Behavioral Responses of Pigeons to High-Intensity 60-Hz Electric Fields

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A conditioned suppression paradigm was used to determine whether pigeons could detect 60-Hz electric fields of 25 kV/m or 50 kV/m (undisturbed uniform field strength). Subjects exhibited significant suppression responses when exposed to a 50 kV/m electric field but not when exposed to a 25 kV/m field. Control experiments failed to demonstrate that suppression was due to artifacts associated with activation of the field, and the current explanation is that subjects were able to detect a 60-Hz electric field calculated to be >10.5 kV/m <21 kV/m at head level. (Note that earlier reference to 50 and 25 kV/m fields pertains to conditions prior to introduction of either conditioning apparatus or experimental subject. Because of its composition, the conditioning chamber introduced some degree of shielding and field distortion resulting in electric field intensities ranging from 10.5 to 21 kV/m at subject head level prior to the introduction of the experimental subject.) If organisms do detect the field, several other types of biological responses might be expected, and this may provide a general explanation of electrophysiological, neuroendocrine, or other responses occasionally observed when subjects are exposed to high-intensity 60-Hz electric fields.

High-voltage transmission lines are necessary to transport electric power from its generation source to homes, farms, factories, and other areas of use. Such transmission lines are surrounded by extremely low frequency (ELF) electromagnetic fields, and a great deal of concern has been generated in recent years about possible health hazards associated with exposure of living organisms to such fields. Unfortunately, very little research has been conducted on this problem; hence, planners and legislators, as well as the general public, have reacted to scattered, and

1 Paper No. 5706 in the journal series of the Pennsylvania Agricultural Experiment Station. Research supported in part by the Electric Power Research Institute. Requests for reprints should be addressed to the Project Leader, Dr. H. B. Graves.
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often contradictory, reports, scientific or otherwise, with confusion and concern.

Recent concern over possible deleterious effects of man-made electromagnetic fields is based in part on reports from the USSR that switchyard personnel working in high-intensity electric fields exhibit headaches and nausea, loss of appetite ("feeling bad"), and reduced sexual responses (Korobkova, Morozov, Stolarov, & Yakub, 1972). General environmental awareness and the climate for ecological concern in the public sphere has also played a role in bringing about public concern over this issue.

All living organisms have an electrical component basic to their functional well-being. Electrical components associated with living organisms are extremely small in magnitude when compared to field intensities generated by transmission lines, electrical appliances, or by extreme natural weather phenomena, and the possibility exists that the presence of external electromagnetic fields may affect organisms in some basic biological way. Recent studies have suggested that high-intensity electric fields in the 60-Hz frequency range may affect biological systems at several levels of organization, including the molecular level (e.g., serum protein concentrations, Marino, Berger, Austin, Becker, & Hart, 1975), the tissue level (e.g., characteristics of bone; McElhaney & Stalnaker, 1968), the organ system level (e.g., EEG; Lott & McCain, 1973), and the organism level (e.g., general activity; Moos, 1964; reaction time, Hauf & Wiesinger, 1973). Hence, the functional organization of plants and animals may well be affected when they are exposed to high-intensity ELF electric fields.

Much of the work to date on biological effects of ELF fields has been conducted without the benefit of knowledge of recently discovered potentials for artifacts in the exposure systems. For example, our research team (Poznaniak, Bankoske, & Mathews, 1977) demonstrated that an unrealistic enhancement of electric field strength can occur during exposure if the height of the experimental subject bridges an appreciable portion of the electrode spacing. Another common problem is that subjects exposed to high-intensity ELF field exposure systems may be shocked when they contact improperly designed feeding or watering systems.

