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Check Mean and Standard Deviation
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# The effect of restricted visual space on the refractive error of the young monkey eye

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*Seven young Macaca nemestrina monkeys were placed in chairs under hoods, which restricted visual space to a distance of 20 inches or less, for a period of 1 year. In comparison with adult animals of similar characteristics in the same situation, the young monkeys did not demonstrate any effects of the situation for 4 or 5 months, whereas the adults began to show effects within the first month. The young animals changed more rapidly once the effect became apparent and continued to change as long as they were in the situation; in contrast, the adults changed more slowly and leveled off at the end of 6 months with no further changes. The amount of myopia developed by the young animals was 1¾ diopters against ¾ for the adults in the same period. Three quarters of the adult animals developed myopia in excess of ½ diopters and 86 per cent of the young developed a similar amount. Significant age and sex differences in amount of myopia developed were found among the young monkeys. The effects of the situation on the young monkeys were similar to those found by Levinsohn, but not as marked.*

The present study is essentially similar to a previous study[1] of the effect of restricted visual space on the refractive error of the adult monkey eye. The earlier study found that a restricted visual space situation induced an average change in refractive error of about ¾ diopters minus in 9 monkeys over a period of 11 months. All of this change occurred in the first 6 months, and 2 of the 9 monkeys demonstrated changes of less than ½ diopter. When the amount of myopia developed, the rate of development and the percentage of adult animals showing significant changes were compared with the results reported by Levinsohn,[2] Essed and Soewarno,[3] and Marchesani[4] obtained on monkeys placed with the body slightly elevated above the head for a period of 6 hours per day, 6 days a week. The only close agreement occurred in the percentage of animals developing myopia. In all cases approximately 75 per cent of the animals showed changes of ½ diopter or more.

Aside from the differences in the experimental situations involved, the animals used by Levinsohn and those who repeated his studies were between 6 and 18 months of age rather than adult animals. Their animals did not begin to show changes until they had been in the situation 1 to 3 months, and once the changes started they continued as long as the animals remained in the situation. Further, the amount of myopia developed ranged between 3 and 7 diopters, which is much higher than the amount found in the restricted space situation. Since these differences may be due to the differences in the ages of the animals

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as well as to the differences in the experimental situations, 7 monkeys that had been born in the colony and were between 11 and 24 months of age were put in the restricted visual space situation for 1 year. A comparison of the results obtained on these young animals with those obtained on the adult animals in the same situation permits an evaluation of the effect of age differences; a comparison with Levinsohn's studies permits an evaluation of the differences in the experimental situations.

## Methods

The same chairs, hoods, and room conditions used on the adult animals[1] were used on the offspring of these animals in this study. Briefly, the waist plate of the restraining chair was painted white to prevent vision downward while the upper part of each chair was enclosed in a hood made of plywood with an open top and front covered with architect's cloth to provide light but prevent vision. The insides of the hoods were painted white except for the rear panel which was formed by the flat black wall of the room. The hoods were not more than 20 inches from the eyes of the monkey at the farthest point and averaged about 14 inches. The chairs and hoods were arranged under a 160 watt fluorescent unit to provide 4 footcandles of illumination on a point midway between the two plates of the chair and 10 inches in front of the centerline of the monkey. No shadows fell on the cloth parts of the hoods, although the light level within the hoods was high enough to permit discrimination of the inner features of the hood and anything within the hood.

The subjects in this study were 7 *Macaca nemestrina* (pigtailed) monkeys (4 male and 3 female) between 11 and 24 months of age, born in the colony at Washington State University or at the University of Washington.

