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The Effect of Quality of Light on Agnostic Behavior of Iguanid and Agamid Lizards

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ABSTRACT- It has been recognized in both the popular and scientific literature that ultraviolet light plays a part in the lives of lizards. It has generally been assumed that ultraviolet light helps prevent or cure rickets although there have been suggestions in the literature that light quality may influence behavior. In this study, behavioral changes by ultraviolet light include threats to conspecifics in Dipsosaurus dorsalis as well as an increase in the frequency of assertion displays in Dipsosaurus and an increased frequency of head nods in Agama agama. One of the more important physical factors in the environment of desert lizards is light.

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Introduction

Although we know that light plays an important role in the lives of reptiles and amphibians, our knowledge of what wavelengths or combination of wavelengths are important is limited. (Oliver, 1955) Popular publications with advice on keeping lizards in captivity suggest that the animals should be exposed periodically to a source of ultraviolet light in order to prevent rickets (Snedigar, 1962; Vogel, 1964). Oliver (1955) noted that desert species in particular appear to need ultraviolet light in small amounts.Snedigar (1963) suggested that certain bulbs, giving off small amounts of ultraviolet, may be kept on the animals on a continuous basis without harming them. That reptile curators are becoming increasingly aware of the importance of light quality in the successful maintenance of reptiles is indicated by the fact that 4 papers in a recent International Zoo Yearbook discuss the use of sunlamps, various fluorescent bulbs and ultraviolet light for the successful exhibition of reptiles (Kauffeld, 1969; Laszlo, 1969; Logan, 1969; Pawley, 1969) Researchers have exposed their animals periodically to a source of ultraviolet light for proper Vitamin D and calcium metabolism (Mayhew, 1964, 1965) and it has been noted in other publications that the animals were periodically exposed to ultraviolet light, but no reason was given (Mayhew, 1963a, b ,c; Tinkel, 1967)

There have been suggestions in the literature that light quality and/or intensity have a behavioral effect on iguanid lizards. Hunsaker (1962) in his ethological study of the torquatus group of the genus Sceloporus observed that ultraviolet light tended to elicit behavioral activity after the radiation period. Greenberg (1945) noted that 400-w photographic lamps had an immediate behavioral effect on the overall aggressiveness of the dominant male in a group of Crotaphytus collaris. He attributed this effect to light, temperature or both. At the Dallas Zoo, Dallas, Texas it has been observed that the males of several iguanids, in a mixed habitat of varanids and iguanids, bobbed and defended territories when kept under a bank of 6 250-w infra-red heat lamps and 2 275-w sunlamps (Murphy, 1969).

While maintaining a group of Dipsosaurus dorsalis to be used in behavior studies involving hormones, it was decided that the animals should be exposed periodically to a sunlamp in order to keep them in good health. It was observed that social interactions occurred more frequently among the group when the sunlamp was on. The main social interaction of this group was the assumption of a threat display, i.e., at the approach of conspecifics, the dewlap was extended and the sides were laterally compressed. Another series of observations also implicated light quality in the social behavior of iguanid lizards. A group of 13 male and female Sceloporus jarrovi was observed to perform assertion displays significantly more frequently when exposed to a sunlamp.

These observations suggested that light quality was playing an as yet poorly understood but important role in the social behavior of iguanid lizards. The primary goal of this study was to demonstrate that light quality affects the social behavior of certain iguanid and agamid lizards.

MATERIALS AND METHODS

Six desert iguanas Dipsosaurus dorsalis, 7 collared lizards, Crotaphytus collaris, 3 rainbow lizards, Agama agama, were used in the observations reported here.

The Crotaphytus and Agama were fed crickets and mealworms while the Dipsosaurus were fed lettuce, dandelion blossoms, and other vegetation. Water was always available in shallow containers. All lizards were toe-clipped and color-marked for individual recognition.

