THE UP-AND-DOWN-METHOD-
A TECHNIQUE FOR OBTAINING PSYCHOPHYSICAL DATA

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ABSTRACT

THE UP-AND-DOWN METHOD -
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Psychophysical techniques, used to obtain points of subjective equality in visual illusions for different age levels, suffer from such inherent flaws as Error of the Standard, Starting Position Effects, and Central Tendency or Context Effects Other factors not controlled by standard techniques include decreasing illusion through repeated exposure and differences in attention span between younger and older subjects. These factors may be related to age and, therefore, confound the measurement of Perceptual Development. The Up-and-Down Method, because of its one-exposure-per-subject testing procedure, the simplicity of the response it requires, and the short time necessary to administer it, minimizes or circumvents those difficulties arising with other psychophysical techniques. Data are presented for five visual illusions; the Ponzo, the Modified Ponzo, the Horizontal-Vertical with Intersect, the Horizontal-Vertical without Intersect, and the Muller-Lyer; for both sexes at seven age levels: kindergarten through fifth grade, and adults; and compared to data found with psychophysical techniques. Reasons are discussed for preferring the Up-and-Down Method.

Approved C. Hanley

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A TECHNIQUE FOR OBTAINING
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By

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INTRODUCTION

The typical investigation of perceptual development attempts to measure the perceptual thresholds for several age levels. For example, if a perceptual illusion is being investigated, thresholds for several age levels are plotted and connected to form a perceptual development curve. All such studies have used psychophysical techniques as assessment instruments. However, these techniques can be criticized on many grounds. The purpose of this study is twofold; first, to demonstrate that the Up-and-Down Method is an adequate measurement instrument, and second, to show that it is free from the criticisms which specifically apply to psychophysical techniques.

Wohlwill (1960) roughly divides the criticisms of perceptual development studies into two categories. The first category includes errors in investigational design, analysis, and procedure. An insufficient number of subjects at any age level or an inadequate number of age levels assessed are likely to disguise the 'true' shape of the development curve. Lack of control in data collection may yield incomparable data across age levels. The use of inappropriate statistical techniques, such as analysis of variance when the data are curvilinear, may erroneously lead the researcher to conclude that age levels do not differ. All of the above criticisms can be eliminated by careful design and execution of research.

Wohlwill's second category deals with specific flaws which are inherent in certain psychophysical techniques that have

been used to assess the perceptual levels. Wohlwill indicates these as: (1) Starting Position Effects, which occur with the Method of Limits (Piaget and Lambercier, 1951; Wapner and Werner, 1957); (2) Error of the Standard, an overestimation of the standard stimulus as in the Method of Constant Stimuli (Piaget and Lambercier, 1943); (3) a Context or Central Tendency Effect, which appears when the comparison stimuli are presented in an ordered series to be matched to a constant standard (Lambercier, 1946).

At least the last of these has been shown to be functionally related to age, i.e., decreases with increasing age according to Tempieri (1955) as cited in Wohlwill, 1960. Considering that the psychophysical methods have been the only research tools available, and that these methods assess many age related changes, it becomes apparent that the resultant empirical curves are not due to perceptual development alone.

Along with the above defects, a few others can be mentioned. First, successive presentation of the same illusion to a single subject can produce a change in the amount of illusion perceived. This is the case with the Muller-Lyer Illusion where the end result is a decrease in the amount of illusion perceived (Judd, 1902; Kohler and Fishback, 1950). The amount of change per exposure is not known nor is it known how children are affected.

Another consideration is the difference in attention span between young subjects and adults. Younger subjects confined to an experimental situation should be more likely to lose interest in the

material being presented. This loss of attention could very well account for the larger individual differences reported for pre-school and early school subjects (Walters, 1942).

The last criticism concerns the comparability of the responses over age levels. In some psychophysical techniques, a degree of procedural sophistication is necessary to be able to respond. When young subjects lack this sophistication, their responses are difficult to compare with those of older individuals.

All of these flaws; design, procedural, methodological, and logical; must be considered in interpreting the meaning of developmental curves obtained with standard psychophysical techniques. The fact that they exist casts doubt on the efficacy of standard techniques as tools for assessing perceptual development. The solution to this problem demands an assessment technique that can control or circumvent these various unwanted age-related contributions to developmental trends. The Up-and-Down Method is such a technique.

