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Abstract
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Degree Type
Thesis

APPARENT VISUAL SIZE AS A FUNCTION OF DISTANCE FOR SELECTED AGE GROUPS

by

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A REVIEW OF THE LITERATURE

The development of perception has long been studied by psychologists. Due to the need for further investigation, we chose to do our research experiment in the area of development studies. Our particular area was concerned with the apparent visual size of an object as a function of distance for varying age groups. Many experiments have been performed on size constancy. We present in the following pages a review of various experiments which shed light on our study.

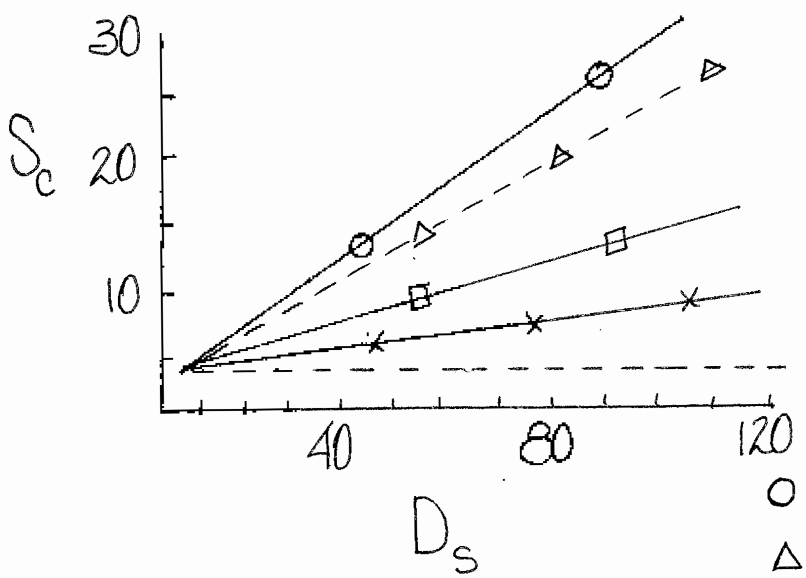
Holway and Boring's classic experiment (1941) was set up to see what effect reduction of a subjects cues to distance had upon the subject's judgment of size.

This was done by placing an O in a chair at the intersection of the two long, darkened corridors where he had an unobstructed view of a standard and a comparison stimulus. A series of disc-shaped standards was employed. Visual angles subtended (1°) were equal for all the standards. The comparison stimulus (a uniformly illuminated circular light-image) was projected on a large white screen, which stood ten feet from O through out the experiment. This target could be continuously varied in size by means of an iris diaphragm conjugate with the screen. The standard stimulus was provided in a similar manner by another projector.

The E regulated the size of the comparison stimulus until O signified that the standard and comparison stimuli appeared equal in size.

To accomplish a progressive reduction of the "distance cues" the following viewing conditions were used: binocular viewing, monocular natural pupil, monocular artificial pupil, and monocular artifical pupil-reduction tunnel.

The following graph represents the data collected using the various viewing conditions listed above.



O Binocular viewing

△ Monocular natural pupil

□ Monocular artifical pupil

X Monocular artifical pupil reduction tunnel

Determinants of Apparent Size With Distance Variant

Apparent size as a function of distance for four sets of conditions. (After Holway & Boring, 1941)

The figure is based on the averages of all the data obtained in the present experiment. As the number of cues is diminished, the slope of the function approaches zero as a limit, i.e., it approaches the law of the visual angle.

The results show the functions for the various conditions brought into relation with each other as straight lines with different slopes. These functions summarize about 1,500 measurements altogether. Their slopes diminish regularly as distance cues are eliminated.

Holway and Boring in interpreting the relationship proposed two theoretical limits of variation:

1) " Size Constancy. It is possible that size constancy represents one limit of variation, that perceptual organization, as Brunswik has suggested, occurs in the interest of stabilizing the perceptual world. The organism utilizes, therefore, additional cues which tend to keep the apparent size of an object constant when its visual angle varies with changing distance. According to this view,we should not expect to find an over-estimation, by which a receding object would increase in apparent size while its retinal image diminished.

2) Visual Angle. Retinal size, as indicated by the visual angle, must be the limit of reduction and yield a function in which the slope is zero. For all that has been said by Gestalt Psychologists against the validity of the law of the visual angle, it would never the less appear that, when no relevant datum other than retinal size is avaible, then the perception of size will, after all, vary solely with the visual angle. That statement is a tautology and must be true. Size constancy can be the law of size, therefore, only when determination is complex." (Holway and Boring, 1941)

The Holway and Boring experiment is important to our study because it showed that there is a general reliance on empirical distance cues of constancy.

Specifically, experience with distance cues and distance judgment may be an important factor differentiating the performances of children and adults.

A study which compares the size judgments of children and adults (in a constancy framework), is one Zeigler and Leibowitz.

The procedure was modeled after that used by Holway and Boring. A series of standard stimulus-objects, (one-inch diameter wooden dowels) was prepared such that at the distances used in the study, the objects subtended a visual angle of 0.96° at the S's eye. The comparison-object, also a one-inch diameter dowel, was so arranged that the visible portion of its length could be varied continuously by moving it up or down through a hole cut in the center of a board.

The experiment was conducted in a large room, 108 x 22 feet. From the S's position, three windows were visible on one side of the room and one at the extreme end. There were several pieces of furniture visible along the walls. Illumination was provided by six 100 watt bulbs in addition to the windows, and the experiments were conducted in the early afternoon and only on sunny days.

In the Holway and Boring experiment the S's looked down a dark narrow hallway, there were fewer visible cues as to the debth of the hall. All the size judgments were made without a full complement of cues normally avaible in everyday environment.

Zeigler and Leibowitz have provided for the S's as many depth and relative size cues as possible to maximize any tendencies toward size-constancy.

The results showed that the adults conformed very closely to the predicted size-constancy, previously reported by Holway and Boring. The data for the children, however, fell at positions closer to the line representing the law of the visual angle. These results are consistent with the conclusions of Beyrl,(1926) but differ with respect to the magnitude of the difference in size-constancy. As was pointed out by Epstein (1967), all of Beyrl's Ss, including his two-year old children, demonstrate rather high constancy.

These results (Zeigler & Leibowitz) differ only in that for comparable stimulus-distances the children showed less consistancy than did Beyrl's. In addition, this experiment indicates that the differences between children and adults increase with the distance of the test-object.

Zeigler and Leibowitz also note that their results are consistant with those of previous investigators, in that there was an increase in variability with distance. These results are interpreted as supporting the view that size-constancy increases with age.

Zeigler and Leibowitz, did not control the variables associated with the different ages of their subjects: namely height, and pupillary distance, and this has placed an obstacle in the path of interpretation. (Epstein, 1967)

The position is that a taller subject is presented with a different stimulus field than is the shorter subject. Similarily, a wider pupillary distance receives different stimulus cues than a narrower one.

Judgments displaying size-constancy vary with the age of the subject and operate most effectively when full depth cues are present. Wohlwill, wishing to study the effects of age on depth perception did a study in 1963; which bears on the issue of what depth cues are likely to be differentially used by children and adults.

His research was designed to study the effects of perspective and texture gradients on the perception of linear judgments of distance in the plane of the drawing. Main reference here was to the apparent size and the apparent distance between points on a plane.