The Dipsosaurus were observed in 50.8 cm X 30.5 cm X 30.5 cm glass-fronted cages. The tops consisted of screen wire and, in addition, a 9.2 cm circular screened wire opening was at one end of the cages. The bottom of the cages was covered with 7 cm of sand. The wooden cages were painted inside and out with aluminum paint. The Crotaphytus were observed in a large inside enclosure constructed of sheet metal and measuring 2.4 m X 1.9 m X 0.9m. The floor of the enclosure was covered with 7 cm of sand and there were 3 cement blocks present for the animals to climb on. Black vinyl plastic on 3 sides above the sheet metal helped eliminate outside disturbances. At one end of the enclosure had a window measuring 21.9 cm X 51 cm through which observations were made. The glass in the window was covered on the inside with scotch tint. This produced somewhat the same effect as one-way glass and tended to prevent visual distraction of the animals. The Agama were observed in both the large shet metal enclosure and the small wooden cages. They were much more wary than either the Dipsosaurus or Crytaphytus and scotch tint was applied to the inside of the glass of the small cage as well as to the inside of the window of the sheet metal enclosure. Under these conditions they did not appear to be unduly disturbed by the presence of the observer.

Three 250-w heat lamps were used to light and heat the large sheet metal enclosure. The substrate temperatures varied from 47 C directly under a heat lamp to 26 C in more distant parts of the enclosure. The small wooden cages were generally lighted and heated by a single 100-w incandescent bulb in a reflector.

The source of ultraviolet light used in these observations was 2 commercial 275-w mercury vapor sunlamps, one manufactured by Sylvania, the other by Westinghouse for Sears Roebuck and Company. Commercial sunlamp specifications are regulated by the American Medical Association and the erythemal reaction, which occurs from 290 to 313 nm, is used to judge their effectiveness (Koller, 1965). Figure 1 ilustartes the spectral output of visible and ultraviolet radiation of a commercial sunlamp.

A metal box lined with asbestos was used to house a sunlamp in experiments in which filters were used. The asbestos lining was painted with aluminum paint to insure reflectance.

Two Corning glass filters, c.s. no.7-60 and c.s. no.3-74, both measuring 15 X15 cm were used in these experiments. The former was used in the metal box to filter out most of the visible light produced by a sunlamp, the latter filtered out most of the ultraviolet light of a sunlamp. The approximate transmission per cent for various wavelengths for filter c.s. no.7-60 is shown in Fig.2; that of c.s. no. 3-74 is shown in figure.3.

All temperatures were measured to the nearest degree C with an electronic thermometer and a small animal thermistor probe.

Behavioral data on the lizards in the small cages were collected with a 20-pen Esterline-Angus event recorder activated by a pushbutton keyboard. Data in the large enclosure were collected with a Sony tape recorder and later transcribed. A 60 sec stopwatch was used for certain measures and to determine the length of observation periods. A 16 mm movie camera was used to record the threat response of Disposaurus and Crytaphytus.

