CONVERGENCE*

An investigation into the normal standards of age groups

BY

A. MELLICK

GLASGOW

A SURVEY of the literature reveals that there is considerable discrepancy as to the normal values of the horizontal ductions of the eyes. Table I analyses the results obtained by various authorities. It will be seen that the results vary widely, and difficulty is encountered in explaining these divergent findings. Unfortunately comparison between the conclusions of different observers is rendered difficult, since in many instances no mention is made of the type of instrument employed, or of the kind of target used.

The present investigation represents an attempt to establish the normal range of ductions. For this purpose, the following procedure was adopted.

TABLE I.—*Duction Values by Various Observers*

Figures are in prism dioptres

Author	ABDUCTION		ADDUCTION	
	Distance	Near	Distance	Near
A. Græf		5-10		30 or more
Berens, Losey and Hardy ...	6	16 19	16	38-41
C. Sheard				30
M. Dobson	8	18	24	30
Weymouth, Brust and Gobar		17		20
S. V. Abraham		21		19
G. H. Giles	7-8	16-18	24	24
L. C. Peter	4-8		15-18	
N. A. Stutterheim			50	
J. Maxwell				18
Scobee and Green			19	

Certain criteria were essential in the selection of cases. It was in the first place, necessary to exclude any subject who suffered from gross ocular disease. The material was derived from the out-patients of the Glasgow Eye Infirmary, and the major portion consisted of those who had been treated for, and had recovered

* Received for publication, July 14, 1949.

from, such minor disabilities as conjunctivitis and chalazion. The residual group comprised those who attended for correction of errors of refraction, provided the latter did not exceed 4 dioptres of hypermetropia or myopia. Furthermore, the presence of heterophoria rendered the individual unsuitable for inclusion in the survey. The group, accordingly, cannot be taken to represent a complete cross-section of the community, but it does offer a reasonable basis for the object in view. The effect of age obviously merits special study, and accordingly the results have been analysed in terms of age groups.

A wide variety of instruments for testing ductions is available. Broadly speaking, these utilise one of two principles. One type is based on the principle of applying gradual increase of prism power, and is represented by the variable prism stereoscope. In the second type of instrument, two fused images are separated or approximated by rotating the slide-carriers of the synoptophore. Both principles were adopted, so that comparison of the results of the two groups could be obtained, each patient being tested with the variable prism stereoscope and the synoptophore.

The possible influence of the nature of the target requires further investigation, but in the present study, use was made of only two targets. One was a simple flat fusion target, and the other was a stereoscopic target of the bucket type. With the variable prism stereoscope, the target at distance was a letter of the 6/6 or 6/9 line of Snellen type; while at near, the line of letters on the Sheard card was employed. For measuring the ductions at distance with the stereoscopic target using the variable prism stereoscope, the pictures were placed in the instrument with +3·00 dioptre lenses in the eye-pieces, and these were removed for measuring the corresponding ductions at near.

Measurements were taken after the existing error of refraction had been corrected. The inter-pupillary distance of each patient was measured, the distance phoria was read on the Maddox tangent scale, and the Maddox wing was used for measuring the near phoria. Examination of the subject was completed with one

TABLE II

Distribution of patients in age-groups

Age	0-20	21-30	31-40	41-50	51-60	61+	Total
Number	115	128	96	116	53	53	561

instrument before testing with the other, the variable prism stereoscope usually being first employed. In the event of any persistence of convergence after measurement of adduction, sufficient time was allowed to permit of relaxation.

Observations were made on 561 subjects. The numbers in the respective age groups are shown in Table II.

TABLE III.—*Variable Prism Stereoscope*

ABDUCTION

Mean Values and Standard Errors

Prism Dioptres

Measures	Age 0-20 years	Age 21-30 years	Age 31-40 years	Age 41-50 years	Age 51-60 years	Age 61+ years	All Ages
D1 ...	8·2±0·2	8·2±0·3	7·8±0·3	7·8±0·2	7·9±0·3	7·5±0·3	7·97±0·10
D2 ...	9·0±0·4	8·6±0·4	8·5±0·4	9·2±0·3	9·7±0·4	9·5±0·3	9·09±0·15
N1 ...	13·2±0·3	13·8±0·4	13·7±0·4	13·9±0·3	14·3±0·5	12·6±0·5	13·61±0·16
N2 ...	11·7±0·3	11·9±0·3	12·7±0·4	12·3±0·3	11·8±0·4	11·7±0·4	12·04±0·15