Distance judgments were made by moving a ball along a thread in line with the vanishing point. The observer stops the movement of the ball when the half-way point is reached. The observer was asked not to make judgment on the basis of phemonenal or by use of deductive cues--but, rather, to be objective and tell when the ball appeared to be half-way.

Subjects were also asked to judge size of a variable rectangle. A standard rectangle was located at the bottom of the drawing and a variable rectangle was located at the top. The S was instructed to tell the E to stop the movement of the rectangle when it appeared to be the same size as the standard rectangle.

The procedure followed was that all subjects made two judgments--one ascending and one descending--of both size and distance on each of the six panels.

Four groups of subjects were used, with 24 in each group. The groups were: grade 1(age7); grade 4(age9 and 10) grade 8(age14); and college(age20).

One major result is that all subjects were equally affected in their distance judgments by the various manipulations of texture and perspective.

In the size judgments, the illusion of depth is shown by the fact that when the standard is at the bottom of the panel the variable at the top of the panel was made smaller to look equal; when the standard was at the top, the variable at the bottom was enlarged.

Each of the stimulus panels produced about the same effect on size judgments; age did not appear to affect the judgments of the subjects.

An overestimation of the standard at any set distance was noted. When the variable was at the top, the average size was 7.44 and when it was at the bottom, the average size was 7.36.

Since there was no increase in the perspective depth with age, it would appear that, if the illusion is learned, the learning must occur early in life. It seems that size-constancy does not develop with the perception of depth.

Depth based on these cues was not affected by the varables of age, yet size-constance seems to be. It appears evident that some emphasis must be given to the time at which size-constance develops and what varables seem to affect it. On the basis of Wohlwill's study, it would seem that perspective and texture are not among the variables that affect it.

Harway (1963), wished to determine in his study of distance judgment of children and adults; whether height was a significant factor affecting development of distance judgement.

This study is a repetition of a well known study by Gilinsky, using a larger number of children in each age group and two different height settings for each subject as his control for the height variable.

In Gilinsky's study it was found that judgment of successive one-foot intervals in distance became more accurate with age. It was suggested, then, that this was a function of subject height and pupillary distance.

Harway used five groups of subjects: 5½ year olds; 7 year olds; 10 year olds; 12 year olds; and adults (23). Subjects were presented with a one-foot distance positioned directly in front of them. They were asked to tell the experimenter when a pointer had been moved an equal distance from the first marker. Successive judgments were made for the entire length of the field.

After having once judged the distances, standing at their normal height, all but the adult group repeated the experiment standing on tables. The adults repeated the judgments from a kneeling position.

Subjects' judgments were evaluated in terms of visual angle and constancy. As more distant targets were used, the perspective changes required a longer physical distance to subtend the same visual angle. For the subjects to display constancy every time, the same physical distance had to be measured. If underconstancy were displayed, then the deviation in the distance judgments would be in the direction of the visual angle. If overconstancy were displayed, then a shorter physical distance than required to display perfect constancy would be noted.

All groups displayed overconstancy which increased in proportion to the distance from the subject; also, regardless of height, the younger group showed more overconstancy than the two older groups.

Harway has shown that varation in height of a subject does not significantly affect that subject's judgments of size-constancy. Height here even though varied per se was not held constant. Suppose a subject from past experience knew that by standing on a table stimulus would appear different. Also the subject would have a very definite feed back as to how the world was orientated to him as he was standing both times. Height, from feet to eyes, was constant for each of the children. We wished to change this height feed-back by placeing all our S's in a chin-rest and having them all seated.

As has been shown in the other experiments cited size-constancy may not be dependent upon perspective or texture. Size-constancy is greatest under binocular conditions, but is not deminished greatly by monocular viewing. At the distances most of these studies used accommodation and convergence should not significantly effect judgments of size and thus would not have an effect on size-constancy. Motion parallax, while reduced by placing S in a head-rest may affect size-constancy.

Our aproach is geared after Harway's. We addressed ourselves to the question of a comparison of size-constancy judgments of children age6; age 11; and young adults age 15; when depth and relative size cues were present and height was held constant.

APPARENT VISUAL SIZE AS A FUNCTION OF DISTANCE FOR SELECTED AGE GROUPS

EXPERIMENTAL TECHNIQUE

I. Purpose:

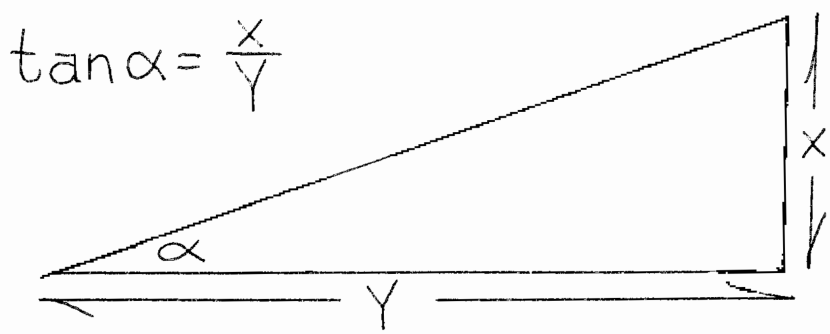
To study the apparent visual size as a function of distance for selected age groups.

II. Apparatus:

We conducted our experiment in the gymnasium of Joseph Gale Elementary School in Forest Grove, Oregon. The illumination was held constant.

In this experiment, we used five different distances for our standards; they varied proportionately so that each would subtend a visual angle of $.96^{\circ}$ at the retina.

Distance:	20"	33.3"	46.66"	60"	73.3"
Size of Target:	6"	10"	12"	18"	22"



Each standard was a disc - painted white and supported by a wooden stand. The comparison object was a circle projected onto a screen by means of a diaphragm aperature. The comparison object could be varied in size by means of the diaphragm. This part of the apparatus was placed at 10' from the S and slightly off to the left of his visual axis so that the standards could easily be seen by the subject.

III. Experimental Procedure:

The children were brought into the gymnasium two at a time. Their names, ages, birthdates, and sex were recorded. The children were then administered the Howard-Dolman Peg Test as a check on their stereopsis. While one child was taking the Peg Test, the other child was measured for height and pupillary distance. Next, the children were taken to the refracting area.

The first step was to take the visual acuity (OD, OS, OU). If they were found to have 20/20 acuity, they were then placed behind the Green's Refractor, and plus lenses were added until a 20/40 blur was obtained. The OS was then occluded and the OD was brought down to just a readable 20/20 acuity. The same procedure was followed for OS and then a -0.50 was subtracted from this amount for the subjective refraction. This procedure was employed so that we could eliminate from our data any gross refractive problems that might alter the study. If 20/20 acuity could not be reached, a Four-Ball cylinder test was run to determine if there were any astigmatic factor hindering visual acuity. A phoria was also taken to check the dissociated posture at far. If an esophoric posture was found, then a Base Out duction was also taken.