LIGHT AND BEHAVIOR IN LIZARDS

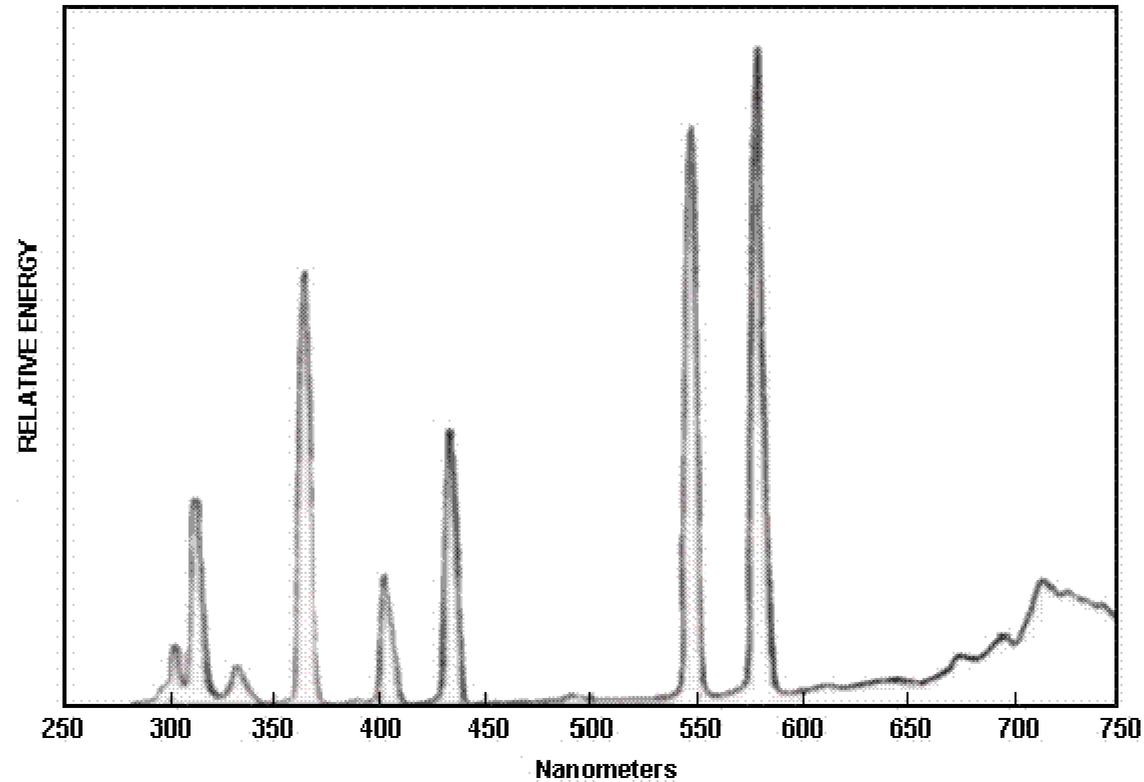

FIGURE 1. Ultraviolet and visual spectral energy distribution of a 275-w sunlamp.

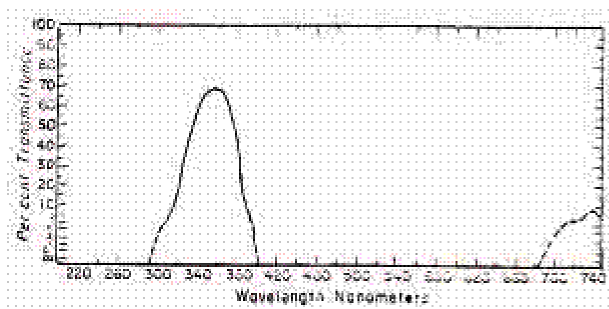

FIGURE 2. Transmittance curve of glass filter c.s. no. 7-60.

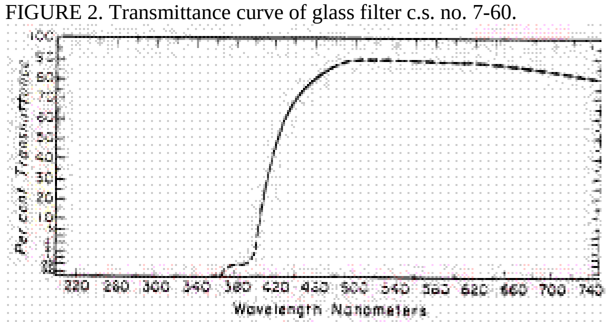

FIGURE 3. Transmittance curve of glass filter c.s. no. -74.

Observation periods in the large inside enclosure were generally of .5 hr duration. Periods in which a sunlamp was used were alternated with those in which it was not used. Observations in the small cages involving the use of a sunlamp were of 2 types. Unfiltered experiments were of .5 hr duration. During the first 10 min, the animals were exposed only to the incandescent bulbs: during the second 10 min period, the sunlamp was turned on and during the final 10 mm period, the sunlamp was turned off. In experiments involving filters, observation periods were again of 30 minute duration, one 15 min period with the c.s. no. 7-60 filter in place and the second 15 min period with the c.s. no. 3-74 filter in place. A 5 min period during which filters were changed and the sunlamp cooled down intervened between the first and second 15 min observation periods. Data were obtained on one day furst under ultraviolet light and on the next day first under visible light. For any one group of animals only one observation period a day was run.

The data were analyzed with nonparametric statistical tests (Siegel, 1956).

Behavioral patterns recorded included assertion displays and challenge displays (see Carpenter, 1962, 1967) as well as threat displays. In this paper threat refers to an elevation of the body accompanied by dewlap extension and lateral compression. The display is not characterized by up and down movements and it may be performed by juveniles, females, intact and castrated males. Threat displays are performed at the approach of conspecifics (see Harris, 1964 for a different usage of the term threat display). Avoidance is used to refer to the tendency of lizards to avoid close contact with conspecifics and is achieved by circling, running rapidly from or [illegible] and moving away from a conspecific. Head nods (see Harris, 1964) were counted in *Agama agama*.