The young monkeys were refracted throughout the study by the same refractionist,* who was not allowed to see the records obtained on the monkeys. This person did not refract the adult animals. Instead of the homatropine Paredrine cycloplegic used with the adults, cyclopentolate hydrochloride (Cyclogyl) was used for monthly refractions and was administered as follows: one drop of 1 per cent Cyclogyl 6 to 12 hours before refraction, one drop of 0.5 per cent 60 to 90 minutes before refraction, and one drop of 0.5 per cent 50 to 80 minutes before refraction. All monthly refractions were made under ether anesthesia. The initial and final refractions were made under atropine cycloplegia with and without ether. Three drops of 1 per cent aqueous atropine were given daily for 5 days. Sparine, in a dosage of 1½ mg. per pound of body weight, was given intramuscularly to every animal 1 to 1½ hours before every refraction. A headholder was used for refractions made without ether. All findings were taken to the nearest quarter of a diopter with the use of a Grout streak retinoscope and trial case lenses. The spherical lens power required to neutralize movement in each axis was recorded and translated into equivalent sphere. The monkeys were removed from the chairs and hoods after each refraction for a 2 day period.

The differences between the adult and young monkey studies may be summarized as follows: different refractionist, use of ether for refraction, use of Cyclogyl instead of homatropine and Paredrine, and refraction at monthly intervals instead of biweekly intervals. An attempt has been made to evaluate the effect of these differences on the comparisons drawn between the two sets of data.[5] Both refractionists refracted the same animals under the same conditions using atropine. The results show agreement on 4 of 14 eyes, 0.25 diopter difference on 7 eyes, 0.50 diopter difference on 2 eyes, and 0.75 diopter difference on 1 eye. When the signs of the differences are considered, the mean difference is 0.11 diopters more plus for the person doing the refractions in the present study and will be ignored in comparing the two groups.

The use of ether in refraction resulted in a significant increase in amount of minus demonstrated by female monkeys under atropine when compared with the no-ether refraction.[6] The male monkeys did not show this effect with atropine but did show a significant increase in minus with Cyclogyl, whereas the female monkeys did not show the increase when Cyclogyl was used. The effect of ether was consistent over time and makes it impossible to compare the absolute amounts of error found for the adult and young monkeys on monthly refractions since the adults were refracted without ether. However, the groups may be compared on the initial and final refractions which were made with atropine and without anesthesia. The monthly findings within each group are comparable because they were taken under the same conditions. A comparison of 28 monkey eyes under atropine, homatropine, and Paredrine, and with Cyclogyl, indicates that only 1 eye out of 28 varied more than a ¼ diopter between extreme findings under the three cycloplegics. This one discrepancy was ½ diopter. Finally, the midmonthly refractions

*M. T. Swindal, O. D., a Pullman optometrist, refracted the monkeys in this and in other studies done in the past 5 years, except as noted.

were dropped since they did not add enough information to justify the time expended in refraction.

## Results

The changes in refractive error of young and adult monkey eyes, as a result of confinement within a restricted visual space situation, are compared in Table I. Comparisons are made in terms of both mean and median changes by sexes separately and combined. The average differences between initial and final refractions under atropine without anesthesia are shown to be significant at the .1 per cent level for both groups. The groups are also compared in terms of the amount of change occurring in the first half year and the second half year. The average monthly rate of change and the number of eyes which have refractive errors in excess of .50 diopters are presented by sexes separately and combined. The correlation between rate of change and total amount of change achieved at the end of the year is presented for each group.

The standard deviations obtained monthly under ether are compared in Table II. The total number of months for the adult monkeys is 11 instead of 12 as an extra 2 days each month were lost because of removal from the chairs following

