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Myoclonus induced by cathode ray tube screens and low frequency lighting in European starling (*Sturnus vulgaris*).

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It has been proposed that birds may have finer temporal resolution than humans, and may therefore perceive both low frequency fluorescent light (LF:100 Hz in U.K., 120 Hz in the U.S.A.) and images on televisions and standard computer screens as flickering (Nuboer and others 1992; D'Eath 1998; Fleishman and Endler 2000). Although some species may be more sensitive than others (e.g. pigeon electroretinogram response to 140 Hz, Dodt & Wirth 1953, cf. 75.1 to 120 Hz for a behavioural measure of critical flicker fusion frequency in domestic fowl, Jarvis and others 2002; Prescott and others 2003), it is noteworthy that critical flicker fusion frequency (CFF) varies greatly according to the measurement method, making results difficult to compare across studies (Smith 2003). For example, whilst human CFF is often cited as being 60 Hz (e.g. D'Eath 1998), human electroretinogram responses have been recorded to frequencies as high as 162 Hz (Berman and others 1991).

In susceptible humans, flicker can induce anxiety, eyestrain, headaches and seizures, but serious effects typically occur only at frequencies well below 100 Hz (see reviews, Wilkins and others 1984, Wilkins 1995). Although 100 Hz light has been shown to affect some aspects of bird behaviour (e.g. Boshouwers and Nicaise 1992), there is currently no evidence that 100 Hz flicker seriously impairs their welfare (Maddocks and others 2001; Smith 2003; Greenwood and others 2004). Therefore, when we chose a Cathode Ray Tube (CRT) monitor to present images at 120 Hz to four 10 month-old starlings in a colour perception experiment, we did not anticipate any problems. However, all four birds frequently behaved abnormally when viewing the screen. A tiny tremor would appear in the bill, after which their entire head would often twitch in a rapid and apparently involuntary fashion, mostly in a vertical plane. We consulted the University veterinary surgeon and instigated a systematic investigation into whether this was a photosensitive reaction, using a single female bird.

The bird was trained to jump on a perch in her cage, look through a window at a stimulus positioned 40cm away, and then peck a button on a console, for which she was rewarded with a mealworm. In the present set of experiments, we continued with this procedure, changing the stimulus that was visible through the window, and videoing the bird's response. Each stimulus was shown for 15 minutes. We recorded how often the bird visited the viewing perch, how long she spent there, whether she had a muscle jerk (myoclonus), and if so, how severe it was (on an arbitrary scale where 1=mild, and 2=multiple or severe twitches). To control for any variation over time, we recorded the bird's responses to a control stimulus for 15 minutes before (Control Phase 1), and 15 minutes after (Control Phase 2), the experimental stimulus (Treatment Phase). The normal ambient room lighting, provided from overhead high frequency (110kHz) fluorescent lamps, remained on throughout. Measurement with an oscilloscope (3133 Crotech 25 MHz dual trace, with Kodak light sensor, Crotech Instruments Ltd, U.K.) confirmed that these lights, and all of our stimuli, ran at the frequencies stated.

We first compared the bird's response to 1) a uniform grey field (37 x 28cm) displayed on a 120 Hz Sony Trinitron monitor (Model GDM-F520, Sony, U.K.) to 2) a grey isoluminant field (29 x 36cm) displayed on a 110kHz LCD screen (Model LM919, AOC International, Berlin, Germany). In both cases, the control phases involved leaving each monitor running, but occluded by a blanket placed over the screen. Mean luminance (ML) of the stimuli was measured using a Minolta Chroma Meter (CS-100, Minolta, Switzerland), from a position above the bird's perch through the viewing window. We did not need a device that could measure bird-perceptible ultraviolet light, since the viewing window was ultraviolet-blocking. We altered the luminances of all stimuli to match the CRT screen, which had the lowest ML when running at maximum brightness (Sony: ML= 70.62 cd /m^2, SD= 0.77; LCD: ML=71.10 cd /m^2, SD=0.42). The bird only twitched once when the monitors were occluded, but frequently did so when the CRT screen was uncovered (see Table 1, plus Figure 1a). As magnetic fields and sound would have passed through the blanket, this indicates that the trigger was visual. The bird was more likely to experience myoclonus, and to have muscle jerks of worse severity, when viewing a 120 Hz stimulus than a LCD screen (see Figure 1a).

