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Environmental Lighting and Human Salivary Gland Function[1] (38625)

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We have previously reported that the resting rate of function of the human parotid gland is significantly depressed during light deprivation either by blindfolding (1, 2) or by room darkening (2). These observations suggested that a major portion of the minute, yet persistent, unstimulated (resting) secretion is controlled by light-influenced sympathetic neuronal activity. Further, based upon biochemical similarities in response to light and darkness by salivary and pineal glands (3, 4), we have proposed that the established nervous pathway for photic input from the retina via the superior cervical ganglion to the pineal is duplicated functionally in the human parotid system.

Since the human submandibular gland also receives post-ganglionic fibers from the superior cervical ganglion, the present study was undertaken to determine if this gland responds to light deprivation in the same fashion as does the parotid. Parotid studies were also extended by testing for accommodation to darkness and evaluating the effects of widely varying intensities of light on parotid function.

Materials and Methods. Fasting, healthy male dental students served as subjects and sampling was initiated daily at approximately 6:30 AM. All sampling was accomplished without exogenous stimulants and each sample was collected over a 20-min period.

The first experiment tested the effect of light deprivation on resting submandibular flow rate. Individualized acrylic collectors were fabricated for each of the five subjects and samples were collected and discarded for 5 days to assure patient comfort with the device in place, and to familiarize subjects with the collection procedures. A 10-day test period followed. After the collection device was positioned a drop of citric acid solution was placed on the tongue to elicit flow and fill the collector with submandibular fluid. Each subject rinsed his mouth well and sat quietly for 15 min to allow the gland to return to its resting state. A 20-min unstimulated sample was then collected under routine laboratory lighting (cool-white fluorescent) and a second sample was collected with complete light deprivation assured by blindfolding. Over the second 5 days of the test period this order was reversed and the blindfold sample was taken first.

The second experiment investigated the effect of light and darkness on parotid flow. Each of three subjects provided a series of five 20-min samples on a daily basis over 16 days. The first sample was collected under routine laboratory lighting. Light deprivation was then imposed, three consecutive samples were taken, and lighting was restored for the collection of the fifth sample in the series. During the first 8 days of the experiment, light deprivation was by blindfolding, and during the second 8-day period a dark room was utilized.

In the final experiment, parotid flow responses to various light intensities were studied in five subjects. On each day paired 20-min collections were made from each subject under two different environmental lighting conditions, with the order of application reversed on successive days. A total of 40 pairs of samples were collected with each light-intensity comparison. The first phase compared a light intensity of 0.1 fc to total darkness. The second compared 0.1 and 40 fc, and the final comparison was between 0.1 and 150 fc. In all cases the light intensity was measured at eye level.

Results. Resting submandibular flow rate data for the two 5-day periods were pooled

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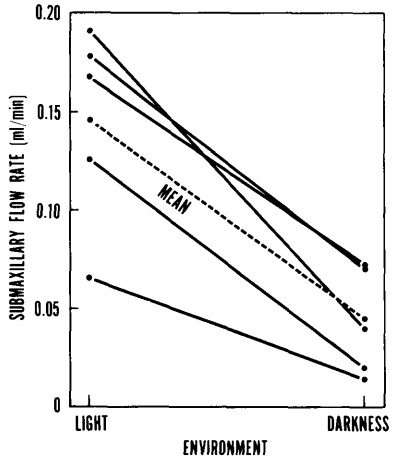

FIG. 1. Individual subject flow rate responses to light deprivation.

since order of exposure to light and darkness did not significantly affect the results. Figure 1 points out that the submaxillary flow mean under routine lighting, 0.146 ml/min (SD = 0.077), fell to only 0.045 ml/min (SD = 0.036) when the participants were blindfolded. The significant ($P = 0.01$) decrease in flow found for each subject is also plotted in this figure. The over-all 69% decrease in flow is in essential agreement with our past observations on the human parotid (1, 2).

Parotid flow rate means produced during the five collection periods in the second experiment are presented in Table I. Since there were no significant differences noted between responses during room darkening and blindfolding, the data were combined. Invariably, light deprivation produced significant ($P < 0.01$) decreases in rate of flow. There were no significant differences between the three samples collected sequentially in darkness. Neither did the final control sample differ significantly from the initial control collection. As compared to the pooled control sample means, the successive decreases in flow found in the samples collected in darkness were 62%, 52%, and 45%, respectively.

Results of varying light intensity on parotid flow are presented in Table II. In the three phases of the experiment, exposure

TABLE I. EFFECT OF LIGHT DEPRIVATION ON UNSTIMULATED PAROTID FLOW RATE.

Environment	Parotid flow rate (ml/min)	
	Mean	SD
Light	0.040	0.021
Dark	0.017	0.013
Dark	0.019	0.014
Dark	0.023	0.016
Light	0.044	0.021

TABLE II. ENVIRONMENTAL LIGHT AND PAROTID FLOW RATE.

Environmental light (fc)	Parotid flow rate (ml/min)	
	Mean	SD
0.1	.052	.027
0 (darkness)	.026	.018
0.1	.047	.022
4.0	.050	.022
0.1	.050	.018
150	.052	.018

to 0.1 fc elicited mean flow rates of 0.052 ml/min (SD = 0.027), 0.047 ml/min (SD = 0.022), and 0.050 ml/min (SD = 0.018). Differences between responses to this intensity of light were not significant. Increasing the light intensity above 0.1 fc did not significantly alter the rate of flow. However, decreasing the intensity from 0.1 fc to complete darkness brought about a significant ($P < 0.01$) 50% decrease in rate of parotid function.