RESULTS

Dipsosaurus dorsalis

The first group of *Dipsosaurus* observed were 3 males that had been castrated in anticipation of hormonal work. Measurements were made of the frequency and duration of threats. Figure 4 shows the mean per cent of time spent in threat displays by the animals during ten 30-min observation periods when the sunlamp was on during the second 10-min interval. Figure 5 shows the frequency of the threat displays. There is a significant difference in the per cent of time spent in threat between the eleventh and twelfth min of observation (Mann-Whitney U test $P < 0.001$, one-tailed test). A Spearman Rank correlation coefficient shows a significant decrease in the per cent of time spent in threat displays over the second 10-min observation period ($P < 0.05$) and a significant decrease over the duration of the experiment ($P < 0.05$).

Figure 6 shows the results in per cent time spent in threats when the visible portion of the spectrum is filtered out with filter no. c. s. 7-60. Figure 7 shows the data in terms of frequency. A comparable amount of observation with filter no. c. s. 3-74 revealed only two instances of threats totaling 16.5 sec, whereas for the no. c. s. 7-60 filter 142 threat displays with a total of 1280 sec was recorded. A Mann-Whitney U test on the data from Fig. 6 shows a significant difference between the first and second min of observation ($P < 0.01$, one-tailed test). A Spearman Rank

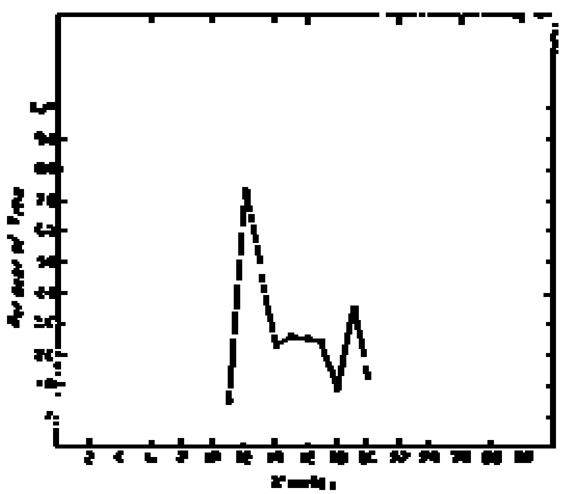

FIGURE 4. Mean per cent of time spent in threat displays by 3 castrated *Dipsosaurus dorsalis* when exposed to a sunlamp during the second 10 min of ten 30-min observation periods.

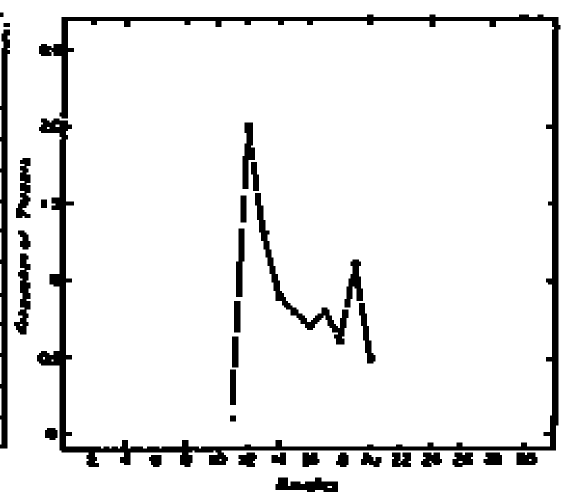

FIGURE 5. Frequency of threat responses by 3 castrated *Dipsosaurus dorsalis* when exposed to a sunlamp during the second 10 min of ten 30 min observation periods.

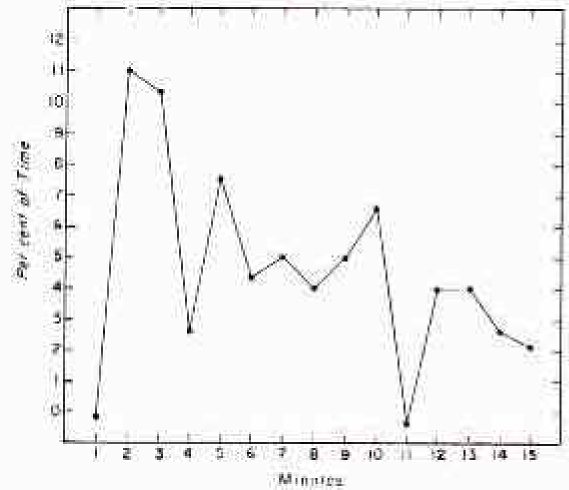

FIGURE 6. Mean per cent of time spent in threats by 3 castrated *Dipsosaurus dorsalis* when observed with the c. s. no. 7-60 filter.