THE UP-AND-DOWN METHOD

The Up-and-Down Method (Dixon and Mood, 1948) was originally devised for dosage-mortality work as an alternative to the Probit Method. In such work, the problem is finding the average dose of a drug that will kill an organism. Any organism subjected to a toxic substance may be killed by it, build up a tolerance to it, or become so sensitized that a later lesser dosage will result in death. The result is that a single experimental organism can be dosed just once. If the organism does die, one cannot be sure that a lesser dosage would not have killed it. The Probit Method requires testing several groups, each at a predetermined dosage level, and calculating the average dose which will produce death from the percentages of deaths occurring in all groups. At best, it demands large samples, and if the predetermined dosage levels deviate from the average dosage level, the efficiency of the technique drops rapidly. The Up-and-Down Method needs fewer subjects and automatically concentrates testing at or near the mean dosage needed to produce the sought-for effect However, this method requires subjects to be tested individually whereas groups can be tested simultaneously with the Probit Method.

As an example of the application of the Up-and-Down Method, Dixon and Massey (1957, pp 318-327) consider dynamite caps that explode if dropped from a sufficiently great height. When a single cap dropped from a given height explodes, there is no way to determine if it would have detonated if dropped from a lesser height. Conversely, if the cap does not explode, the powder

in it will be more closely packed as a result of the impact, thus changing its explosive characteristics and making it useless for further study. Estimating the mean explosion height of dynamite caps by the Up-and-Down Method involves selecting several testing heights from which individual caps are to be dropped. The height of each trial drop except the first is determined in advance by the results of the preceding trial; the height initially chosen for the first drop is determined in advance by the tester. As an example, call the heights h_0, h_1, and h_2. These heights differ by a given interval "d" such that $h_0 + d = h_1$ and $h_1 + d = h_2$.

Next, suppose that cap_1 is dropped from h_1, the level predetermined by the tester for the first drop. If cap_1 does not explode, cap_2 will be dropped from h_2, the next greater height. If cap_1 does explode, the next lower height, h_0 will be used for cap_2. In this way, the test height of any single cap except the first depends on the reaction of the previous cap at the height from which it was dropped.

Although it does not make a great deal of difference what the first level is, the method is most economical if that level is close to the true mean. If the first cap is dropped from a level departing grossly from the true mean, the method is self-correcting and after a few trials, will concentrate testing around the mean. Unlike the Probit Method, the Up-and-Down Method does not suffer a great loss in efficiency if the test levels chosen are not close to the true mean.

There are a few restrictions on the use of the Up-and-Down Method. First, the method uses approximately one-half of the total number of observations collected, e.g., either the number of caps that explode, or the number that do not, whichever is smaller. Thus, the mean ($\bar{X}$) and standard deviation (SD) estimates are based, in effect, on about one-half of the total sample tested. The $\bar{X}$ and SD estimates thus can be very misleading when based on total sample sizes of forty or less, since the effective sample sizes would be less than twenty.

Secondly, the method requires that the variate under consideration be normally distributed, a common assumption in psychophysical scaling techniques. This can be checked readily enough by plotting data on normal probability paper. If normality does not exist, then normalizing transformation procedures are required.

A final restriction is peculiar to the method. The ease of analysis depends on the relative size of "d", the interval between test levels, and the SD of the variable being measured. Dixon and Mood (1948) offer two methods of SD determination. The first is a simple linear approximation whereas the second is a tedious interpolation technique. The adequacy of the first, the linear approximation, depends on the size of the d/SD ratio using the SD calculated by it. As long as this ratio is between .5 and 2.00, the more complicated estimation technique does not yield a better SD approximation. When this ratio exceeds 2.00, the simple SD estimate is no longer satisfactory and the more tedious approximation technique is warranted. Use of the simpler form is preferable considering the calculation involved, but depends on an advance estimate of the SD such that a "d" can be chosen so that the resultant d/SD ratio falls between the .5 to 2.00 limits. In most cases, a little preliminary testing will approximate the SD of the variable closely enough so as not to force the use of the more difficult technique.

On paper, because of its one-exposure-per-subject technique, the Up-and-Down Method appears immune to criticisms involving Error of the Standard, Starting Position Effects, Attention Span Differences, Methodological Sophistication, and Response Comparability. The purpose of this research is to demonstrate the practical utility of this method for the measurement of changes in susceptibility to illusion as a function of age.