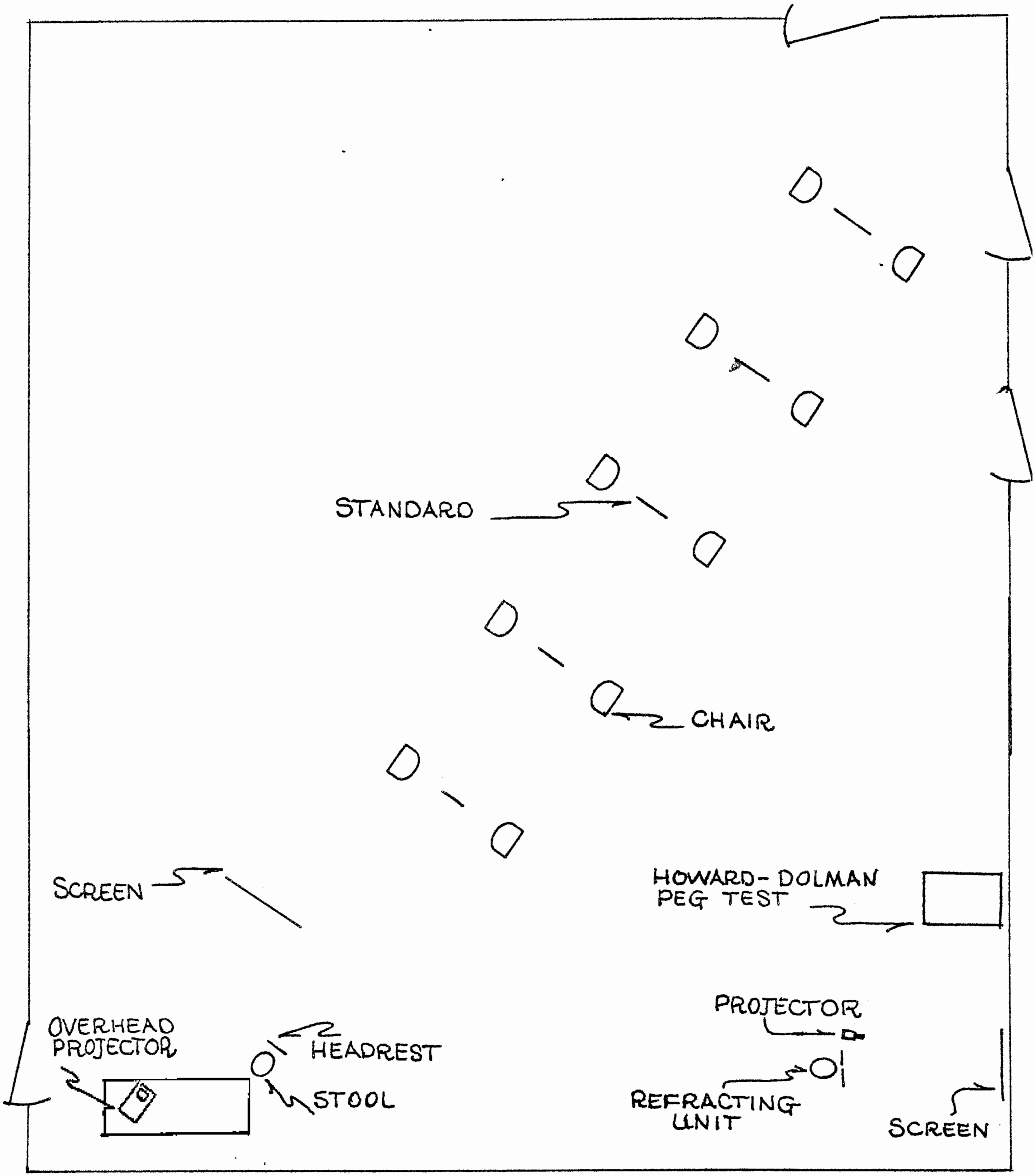
After the refractive tests were finished, the children were taken to the experimental area. The child was seated on the stool and his head was placed in the headrest. At this time the instructions were given as follows:

> Can you see the circle (Disc) out there?
> Now, can you see the circle (Disc) on the screen?
> I am going to change the size of the circle (Disc) on the screen and when it is the same size as the circle (Disc) out there, I want you to say "Now."

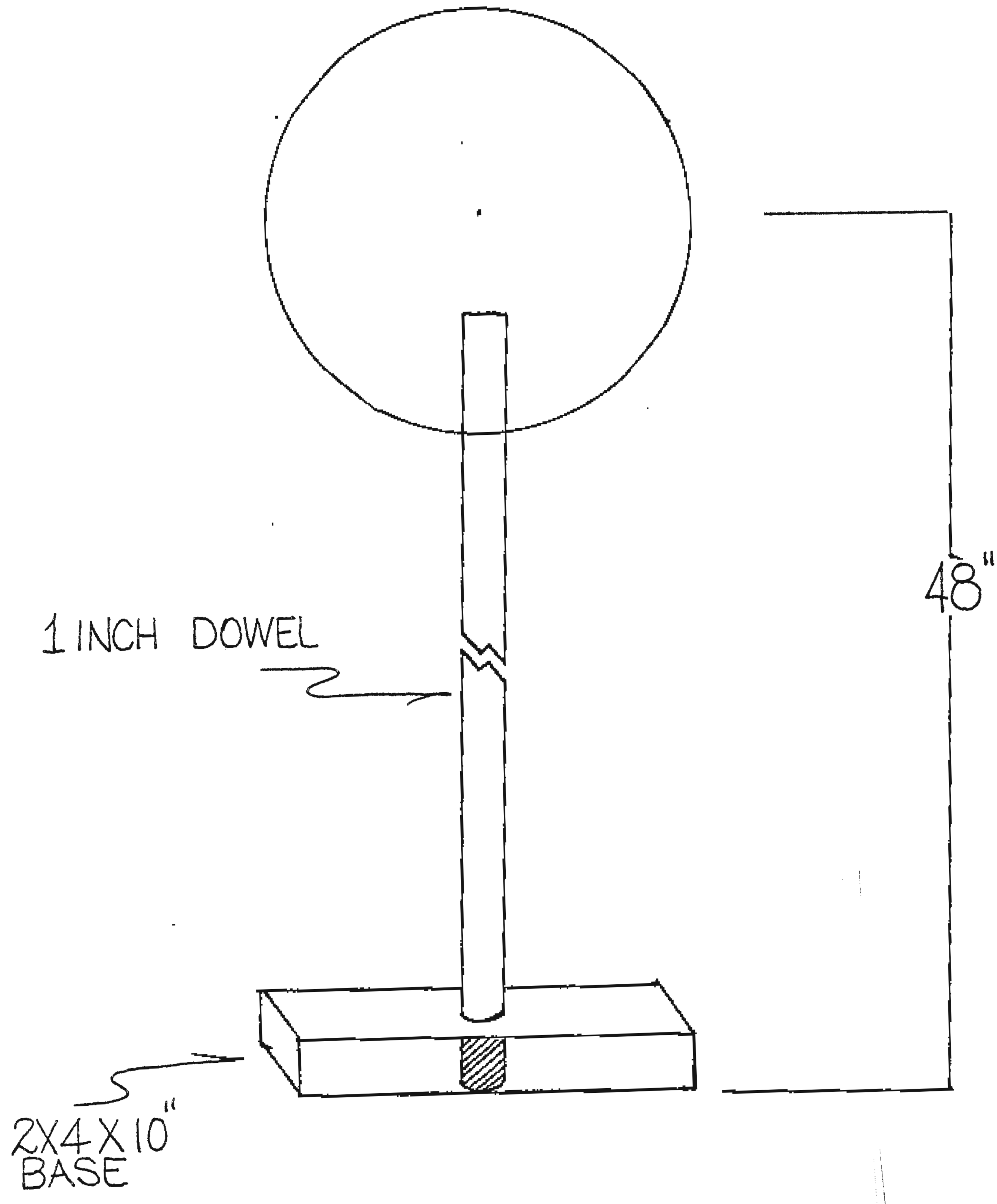
Each standard was placed randomly according to a table of random numbers and the child's view was occluded each time the standards were changed.

