000 Effect of ultraviolet radiation on the performance of intact male turkeys. *Poultry Science 79*: 850-855

Maddocks SA, Bennett ATD, Hunt S and Cuthill IC 2002 Context-dependent visual preferences in starlings and blue tits: mate choice and light environment. *Animal Behaviour 63*: 69-75

Maddocks SA, Cuthill IC, Goldsmith AR and Sherwin CM 2001 Behavioural and physiological effects of absence of ultraviolet wavelengths for domestic chicks. *Animal Behaviour 62*: 1013-1019

Moinard C and Sherwin CM 1999 Turkeys prefer fluorescent light with supplementary ultraviolet radiation. *Applied Animal Behaviour Science 64*: 261-267

Nuboer JFW 1993 Visual ecology in poultry houses. In: Savory CJ and Hughes BO (eds) *Proceedings of the Fourth Symposium of Poultry Welfare* pp 39-44. World's Poultry Science Association: Edinburgh, UK

Osorio D, Vorobyev M and Jones CD 1999 Colour vision of domestic chicks. *The Journal of Experimental Biology 202*: 2951-2959

Prescott NB and Wathes CM 1999a Spectral sensitivity of the domestic fowl (*Gallus g. domesticus*). *British Poultry Science 40*: 332-339

Prescott NB and Wathes CM 1999b Reflective properties of domestic fowl (*Gallus g. domesticus*), the fabric of their housing and the characteristics of the light environment in environmentally controlled poultry houses. *British Poultry Science 40*: 185-193

Satterlee DG, Abdullah RB and Gildersleeve RP 1980 Plasma corticosterone radioimmunoassay and levels in the neonate chick. *Poultry Science 59*: 900-905

Satterlee DG and Johnson WA 1988 Selection of Japanese quail for contrasting blood corticosterone response to immobilization. *Poultry Science 67*: 25-32

Sherwin CM 1998 Light intensity preferences of domestic male turkeys. *Applied Animal Behaviour Science 58*: 121-130

Sherwin CM and Devereux CL 1999 Preliminary investigations of ultraviolet-induced markings on domestic turkey chicks and a possible role in injurious pecking. *British Poultry Science 40*: 429-433

Sherwin CM, Lewis PD and Perry GC 1999 Effects of environmental enrichment, fluorescent and intermittent lighting on injurious pecking amongst male turkey poults. *British Poultry Science 40*: 592-598

Smith EL, Greenwood VJ and Bennett ATD 2002 Ultraviolet colour vision in European starlings and Japanese quail. *Journal of Experimental Biology 205*: 3299-3306

Widowski TM, Keeling LJ and Duncan IJH 1992 The preferences of hens for compact fluorescent over incandescent lighting. *Canadian Journal of Animal Science 72*: 203-211

Wingfield JC 1994 Modulation of the adrenocortical response to stress in birds. In: Davey KG, Peter RE and Tobe SS (eds) *Perspectives in Comparative Endocrinology* pp 520-528. National Research Council of Canada: Ottawa, Canada

Wingfield JC and Ramenofsky M 1997 Corticosterone and facultative dispersal in response to unpredictable events. *Ardea 85*: 155-166

Wingfield JC, O'Reilly KM and Astheimer LB 1995 Modulation of the adrenocortical responses to acute stress in arctic birds: a possible ecological basis. *American Zoologist 35*: 285-294

Wingfield JC, Smith JP and Farner DS 1982 Endocrine responses of white-crowned sparrows to environmental stress. *Condor 84*: 399-409

Wingfield JC, Vleck CM and Moore MC 1992 Seasonal changes in the adrenocortical response to stress in birds of the Sonoran Desert. *Journal of Experimental Zoology 264*: 419-428