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HUMIDITY, COMFORT AND CONTACT LENSES

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ABSTRACT

The human eye is a bodily organ that is dependent upon an adequate and balanced supply of water and, therefore, is prone to irritation when exposed to low humidity. The purpose of this study was to examine the influence of two humidity conditions (10% rh, 30% rh) on the comfort of the human eye with and without soft contact lenses over a 10-hour period. The results showed that acuity, refractive errors, and cornea curvatures of the eye were not significantly affected by humidity. However, a perceivable level of annoyance was felt in the eyes with and without contact lenses at relative humidities of 30% or less. This type of eye discomfort was most pronounced after an exposure exceeding four hours.

INTRODUCTION

Many individuals live in areas where the relative humidity is generally above 50%. When these individuals are exposed to arid conditions, they may experience discomfort. This effect is identifiable by dryness in the nose and throat, irritation of the eyes, dry skin, and chapped lips. The sensitivity of the eye to low humidity is correlated to its need for an adequate and balanced supply of water, and contact lens wear may exacerbate the irritation. A common complaint associated with air travel is a gritty feeling in the eyes. This discomfort may be attributable to the 10% or less relative humidity that is typical of an aircraft cabin. Arid conditions also exist in more common environments, and individuals are routinely subjected to exposure during their daily activities. For example, the average afternoon relative humidity in Las Vegas, Nevada, during April, May, June, and July is 15%, 13%, 10%, and 15%, respectively (1987 World Almanac). This study examined the effect of low humidity on the comfort of the human eye with and without soft contact lenses.

METHODS AND PROCEDURES

Design

Two environmental (humidity) conditions were selected for study: 75 F (23.9°C) at 30% rh and 75 F (23.9°C) at 10% rh. Each condition was replicated three times using a different group of four subjects for each trial. Within each group, two subjects were male and two were female; a total of 24 individuals participated. During the test, each subject served in both control and experimental roles by wearing a contact lens in one eye and no lens in the other. The contact lens was removed from the subject's nondominant eye so as to minimize any effect associated with the uncorrected vision. The test lasted 10 hours; during this time, both physical and subjective measurements were taken 10 times on each subject. A total of 480 observations (12 subjects x 2 genders x 2 eyes x 10 observation times) were recorded for each of the dependent measures.

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Subjects

Subjects were 24 college students ranging in age from 18 to 22 years; all had worn soft contact lenses for at least eight hours a day for three months. Prior to selection as a test participant, candidates were examined by a licensed optometrist. The optometrist ensured that all test participants had properly fitting contact lenses that were in good condition. In addition, each candidate was screened to confirm that their eyes were in good health, and the dominant and nondominant eye was determined. All subjects were volunteers; for their participation they were paid \$40.00 and received a comprehensive eye examination free of charge.

Apparatus and Equipment

All tests took place in a university environmental chamber. The chamber was 11 feet (3.35 m) in length, 8 feet (2.44 m) wide, and had a ceiling height of 8 feet (2.44 m). The environmental support equipment for the chamber was modified with a commercial dehumidifier to permit more stringent control over the humidity conditions. The chamber itself was modified by lining the walls with 2 inches (5.08 cm) of styrofoam and covering it with wood paneling. A portable toilet was placed in the chamber and isolated from the occupants for privacy. Each subject wore a cotton-polyester shirt and trousers. The insulation (clo) value measured 0.6 when subjects were fully dressed. Subjects were given a long-sleeved pullover sweater (0.25 clo); its use was optional. Lunch and a continuous supply of soft drinks and water were also provided.

A 16-item rating scale was used to record subject responses of eye comfort (Figure 1). On this scale the rater was required to evaluate each of the 16 descriptors using a seven-category scale. Acuity and refractive error of the eye were measured with an auto-refractometer. An automatic Keratometer was used to determine the cornea curvature.

Procedure

Upon reporting for the test, each subject was given the standard clothing ensemble to be worn. When the subjects were appropriately attired, they were oriented concerning the test protocol and balloting procedures. The subjects then entered the test chamber, were seated, and the experiment began. The duration of the test was 10 hours. Both physical and subjective evaluations for both eyes (contact and naked) were made upon entering the test room (0 hour) and at the following subsequent times: 0.5 h, 1.0 h, 1.5 h, 2.0 h, 3.0 h, 4.0 h, 6.0 h, 8.0 h, and 10.0 h. When the subjects completed the final evaluations (10.0 h), they changed back into their own clothes, were paid, and dismissed.