**Table I.** Young and adult monkeys compared on a variety of measures taken under comparable conditions

| | Adult | | | Young | | |
|---|---|---|---|---|---|---|
| | *Males* | *females* | *Combined* | *Males* | *females* | *Combined* |
| | *No. 2* | *No. 4* | *No. 6* | *No. 4* | *No. 3* | *No. 7* |
| Mean initial refraction | -0.44 | -0.28 | -0.33 | -0.81 | -0.94 | -0.87 |
| Mean final refraction | -1.38 | -0.97 | -1.10 | -1.69 | -3.75 | -2.57 |
| Mean difference | -0.94 | -0.69 | -0.77 | -0.88 | -2.81 | -1.71 |
| t (mean difference) | | | 5.66 | | | 5.60 |
| Significance of t | | | .1% level | | | .1% level |
| Per cent of total mean change | | | | | | |
| First 6 months | | | 100% | | | 22% |
| Second 6 months | | | 0% | | | 78% |
| Median initial refraction | -0.38 | -0.25 | -0.33 | -0.50 | -1.00 | -0.75 |
| Median final refraction | -1.38 | -0.75 | -0.87 | -1.13 | -3.75 | -3.00 |
| Median difference | -1.00 | -0.50 | -0.54 | -0.81 | -2.75 | -1.88 |
| Per cent of total median change | | | | | | |
| First 6 months | | | 100% | | | 31% |
| Second 6 months | | | 0% | | | 69% |
| Average monthly rate of change | -0.09 | -0.06 | -0.07 | -0.07 | -0.18 | -0.11 |
| r (rate-total amount) | | | 0.62 | | | 0.95 |
| Myopic eyes in excess of ½ diopter | | | | | | |
| Initial | 1 | 1 | 2 | 2 | 4 | 6 |
| Final | 4 | 5 | 9 | 6 | 6 | 12 |

**Table II.** Standard deviations (diopters) of monthly refractions of young and adult monkeys

| | *Months* | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* |
| Adult | 0.28 | 0.31 | 0.32 | 0.39 | 0.49 | 0.46 | 0.53 | 0.54 | 0.55 | 0.57 | 0.57 | 0.57 | |
| Young | 1.31 | 1.31 | 1.32 | 1.26 | 1.48 | 1.61 | 1.82 | 2.07 | 2.01 | 1.97 | 2.03 | 2.22 | 2.49 |

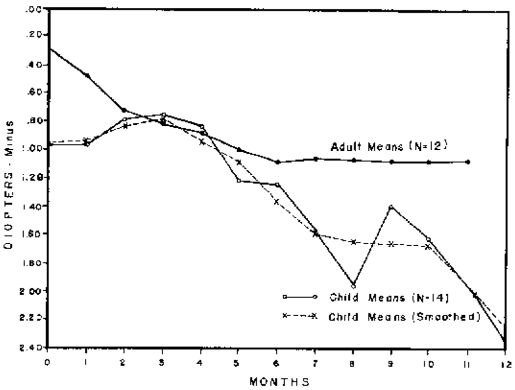


Fig. 1. Mean refractive changes in adult and young (child) monkey eyes during 11 or 12 months in a restricted visual space.

MEANS

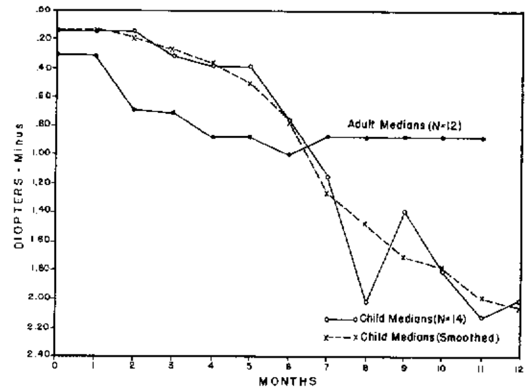


Fig. 2. Mean refractive changes in adult and young (child) monkey eyes during 11 or 12 months in a restricted visual space.

MEDIANS

the semimonthly refraction which was not performed on the young animals.

In Fig. 1 the average monthly refractions are plotted for the adult and young monkeys. As has been indicated, these values were obtained under ether for the young monkeys and without ether for the adults, and are not strictly comparable. The shapes of the curves are comparable, however, because the methods were consistent within each group. Since the young animals show much more variability, their curve has been smoothed by averaging adjacent values to make it more comparable to the adult curve. Similar data based on medians are presented in Fig. 2.

The initial and final refractions for the young monkeys by age and sex taken with atropine and no anesthesia are presented in Table III.

