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Effect of high ambient temperature on the kinetics of the pupillary light reflex in healthy volunteers

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Miotic responses to brief light stimuli were studied in healthy volunteers under two ambient temperature conditions, 22° C and 40° C. The latency and amplitude of the light reflex did not differ between the two conditions, but the recovery time of the reflex was significantly shorter under the 40° C condition than under the 22° C condition. The results are consistent with the hypothesis that exposure to high ambient temperature results in an increased sympathetic drive to the iris dilator muscle but does not influence the parasympathetic light reflex.

Keywords ambient temperature pupillary light reflex sympathetic reflex

Introduction

Exposure to high ambient temperature results in changes in autonomic functions, for example enhancement of physiological tremor (Al-Eithan *et al.*, 1991) and hyper-responsiveness of eccrine sweat glands to intradermally injected cholinomimetics (Banjar *et al.*, 1987), which have been attributed to increased impulse flow in peripheral sympathetic nerves (e.g. Bini *et al.*, 1980; Szabadi *et al.*, 1988). We report here the effects of high ambient temperature on the kinetics of the pupillary light reflex. The latency and amplitude of the miotic response to light stimulation are determined by the parasympathetic reflex arc, whereas the recovery time of the response is believed to be determined in part by sympathetically mediated redilatation (Ishikawa *et al.*, 1977; Smith, 1988).

Methods

Subjects

Twelve drug-free healthy male volunteers (19–45 years) participated. All gave their written informed consent. The study was approved by the local Ethics Committee.

Apparatus

Pupil diameter was monitored using an infrared television pupillometer (Applied Science Laboratories). Twelve 200 ms light stimuli of graded intensities were delivered via an assembly of three light-emitting diodes (peak wavelength, 565 nm) mounted on a headband and positioned 1 cm from the cornea of the subject's right eye. The intensities of the stimuli (incident light intensity, measured 1 cm from the source) ranged from 5.3×10^{-5} to 3.59 mW cm^{-2}. Stimulus presentation was controlled by a BBC-B microcomputer, which also recorded the pupillometric data.

Procedure

Each subject participated in two sessions 7 days apart. In one session the test cubicle was maintained at 22° C ± 2° C, and in the other it was maintained at 40° C ± 2° C, the order of conditions being counterbalanced across subjects. At the beginning of each session the subjects were first acclimatized to red light (30 min) and to the ambient temperature in the test cubicle (20 min). Then resting pupil diameter was measured, followed by miotic responses to the twelve light stimuli. The stimuli were presented at 30 s intervals in the order of increasing intensity.

Analysis

Resting pupil diameter was compared between the two temperature conditions using Student's *t*-test (paired comparisons). The latency, amplitude and 75% recovery time of the miotic responses to the light stimuli (Bakes *et al.*, 1990) were analyzed by two-factor analyses of variance (temperature condition, light intensity), with repeated measures on both factors. Pearson's product-moment correlation coefficient was calculated for the

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relationship between each parameter of the light reflex and the logarithm of the light intensity under each temperature condition.

Results

The mean (± s.e. mean) resting pupil diameter did not differ significantly between the two temperature conditions (22° C: 6.7 mm ± 0.4 mm; 40° C: 6.8 mm ± 0.2 mm; $t(11) = 0.6$; $P > 0.1$).

Under both temperature conditions, the latency, amplitude and 75% recovery time of the miotic responses were approximately linearly related to the logarithm of the light intensity (Figure 1, Table 1). Analysis of variance revealed a significant main effect of light intensity on each parameter (latency: $F(11, 121) = 49.7$; amplitude: $F(11, 121) = 117.9$; 75% recovery time: $F(11, 121) = 26.8$; $P < 0.001$ in each case). In the case of latency and amplitude, there was no significant main effect of temperature condition (latency: $F(11, 121) = 1.1$; amplitude: $F(11, 121) = 0.8$; $P > 0.1$ in each case). 75% recovery time showed a significant main effect of temperature condition ($F(1, 11) = 7.3$; $P < 0.02$), and a significant interaction effect ($F(11, 121) = 3.1$; $P < 0.01$), reflecting a shortening of the recovery times of responses to higher light intensities under the 40° C condition.