The headrest was adjusted so that the Ss' visual axes were 48" from the floor level (this was kept constant throughout the experiment). The standards were all divided equally by the S's visual axis.

EXPERIMENT SETUP
JOSEPH GALE GYMNASIUM



STANDARD



EXPERIMENTAL DATA

MEANS FOR FIRST GRADE

Subjects	Distances 1	2	3	4	5
L. H.	5.44	11.50	14.63	17.18	19.75
S. S.	7.65	13.00	15.50	18.19	16.94
K. K.	7.44	10.13	13.94	14.50	20.56
L. S.	10.00	12.63	20.12	20.19	16.38
K. D.	18.86	20.63	20.75	17.31	12.75
D. B.	6.75	11.75	16.06	18.88	21.75
B. I.	7.64	11.25	14.50	16.94	18.13
T. H.	6.63	15.06	16.63	15.63	21.63
S. G.	13.25	20.88	20.94	19.36	22.86
J. D.	9.63	15.31	15.39	19.94	19.75
K. H.	7.00	11.50	12.87	17.56	18.06
K. L.	6.75	16.00	16.44	18.75	19.81
S. C.	9.13	15.63	15.69	18.88	21.00
K. F.	10.93	12.13	15.75	15.69	18.86
P. B.	11.88	13.75	13.69	14.88	17.25
R. H.	8.69	11.06	12.73	16.63	18.13
D. A.	10.06	15.25	16.50	19.38	23.06
S. L.	7.87	13.00	14.69	16.94	18.56
H. B.	7.00	10.00	15.38	17.50	18.75
Totals	172.60	260.71	302.20	334.33	363.98
N=19					
MEAN	9.08	13.71	15.91	17.60	19.15

Standard Deviations for First Grade

3.02	3.05	2.4	1.73	2.48
$\sqrt{\frac{173.83}{18}}$	$\sqrt{\frac{177.56}{18}}$	$\sqrt{\frac{106.95}{18}}$	$\sqrt{\frac{56.87}{18}}$	$\sqrt{\frac{117.28}{18}}$

$$\sqrt{\frac{x^2}{n-1}} = \text{Standard Deviation}$$

X = Average response of each subject
x = Mean - X

MEANS FOR FIFTH GRADE

Subjects	Distances 1	2	3	4	5
N. M.	6.87	13.38	18.31	19.44	23.44
J. M.	6.13	12.75	18.00	18.56	23.44
L. S.	8.63	15.50	15.75	18.69	22.81
K. P.	7.81	13.81	15.25	19.19	19.94
L. M.	10.81	14.69	17.38	18.25	24.25
B. S.	14.38	11.88	18.31	18.94	23.75
D. S.	8.31	13.63	15.13	17.19	22.10
B. T.	9.63	16.69	21.00	22.25	24.00
T. M.	9.75	14.00	22.06	19.13	23.38
M. P.	6.44	10.50	11.50	16.44	18.44
L. M.	9.06	12.18	14.38	14.69	17.44
C. P.	8.18	13.63	20.00	19.94	21.06
C. P.	8.63	14.69	17.50	20.25	20.31
A. R.	11.00	14.75	19.33	20.00	24.00
D. P.	11.81	16.38	20.56	19.81	25.06
B. U.	6.75	13.38	13.88	16.31	19.63
P. M.	8.13	11.38	15.56	16.94	18.75
Totals	152.32	233.22	293.90	316.02	373.80
N=17					
MEAN	8.96	13.71	17.28	18.59	22.00

Standard Deviations for Fifth Grade

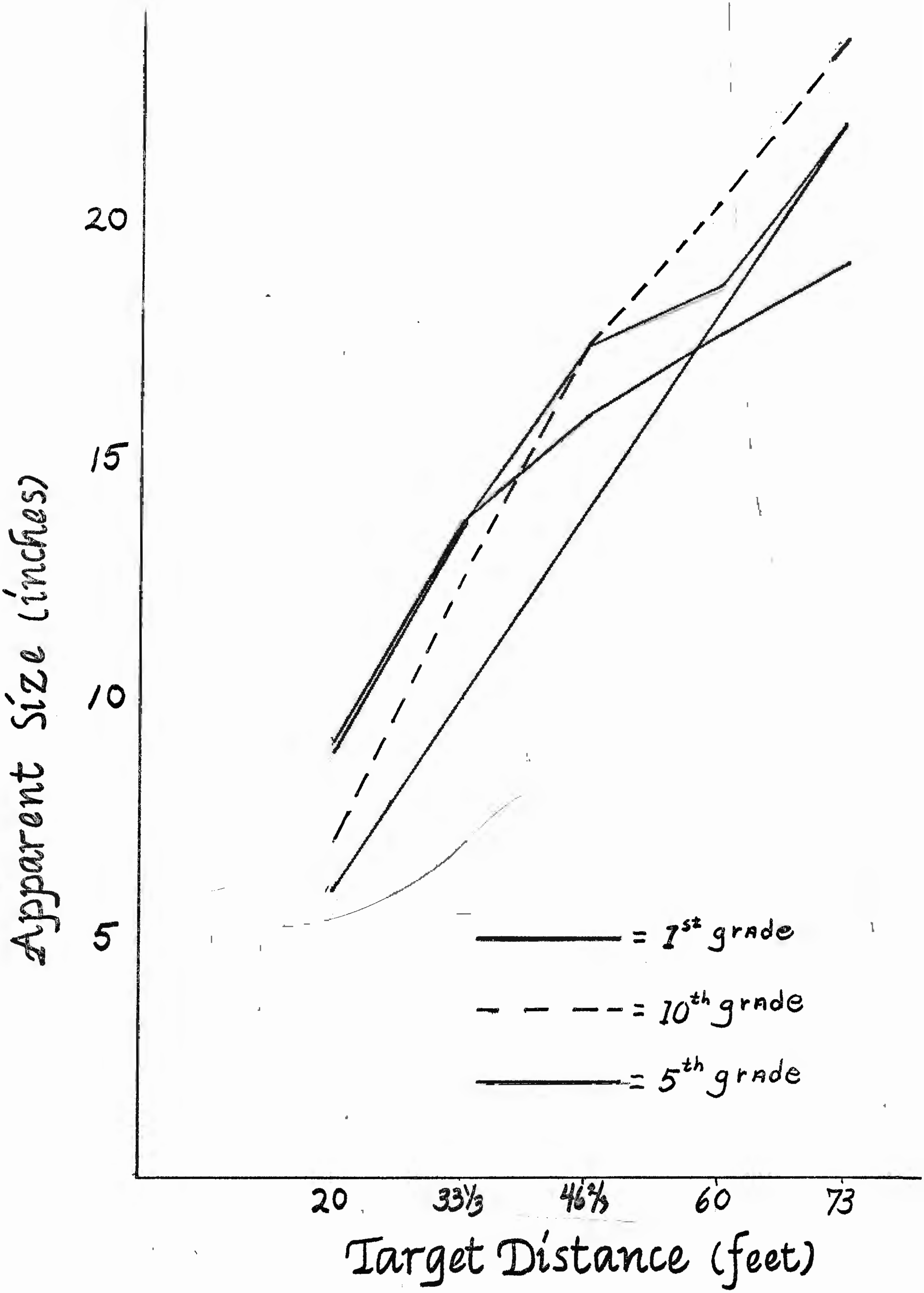
	1	2	3	4	5
SD	2.14	1.71	2.86	1.8	2.17
	$\sqrt{\frac{73.13}{16}}$	$\sqrt{\frac{46.71}{16}}$	$\sqrt{\frac{129.86}{16}}$	$\sqrt{\frac{52.50}{16}}$	$\sqrt{\frac{75.69}{16}}$