TABLE IV.—*Variable Prism Stereoscope*

ADDUCTION

Mean Values and Standard Errors

Prism Dioptres

Measures	Age 0-20 years	Age 21-30 years	Age 31-40 years	Age 41-50 years	Age 51-60 years	Age 61+ years	All Ages
D1 ...	18·0—0·6	17·0±0·6	16·6±0·6	18·1±0·6	17·8±0·7	19·5±0·8	17·68±0·26
D2 ...	17·8±1·7	16·5±1·0	16·0±1·4	18·2±1·1	18·9±1·3	22·6±1·1	18·29±0·50
N1 ...	26·5±0·9	25·8±0·8	27·6±1·1	26·3±0·8	25·0±1·3	27·3±1·1	26·42±0·39
N2 ...	21·9±0·9	21·7±0·7	21·3±0·9	21·9±0·8	22·0±1·1	26·1±0·9	22·18±0·36

Tables III to VI summarise in tabular form the results obtained, analysed in their various age-groups, together with their standard errors; while in Table VII, the combined results for all ages are given. In the tables, D represents the duction at distance, N the duction at near, 1 represents a flat target, and 2 a stereoscopic target. All results are expressed in prism dioptres. Table VIII shows those groups where significance, or bordering on significance, has been established.

TABLE V.—*Synoptophore*

ABDUCTION

Mean Values and Standard Errors

Prism Dioptres

Measures	Age 0-20 years	Age 21-30 years	Age 31-40 years	Age 41-50 years	Age 51-60 years	Age 61+ years	All Ages
D1 ...	10·4±0·2	11·0±0·3	11·1±0·3	11·0±0·3	10·5±0·4	10·2±0·4	10·78±0·12
D2 ...	12·2±0·4	11·9±0·4	11·9±0·4	11·6±0·3	11·5±0·4	11·2±0·5	11·77±0·16
N1 ...	12·5±0·3	12·8±0·3	13·5±0·4	12·9±0·3	11·7±0·4	11·5±0·4	12·63±0·13
N2 ...	13·9±0·4	13·3±0·4	13·9±0·4	13·5±0·3	12·7±0·5	12·0±0·5	13·36±0·16

TABLE VI.—*Synoptophore*

ADDUCTION

Mean Values and Standard Errors

Prism Dioptres

Measures	Age 0-20 years	Age 21-30 years	Age 31 40 years	Age 41-50 years	Age 51 60 years	Age 61+ years	All Ages
D1 ...	37·8±1·2	39·3±1·7	40·8±2·2	36·4±1·6	35·8±1·8	40·9±1·7	38·47±0·76
D2 ...	39·3±1·9	42·2±1·9	42·2±2·2	37·0±1·6	39·3±1·9	42·1±1 4	40·33±0·79
N1 ...	51·9±1·4	53 7±1·9	55·4±2·1	47 4±1·9	48·2±2·5	48·9±2·1	51·36±0·83
N2 ...	50·6±1·8	54·3±2·0	55·0±2·5	48·3±1·8	48·9±2·1	51·0±1·9	51·68±0·86

Influence of Age.—From an examination of those rows of Tables III to VI where significance (or bordering on significance) has been established, the following results are obtained:—

Variable Prism Stereoscope:—

Adduction D2. Apart from age group 0-20, the means show a progressive increase as age increases.

Adduction N2. The significance is due mainly to the influence of age group 61+.

Synoptophore:

Abduction N1. The means increase in value up to age group 31-40, followed by a progressive falling-off as age increases.

Abduction N2. The means remain steady up to age group 41-50, and then decline for the remaining two groups.

Adduction D1. A progressive increase to ages 31-40, and then a decrease for the next two groups, followed by a rise for ages 61+.

Adduction N1. A progressive increase to ages 31-40, but the remaining groups are more or less steady at a much lower level.

The above analysis does not appear to show any general law regarding the influence of age on the measurements. When this finding is coupled with the fact that where significance has been established for any one row of tables III to VI for one type of instrument, there is no corresponding significance for the other type, it would appear that, while noting the significance, no particular importance should be attached to it. It is therefore assumed that all ages can be combined, and the mean differences between the two types of target can now be discussed.

Influence of type of target.

Table VII gives the means for all ages, with the two types of target. In order to find whether there was any significant difference between D1 and D2, and between N1 and N2 for abduction and adduction for each of the instruments used, Table IX was drawn up; this gives the results of the analysis.

