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

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IT has been suggested that birds may have a finer temporal resolution than human beings, and may therefore perceive both low-frequency fluorescent light (100 Hz in the UK, 120 Hz in the USA) 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, for example, the pigeon has an electroretinogram response to 140 Hz (Dodt and Wirth 1953), compared with 75·1 to 120 Hz for a behavioural measure of critical flicker fusion frequency (CFF) in domestic fowl (Jarvis and others 2002, Prescott and others 2003), it is noteworthy that CFF varies greatly according to the measurement method, making results difficult to compare across studies (Smith 2003). For example, while the human CFF is often cited as being 60 Hz (for example, D'Eath 1998), human electroretinogram responses have been recorded to frequencies as high as 162 Hz (Berman and others 1991).

In susceptible human beings, flicker can induce anxiety, eyestrain, headaches and seizures, but serious effects typically occur only at frequencies well below 100 Hz (Wilkins and others 1984, Wilkins 1995). Although 100 Hz light has been shown to affect some aspects of bird behaviour (for example, 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, no problems were anticipated when a cathode ray tube (CRT) monitor was chosen to present images at 120 Hz to four 10-month-old starlings in a colour perception experiment (Smith and others 2003). However, all four birds frequently behaved abnormally when viewing the screen. A tiny tremor would appear in the bill, after which the bird's entire head would often twitch in a rapid and apparently involuntary fashion, mostly in a vertical plane. The University of Bristol's veterinary surgeon was consulted, and a systematic investigation was carried out into whether this was a photosensitive reaction. This short communication describes the findings.

A single female bird was trained to jump on a perch in its cage, look through a window at a stimulus positioned 40 cm away, and then peck a button on a console, for which it was rewarded with a mealworm. The stimulus that was visible through the window was changed and the bird's response was videoed. Each stimulus was shown for 15 minutes. The number of times the bird visited the viewing perch, how long it spent there, whether it had a muscle jerk (myoclonus) and, if so, how severe it was (on an arbitrary scale of 1 Mild and 2 Multiple or severe twitches), were recorded. To control for any variation over time, 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) were also recorded. The normal ambient room lighting, provided from overhead high-frequency (110 kHz) fluorescent lamps, remained on throughout. Measurement with an oscilloscope (3133 Crotech 25 MHz dual trace, with Kodak light sensor; Crotech Instruments) confirmed that the lights, and all of the stimuli, ran at the frequencies stated.

TABLE 1: Total number of visits made by the starling 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 for each investigation

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

CRT Cathode ray tube, LCD Liquid crystal display, HF High frequency, LF Low frequency

The bird's responses to a uniform grey field (37 x 28 cm) displayed on a 120 Hz CRT monitor (Trinitron monitor model GDM-F520; Sony), and a grey isoluminant field (29 x 36 cm) displayed on a 110 kHz liquid crystal display (LCD) screen (model LM919; AOC International) were recorded and compared. In both cases the control phases involved leaving each monitor running but occluded by a blanket placed over the screen. The mean luminance (ML) of the stimuli was measured (Minolta Chroma Meter CS-100; Minolta) from a position above the bird's perch through the viewing window. A device that could measure bird-perceptible UV light was not required, since the viewing window blocked UV light. The luminances of all stimuli were altered to match the CRT monitor, which had the lowest ML when running at maximum brightness (mean [sd] ML 70·62 [0·77] cd/m^2 for the CRT monitor, and 71·10 [0·42] cd/m^2 for the LCD). The bird only twitched once when the monitors were occluded, but frequently did so when the CRT monitor was uncovered (Table 1, Fig 1a). As magnetic fields and sound would have passed through the blanket, this indicated that the trigger was visual. The bird was more likely to experience myoclonus, and to have muscle jerks of worse severity, when viewing the 120 Hz stimulus than the LCD screen (Fig 1a).

The two monitor types differed in their spatial properties as well as in their flicker rate (D'Eath 1998, Fleishman and Endler 2000). Certain spatial frequencies can be visually provocative, at least to human beings (Wilkins 1995) so, to determine specifically whether the flickering light was a trigger, the bird's responses to either high-frequency (100 kHz) light (Durotest Truelite 18W, ballast; Tridonic) or low-frequency (100 Hz) fluorescent light (Durotest Truelite 18W, ballast; Fitzgerald Lighting) falling on to a 76 x 52 cm white card were compared. During control phases, the fluorescent lights were turned on, but their light emissions were blocked by a blanket. The mean stimulus radiance was equated to that of the monitor and screen in the previous test, by placing strips of neutral density filter (Filter number 210, 0·6 ND; Lee Filters) over the lamps as required (high frequency: ML 72·28 [24·80] cd/m^2, low frequency: ML 75·40 [28·43] cd/m^2). Previous measurements of the same lights showed that the emitted wavelength spectrum of the high- and low-frequency lights were similar (Greenwood and others 2004) and that the modulation of the type of lamps used was close to 100 per cent (Wilkins and Clark 1990). 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 (Table 1, Fig 1b). The