ANALYSIS

Scale Development Procedure

The responses from the 10.0 h voting period were subjected to a statistical scaling procedure (Laviana and Rohles 1987; Rohles and Milliken 1981). In this procedure, 16 separate analyses of variance (ANOVA) models — one for each of the 16 descriptors — with the sources of variance being humidity, gender, eye (contact vs. naked), and their interactions, were computed. The residuals from each ANOVA model were then used to construct a correlation matrix that was used in a subsequent principal component (PC) analysis.

From the PC analysis, components having eigenvalues (characteristic roots) greater than or equal to 1 were retained and subjected to a varimax rotation. To determine which dimension a rotated component was measuring, only the descriptors that had loadings (values corresponding to each of the descriptors in the component) greater than .700 or less than -.700 were used.

Derived Scales

This procedure yielded two separate scales. The first, which we called Discomfort I, was composed of the following adjectives and their respective loadings:

0.891	annoying
0.854	uncomfortable
0.833	strained
0.752	tired
-0.734	moist.

With these descriptors, it was clear we were measuring some factors contributing to annoyance.

The second scale, Discomfort II, measured the attribute of painfulness. The descriptors and respective loading were as follows:

0.882	scratchy
0.863	tearful
0.813	painful
0.785	burning.

A score for each of the scales was generated for each subject by multiplying the loading for each descriptor by the subject's response to that descriptor. The products were then summed to yield the individual's score on the particular scale in question. The resulting score for each individual served as the dependent measure in subsequent analyses of variance.

RESULTS AND DISCUSSION

A repeated measure analysis of variance was conducted for each of the dependent measures: acuity, refraction error, cornea curvature, annoyance, and painfulness. The sources of variance were: humidity (10% rh vs. 30% rh), gender, eye (contact vs. naked), time (voting period), and the interactions between these variables.

From the analysis, none of the sources of variance associated with the acuity, refractive error, or cornea curvature yielded F-ratios that were statistically significant ($p \leq .05$).

To facilitate their understanding, the scores on the annoyance scale were expressed in terms of a percentage by use of the following formula:

$$\text{Annoyance (\%)} \text{ Score} = (\sum (\text{ratings} \times \text{loadings}) + 3.276) / 3.076.$$

When the annoyance votes were analyzed, eye was a significant source of variance ($F_{1,20} = 4.62$, $p \leq .04$). Subjects rated the naked eye ($\bar{X} = 30.21$) as being significantly more annoying than the eye containing the contact lens ($\bar{X} = 24.80$). Figure 2 presents the mean annoyance votes of the eyes with contacts and naked eyes for each voting period. As shown in Figure 2, the level of annoyance tends to increase with the duration of exposure, and the naked eye is consistently rated as more annoying than the eye adapted with the contact lens. However, the response associated with the contact eye shows a substantial increase in annoyance after the 8.0 hour time period and comes close to convergence with the annoyance level for the naked eye at 10.0 hours.

Discussion of this significant effect in relation to the experimental design of the test is warranted. Having each subject wear a contact lens on the dominant eye and remove a lens from the nondominant eye had several advantages. First, this procedure allowed each subject to simultaneously experience both "control" and "experimental" treatments; this, in turn, allowed for greater control over subject heterogeneity (i.e., individual differences). Second, this design permitted a smaller number of subjects and therefore had

considerable cost advantages. The main disadvantage was having a subject with uncorrected vision in one eye (a somewhat unnatural state) serve as a test participant. It is this latter consideration that may account for the naked eye being rated as more annoying than the contact eye at the baseline voting period (0 hours); see Figure 2.

In subsequent examination, the mean annoyance (%) scores presented in Figure 2 were adjusted by subtracting the initial baseline response from the scores for each of the nine remaining voting periods. As shown in Figure 3, when the differences in the initial baseline scores are accounted for, the eye adapted with the contact lens is actually rated as more annoying in eight of the nine voting periods. The difference between the contact and naked eye is much less pronounced with the adjusted scores than the original scores. However, both scores indicate a dramatic increase in annoyance after an exposure of four hours.