The two monitor types differed in their spatial properties as well as in their flicker rate (see D'Eath 1998, Fleishman and Endler 2000). As certain spatial frequencies can be visually provocative, at least to humans (Wilkins 1995), we specifically tested whether flickering light was a trigger, by comparing the bird's response to either high frequency (HF, 100 kHz, lamp: Durotest Truelite 18W, ballast: Tridonic, Basingstoke, U.K.), or low frequency fluorescent (LF, 100 Hz, lamp: Durotest Truelite 18W, ballast: Fitzgerald Lighting Ltd., Bodmin, U.K.) light falling onto a white card (76 x 52cm). During control phases, the fluorescent lights were turned on, but their light emissions were blocked by a blanket. Mean stimulus radiance was equated to that of the monitor screens in the previous test, by placing strips of neutral density filter (Filter #210, 0.6ND, Lee Filters, Andover, U.K.) over the lamps as required (HF: ML= 72.28 cd /m^2, SD= 24.80; LF: ML= 75.40 cd /m^2, SD= 28.43). Previous measurements of the same lights showed that the emitted wavelength spectrum of the HF and LF lights are similar (see Greenwood and others 2004) and that the modulation of Truelite lamps is close to 100% (Wilkins and Clark 1990). We found that the bird was more likely to have a muscle jerk when the fluorescent light was not occluded, regardless of flicker rate. However, the probability of myoclonus occurring was much higher upon exposure to 100 Hz than upon exposure to

100 kHz (see Table 1, plus Figure 1b). The mean severity of observed twitches was similar across conditions.

Having confirmed that flicker was a trigger, we then directly compared the bird's response to grey fields of similar size and luminance shown on the LCD and CRT screens. We varied the frequency of the CRT to find the threshold above which the birds did not get a more severe response than to the LCD (test frequencies of CRT: 120, 130, 135, 140, 150 Hz). Here, presentation of the CRT screen formed the treatment phase, with the LCD being displayed before and after this as a control. We calculated the mean probability of muscle jerks occurring, and their mean severity, for the control phases. We then subtracted these figures from the mean probability and severity scores for each treatment phase. This shows the degree to which exposure to flicker of a given frequency increased myoclonus above background level (see Table 1, plus Figure 2). The probability of muscle jerks decreased with increased monitor frequency, and by 150 Hz the CRT monitor did not elicit a worse reaction than to the LCD (Figure 2). Whilst the severity of myoclonus was more variable, the general trend was for severity to decrease with increased frequency (Figure 2).

In summary, we have shown that this European starling exhibits myoclonus in almost immediate response to both standard computer monitors and conventional fluorescent lighting. Light-induced myoclonus has been previously reported in one strain of poultry in response to 14 Hz (Crawford 1970, Batini and others 1996). Here, 140 Hz has been shown to cause a similar, although milder response. It is unknown whether the 'epileptic' strains of chickens would also show a reaction to 140 Hz. However, these birds were artificially selected for a tendency to have convulsive responses, whereas the wild starlings used in our experiments were not. However, in humans, viral infection is known to increase visual sensitivity (Smith and others 1992), and some of the birds' cohort had developed avian pox lesions shortly after capture. That said, this was over 6 months prior to the present experiment, and both we and the University veterinary surgeon felt that the starlings were in otherwise excellent health. Therefore, it may be that CFF, and consequently the risk of suffering adverse effects, is higher in some bird species than in poultry or humans.

Humans who experience myoclonus typically report concurrent malaise and unpleasant emotions (Mundy-Castle 1953a,b). The birds experiencing myoclonus often flew away from the viewing window *without* first going to their food hopper to collect a mealworm (pers. obs.). As mealworms are their favourite food, this indicates that the experience of myoclonus was probably unpleasant. Consistent with this is the observation that starlings prefer HF to LF light (Greenwood and others 2004). Although myoclonic reactions stopped above 140 Hz, one should not conclude that frequencies higher than 140 Hz have no adverse effect, or do not appear to the animal as perceptible flicker. In humans, frequencies above those that are perceived as flickering can still cause headaches, migraines and eyestrain (Wilkins 1995). Also, since we used stimuli of fairly low luminance, it is likely that a bright stimulus presented at higher frequencies could still cause myoclonus.

The CRT computer monitor we used was non-interlaced, i.e. each line of pixels refreshes simultaneously. However, traditional CRT televisions refresh each line alternately, producing even lower modulations. New digital televisions vary in refresh rate according to format, but still at rates lower than 100 Hz. We therefore advise that pet owners do not put their birds close to their television sets or computers, or house them under LF fluorescent lights. Further research with different species is needed to confirm whether this is a widespread welfare issue.

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Table 1: Results for Experiments 1-3, showing total number of visits the bird made to the viewing perch (V), the total time in seconds spent viewing the stimulus (T) and the total number of muscle jerks (J) in each phase.