TABLE VII

Mean Values and Standard Errors, All Ages

Prism Dioptres

	Variable Prism Stereoscope		Synoptophore	
	ABDUCTION	ADDUCTION	ABDUCTION	ADDUCTION
D1	7·97±0·10	17·68±0·26	10·78±0·12	38·47±0·76*
D2	9·09±0·15	18 29±0·50*	11·77±0·16	40·33±0 79
N1	13·61±0·16	26·42±0·39	12·63±0·13*	51·36±0·83*
N2	12·04±0·15	22·18±0·36*	13·36±0·16*	51·68±0·86

*Significance or bordering on significance.

The differences were tested by the use of the formula

$$\text{Standard error of differences} = \sqrt{S_1+S_2}$$

where S_1 and S_2 are the standard errors of the means of the component parts, as given in tables III to VI.

Where, however, this method did not yield significant differences, the more rigorous method of using individual differences was used; that is to say, if D1 and D2 were to be compared, the difference D1-D2 was calculated for each

individual. The standard errors computed in this way do not thus include variations due to differences in individuals.

TABLE VIII

Differences between Means of any one row of Tables III—VI for different ages

Variable Prism Stereoscope	Synoptophore
ABDUCTION	
D1 No Significant Difference	No significant Difference
D2 No Significant Difference	No significant Difference
N1 No Significant Difference	Significant Difference
N2 No Significant Difference	Significant Difference
ADDUCTION	
D1 No Significant Difference	Bordering on Significance
D2 Significant Difference	No Significant Difference
N1 No Significant Difference	Significant Difference
N2 Significant Difference	No Significant Difference

TABLE IX

The Differences D1-D2 and N1-N2 (all ages)

Prism Dioptres

Variable Prism Stereoscope		Synoptophore	
ABDUCTION		ABDUCTION	
D1	7·97	D1	10·78
D2	9·09	D2	11·77
D1-D2	-1·12*	D1-D2	-0·99*
N1	13·61	N1	12·63
N2	12·04	N2	13·36
N1-N2	+1·57*	N1-N2	-0·67*
ADDUCTION		ADDUCTION	
D1	17·68	D1	38·47
D2	18·29	D2	40·33
D1-D2	-0·61	D1-D2	-1·86 (bordering on significance)
N1	26·42	N1	51·36
N2	22·18	N2	51·68
N1-N2	+4·24*	N1-N2	-0·32

* Significant Difference

Table IX shows that significant difference in the two types of target is present in most but not all of the ductions tested. These differences were not all in the same direction, nor, from the practical point of view, could they be considered as being great.

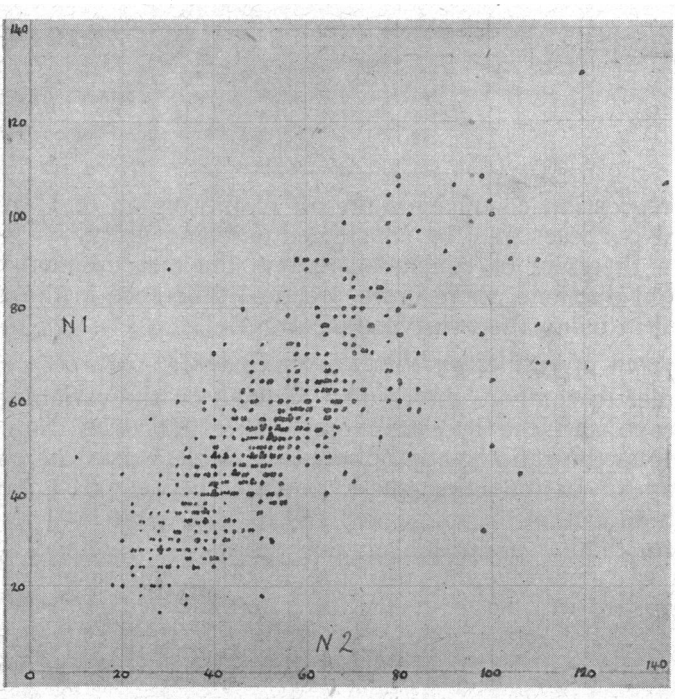
TABLE X

Regression Co-efficients
a and c where
D1=a D2; N1=c N2; for all ages

	Variable Prism Stereoscope	synoptophore
ABDUCTION		
D1 = a D2	0·81	0·91
N1 = c N2	1·15	0·94
ADDUCTION		
D1 = a D2	0·98	0 97
N1 = a N2	1·20	1·01

TABLE XI

Relationship between N1 and N2
Synoptophore, all ages, adduction
Prism Dioptres



Regression Co-efficients.—Assuming that there was a constant relationship between D1 and D2, and between N1 and N2, the regression co-efficients were calculated for the various age groups, based on the formulae

$$D1 = aD2$$
$$N1 = cN2$$

where a (or c) measures the ratio of D1 to D2 (or of N1 to N2).