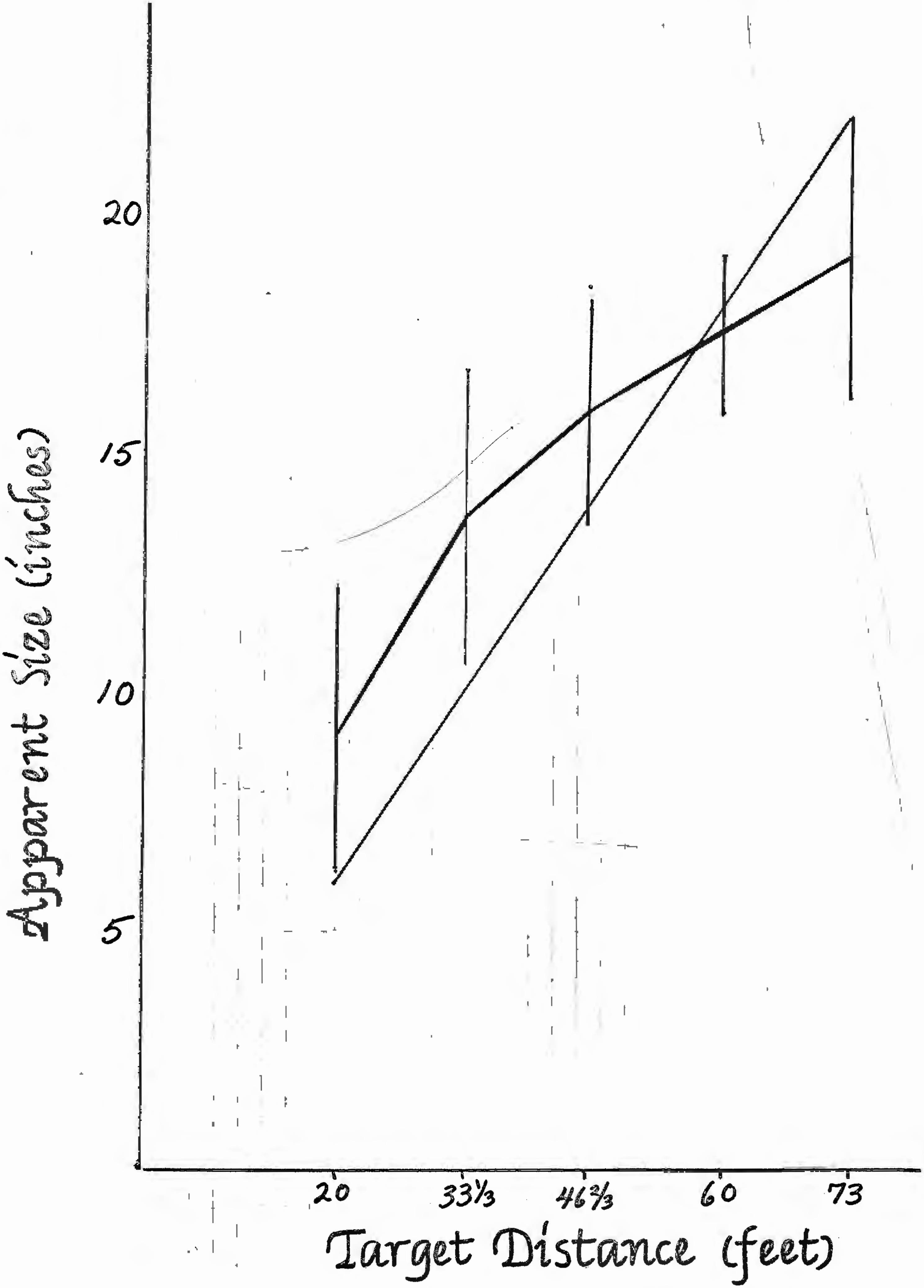
MEANS FOR THE TENTH GRADE

Subjects	Distances 1	2	3	4	5
D. B.	8.38	12.94	23.50	19.44	22.13
G. N.	6.81	13.19	16.75	20.94	22.44
J. M.	7.31	13.43	18.13	22.31	23.81
A. M.	7.31	10.38	11.88	16.75	21.81
W. V.	6.38	12.38	16.69	20.06	25.75
J. H.	5.81	11.44	15.31	19.55	24.50
G. C.	8.81	13.44	18.69	22.81	24.19
T. S.	5.43	13.25	17.56	20.88	26.18
Totals	56.24	100.45	138.51	162.74	190.81
N=8					
MEAN	7.03	12.55	17.38	20.38	23.85