Experiment 1			
Stimulus	Control Phase 1	Test Phase	Control Phase 2
120 Hz CRT screen	V=35, T=108, J=1	V=42, T=105, J=20	V=4, T=7, J=0
110 kHz LCD screen	V=26, T=125, J=0	V=40, T=126, J=1	V=6, T=24, J=0
Experiment 2			
Stimulus	Control Phase 1	Test Phase	Control Phase 2
100kHz HF light	V=39, T=107, J=1	V=74, T=185, J=5	V=75, T=192, J=1
100 Hz LF light	V=50, T=107, J=1	V=65, T=167, J=27	V=38, T=81, J=0
Experiment 3			
Stimulus	Control Phase 1	Test Phase	Control Phase 2
CRT 120 Hz	V=26, T=60, J=1	V=2, T=11, J=2	V=15, T=44, J=2
CRT 130 Hz	V=14, T=38, J=0	V=19, T=36, J=4	V=18, T=31, J=0
CRT 135 Hz	V=22, T=49, J=0	V=29, T=70, J=3	V=33, T=80, J=0
CRT 140 Hz	V=4, T=20, J=0	V=17, T=45, J=2	V=6, T=25, J=1
CRT 150 Hz	V=25, T=63, J=0	V=24, T=54, J=0	V=17, T=28, J=0

Figure 1: Effect of viewing different stimuli on the probability and severity of myoclonus. During control phases, the relevant light source is occluded.

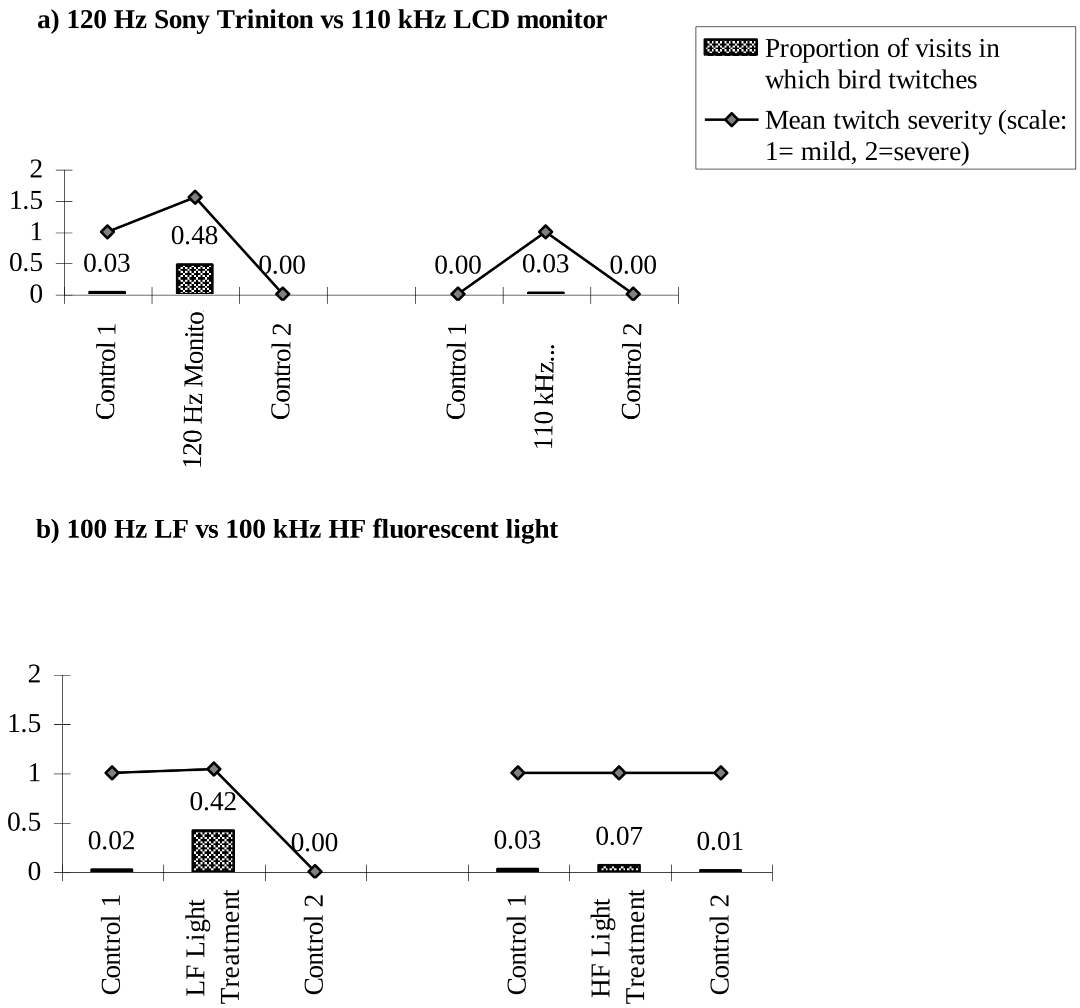

Figure 2: Probability and severity of muscle jerks in response to CRT monitor frequencies between 120 and 150 Hz. These data are all corrected for the mean background level and severity of muscle jerks observed in control phases before and after each test phase.