Since the value of the results presented in this paper depends in great part on the accuracy of retinoscopy, an attempt was made to evaluate the accuracy of the retinoscopic technique of the refractionist. The refractionist and I each scoped 25 lens combinations twice in a random order of presentation. The lens combinations covered the range of refractive errors including astigmatism found in the monkeys and were masked in an identical manner and coded. Each combination was placed on a B and L Fisher schematic eye by me, and scoped at 20 inches with trial cases lenses by the refractionist. Neither the refractionist nor I knew the value of the lens combination. After refraction by both myself and the refractionist in this manner, each lens combination was placed on a B and L vertometer and its value determined by the author. The masks were then removed and the values on the lens were recorded.

The correlations between the values determined by retinoscopy and those taken from the lenses and vertometer indicate the validity of the technique, while the correlations between the two measures made by each person indicate the reliability of each. The correlation between the results obtained by the 2 refractionists indicates the consistency with which the method may be used. Except for the reliability correlation, the average value was used and all values were in terms of equivalent spheres.

The standard error of estimate indicates the limits of error to be expected for validity, and the standard error of measurement the limits of error for reliability. As a further check on accuracy the correlation between the values given on the lenses and the vertometer reading was determined along with its standard error. The obtained correlations and standard errors are presented in Table IV.

Both refractionists showed a high reliability since the errors of measurement indicated that the obtained values would not deviate more than a quarter of a diopter from the true value in 95.5 per cent of the measurements made. The validity of the refractionist's measurements with the retinoscope against the lens values (error of estimate .12 diopter) and against the lensometer values (error of estimate .11 diopter) are only slightly poorer than the relationship between the lens values and the lensometer readings (error of estimate .08 diopter). Thus 68 per cent of his measurements would not deviate more than .12 diopter from the true value, 95.5 per cent .24 diopter, and 99.9 per cent .36 diopter. While such high validity cannot be expected with the monkey eye, it is reasonable to expect an approximation of these values on the eye of an anesthetized animal under an effective cycloplegic. Moreover, the refractionist's errors would tend to sum to zero over all animals, leaving a clear indication of the trend.

## Discussion

The results presented in Tables I and II and in Figs. 1 and 2 indicate a number of differences in the responses made by the young and adult animals to the same environmental situation. Whereas the adult animals begin to change toward myopia within the first month (Fig. 1) or just after the first month (Fig. 2), the young animals do not show a major change toward myopia until after the fourth or fifth month (Figs. 1 and 2, respectively). Further, the adult animals demonstrated the major portion of the change within the first 4 months and all of the change by the sixth month and showed no change toward myopia for the remaining 5 months in the restricted visual space situation. Thus the young animals did not seem to be affected by the situation during the time that it had its major effect upon the adult animals. This conclusion is supported by the results presented in Table I. The per cent of change occurring in 6 month intervals for the two groups indicates that all of the change occurred in the first 6 months for the adults when either the mean or the median

**Table III.** Initial and final refractions (diopters) by sex and initial age

| *Monkey* | *Initial age (months)* | *Initial refraction* | | *Final refraction* | |
|---|---|---|---|---|---|
| | | *OD* | *OS* | *OD* | *OS* |
| Male 1 | 12 | .00 | .00 | - .50 | - .50 |
| Male 2 | 15 | - .75 | - .75 | - .88 | - .88 |
| Male 3 | 11 | - .25 | - .25 | -1.38 | -1.38 |
| Male 4 | 18 | -2.25 | -2.25 | -4.25 | -3.75 |
| Female 1 | 24 | - .12 | - .12 | -3.00 | -3.00 |
| Female 2 | 11 | -1.00 | -1.00 | -3.75 | -3.75 |
| Female 3 | 24 | -1.88 | -1.88 | -4.50 | -4.50 |