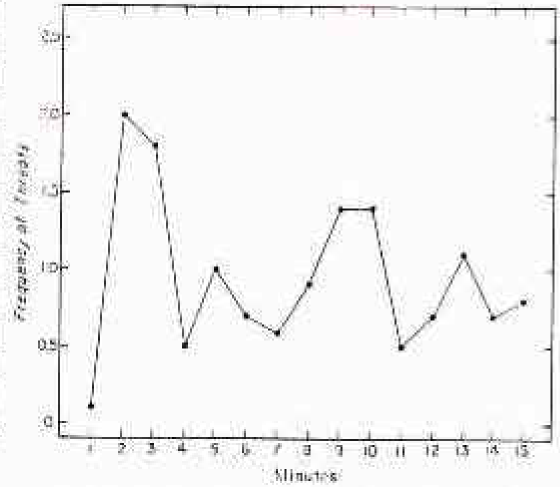

FIGURE 7. Frequency of threats displayed by 3 castrated *Dipsosaurus dorsalis* when observed with the c. s. no. 7-60 filter.

correlation revealed a significant decrease over the 15-min observation period ($P < 0.05$) and over the duration of the experiment ($P < 0.01$). The lizards behaved in a similar manner when exposed to two 15-w BLB black fluorescent bulbs.

Temperature measurements on the castrated *Dipsosaurus* indicated that infrared radiation from the sunlamp was having a negligible effect on the behavioral response. The mean temperature of the lizards taken before a sunlamp was turned on (without a filter) was 38.9 C (38-40 C). After a full 10-min radiation period, the mean was 39.6 C (36-42 C). These data are based on 60 temperature readings. Both of the filters used permitted passage of some infrared radiation. Temperatures recorded at the top of the cages indicated that filter c. s. no. 3-74 was allowing more infrared to pass through than c. s. no. 7-60. The mean rise in temperature for the c. s. no. 3-74 filter was 3.2 C whereas that for the c. s. no. 7-60 filter was 1 C. Attempts to evoke agonistic behavioral responses by using an infrared lamp rather than a sunlamp were not successful. The short latency to a behavioral response together with the temperature results cited above indicated that temperature, within the range cited above, has little effect on the observed agonistic behavior.

Three intact male *Dipsosaurus* were observed under the same conditions as the first experiment run on the castrated *Dipsosaurus*. During the 200 min when the sunlamp was not on, no assertion displays were observed whereas during the 100 min when the sunlamp was on, the yellow male, who appeared to be dominant, performed 46 assertion displays. Twenty (43 per cent) of these displays were performed during the second min that the sunlamp was on. The dominant yellow male threatened less than did the castrated *Dipsosaurus* when exposed to a sunlamp.

An obvious behavior pattern influenced by sunlamps was avoidance behavior. In the intact *Dipsosaurus* for example, the red and green males neither asserted nor threatened but tended to avoid close contact with the yellow male and with each other when the sunlamp was on. The same was true of the castrated males; all 3 tended to avoid close contact with the other animals. Often avoidance consisted of running rapidly from a conspecific contact, in other instances an animal simply circled a conspecific as it was moving along to avoid contact. In some instances after an animal performed a threat display it moved away from the conspecific.

Crotaphytus collaris

Ten hours were spent in observing a group of 6 *Crotaphytus* in the large inside enclosure. These observations consisted of a comparison of the behavior of *Crotaphytus* under three 250-w

TABLE 1. Frequencies of threats, challenges and courtship or copulation attempts by *Crotaphytus collaris* during sunlamp experiment.

Subject	3 250-W Infrared Lamps Plus One 275-W Sunlamp			3 250-W Infrared Bulbs Only		
	Threat	Challenge	Courtship or Attempted Copulation	Threat	Challenge	Courtship or Attempted Copulation
Red-yellow male	—	—	3	—	—	—
Yellow-red male	35	4	—	1	2	—
Pink-yellow male	—	—	—	—	—	2
Red-pink male	—	—	1	—	—	—
Blue-yellow female	70	1	—	—	—	—
Yellow-blue female	20	—	—	1	—	—
Totals	125	5	4	2	2	2

infrared lamps, as opposed to 3 250-w infrared lamps and a sunlamp. Table 1 presents the frequencies of threats, challenges and courtship or copulation attempts under these conditions.