Conditioned suppression, originally described by Estes and Skinner (1941) and reviewed by Sidman (1960), Lyon (1968), and Smith (1970) has been used to determine detection capabilities and thresholds for various types of stimuli. For example, Morris (1966) and Taylor, Smith, and Hatfield (1967) used the procedure to determine that rats and rhesus monkeys, respectively, could detect X-rays. Henton (1966) used the technique to determine that pigeons could detect a 3% level of vapor saturation of anil acetate via the olfactory system.
In the present study, conditioned suppression was used to determine whether or not domestic pigeons were capable of detecting the presence of high-intensity 60-Hz electric fields of various intensities.

**MATERIALS AND METHODS**

**Conditioned Suppression Paradigm**

Conditioned suppression requires a stable pattern of operant responding in a food-deprived animal under an intermittent schedule of food reinforcement. After stable performance is established, a stimulus is presented to the organism for several seconds and this stimulus is terminated with an unavoidable shock of about 30 msec duration. These stimulus–shock pairings are presented between food reinforcements.

The pairing of the stimulus with shock represents a classical conditioning situation. After stimulus–shock pairings, operant responding will be suppressed during the stimulus presentation if the stimulus is detected. The extent to which the stimulus changes the ongoing rate of operant behavior is directly related to the detectability of the stimulus by the organism (e.g., Smith, 1970).

**Subjects**

Six experimentally naive Silver King Pigeons (Palmetto Pigeon Plant, Sumter, S. C.) ranging from 5 to 12 months of age, served as subjects in the experiment. The pigeons were housed in individual cages and maintained at 80% of their free-feeding weights. Water and grit were made available at all times.

**Grid and Chamber Design**

The electrode system used to produce the electric field was composed of two flat 1.80 × 1.80-m expanded metal grids supported in each corner by threaded PVC rods. A 2.54 × 10⁻²-m diameter steel tube was welded around the perimeter of each grid in order to eliminate corona discharges at the edges of the grids. The bottom grid was grounded, while a 60-Hz, 2.5 kVA, 0- to 50-kV power supply was connected between the upper grid and ground. The spacing between the grids was adjustable and, for a constant input voltage, spacing determined the intensity of the undisturbed uniform electric field within the system. The distance between the grids was set at 1 m in this study, and specimen height limited to 25% of the electrode spacing in order to minimize the degree of unrealistic field enhancement (Poznaniak et al., 1977). At 50 kV/m, the displacement current flowing between the center grid and ground was 0.0724 mA.

The test chamber used was black Plexiglas with a 0.37 × 0.37 × 0.50-m work area for the pigeon being tested. A plastic transilluminated food key and a 3-W lamp were located on one wall, 0.25 m from the floor.
bottom of the chamber. A loudspeaker delivered white noise (40 db) in order to mask any potential auditory cues. The chamber was placed on the bottom grid with a grain dispenser (Lehigh Valley Electronics, Fogelsville, Pa.) positioned at the edge of the grid to minimize field distortion. Some distortion and shielding from the grain dispenser, food key, associated lamp, and loudspeaker was, however, evident during electric field mapping studies.

Results of a comprehensive study designed to eliminate noise, vibration, and other artifacts as potential cues associated with the test procedure are presented in a companion paper by Graves (1981).

Electrode Implants

Stainless-steel wire electrodes, 0.025 cm (10 mil) in diameter, were implanted through the pubic bones of each pigeon and connected to a 1 x 0.3-cm solder lug. The solder lug was the only exposed metallic surface on each pigeon. These electrodes were connected to a miniature two-pronged plug on a retractable cable and then to a 60-Hz powerstat which supplied an unavoidable shock to the test pigeon when activated.

The threshold detection level to 60-Hz shock applied through the pelvic electrodes was determined by applying five 30-msec shocks, ranging in intensity from 0 to 3 mA, in 0.1-mA increments to each of the pigeons. Responses to the shocks were recorded; the threshold value of detection was approximately 0.30 mA. Reliable responding occurred at 2.5 mA. and this level was established as the level applied to each pigeon during each of the trials.