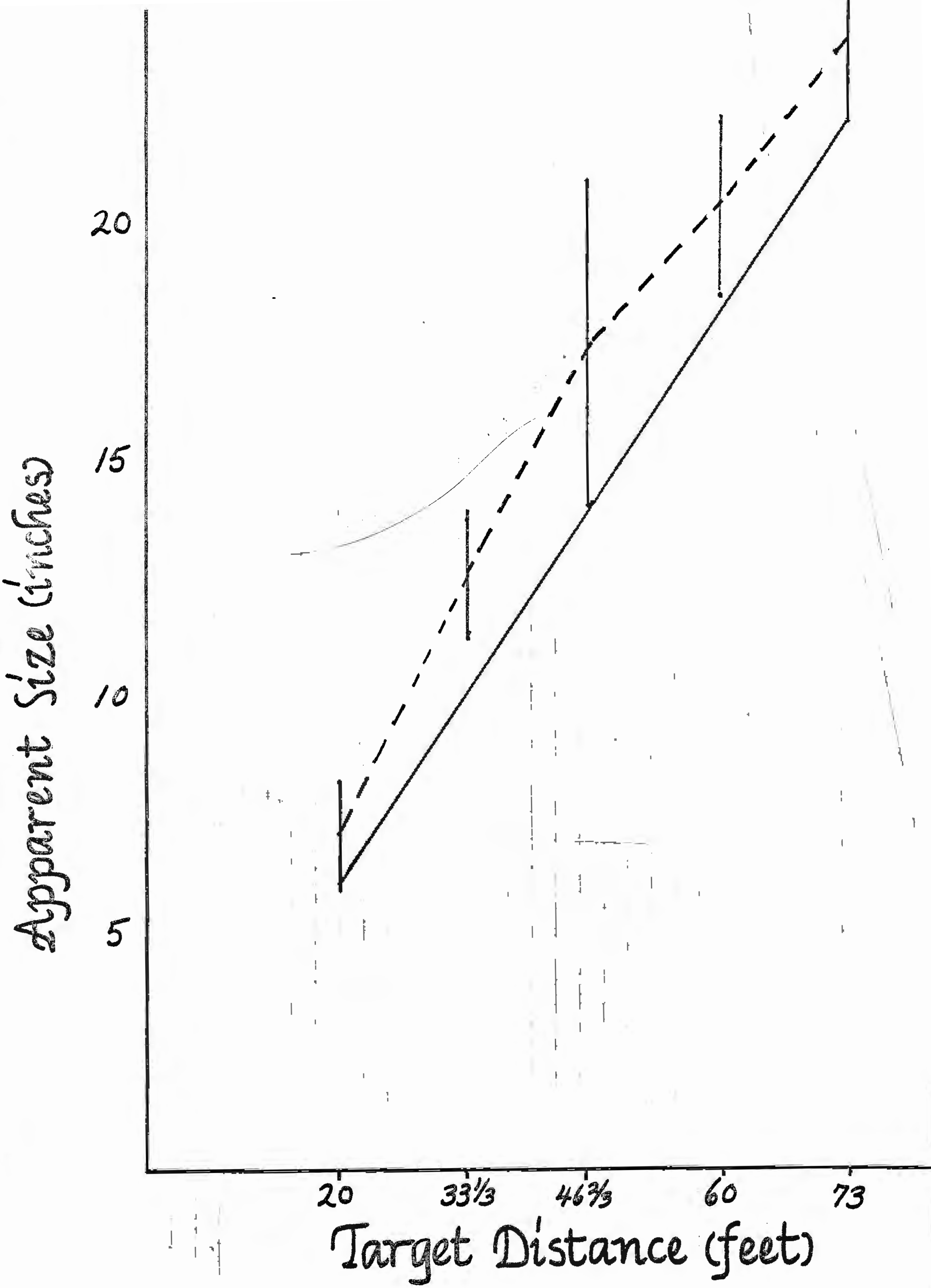
Standard Deviations for the Tenth Grade

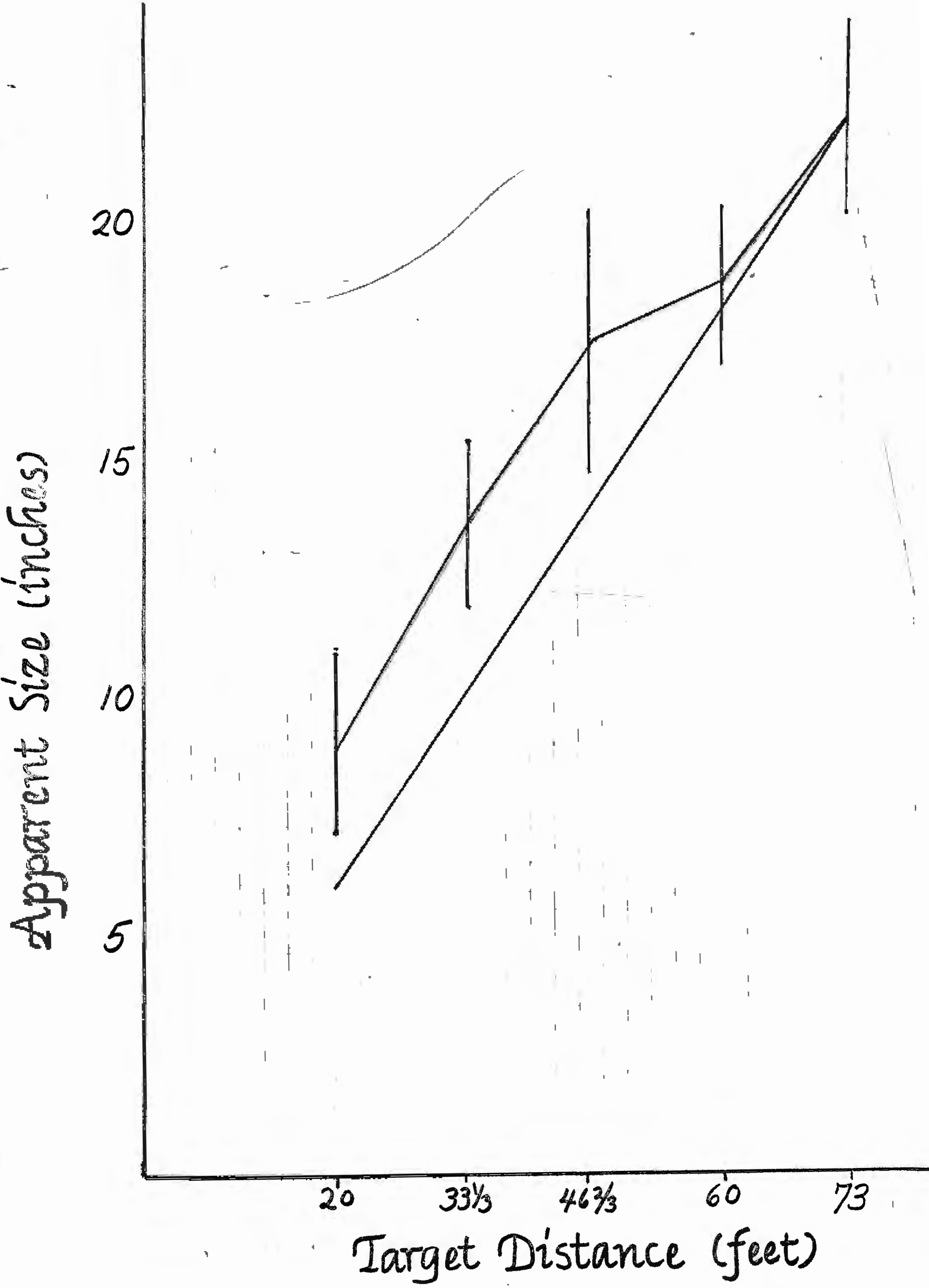
1.25	1.49	3.27	1.83	1.63
$\sqrt{\frac{11.11}{7}}$	$\sqrt{\frac{15.72}{7}}$	$\sqrt{\frac{75.17}{7}}$	$\sqrt{\frac{23.66}{7}}$	$\sqrt{\frac{18.69}{7}}$


Apparent Size (inches)
20
15
10
5
= 1st grade
= 10th grade
= 5th grade
20
33⅓
46⅔
60
73
Target Distance (feet)



Apparent Size (inches)
20
15
10
5
20
33⅓
46⅔
60
73
Target Distance (feet)


Apparent Size (inches)
5
10
15
20
Target Distance (feet)
20
33⅓
46⅔
60
73



Apparent Size (inches)
20
15
10
5
20
33⅓
46⅔
60
73
Target Distance (feet)

IV. Discussion:

Height

Height has always been a variable in past studies of size constancy; in fact, some experimenters make no mention at all of height. In past experiments many experimenters cited height as the variable which explained the phenomenom of overconstancy. For example, Holway and Boring used height to explain overconstancy. On the other hand, Harway tried to determine if height were a significant factor in distance judgement by placing his subjects at two different heights. He used the extremes of one high and one low height level. Harway found overconstancy regardless of height. The younger subjects showed more overconstancy than the older subjects. In our experiment we held height constant by having the subjects view the standards from a height of 48 inches by the use of a chin-rest.