Avoidance of conspecific contacts was characteristic of *Crotaphytus*. As an individual approached another or a group, it would often circle to avoid close or direct contact. Avoidance often followed threats; e.g., the blue-yellow female would frequently go into a threat, hold it for a short period of time and then run rapidly to the opposite end of the enclosure.

Duration scores of the threat display showed that they were frequently maintained for a long period of time. Scores of 2 threats by the yellow-red male were 17 and 25 sec whereas scores of 2 threats by the blue-yellow female were 22 and 100 sec. Frequently a threat turned into an actual attack as the animal being threatened was sometimes bitten on the head or snout if he continued to approach. Threat was not elicited in certain lizards when exposed to the sunlamp. However, that their behavior was in fact modified by the sunlamp is illustrated by the following observation. Prior to the observation period the pink-yellow male, who never threatened, had been lying near the yellow-red male. After the sunlamp had been turned on, they continued to lie side by side for about 2 min until the yellow-red male made a slight movement of a non-aggressive nature. The pink-yellow male then jumped approximately 8 cm into the air and away from the yellow-red male.

Agama agama

Fifteen hours were spent observing 2 male and one female *Agama agama*. Data from 10 hr of observation made in the large inside enclosure are presented in Table 2. Five hrs of data using the 2 filters were obtained in one of the small cages; these data are presented in Table 3. The female

TABLE 2. Frequency of head nods performed by *Agama agama* during 10 hrs of observation in large inside enclosure.

Subject	3 250-W Infrared Lamps	3 250-W Infrared Lamps Plus one 275-W Sunlamp
Female	3	33
No. 1 male	1	21
No. 2 male	0	8
Totals	4	64

TABLE 3. Frequency of head nods performed by *Agama agama* in ten 30-minute trials in small enclosure. *Female died after third trial.

Subject	Filter No. C. S. 3-74	Filter No. C. S. 7-60
Female*	0	11
No. 1 male	11	54
No. 2 male	1	9
Totals	12	74

tended to avoid the males and to extend her dewlap upon their approach during periods of time when the animals were exposed to a sunlamp or ultraviolet light.

DISCUSSION

There are a few known biological effects of ultraviolet radiation where adequate quantitative information exists (Koller, 1965), i.e., erythema, prevention and cure of rickets and the germicidal effect. Insects are known to be able to see in the ultraviolet down to 300 nm and the honeybee's greatest visual sensitivity is at 350 nm (Marler and Hamilton, 1966). With these exceptions biologists have generally been reluctant to attribute biological effects to ultraviolet light. However, Allee et al. (1949) write: "...the extent to which these shorter wavelengths are important to nonhuman animals, insects particularly, in such matters as protective coloration, mimicry, and sex recognition in dimorphic species, is still an open question." In regard to reptiles, Kauffeld (1969) reported "I have encountered a surprisingly large number of reptile keepers, amateur and professional, who are convinced that ultraviolet light is beneficial if not essential to snakes, crocodilians, turtles and lizards. Certain families of lizards—notably the Iguanidae and Agamidae—without a doubt do require ultraviolet rays, especially for the proper growth of the young."

Kauffeld is no doubt thinking of possible antirachitic effects of ultraviolet when he speaks of the proper growth of young iguanids and agamids. The results of the present study demonstrate that ultraviolet light facilitates agonistic behavior in certain iguanids and agamids. One effect of ultraviolet is the production of threat responses in iguanids such as *Dipsosaurus dorsalis* and *Crotaphytus collaris*. I have also observed it in *Crotaphytus wislizeni*. It is significant that all of these iguanids are inhabitants of arid or semi-arid environments. In the hierarchy of iguanid social behavior patterns—threat, assertion and challenge—threat ranks low on the scale. Inasmuch as castrated *Dipsosaurus* will display threats to conspecifics, this also suggests that threat represents a low intensity display and that elicitation is not dependent upon gonadal androgens. A second effect of ultraviolet appears to be a lowering of the threshold for performing assertion displays. This effect has been observed in *Dipsosaurus dorsalis, Sceloporus jarrovi, Anolis carolinensis* and *Uta stansburiana*. This effect may depend at least in part on the internal physiological state of the animal. In all of these species, assertion displays will be given, but at a significantly lower rate, under either incandescent or infrared bulbs.