**Table IV.** Correlations (r) and standard errors (S.E.) of reliability, of validity with lens values (LV) and vertometer readings (VR) by refractionist, between refractionists, and between LV and VR

| *Refractionist* | *Reliability* | *Validity (LV)* | *Validity (VR)* | *r and S.E. M.T.S.-F.A.Y.* | *r and S.E. (LV)-(VR)* |
|---|---|---|---|---|---|
| M. T. Swindal | (r) .9982<br>(S. E.) .128 D. | .9984<br>.117 D. | .9986<br>.114 D. | .9969<br>.169 D. | .9993<br>.078 D. |
| F. A. Young | (r) .9982<br>(S. E.) .128 D. | .9973<br>.152 D. | .9975<br>.152 D. | | |

measures are used, whereas for the young animals only 22 per cent of the mean change and 31 per cent of the median change occurred in the same period. Also, no leveling-off occurs with the young monkeys, but, rather, they continue to show change toward myopia up to the end of the year under the hoods.

When the two groups are compared in terms of rate of change toward myopia, amount of myopia developed, and the correlation between rate and amount, the differences are notable. The average amount of myopia developed by the young monkeys is 1¾ diopters compared with ¾ diopters for adults. The median amount is 1⅞ diopters against ½ diopter for the adults. Since the amount of myopia developed is greater for the young animals and the time in which it is developed is the same for both groups, the rate of development is 60 per cent higher for the young animals. The correlation between rate and amount, which is .62 for the adults, jumps to .95 for the young monkeys. This is partly due to the greater variability in the refraction found among the younger animals as is shown in Table II.

The average increase in myopia over the period is practically identical for the young (–0.88) and adult (–0.94) males while the young females developed 4 times as much myopia as did the adult females. In fact, the male-female differences in the two groups are reversed, with males developing more myopia in the adult groups and the females more in the young group. The sex difference in the young monkeys is significant at the .1 per cent level ($t = 7.72$).

There may appear to be a relationship between age and minus refractive error in Table III and, in fact, there is a significant difference (.05 level) between the 3 oldest animals and the 4 youngest animals. However, since this disappears when the 4 oldest animals are compared with the three youngest animals, it is an artifact of selection rather than a meaningful relationship. The correlation between age and OD refractive error of –.55 is not significantly different than zero.

The changes occurring in the standard deviations with time show some similarity in the two groups even though the variability in the younger group is 3 to 5 times that of the older group. For both groups the standard deviations remain constant for the first 3 months, increase for 3 or 4 months, and level off again for 3 or 4 months. At the end of this period the young group begins to increase again but no further data are available on this last progression. This increase in variability in both groups results from the fact that some animals do not change while others show continuing changes. Thus, from Table I, 2 of 12 adult eyes had myopia of more than ½ diopter before introduction into the experimental situation while 9 of 12 had more than ½ diopter of myopia at the end of 1 year. For the young animals 8 of 14 eyes were more myopic than ½ diopter at the initial refraction while 12 of 14 fell into this category at the end of the experimental year. Three quarters of the adult eyes were more than ½ diopter myopic at the conclusion of the study while 86 per cent of the young eyes had this much or more myopia. Three of the young animals had an average of 2.33 diopters of myopia at the beginning and 4.54 diopters at the end of the study. These animals which were born and raised in laboratory cages had a much higher percentage and much greater degree of myopia than their parents, initially.

When the results obtained with the young monkeys are compared with those obtained by Levinsohn, there appears to be a closer agreement than that found when the adults are compared. The monkeys in both situations did not begin to change immediately but only after several months in the situation, although the Levinsohn animals started to change earlier than the animals in this study. In both cases, the changes continued as long as the animals were in the situation. Although the amount of change is still greater in the Levinsohn group than that in the present group, the agreement is closer than was the case with the adult monkeys. The Levinsohn situation must introduce more stress than the present situation because the effects seem to be greater. However, at least part of the differences found between his animals and the adult animals is due to age and the remainder to the differences in the experimental situations. This point could be clarified by placing adult animals in the experimental situation used by Levinsohn.

N=14

| MEAN | MEAN 12 MONTH |
| --- | --- |
| -.95 | -2.4 |
| S.D. | SD |
| 1.31 | 2.49 |

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