In our research we felt the differences in size constancywere not attributed to differences in height. It is shown by our graphs of the responses for the individual age groups that each group follows approximately the same slope until the third distance. It clearly appears that the changes in constancy judgements between our three age groups are not a function of height but are dependent upon some other variable -

Binocular cues

We attempted, in our experiment, to give the subjects as many cues as possible. This procedure was not followed in the Holway and Boring experiment but was followed by Beryl. We used a variety of cues - the chairs which were placed on either side of the standard holders, the texture of the floor pattern, and the wooden slats of the gymnasium walls. Additional cues were provided by the shadows produced by the lights which were on throughout the experiment.

Accommodation

Variations in size-constancy have, in the past, been attributed to accommodation (as in the Kilpatrick and Ittelson experiment in 1953; and the Ohwaki experiment in 1954). In our experiment, the effects of accommodation are minimized due to the distance of the screen and standards from the subjects. Although accommodation has minimal effect up to 1800 ft., it is so slight for the purposes of judgments of size constancy that it is insignificant. For example, at 10 feet there is approximately .33 diopters; at 20 feet, approximately .16 diopters; and at 33.33 feet, approximately .08 diopters.

Border of the Screen

We feel that the border of the screen might possibly have aided the subjects in their size judgments, especially for the most distant and the nearest standards. This provided a primitive guage of sorts in estimation of size, although the random presentation and the lack of knowledge on the part of the subjects as to actual size minimized the border as cue. If the border of the screen were significant, as a clue, it would have produced a constant slope instead of the changing ones that we found in the three groups. Another factor that should be considered is that the screen was in the same location and at the same height for each subject - so any influence that it might have had in the size judgements would have been constant for each subject and, therefore, not capable of producing a differential.

Practice:

The effect of practice was minimized as there were no practice runs; the standards were presented in random order, selected from a table of random numbers. Although the subjects may have become more familiar with the task as the sequence progressed, we feel that this was not a significant factor or the slopes would have approached a linear dimension. To further minimize the effect of practice, we used two ascending and two descending judgements for each standard.

Pupillary distance:

The changes in the slopes of the three groups do not seem to be functions of the differences in the distances between the eyes of the subjects. Statistical analysis shows no correlation of pd to the mean size of the most distant standard for the fifth graders. We chose this group on which to base our correlation since it provided the greatest variation of pd's (ranging from 54 to 61 millimeters).

Error of habituation or anticipation:

In an effort to minimize error by habituation or anticipation, complete occlusion was effected during the intervals between presentations of standards. Also, as stated above, the two presentations of standards (ascending and descending) minimized the error of habituation or anticipation.

Error of the standard:

Due to the limitation of time, we made no attempt to eliminate possible error of the standard in the collection of our data. We realize that the error of the standard might have been eliminated through expansion of the procedure as follows: setting the screen and projector at the five different distances; presenting to the subjects each of the five standards; varying the disc aperature in accordance with the subject's instructions; recording the disc diameter.

From Wohlwill's study (1962), the error of the standard does not seem to be significant since no constant differences of interaction appeared between the age groups of his study. Wohlwill did, however, find an overestimation of the standard taking place regardless of the position of the standard to the subject.

Directional changes in Our Graph:

We do not have an explanation for the tendency of the slopes of our subjects' age-groups to deviate from perfect size-constancy in the pattern illustrated in our graph which is included in the data section of this paper. In their classical study, Holway and Boring found perfect size-constancy - possibly due to the sophistication of their subjects. From our data, and the data collected by Zeigler, Leibowitz, Gilinsky, and Harway, the assumption of perfect size-constancy is improbable. (Note: Harway's data suggest overconstancy in all groups.)

Referring to the directional changes shown in our graph, our data tends to support the findings of Piaget and Lambercier (1943) that children do not show overconstancy when judgment of the size is made in relation to the two most distant standards.

CONCLUSIONS

Methodological considerations are a "must" in the design of an experiment dealing with developmental studies. Two basic considerations are necessary: the limits imposed by the age-correlation variation; and the actual choice of the age groups to be studied. We realized that, for developmental studies to be of value, we must make a contribution to the understanding of perceptual learning. We endeavored to identify the processes responsible for differences in judgements of apparent size in order to contribute to our understanding of perception.

We believe that the differences in size constancy are due to processes of learning and not to optical variables or to physical limitations such as height.

Our hypothesis is that we learn through seeing and these acts of learning are essential to meet the needs of our environment. Size judgements are based upon comparisons within the experiences of the individual. The individual strengthens and refines his size judgements through new and repeated experiences. This is a developmental process which enables a person to deal more effectively with his environment.

Accept ______________ Reject ______________

Name ____ F M

Date of Birth ______________________________

Grade ______________________________

Height ______________________________

Pd / Pupil Size ______________________________

Dominant Hand ______________________________
Eye ______________________________

Howard - Dolman
Peg Test ______________________________

Subjective O.D. ______________________________
O.S. ______________________________
____
____

	1	4	3	2	5
Raw Data					
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1.					
2.					
3.					
4.					

Raw Data for Calculating the Standard Deviation for Grade One

Distance One

X	Mean	Mean-X=x	x^2
5.44	9.08	3.64	13.25
7.65	9.08	1.43	2.04
7.44	9.08	1.64	2.69
10.00	9.08	.92	.85
18.86	9.08	9.78	95.65
6.75	9.08	2.33	5.43
7.64	9.08	1.44	2.07
6.63	9.08	2.45	6.00
13.25	9.08	4.17	17.39
9.63	9.08	.55	.30
7.00	9.08	2.08	4.32
6.75	9.08	2.33	5.43
9.13	9.08	.05	.25
10.93	9.08	1.85	3.42
11.88	9.08	2.80	7.84
8.69	9.08	.39	.15
10.06	9.08	.98	.96
7.87	9.08	1.21	1.46
7.00	9.08	2.08	4.33
		$\sum x^2 =$	173.83

Distance Two

X	Mean	Mean-X=x	x^2
11.50	13.71	2.21	4.88
13.00	13.71	.71	.50
10.13	13.71	3.58	12.82
12.63	13.71	1.08	1.16
20.63	13.71	6.92	47.88
11.75	13.71	1.96	3.84
11.25	13.71	2.46	6.05
15.06	13.71	1.35	1.82
20.88	13.71	7.17	51.41
15.31	13.71	1.60	2.56
11.50	13.71	2.21	4.88
16.00	13.71	2.28	5.19
15.63	13.71	1.93	3.72
12.13	13.71	1.58	2.49
13.75	13.71	.04	.16
11.06	13.71	2.65	7.02
15.25	13.71	1.54	2.37
13.00	13.71	.71	5.04
10.00	13.71	3.71	13.76
		$\sum x^2 =$	177.56

Distance Three

X	Mean	Mean-X=x	x^2
14.63	15.91	1.28	1.64
15.50	15.91	.41	.17
13.94	15.91	1.97	3.88
20.12	15.91	4.21	17.72
20.25	15.91	4.84	23.43
16.06	15.91	.15	2.25
14.50	15.91	1.41	1.99
16.63	15.91	.72	.52
20.94	15.91	5.03	25.30
15.39	15.91	.52	.27
12.87	15.91	3.04	9.24
16.44	15.91	.53	2.81
15.69	15.91	.22	.49
15.75	15.91	.16	.26
13.69	15.91	2.22	4.93
12.73	15.91	3.18	10.11
16.50	15.91	.59	.35
14.69	15.91	1.22	1.48
15.58	15.91	.33	.19
		$\sum x^2 =$	10 6.95