METHOD

Apparatus

Five visual illusions were chosen for this study, primarily because equipment necessary to present them is easily transported. They were the:

1 Ponzo (Figure 1)

2. Modified Ponzo (Figure 2)

3. Horizontal-Vertical with Intersecting Lines (Figure 3)

4. Horizontal-Vertical without Intersecting Lines (Figure 4)

5. Muller-Lyer (Figure 5)

The literature contains developmental curves obtained using psychophysical techniques for all of these illusions except the Modified Ponzo.

Each illusion appears in its indicated figure as it was presented to the subject. All illusions were drawn in india ink on white 5" x 8" unlined filing cards. Several cards were drawn for each illusion. Cards of a given illusion differed only in the length of the variable line, e.g., the standard line of the Muller-Lyer illusion was two inches in length on each of the seven cards in its series whereas the variable line length varied from 1.75 inches as the smallest in the series to 3.25 inches in the largest. The standard and variable lines are indicated in Figures 1 through 5. The term "standard line" refers to the fact that one line for each illusion was the same length on all cards whereas the "variable line" was varied in length over the series

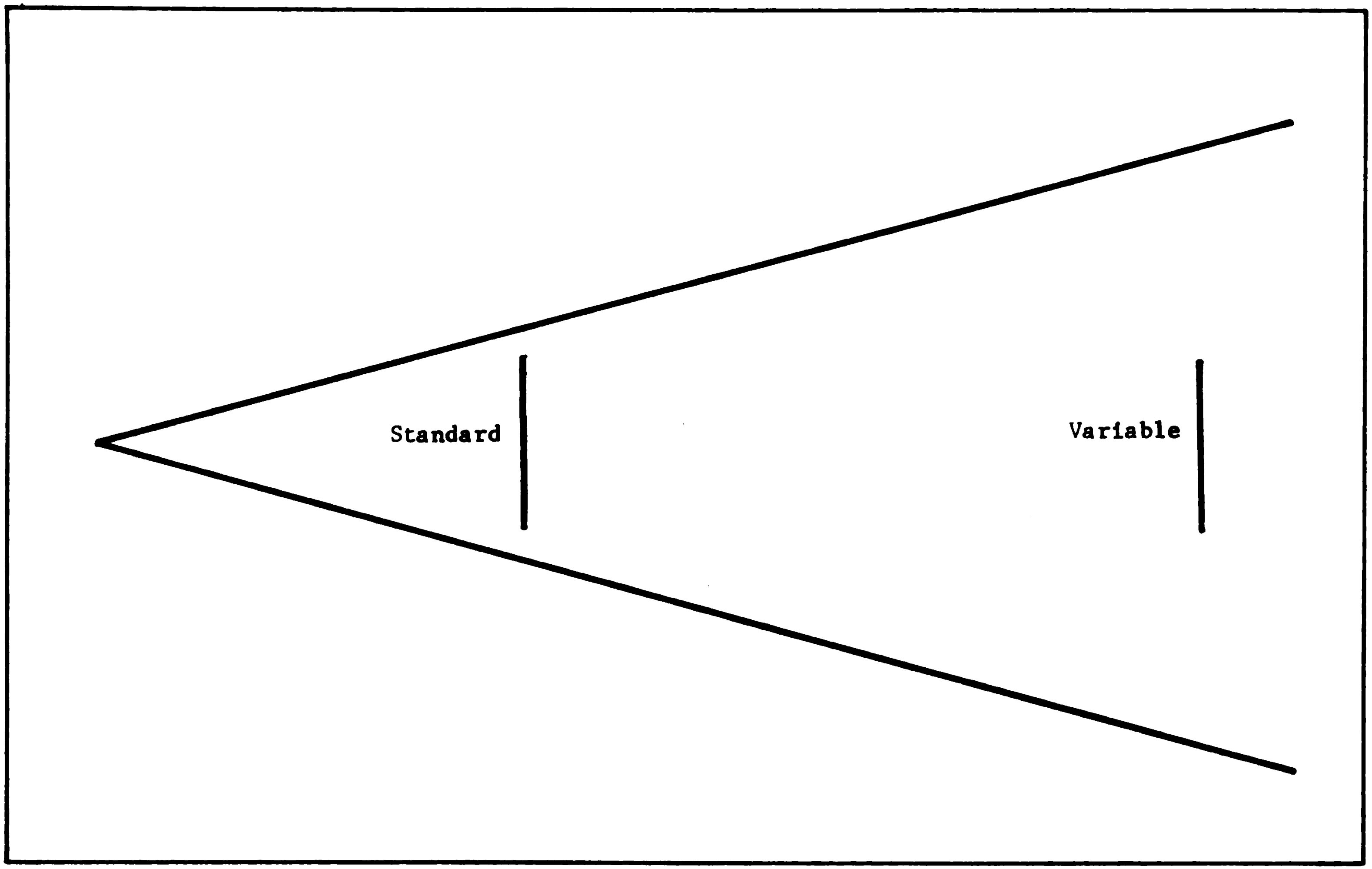

FIGURE 1. The Ponzo Illusion. Size and axial orientation are the same as presented to the subjects in the actual drawings. The standard and variable lines are drawn in blue india ink. The standard and variable lines are each 8 "d" units long in this example.

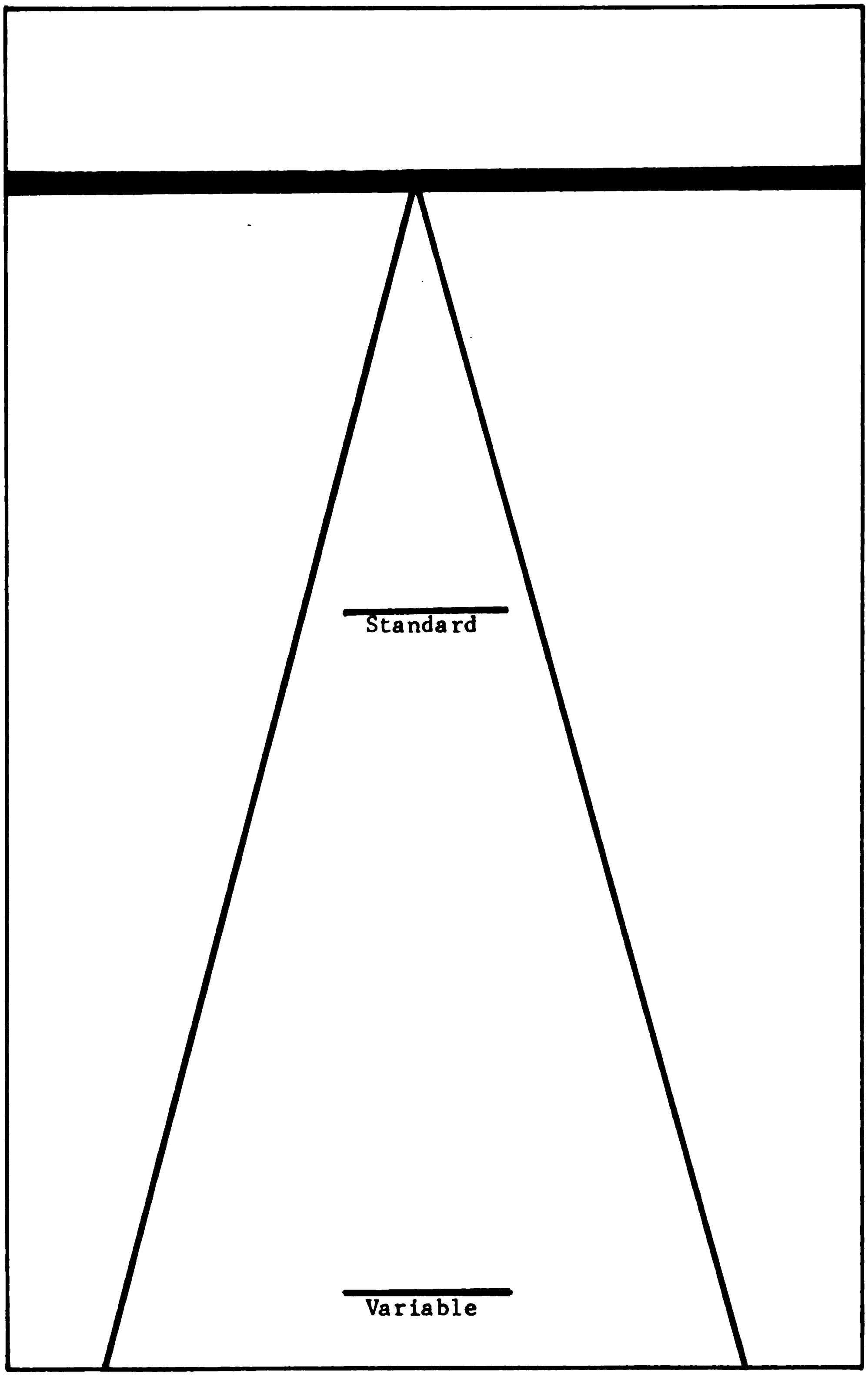

FIGURE 2. The Modified Ponzo Illusion. Size and axial orientation are as presented to the subjects. In the actual drawings, the variable and standard lines are drawn in blue india ink. The standard and variable lines are 8 "d" units long in this example.