Table 1 Correlation coefficients (r) for relationships between parameters of the light reflex and log light intensity under the two temperature conditions (c.f. Figure 1)

	Temperature	
	22° C	*40° C*
Latency	−0.947*	−0.993*
Amplitude	+0.990*	+0.991*
75% recovery time	+0.971*	+0.964*

*$P < 0.001$

Discussion

The latency and amplitude of the miotic response to light are determined by activity in the parasympathetic reflex arc, whereas the recovery time of the response is believed to be determined, in part, by active redilatation brought about by the sympathetic innervation of the radial muscle of the iris (Smith, 1988). The present finding that exposure to high ambient temperature shortened the recovery time of the light reflex without affecting the latency or amplitude of the response is thus consistent with the hypothesis that exposure to high temperature results in an increased sympathetic drive to the radial muscle, but does not influence the parasympathetic reflex. The present results are also consistent with our previous findings that systemic treatment with clonidine, a drug which is believed to suppress sympathetic outflow (Kobinger, 1978), prolongs the recovery time of the light reflex (Morley *et al.*, 1991).

The present results may have implications for the changes in autonomic function seen in clinical anxiety states. Such changes have traditionally been ascribed to sympathetic overactivity (see Szabadi & Bradshaw, 1988). However, we recently observed that the amplitude of the light reflex (an index of parasympathetic activity) was smaller in a group of patients suffering from generalized anxiety disorder than in a matched group of healthy volunteers, whereas the 75% recovery time of the reflex did not differ between the two groups (Bakes *et al.*, 1990), suggesting that there may be suppression of the parasympathetic drive, rather than facilitation of the sympathetic drive to the iris in these patients. This interpretation is strengthened by the demonstration that interventions believed to suppress (clonidine) or enhance (high ambient temperature) impulse traffic in sympathetic nerves selectively alter the recovery time of the light reflex, without affecting its amplitude.

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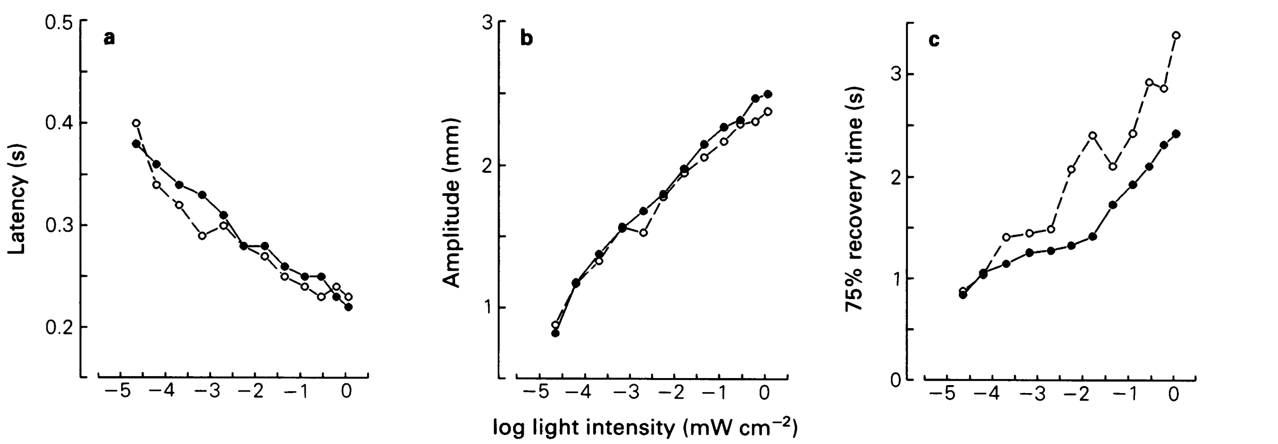

Figure 1 Relationship between parameters of the light reflex and the intensity of the light stimulus. *Ordinates*: A, latency (s); B, amplitude (change in pupil diameter, mm); C, 75% recovery time (s). *Abscissa*: light intensity (mW cm^{-2}, logarithmic scale). Points are mean data ($n = 12$); symbols indicate treatment conditions: ○ 22° C; ● 40° C.

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