Distance Four

X	Mean	Mean-X=x	x^2
17.18	17.60	.42	.18
18.19	17.60	.59	.35
14.50	17.60	3.10	9.61
20.19	17.60	2.59	6.71
17.31	17.60	.29	8.41
18.88	17.60	1.28	1.64
16.94	17.60	.66	.44
15.63	17.60	1.97	3.88
19.36	17.60	1.76	3.09
19.94	17.60	2.34	5.47
17.56	17.60	.04	.16
18.75	17.60	1.15	1.32
18.88	17.60	1.28	1.64
15.69	17.60	1.91	3.65
14.88	17.60	2.72	7.40
16.63	17.60	.97	.94
19.38	17.60	1.78	3.17
16.94	17.60	.66	.44
17.50	17.60	.10	.01
		$\sum x^2 =$	56.87

Distance Five

X	Mean	Mean-X=x	x^2
19.75	19.15	.60	.36
16.94	19.15	2.21	4.88
20.56	19.15	1.41	1.98
16.38	19.15	2.77	7.67
12.75	19.15	6.40	40.96
21.75	19.15	2.60	6.76
18.13	19.15	1.02	1.04
21.63	19.15	2.48	6.15
22.86	19.15	3.71	13.76
19.75	19.15	.60	.36
18.06	19.15	1.09	1.18
19.81	19.15	.66	4.35
21.00	19.15	1.85	3.42
18.86	19.15	.29	.84
17.25	19.15	1.90	3.61
18.13	19.15	1.02	1.04
23.06	19.15	3.91	15.28
18.56	19.15	.59	3.48
18.75	19.15	.40	.16
		$\sum x^2$ =	117.28

Raw Data for Calculating the Standard Deviation for Grade Five

6.87	8.96	2.09	4.37
6.13	8.96	2.83	8.01
8.63	8.96	.33	.11
7.81	8.96	1.15	1.32
10.81	8.96	1.85	3.42
14.38	8.96	5.42	29.38
8.31	8.96	.65	.42
9.63	8.96	.67	.45
9.75	8.96	.79	.62
6.44	8.96	2.52	6.35
9.06	8.96	.10	.10
8.18	8.96	.78	.61
8.63	8.96	.33	.11
11.00	8.96	2.04	4.16
11.81	8.96	2.85	8.12
6.75	8.96	2.21	4.88
8.13	8.96	.83	.69
		$\sum x^2$	= 73.13

Distance Two

X	Mean	Mean-X=x	x^2
13.38	13.71	.33	.11
12.75	13.71	.96	.92
15.50	13.71	1.79	3.20
13.81	13.71	.10	.10
14.69	13.71	.98	.96
11.88	13.71	1.83	3.35
13.63	13.71	.08	.01
16.69	13.71	2.98	8.88
14.00	13.71	.29	.84
10.50	13.71	3.21	10.30
12.18	13.71	1.53	2.34
13.63	13.71	.08	.01
14.69	13.71	.98	.96
14.75	13.71	1.04	1.08
16.38	13.71	2.67	7.13
13.38	13.71	.33	.11
11.38	13.71	2.33	5.43
			$\sum x^2 = 46.71$

Distance Three

X	Mean	Mean-X=x	x^2
18.31	17.28	1.03	1.06
18.00	17.28	.72	.52
15.75	17.28	1.53	2.34
15.25	17.28	2.03	4.12
17.38	17.28	.10	.10
18.31	17.28	1.03	1.06
15.13	17.28	2.15	4.62
21.00	17.28	3.72	13.84
22.06	17.28	4.78	22.85
11.50	17.28	5.78	33.41
14.38	17.28	2.90	8.41
20.00	17.28	2.72	7.39
17.50	17.28	.22	.49
19.37	17.28	2.09	4.37
20.56	17.28	3.28	10.76
13.88	17.28	3.40	11.56
15.56	17.28	1.72	2.96
			$\sum x^2 = 129.86$

Distance Four

X	Mean	Mean-X=x	x^2
19.44	18.59	.85	.72
18.56	18.59	.03	.001
18.69	18.59	.10	.01
19.19	18.59	.60	.36
18.25	18.59	.34	.12
18.94	18.59	.35	.12
17.19	18.59	1.40	1.96
22.25	18.59	3.64	13.25
19.13	18.59	.54	.29
16.44	18.59	2.15	4.62
14.69	18.59	3.90	15.21
19.94	18.59	1.35	1.82
20.25	18.59	1.64	2.69
20.00	18.59	1.39	1.93
19.81	18.59	1.22	1.48
16.31	18.59	2.28	5.20
16.94	18.59	1.65	2.72
			$\sum x^2 = 52.50$

Distance Five

X	Mean	MEAN-X=x	x^2
23.44	22.00	1.44	2.07
23.44	22.00	1.44	2.07
22.81	22.00	.81	.66
19.94	22.00	2.06	4.24
24.25	22.00	2.25	5.06
22.10	22.00	.10	.10
24.00	22.00	2.00	4.00
23.38	22.00	1.38	1.90
18.44	22.00	3.56	12.67
19.44	22.00	2.56	6.55
21.06	22.00	.94	.88
20.31	22.00	1.69	2.86
24.00	22.00	2.00	4.00
25.06	22.00	3.06	9.36
19.63	22.00	2.37	5.62
18.75	22.00	3.25	10.56
23.75	22.00	1.75	3.06
			$\sum x^2 = 75.69$

Raw Data for Calculating the Standard Deviation for Grade Ten

Distance One

X	Mean	Mean-X=x	x^2
8.38	7.03	1.35	1.82
6.81	7.03	1.22	1.49
7.31	7.03	.28	.08
7.31	7.03	.28	.08
6.38	7.03	.65	.42
5.81	7.03	1.22	1.49
8.81	7.03	1.78	3.17
5.43	7.03	1.60	2.56
			$\sum x^2 = 11.11$

Distance Two

12.94	12.55	.39	.15
13.19	12.55	.64	.41
13.43	12.55	.88	.77
10.38	12.55	2.17	4.71
12.38	12.55	.17	.03
11.44	12.55	1.11	1.23
13.44	12.55	.89	7.92
13.25	12.55	.70	.49
			$\sum x^2 = 15.72$

Distance Three

23.50	17.38	6.12	37.45
16.75	17.38	.63	.39
18.13	17.38	.75	.56
11.88	17.38	5.50	30.25
16.69	17.38	.69	.48
15.31	17.38	2.07	4.28
18.69	17.38	1.31	1.72
17.56	17.38	.18	.03
			$\sum x^2 = 75.17$

Distance Four

X	Mean	Mean-X=x	x^2
19.44	20.38	.94	.88
20.94	20.38	.56	.31
22.31	20.38	1.53	2.34
16.75	20.38	3.63	13.18
20.06	20.38	.32	.10
19.55	20.38	.83	.69
22.81	20.38	2.43	5.90
20.88	20.38	.50	.25
			$\sum x^2 = 23.66$

Distance Five

22.13	23.85	1.72	2.96
22.44	23.85	1.41	1.99
23.81	23.85	.04	.001
21.81	23.85	2.04	4.16
25.75	23.85	1.90	3.61
24.50	23.85	.65	.42
24.19	23.85	.34	.12
26.18	23.85	2.33	5.43
			$\sum x^2 = 18.69$

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