A significant effect was also associated with time (voting period) ($F_{9,360} = 14.89$, $p \leq .0001$). Table 1 presents the results of a Tukey's HSD post-hoc analysis for the means associated with time; as may be expected, due to the large number of means, the results were inconclusive. Graphic illustration of the mean annoyance (%) scores for each voting period (Figure 4) indicated that the level of annoyance increased with time and was most evident after prolonged (4-10 hours) exposure to the low-humidity conditions.

As with the annoyance scale, the scores associated with the painfulness scale were also expressed in terms of a percentage score using the following formula:

$$\text{Painfulness (\%)} = \frac{(\sum (\text{rating} \times \text{loadings}) - 3.343)}{3.739}.$$

When these scores were subjected to an analysis of variance, the only source of significance to emerge was associated with time ($F_{9,360} = 1.94$, $p \leq .04$). The results of a Tukey HSD analysis are presented in Table 1; the only clear differentiation is between the 0-hour and 10-hour votes. As shown in Figure 4, the mean painfulness (%) scores showed a gradual increase over time. The most pronounced rate of increase occurred during the first hour of exposure, after which the rate of increase diminished.

SUMMARY AND CONCLUSIONS

This study examined the influence of two low humidity conditions on the comfort and physiology of the human eye with and without soft contact lenses. The 30% rh condition was indicative of environmental conditions that may occur on a summer's afternoon in many areas (e.g., Phoenix, AZ; Boise, ID; Albuquerque, NM). The 10% rh condition was representative of the environmental conditions in an aircraft cabin during a prolonged flight. Eye discomfort was assessed from two varying perspectives: painfulness and annoyance. Although the level of the painfulness scores increased over the 10 hour test, the net change from the initial response (0 hour) was slight (\bar{X} , 0 h = 9.73, \bar{X} , 10 h = 14.60; $\Delta = 4.87$). Conversely, the net increase in the annoyance scores over the duration of the test was substantial (\bar{X} , 0 h = 20.62; \bar{X} , 10.0 h = 36.55; $\Delta = 15.73$). From this, it appears that the main constituent of the eye discomfort response was associated with varying levels of annoyance. However, no differentiation in the severity of this response was derived between the 10% rh and 30% rh conditions. Within the context of this study, it is concluded that a perceivable level of annoyance is experienced by both wearers and nonwearers of soft contact lenses at relative humidities of 30% or less. This type of eye discomfort is most pronounced after an exposure exceeding four hours. However, the low-humidity conditions did not significantly affect the physical measures of acuity, refractive error, or cornea curvature for either the contact or naked eye.

These findings should be considered in light of several facts. First, it is estimated that over 5,000,000 persons in the United States suffer from chronic dry eye symptoms, and many of the more than 20 million contact lens wearers experience discomfort due to this condition. Because of this, the use of lubricating "eye drops" is recommended when

exposure to low-humidity conditions cannot be avoided. When extended travel is involved, the use of a case containing saline solution for lens storage is suggested. Moreover, a supplemental pair of spectacles should always be available when anticipated exposure to low humidities is to occur.

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TABLE 1

Mean Annoyance and Painful Scores (%)
for Each of the Ten Time Periods

<u>Annoyance (%) Score</u>			<u>Painfulness (%) Score</u>		
<u>Time</u>	<u>Mean</u>	<u>Grouping*</u>	<u>Time</u>	<u>Mean</u>	<u>Grouping*</u>
10.0	36.35	A	10.0	14.60	A
8.0	33.01	A	8.0	14.04	A B
6.0	31.10	A B	6.0	12.89	A B
2.0	26.60	B C	1.0	12.40	A B
3.0	26.37	B C	1.5	12.28	A B
1.0	26.14	B C	3.0	12.23	A B
1.5	25.94	B C D	4.0	12.15	A B
4.0	25.05	C D	0.5	11.51	A B
0.5	23.85	C D	2.0	11.35	A B
0	20.62	D	0	9.73	B

* Means with the same letter designation do not differ statistically at $p \leq .05$ on a Tukey's HSD test.