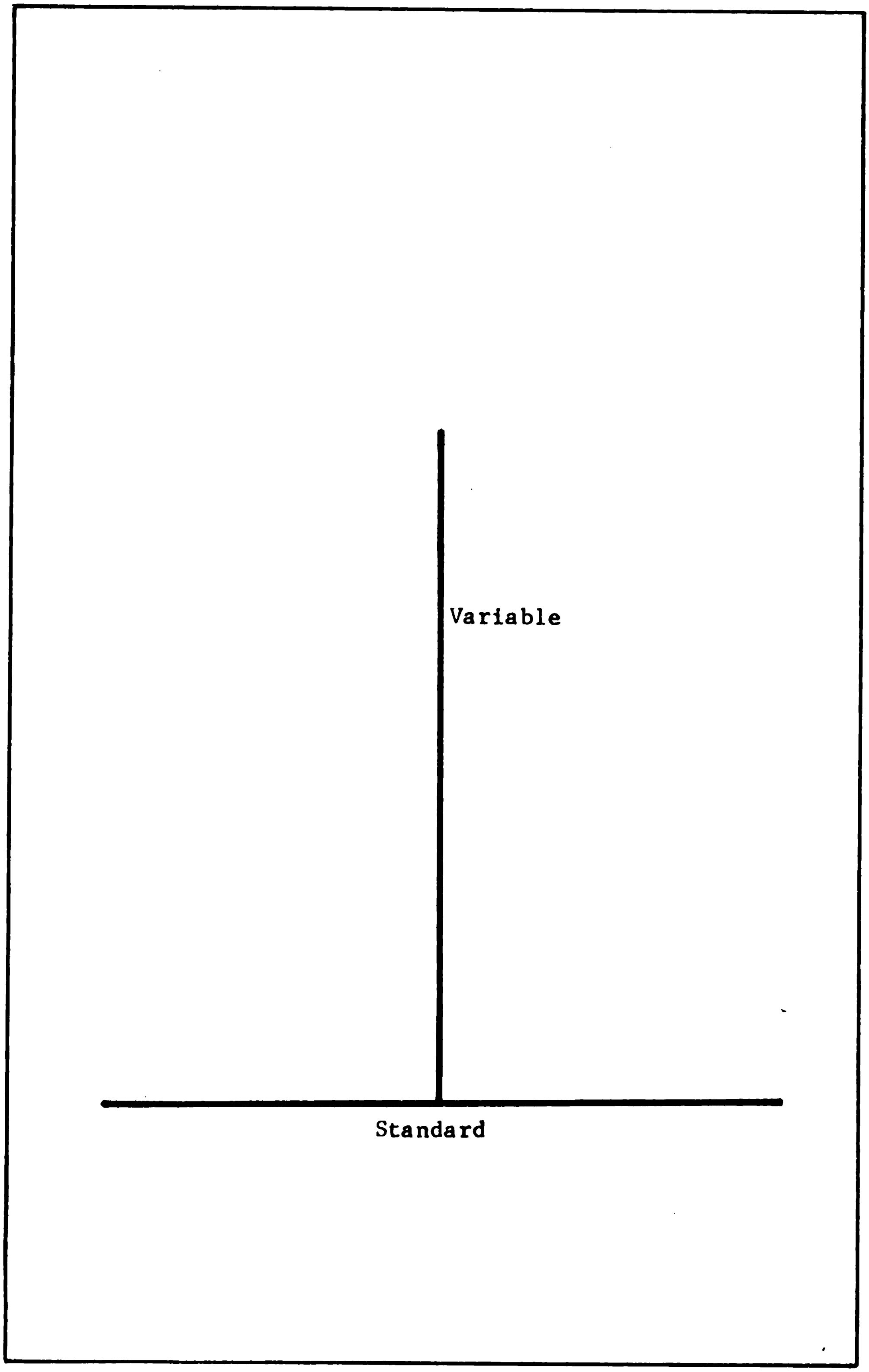

FIGURE 3. The Horizontal-Vertical with Intersect Illusion. Size and axial orientation are as presented to the subjects. In the actual drawings, the variable line is drawn in blue india ink. The standard and variable lines are each 16 "d" units long in this example.