Veterinary Record (2005) **157**, 148-150

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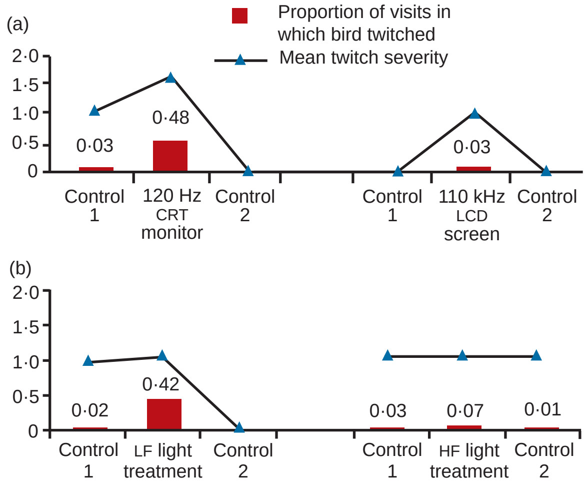

FIG 1: Effect of viewing (a) a 120 Hz cathode ray tube (CRT) monitor v a 110 kHz liquid crystal display (LCD) screen and (b) 100 Hz low-frequency (LF) v a 100 kHz high-frequency (HF) fluorescent light on the probability and severity (scale 1 mild, 2 severe) of myoclonus in a starling. During control phases, the relevant light source was occluded

mean severity of observed twitches was similar across conditions.

Having confirmed that flicker was a trigger, the bird's responses to grey fields of similar size and luminance shown on the LCD screen and CRT monitor were directly compared. The frequency of the CRT was varied (120, 130, 135, 140 and 150 Hz) to find the threshold above which the bird did not get a more severe response than to the LCD screen. In this investigation, presentation of the CRT monitor formed the treatment phase, with the LCD screen being displayed before and after this as a control. The mean probability of muscle jerks occurring and their mean severity were calculated for the control phases. These figures were then subtracted from the mean probability and severity scores for each treatment phase. This showed the degree to which exposure to flicker of a given frequency increased myoclonus above background level (Table 1, Fig 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 the LCD screen (Fig 2). While the severity of myoclonus was more variable, the general trend was for severity to decrease with increased frequency (Fig 2).

These studies show that the 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). In the present investigation, 140 Hz was 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, but those birds were artificially selected for a tendency to have convulsive responses, whereas the wild starling used in the present studies was not. In human beings, viral infection is known to increase visual sensitivity (Smith and others 1992), and some of the starling's cohort had developed avian pox lesions shortly after capture. However, that was over six months before the present investigation, and both the authors and the university's veterinary surgeon felt that the starling was 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 human beings.

Human beings who experience myoclonus typically report concurrent malaise and unpleasant emotions (Mundy-Castle 1953a, b). When the bird experienced myoclonus, it often flew away from the viewing window without first going to the food hopper to collect a mealworm (E. L. Smith, J. E. Evans, personal observations). As mealworms are its favourite food, this indicates that the experience of myoclonus was probably unpleasant. Consistent with this is the observation that starlings prefer high-frequency to low-frequency light (Greenwood and others 2004). Although myoclonic reactions stopped at frequencies above 140 Hz, it cannot be concluded that frequencies higher than 140 Hz have no adverse effect or do not appear to the animal as perceptible flicker. In human beings, frequencies above those that are perceived as flickering can still cause headaches, migraines and eyestrain (Wilkins 1995). Also, since stimuli of fairly low luminance were used, it is likely that a bright stimulus presented at higher frequencies could still cause myoclonus.

The CRT monitor used was non-interlaced, that is, each line of pixels refreshed 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. It is therefore advised that pet owners do not put their birds close to television sets or computers, or house them under low-frequency fluorescent lights. Further research with different species is needed to confirm whether this is a widespread welfare issue.

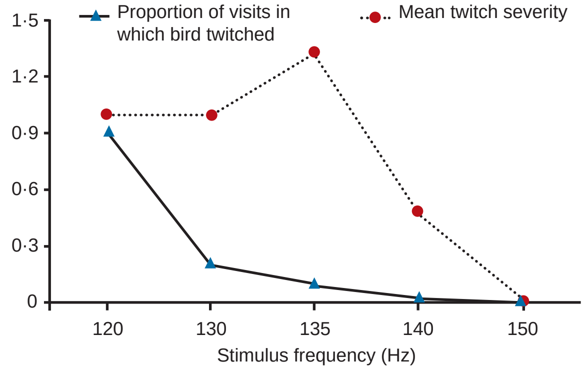

FIG 2: Probability and severity of muscle jerks of a starling in response to cathode ray tube monitor frequencies between 120 and 150 Hz. These data are all corrected for the mean background level and severity of muscle jerks (scale 1 Mild, 2 Severe) observed in control phases before and after each test phase

ACKNOWLEDGEMENTS

The authors thank Di Flower, Sadie Iles-Ryan and Rob Massie for caring for the animals, and Ute Leonards and George Lovell for the loan of a lightmeter and an oscilloscope. They also thank Jo Roe, Innes Cuthill, Julian Partridge and Tom Troscianko for discussion. The research was funded by a Biotechnology and Biological Sciences Research Council grant to I. C. Cuthill, T. Troscianko and J. C. Partridge.

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