EYE COMFORT BALLOT

EYE: RIGHT

Name: _____

Instructions: Below is a list of words that can be used to describe how your eyes may feel. We would like you to rate how accurately the words below describe how your eyes feel at this time. Use the following 1-7 scale for each of your answers.

- 7 = Completely accurate
- 6 = Moderately accurate
- 5 = Slightly accurate
- 4 = Neutral, neither accurate nor inaccurate
- 3 = Slightly inaccurate
- 2 = Moderately inaccurate
- 1 = Completely inaccurate

Please rate each of your eyes independently. The upper right corner of this ballot indicates which eye we want you to evaluate.

- | | |
|-----------------------------|----------------------------------|
| 1. moist. _____ | 9. tearful. _____ |
| 2. good _____ | 10. uncomfortable. _____ |
| 3. itchy. _____ | 11. strained _____ |
| 4. irritated. _____ | 12. burning. _____ |
| 5. sore _____ | 13. sharp vision _____ |
| 6. dry. _____ | 14. scratchy _____ |
| 7. bad. _____ | 15. annoying _____ |
| 8. tired. _____ | 16. painful. _____ |

Figure 1 Eye comfort ballot

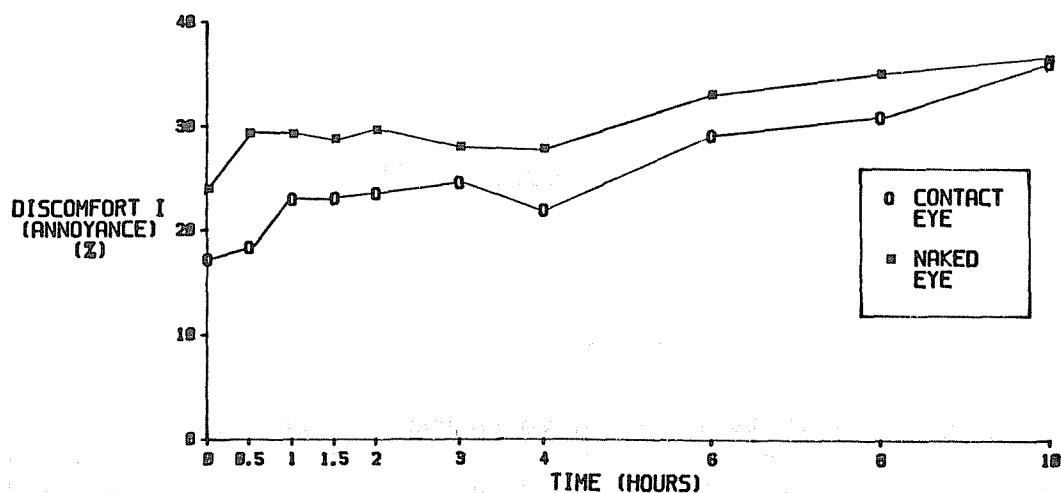


Figure 2 Mean discomfort I (%) scores for the contact and naked eye plotted as a function of time

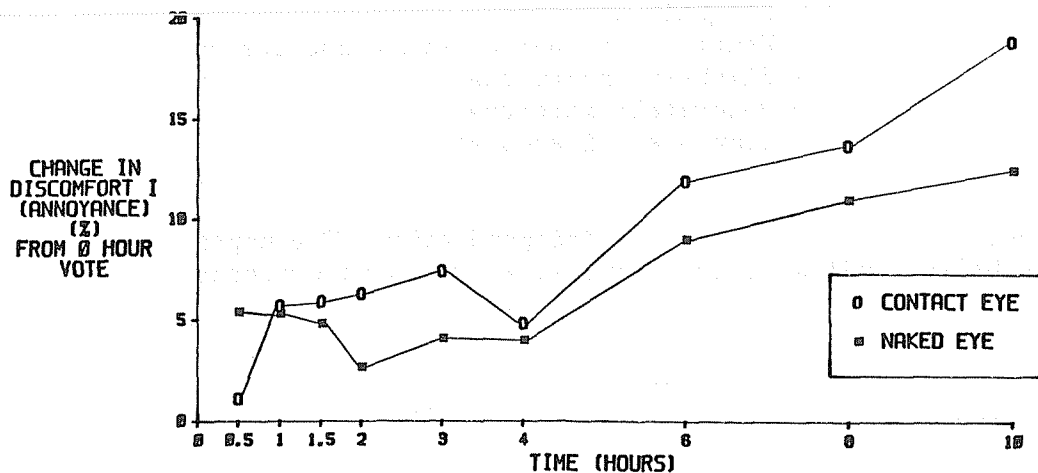


Figure 3 Mean adjusted discomfort I (%) scores for the contact and naked eye over time