Geometric Projection of Pigeon in Test Chamber

The size and shape of test pigeons were approximated by an imaginary projection of a rectangular prism 0.076 x 0.076 x 0.203 m in size for purposes of quantitative analysis of field strengths impinging on the subjects (Fig. 1). This shape was chosen because actual measurements in the test chamber could be made along the various lines of the x-y-z planes. The origin on the coordinate system was chosen to coincide with the front lower corner of the test chamber. The electric field strength was measured on lines x = 2.5, x = 16.5 and x = 33 in the z-x plane designated z2.5, z16.5 and z33.0, respectively.

The center of the pigeon's head and pelvic region was designated H and P in Fig. 1, and their projections on the y-z and the x-z planes are also shown (designated Hyz, Pyz and Hzx, Pxz); the projection shadows of the entire idealized subject on these two planes are also shown. The planes through H and P, and parallel to the z-x plane are depicted and marked "head plane" and "pelvic plane," respectively. The position in Fig. 1 represents the average static location of the bird during testing.
Electric Field Analysis

The electric field in the test chamber was measured using a Monroe Electrostatic Field Differential AC Meter, Model 238-2. The instrument's probe was aligned parallel to the basal plane and, under these conditions, the instrument determines the y-component of the electric field $E'$. The accuracy of the measurements was $\pm 5\%$ for all values of $E'$. $E'$ was determined along the line $z$, $z_{12.5}$, $z_{16.5}$, and $z_{21.0}$ at values of 5, 10, 15, $\ldots$, 45 cm along the z-axis, and within planes parallel to the x-z plane at y-levels of 6.4, 11.4, 17.9, 24.1, and 29.2 cm. Figs. 2 and 3 show the variation of $E'$ over the pelvic and head region, respectively. Two points on the test pigeon were selected to specify the exposure field strength prior to the introduction of the subjects (e.g., pigeons). The first was the center of the head, H, which was exposed to the highest field values and the second was the center of the pelvic region, P.

Field value measurements determined that:

$$E'_H = 21 \pm 3 \text{ (kV/m) rms}$$

$$E'_P = 9 \pm 1.5 \text{ (kV/m) rms}$$

Thus, initially undisturbed field intensities in the head region were approximately twice those in the pelvic region of the test pigeon.
The linearization of $E' (x, y, z)$ in the region around H (Fig. 3) allowed an estimate of the variations of $E'$ in the $x, y, z$ directions. These can be specified as partial derivatives:

\[
\begin{align*}
\left[ \frac{\partial E'}{\partial X} \right] & \quad y = 24.1 \text{ cm} \quad z = 17.9 \text{ cm} \quad 2.5 \leq X \leq 16.5 \text{ cm} \approx 43 \pm 6 \text{ (kV/m$^3$)} \\
\left[ \frac{\partial E'}{\partial Y} \right] & \quad z = 17.9 \text{ cm} \quad x = 6.9 \text{ cm} \quad 17.9 \leq Y \leq 29.2 \text{ cm} \approx 145 \pm 22 \text{ (kV/m$^3$)} \\
\left[ \frac{\partial E'}{\partial Z} \right] & \quad x = 6.9 \text{ cm} \quad y = 24.1 \text{ cm} \quad 15.2 \leq Z \leq 20.3 \text{ cm} \approx 118 \pm 18 \text{ (kV/m$^3$)}
\end{align*}
\]

The effect of slight movement of the bird with respect to H in the nonhomogeneous field can be estimated by using $\Delta x, \Delta y,$ and $\Delta z$ values derived from plotting such movements of observed birds. The largest of these values was $E'_{z_{max}} = 1.5 \text{ kV/m},$ and any effect due to the motion of the pigeon in the nonhomogeneous field is probably negligible as shown by the following equation:

\[ E' = 21 \gg 1.5 > \Delta E'_{z_{max}} > \Delta E'_{x_{max}} > \Delta E'_{y_{max}} \]