Table X gives the results of these calculations, which were found to fit the data very well. Table XI demonstrates one graph constructed to show the relationship between N1 and N2 adduction, for all ages on the synoptophore.

TABLE XII

ALL AGES

Ratio : $\frac{\text{Synoptophore}}{\text{Variable Prism}}$

ABDUCTION	
D1	1·35
D2	1·29
N1	0·93
N2	0·98
ADDUCTION	
D1	2·18
D2	2·21
N1	1·94
N2	2·33

The regression co-efficients are all in the region of 1, and for practical purposes may be considered as being unity.

It can therefore be concluded that in the measurement of the horizontal ductions, there is no practical difference in the results obtained in using the two types of target.

Comparison of results on the two instruments.

In order to compare the results obtained on the variable prism stereoscope and the synoptophore, Table XII was drawn up. This shows the ratio Synoptophore : Variable Prism Stereoscope for all ages. In abduction, the ratio varied between 0·93 and 1·35, while in adduction the range was 1·94 to 2·33. One may conclude therefore, that in abduction similar results are obtained at near on the two instruments; while at distance the results on the synoptophore will be about one-third higher in value than on the variable prism stereoscope. In adduction the results on the synoptophore will be about double those obtained on the variable prism stereoscope.

SUMMARY

561 subjects were examined on the synoptophore and variable prism stereoscope, and their horizontal ductions were compared from the point of view of age and 2 types of target. The effects of age and of both types of target were found to be slight.

Difference in the results obtained on the two instruments are described and analysed.

The above investigation was carried out with the aid of a grant from the Spencer Research Fund. I have to thank Dr. R. A. Robb, of the Mathematics Department of the University of Glasgow, for the statistical work.

REFERENCES

ABRAHAM, S. V. (1943).—*Amer. J. Ophthal.*, **26**, 271.
——— (1943).—*Ibid.*, **26**, 400.
BERENS, LOSEY and HARDY (1927).—*Ibid.*, **10**, 910.
DOBSON, M. (1941).—*Brit. J. Ophthal.*, **25**, 66.
——— (1942).—Binocular Imbalance. London.
GILES, G. H. (1941).—The Practice of Orthoptics. London.
GRAEF, A. (1931).—*Arch. f. Augenheilk.*, **105**, 187.
LYLE and JACKSON (1940).—Practical Orthoptics in the Treatment of Squint. London.
PETER, L. C. (1941).—The Extra-ocular Muscles. London.
SHEARD, C. (1926).—*Amer. J. Phys. Optics*, **6**, 585.
STUTTERHEIM, N. A. (1937).—Eyestrain and Convergence. London.
WEYMOUTH, BRUST and GOBAR (1925).—*Amer. J. Phys. Optics*, **6**, 184.
MAXWELL, J. (1937).—Outline of Ocular Refraction. Omaha, Nebraska. P. 189.
BIELSCHOWSKY, A. (1940). Lectures on Motor Anomalies. Dartmouth College Publications.
SCOBEE, R. G. (1947).—The Oculorotary Muscles. London.
——— (1944).—A.A.F. School of *Av. Med.*, Project 139, Report No. 1.
SCOBEE, R. G. and GREEN, E. L. (1947).—*Amer. J. Ophthal.*, **30**, 436.
——— (1948).—*Ibid.*, **31**, 427.

ADENO-CARCINOMA (MIXED TUMOUR) OF THE LACRIMAL GLAND*

BY

NORMAN FLEMING, LONDON

THE total number of " mixed " tumours of the lacrimal gland hitherto reported appears to be less than three hundred, so any new case is still of importance. The case here described presents certain special features not without interest.

The commonest story is that of a patient complaining of a lump under the outer part of the upper lid, over which the skin is freely moveable. This may or may not be accompanied by exophthalmos, diplopia and loss of vision. Treatment consists of local removal, and in the majority of cases there is no recurrence.

Such tumours sometimes show local malignancy, and may bring about the death of the patient after repeated operation or extenteration of the orbit. A fatal termination may also be due to direct spread, in one case to the meninges and involving the cervical glands (Jack and Verhoeff). Lane found metastasis in seven out

* Received for publication, April 13, 1949.