In both *Dipsosaurus* experiments, the peak of behavioral activity occurred during the second minute after the sunlamp was turned on. The mean latency to a measurable behavioral response for the observation periods is 78 sec (range; 39-132 sec). When first turned on, a sunlamp gives off very little ultraviolet light. It takes approximately 2 minutes for a sunlamp to warm up and emit its full output of ultraviolet light. This varies from lamp to lamp. Numerous qualitative observations over a 4 year period suggest that in *Dipsosaurus* as well as other desert iguanids a measurable behavioral response nearly always occurs during the first two min after the sunlamp has been turned on. The mean latency of a measurable behavioral response to the imposed light treatment in *Crotaphytus collaris* was 158.8 sec (range: 75–262 sec). This is considerably longer than the latency for *Dipsosaurus* but these observations are not comparable. The *Crotaphytus* observations were made in an enclosure 2.4 m long so an animal might be 2 m or more from the sunlamp in contrast to a few cm in the experiments with *Dipsosaurus*. Additionally, since the enclosure was much larger the animals were often more scattered than the *Dipsosaurus*. The fact that an animal would perform a threat 2 m from the sunlamp again argues against possible temperature effects of the sunlamp.

Further studies using commercial sunlamps should take into account the fact that ultraviolet output of a sunlamp decreases with usage. Most of the decrease occurs during the first 100 hr of use. The output is measured in erythemal units but erythemal effectiveness may not be related to the effectiveness of ultraviolet light in promoting iguanid agonistic behavior. While the present study shows that near ultraviolet light influences iguanid agonistic behavior, it remains to be determined which portion of the spectrum between 280 or 290 nm and 400 nm is actually producing the response. The hypothesis suggested here is that the response is due to ultraviolet above the limits of erythemal effectiveness, approximately 313 nm and probably above 350 nm. As can be seen in Fig. 1, a mercury arc is characterized by regions where little or no energy is emitted alternating with strong mercury lines where a considerable amount of energy is emitted. There is a strong mercury line in the 360 to 370 nm range and it may be this line that influences iguanid behavior. This hypothesis fits better the meager published physiological evidence on other organisms than one attributing this effect to regions of the spectrum having erythemal effectiveness. Further studies using narrow bandpass filters will be necessary to test this hypothesis.

A characteristic of desert biomes is the general lack of cloud cover so that approximately 90 per cent of the annual sunshine is received and diurnal animals are exposed to high concentrations of ultraviolet light (Kendeigh, 1961). Because of scattering, the amount of ultraviolet light from the sky may at certain times of the day exceed the amount received directly from the sun thus leading to sunburn in a person sitting in the shade (Koller, 1965). Koller (1965) gives the reflectance of 300 nm ultraviolet from dry dune sand as 17 per cent but the reflectance in the ultraviolet above 300 nm is greater and is greater yet in the visible portion of the spectrum (Norris, 1967). In the desert with scanty vegetation a lizard is exposed to reflected light of various wavelengths coming from different directions and varying distances (Norris, 1967). Diurnal desert lizards, the most conspicuous animals during the day (Kendeigh, 1961), are thus exposed to a great quantity of direct light from the sun, scattered light from the sky and a considerable amount of reflected light from the environment. The role played by reflected light in the present study is unknown; these observations were made in either sheet metal enclosures or cages painted with aluminum paint which is a good reflector of ultraviolet light (Koller, 1965). It would seem best for behavioral studies of desert iguanids, normally exposed to a considerable amount of reflected light to provide them with an enclosure that is highly reflective to ultraviolet as well as visible light.

Jagger (1967) cautioned researchers working with plants that these organisms have evolved under the influence of solar radiation and there are pitfalls to working with different spectra or monochromatic light. Mammals likewise have evolved under the influence of solar radiation and most artificial light sources differ from the solar spectrum received at the earth's surface (Wurtman and Weisel, 1969). Diurnal desert lizards have certainly evolved under the solar spectrum and are subjected to intense direct solar radiation, scattered radiation and reflected radiation coming from many different directions and distances. Radiation from various portions of the solar spectrum can be expected to play a significant role in saurian biology. Hinde (1966, pg. V) states one of the basic axioms of ethology ". . .that the behavior of an animal cannot be properly studied without some knowledge of the environment to which its species has become adapted in evolution." Ethologists studying marine, estuarine and arctic organisms in the laboratory must take into consideration the physical environment in which their subjects evolved. Researchers working with diurnal desert lizards in the laboratory must also be aware of the physical characteristics of the environment to which their subjects have become adapted and one of the more important of these is light.

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