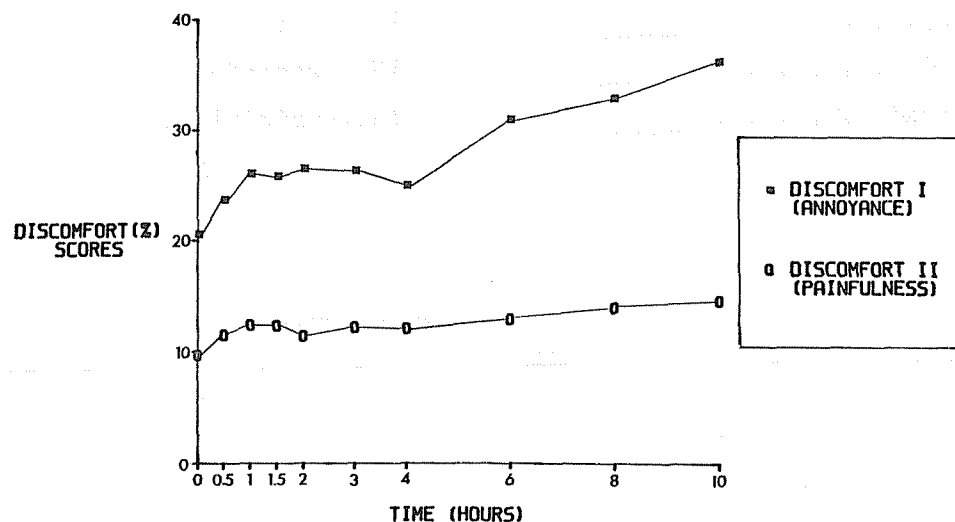


Figure 4 Mean discomfort (%) scores plotted as a function of time

Discussion

R. HASLAM, University of Technology, Loughborough, Leicestershire, England: The authors set out to investigate an interesting and important problem. However, it is possible that the increase in annoyance they measured was due to the subjects' having worn a contact lens in one eye, thus having uncorrected vision in the other eye for a prolonged period of time, and not because of the low humidity at all. Comparison with a control exposure at a higher relative humidity would enable them to determine whether or not this was the case.

J.E. LAVIANA: The experimental design of the study was established in conjunction with an individual having expertise in research involving the human eye. The limitations of this approach and the method for examining adjusted response scores are discussed in the paper. As indicated by the analysis of the adjusted scores, time (duration of exposure) was the only significant effect to emerge. Therefore, further examination of higher relative humidities may warrant less merit than concentration on the duration of exposure, varying types of contact lenses, or airborne contaminants (see below).

J.W. SHEFFIELD, University of Missouri, Rolla: Since the study was focused on the effect of humidity on comfort, an important parameter of future investigations should be a comparison of thin (extended wear) lenses and regular soft contact lenses from a common manufacturer and material of the lens.

LAVIANA: The authors concur that this represents an area for further investigation.

J.E. WOODS, Honeywell, Golden Valley, MN: Contaminants in the air also affect annoyance from contact lenses. Please comment on how contaminants were controlled. What interactions might be expected?

LAVIANA: Air contaminants were controlled through the filtration of the air intake of the environmental chamber. An intensified annoyance may be experienced by airborne contaminants and low rh. The smoking section of an in-flight aircraft would be illustrative of this condition.

WOODS: Is the annoyance effect due to hygroscopicity (i.e., as measured by rh) or to evaporation and diffusion (i.e., as measured by differences in humidity ratios or dew-point temperatures)?

LAVIANA: The annoyance effect measured in this work is a "subjective" human response. The physical correlate causing this response was not specifically identified. However, it is most probably related to an evaporation of protective eye fluids. The use of nondecongesting "eye drops," such as artificial tears, may serve to replenish these fluids and reduce the annoyance.