Discussion. The results of the present study reinforce our past observations (1, 2) that light deprivation brings about a significant decrease in the rate of resting salivary gland function. We suggested that the depression of parotid flow rate was mediated by way of the sympathetic nervous system since specific sympathetic pathways are known to be present from the retina to the parotid gland by way of the superior cervical ganglion. If this premise is valid, one would expect a similar response in the human submandibular gland since it also receives sympathetic fibers from the superior cervical ganglion by way of plexuses on the external carotid and facial arteries. The 69% decrease in submandibular flow found in this

study supports this concept since it is intermediate to the 75% (1) and 50% (2) decreases in parotid flow found in our previous light-deprivation work.

There are additional reasons to suspect that the sympathetic system is involved in this process. Parallel diurnal cycles in catecholamine content of the pineal and salivary glands have been reported by Wurtman, Axelrod, and Delly (3). Moore and Smith (4) confirmed these results and found that in rats housed in diurnal lighting, norepinephrine content of the pineal and salivary glands was highest at the end of a dark period, and lowest at the end of a light period. If animals were maintained in constant darkness, norepinephrine levels remained high, and low levels were found with constant light. In addition, the pineal is a neuroendocrine organ that is controlled by light and receives postganglionic sympathetic fibers from the superior cervical ganglion in a pattern similar to that of the salivary glands. This, plus the striking biochemical similarities, lends credence to the concept that light and darkness are affecting the salivary glands by fundamentally the same processes.

Even if granted that these light-related changes in salivary gland function are mediated by way of the sympathetics, the actual mechanism remains obscure. Sympathetic excitation results in different levels of saliva flow from the various salivary glands in different species. Stimulation in the dog elicits a low rate of flow from the submandibular gland and even less from the parotid (5). The parotid response in cats is very slight but submandibular flow is relatively profuse (5). Further confusion results from the observation that some cats give a very minimal submandibular flow, and some do not flow at all (6, 7).

In the rat both the parotid and submandibular glands flow rapidly after sympathetic stimulation (8, 9). In rabbits parotid flow far exceeds the response of the submandibular gland (10). Stimulation of the sympathetic trunk in the neck of man elicits submandibular but not parotid flow (5). Similarly, epinephrine injections into excretory ducts evoke submandibular but not parotid flow in man (11).

It is also necessary to consider the vasoconstrictor response to sympathetic stimulation in relation to this flow-rate depression. Pronounced vasoconstriction could interfere with flow which would provide an explanation for the decrease in parasympathetic-induced secretion brought about by excitation of sympathetic fibers (12). For this mechanism to apply in the present studies it would be necessary to accept the unlikely premise that darkness was the sympathetic stimulant and that it brought about vasoconstriction sufficient to reduce unstimulated flow to the drastic degree observed.

There is an additional possibility that motor effect of sympathetic stimulation exerts an influence on salivary flow. Mathews (13) suggested in 1898 that submandibular flow in both cats and dogs elicited by sympathetic excitation is due solely to sympathetic motor influences. The myoepithelial cells are usually identified as the contractile tissue responsible for this mechanical effect. Fundamental to this concept is that contraction of myoepithelial cells, induced by sympathetic stimulation, induces expulsion of a preformed saliva from the gland. It has also been suggested that sympathetic stimulation may induce flow by diffusion of sympathin from vasoconstrictor terminals to the secretory cells (14).

Certainly these observations do not establish that the resting flow of saliva is under purely sympathetic control. Our previous work (15) has shown that resting flow of the parotid is indeed sensitive to the oral administration of $\frac{1}{150}$ grain of atropine sulfate. For 300 subjects receiving this dosage the mean resting flow decreased from 0.054 to 0.018 ml/min. This two-thirds reduction very closely resembles that brought about by light deprivation. Thus, there appears to be a functional contribution of both divisions of the autonomic system to maintenance of the resting parotid flow. Experiments are in progress involving light deprivation in subjects receiving anticholinergic drugs as well as work with sympathetic stimulants and blocking agents.

When three parotid samples were collected in sequence in darkness there was no statistically detectable evidence of accom-

modation to this light deprivation. The decrease in flow associated with darkness in this experiment averaged 52%, a figure that falls into the range of our past findings. After initial light deprivation the decrease in flow rate was evident in the first collection and, likewise, with the reinstitution of light, the increase in gland function was quickly restored. These results suggest the desirability of studies involving persons who have been blind for varying lengths of time and such work is being accomplished.

The intensity study indicates that even so little as 0.1 fc of light is sufficient to provide a stimulus to glandular flow, and that increasing the intensity to as high as 150 fc did not significantly affect flow. This all-or-none result is similar to that observed when lights of various specific spectral characteristics evoked similar flow rates (16). It is clear from the present results that the entire action spectrum of light is not required and that only a slight intensity of light is necessary to elicit salivary flow.

Summary. Three experiments were conducted to (a) determine the effect of light deprivation on submandibular flow, (b) test for accommodation in darkness-induced parotid flow-rate depression, and (c) evaluate the effects of lights of widely varying intensities on parotid flow.

Light deprivation decreased submandibular flow rate from 0.146 ml/min to 0.045 ml/min, a decrease of 69%. It is suggested that photic input through the retina provides stimulation to the salivary glands in the human through the superior cervical ganglion in a system similar to that present for the pineal. This implies that the sympathetic nervous system functions in the regulation of a component of the resting flow from both the parotid and submandibular glands.

Series of parotid saliva samples collected in darkness did not reveal a pattern suggestive of accommodation to darkness. The effect of darkness on flow is as strong in the first sample as in those collected later under darkness. Reinstitution of light brings immediate restoration of the routine level of unstimulated salivary flow.

A light intensity as low as 0.1 fc is sufficient to maintain the usual level of resting parotid flow. Increasing intensity up to 150 fc did not significantly increase this rate of flow.

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