**Possible Effects of Electrode Implants on Field Detection**

The total displacement or charging current $I_C$ between the grids energized at 50 kV was measured in order to assess the possibility that the
exposed implants might act as an antenna, providing a mechanism for detection of the electric field. This was done by temporarily grounding the conditioning chamber floor through an ammeter. The displacement current was 0.0274 mA. A second measurement was then made of the displacement current, $I_u$, with a test pigeon standing on the floor of the test chamber. The current $I_u$ was 0.0328 mA, due to the presence of the pigeon. The threshold value for 60-Hz shock response of these birds was 0.30 mA. Even assuming that the entire displacement current occurred through the shock harness electrodes, it seems unlikely that the test birds were affected by their presence since $I_u = 0.0328$ mA, which is roughly one-tenth the shock response threshold, $I^m = 0.30$ mA.

One possibility which remains to be examined is that joule heating at the shock electrode tissue interfaces may cause tissue damage and therefore organism response during the experimental procedures. Such effects may be gauged by calculating $W$, the joule heat generated (measured in watts), and the current density $J$ through each such interface. The dc resistance between the electrodes was determined to be $10^5$ ohms. It is assumed that the total resistance is divided equally between the two interface surfaces. It is further assumed that this interface region extends $10^{-1}$ cm beyond the surface of the electrode and that the current, $I$, is the shock response electrode current of 2.5 mA. Making use of the fact that

$$W = IR,$$

the resultant value of $W$ is equal to 0.31 W.
The effective volume power density \( P \) developed along the electrode length \( l \) of 2.5 cm is defined by

\[
P = \frac{W}{V^{ei}},
\]

where \( V^{ei} \) is the volume of the assumed interface, calculated from

\[
V^{ei} = \pi (r_{ei} + l)^2 - r_{ei}^2 l,
\]

where \( r_{ei} = 0.013 \text{ cm (5.0 mil)} \),

\( l = 2.5 \text{ cm for each electrode.} \)

Substituting values in equations 2 and 3,

\[
P = 3.2 \times 10^{-3} \text{ W/mm}^3.
\]

Such power density levels are not sufficient to cause permanent tissue damage. This conclusion is further borne out by examining the current density, \( J \), that enters the tissues at the tissue electrode interface. \( J \) can be calculated by

\[
J = \frac{I^{ei}}{A^{ei}},
\]

with \( I^{ei} \) the electrode current and \( A^{ei} \) the area of an electrode implant, where

\[
A^{ei} = (2\pi r_{ei}) l,
\]

Substituting the values cited above, \( A^{ei} \) is equal to 0.20 cm\(^2\), and \( J \) equals 0.012 A/cm\(^2\). The low value determined for \( J \) bears out the conclusion that tissue damage due to searing is highly unlikely. Visual inspections of the tissue surrounding the electrode implants of each of the test pigeons disclosed no evidence of tissue damage. However, this is not sufficient evidence, of course, to eliminate the possibility of detection by joule heating.

**Test and Recording Equipment**

The selected intermittent reinforcement schedule was a variable interval (VI). It was controlled by a closed loop tape driven at a rate of 1 mm/sec. At appropriate reinforcement periods a perforation passed through a set of electrical contacts, allowing closure for a period of 3 sec. The pigeon would then receive food if it pecked the key during this 3-sec period; if at least one peck occurred during this time the grain hopper would be energized for a 5-sec period. At the end of the 5-sec period the grain dispenser automatically deenergized, and a reinforcement counter recorded the reinforcement.

In order to quantify the behavior suppression during the stimulus pe-
period, two successive 15-sec intervals, designated O₁ and O₂, were pro-
grammed. This was accomplished by sequential activation of two elec-
tronic timers. The number of key pecks made in each of these intervals
were recorded on electronic digital counters.

At the beginning of the second interval, O₂, of "Treatment Trials" the
variac supplying power to the transformer was turned from zero to 50
kV (Experiment I) or to 25 kV (Experiment II). The rise time from 0
to 50 kV/m was approximately 0.70 sec. At the end of the second interval
the electric field was turned off. The decay time was approximately 0.30
sec. Since the rise time and decay time were so rapid, transients were
large (relative, e.g., to those reported by Larkin & Sutherland, 1977),
who suggested that such transients may be important). Immediately after
the second time interval was completed, the test pigeon automatically
received a 2.50-mA 60-Hz AC shock for 30 msec. The same sequence of
events occurred during "Control Trials" except that the variac re-
mained energized but at zero voltage, so no electric field was generated,
and O₂ was not terminated with electric shock (Figure 4).

Preliminary Training

All subjects were magazine trained with a 4-sec cycle time and then
trained to peck the key through successive approximations. After 50
continuous reinforcements, variable interval (VI) schedules were intro-
duced. The pigeons were successively trained on VI schedules of 15,
30, 60, and 90 sec. After approximately 45 days of training, three of the
pigeons that exhibited high responding rates on the 90-sec schedule
(11–15 k pecks/hour) were selected for use in the detection experiment
and trained during 20 additional days.

EXPERIMENT I

The test situation was one in which the baseline peck rate was recorded
(during the O₁ 15-sec period), and the pigeon was then exposed to the
electric field for 15 sec, the O₂ period, after which an unavoidable shock
(2.5 mA for 30 msec) occurred. The input voltage to the grid system was
50 kV. This produced an undisturbed electric field, E', of 21 kV/m at
H, the center of the head region of the pigeon, and 9 kV/m at the pelvic
region (P). Thus, if the pigeon were able to detect the presence of the

\[
\begin{array}{c|c|c}
15 \text{ seconds} & 15 \text{ seconds} \\
\hline
\text{O₁} & \text{O₂} \\
\text{Pre-stimulus} & \text{Conditioned response} \\
\text{interval} & \text{interval} \\
\end{array}
\]

Fig. 4. Sequence of events for a trial. 'During treatment trials the grid was activated
in this interval. 'Termination with electric shock was only during treatment trials.
electric field, it would, in essence, receive a "notice" that a shock would occur in 15 sec. Since the shock (or anticipation of the shock) inhibits pecking, detection of the field would result in a decreased peck rate during \( O_2 \), the time the electric field was on (Fig. 4).

A total of 170 treatment trials were run on each subject, and an equal number of control trials were run, i.e., without activating the electric field or terminating with shock.

**Statistical Methods**

An independent \( t \) test (Ostle, 1964), comparing the absolute value of the mean differences between the \( O_1 \) and \( O_2 \) intervals for the control and treatment trials, \( \frac{\sum_{i=1}^{n} |O_1 - O_2|}{N} \), was used to determine the effect of electric field activation on key pecking activity.

<table>
<thead>
<tr>
<th>Control trial</th>
<th>Treatment trial</th>
</tr>
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<tbody>
<tr>
<td>( O_1 ) interval</td>
<td>( O_1 ) interval</td>
</tr>
<tr>
<td>( O_2 ) interval</td>
<td>( O_2 ) interval</td>
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<tr>
<td>difference</td>
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<td>( H_0 ): difference (control)</td>
<td>( H_0 ): difference (control)</td>
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<td>=</td>
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<tr>
<td>difference (treatment)</td>
<td>difference (treatment)</td>
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</tbody>
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Further, if \( H_0 \) were rejected at \( p < .05 \), it was essential to determine if the actual value of \( O_1 - O_2 \) for treatment trials were positive, since only if fewer pecks occurred during \( O_2 \) (in treatment trials) would suppression (and therefore detection of the ELF field) be suggested.

**Results and Discussion**

A significant suppression in key pecking activity was found for each bird in response to the presentation of the 21 kV/m (at the head region) electric field (\( p < .05 \)). Ninety-five percent confidence intervals for the mean differences between the \( O_1 \) and \( O_2 \) intervals for the control and treatment trials were calculated and shown in Fig. 5. Absolute differences between \( O_1 \) and \( O_2 \) were smaller for control than for treatment trials for each subject, and actual differences between \( O_1 \) and \( O_2 \) were positive for both control and treatment trials for all subjects. Hence, suppression (\( p < .05 \)) of key pecking activity of all subjects occurred during exposure to the (undisturbed) 21 kV/m (at the head region) field.

During treatment trials using the electric field it was noted that immediately after the onset of the electric field there was a period of approximately 5 sec during which time key peck responding was essentially 0. This led to speculation that detection of the electric field took place during the onset of the field and that once stabilized was either more difficult to detect or not detectable at all. This seems to be corroborated by Larkin and Sutherland (1977). They studied migrating birds' responses to electromagnetic fields and noted that nonlinearity of flight
Fig. 5. Ninety-five percent confidence intervals for the mean differences between the O₁ and O₂ intervals of the control and treatment trials (21 kV/m at the head region) for each test pigeon.

(i.e., veering from the original flight path) was highly significant during the transition from "off" to "on" condition of the field than under any other of the conditions tested. Larkin suggested that the birds may respond with immediacy to the ramp of the signal, i.e., the slope portion of the signal, but may show a latency in responding to the other stimulus conditions tested.

Graves and Poznaniak (1977), Graves (1977), Graves, Long, and Poznaniak (1978) and Hackman and Graves (1981) studying the effects of ELF fields on corticosterone concentration in mice, found that mice exposed to a 60-Hz field of 25 or 50 kV/m exhibit a significant increase in circulating corticosterone concentration after the initial onset of the field. However, the hormone levels quickly returned to a range similar to that of unexposed animals after a short period of time. If the field were left on OR off for a sustained period, the corticosterone level rapidly returned to a normal level of concentration.
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EXPERIMENT II

A second experiment was conducted, identical in procedure to the first, using the same test subjects but with 25 kV applied to the grid system. At least 50 trials were run on each of the subjects.

Interstitial Field Analysis

The electric field intensity within the chamber varies linearly with the applied voltage. A 50% reduction in the input voltage, therefore, will result in a corresponding change in the field value. Thus for a 25-kV grid potential, the field values become,

\[ E_H = 10.5 \pm 1.5 \text{ (kV/m) rms,} \]
\[ E_f = 4.5 \pm 0.75 \text{ (kV/m) rms.} \]

As in the previous experiment, the undisturbed field intensity in the head region was approximately twice that in the pelvic region of the test pigeon in the chamber.

Similarly, the linearization of \( E' \) \((x, y, z)\) over the region about \( H \) allows an estimate of \( \Delta E' \) in the \( x, y, \) and \( z \) directions. Those can be specified from the following derivatives.

\[
\begin{align*}
\left[ \frac{\partial E'}{\partial X} \right]_{y = 24.1 \text{ cm}, \quad z = 17.9 \text{ cm}} & \approx 22 \pm 3 \text{ (kV/m²)} \\
\left[ \frac{\partial E'}{\partial Y} \right]_{x = 6.9 \text{ cm}, \quad z = 17.9 \text{ cm}} & \approx 72.5 \pm 11 \text{ (kV/m²)} \\
\left[ \frac{\partial E'}{\partial Z} \right]_{x = 6.9 \text{ cm}, \quad y = 24.1 \text{ cm}} & \approx 59 \pm 9 \text{ (kV/m²)}
\end{align*}
\]

Results and Discussion

Differences between \( O_1 \) and \( O_2 \) were similar during control and treatment trials \((p > .05; \text{ Fig. 6}); \) hence, no evidence of suppression was obtained.

OVERVIEW AND GENERAL DISCUSSION

Several conclusions may be drawn from the experiments reported here. At 50 kV/m \((\text{e.g., } 21 \text{ kV/m undisturbed field strength at head level})\) significant \((p < .05)\) differences were found between control (no signal) and treatment (signal) trials. No significant differences \((p < .05)\) between the control trials and treatment trials were found at 25 kV/m \((\text{e.g., } 10.5 \text{ kV/m at head level})\) exposure. The harness and shock electrodes attached
Fig. 6. Ninety-five percent confidence intervals for the mean difference between \( O_1 \) and \( O_2 \) intervals of the control and treatment (10.5 kV/m at the head region) for each test pigeon.

To each subject would not seem to be able to enhance the ability of the test pigeons to detect the presence of the electric fields of the magnitude tested here. As described in a companion study (Graves, 1981) elimination of the electric field inside the test chamber with a Faraday cage eliminated the suppression behavior, suggesting that artifacts such as grid vibration or noise which may have been associated with the exposure system were not the means by which pigeons detected onset of the field.

Measurement of electric field intensities at the head level of the subjects suggested a threshold of detection between 10.5 \( \pm \) 1.5 and 21 \( \pm \) 3.0 kV/m. Observations that subjects seemed to suppress behavior during the few seconds following field onset rather than during the entire time the field was energized corresponds well to Larkin and Sutherland's (1977) finding and to findings in our laboratory that serum corticosterone levels in mice exposed to the field exhibited immediate and transient increases following field onset. Hence, these responses of organisms to an ELF field may be more nearly correctly interpreted within the framework of the "orienting reaction" rather than within the framework of stress reactions indicative of the General Adaptation Syndrome (Selye, 1946).

Pavlov (1927) used numerous terms to define the orienting response, chto takoe, "what-is-it?"; 'issledovatel' ski, "investigatory"; and orientirovochny, "orientation reflex." Pavlov noted that: "It is this reflex which brings about the immediate response in man and animals to the slightest changes in the world around them, so that they immediately orientate their appropriate receptor organ or organs in accordance with the perceptible quality in the agent bringing about the change, making full investigation of it. The biological significance of this reflex is obvious. If the animal were not provided with such a reflex its life would hang at every moment by a thread."
According to Sokolov (1960), the orienting reflex has two major components. First, it is an unspecific reflex and is initiated by an increase, decrease, or qualitative change of a stimulus, independent of the modality of the stimulating agent. Second, it is subject to extinction or habituation on repeated presentation. Further, the orienting reflex, which includes some vegetative, somatic, electroencephalographic, and sensory components, is a unitary system, and the role of these components is to increase the discriminatory power of the analyzers. Finally, the orienting reflex is a special functional system which can be differentiated from the other two general types of unconditioned reflex: (1) the adaptive reflex, which is concerned with the direction of a change of stimulus and (2) the defensive reflex, which is a general response of an organism when the stimulus is too strong for normal functioning.

Berlyne (1960) defined the orient response as those processes that focus, direct, or sensitize receptor organs and thus have an unmistakable exploratory function. The response would be more-or-less specific and include proprio and skeletal musculature as well as photochemical, humoral and vegetative responses. More generally, Berlyne suggests that the orient reaction is the outwardly visible orienting behavior; that is, the postural changes and receptor adjustments that he classed as orient responses form part of a whole constellation of physiological processes permeating the entire organism which can be elicited by the onset, termination, intensification, weakening, or modification in any other way of any kind of stimulation. Further, Berlyne suggests that adaptive reactions act in an opposite direction to the orientation reaction since they tend either to diminish the impact of a change in stimulation, to desensitize, or to restore excitation to some optimal level. The general rule, then, is that the orientation reaction marks the first onset of a stimulus and is later replaced by adaptive responses. Finally, Berlyne notes that defensive reactions resemble adaptive responses in that they act to counteract stimulation. Yet they share with the orientation reaction a generalized and pervasive character. The stimuli that evoke the defensive reaction are those with extremely high intensity or with a painful quality.

The results presented here suggest that pigeons do detect high-intensity ELF electric fields; it remains to be seen whether such fields are associated with deleterious biological responses.

REFERENCES