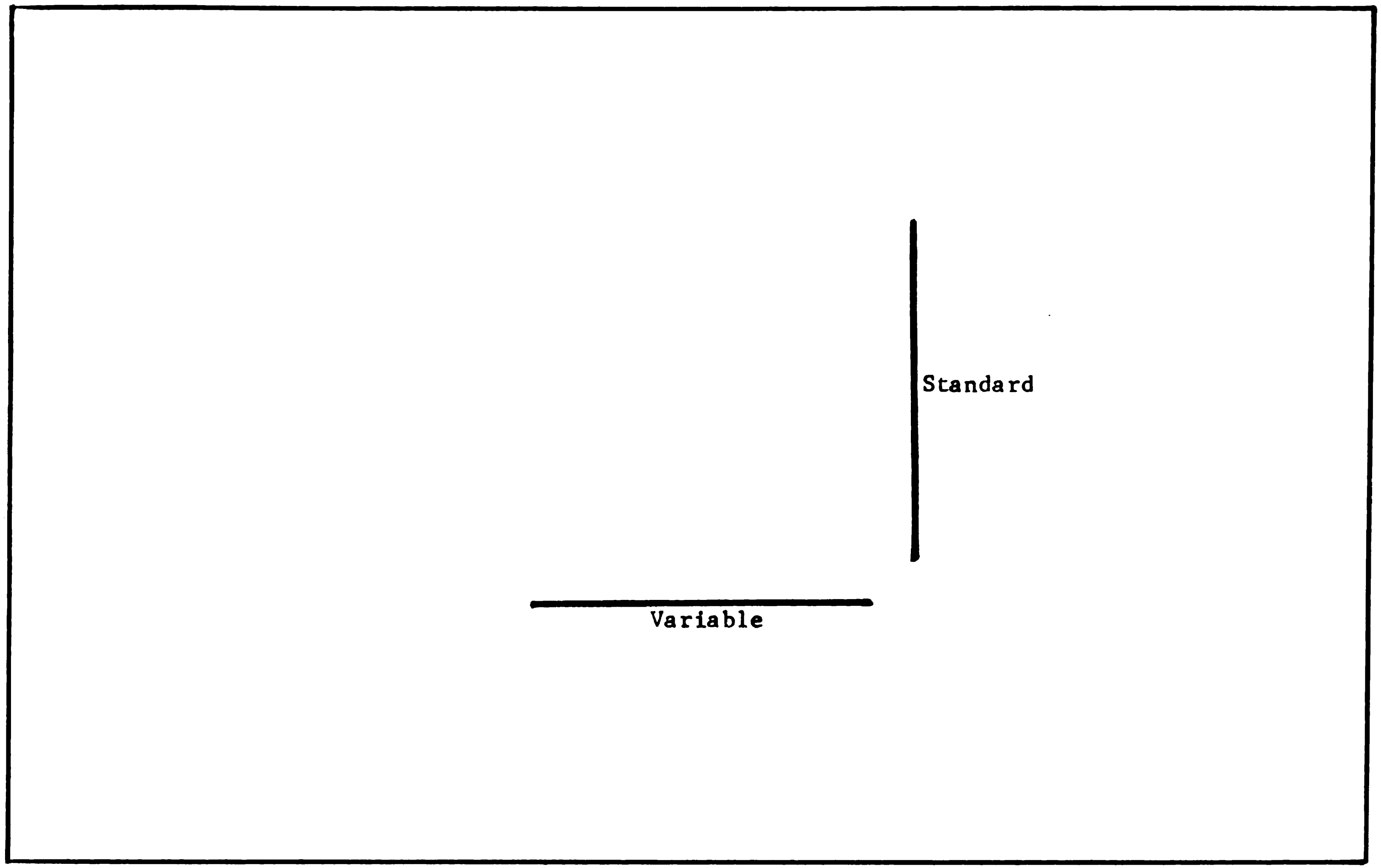

FIGURE 4. The Horizontal-Vertical without Intersect Illusion. Size and axial orientation are the same as the drawings presented to the subjects. In the actual drawings, the variable line is drawn in blue india ink. The standard and variable lines are each 16 "d" units long in this example.

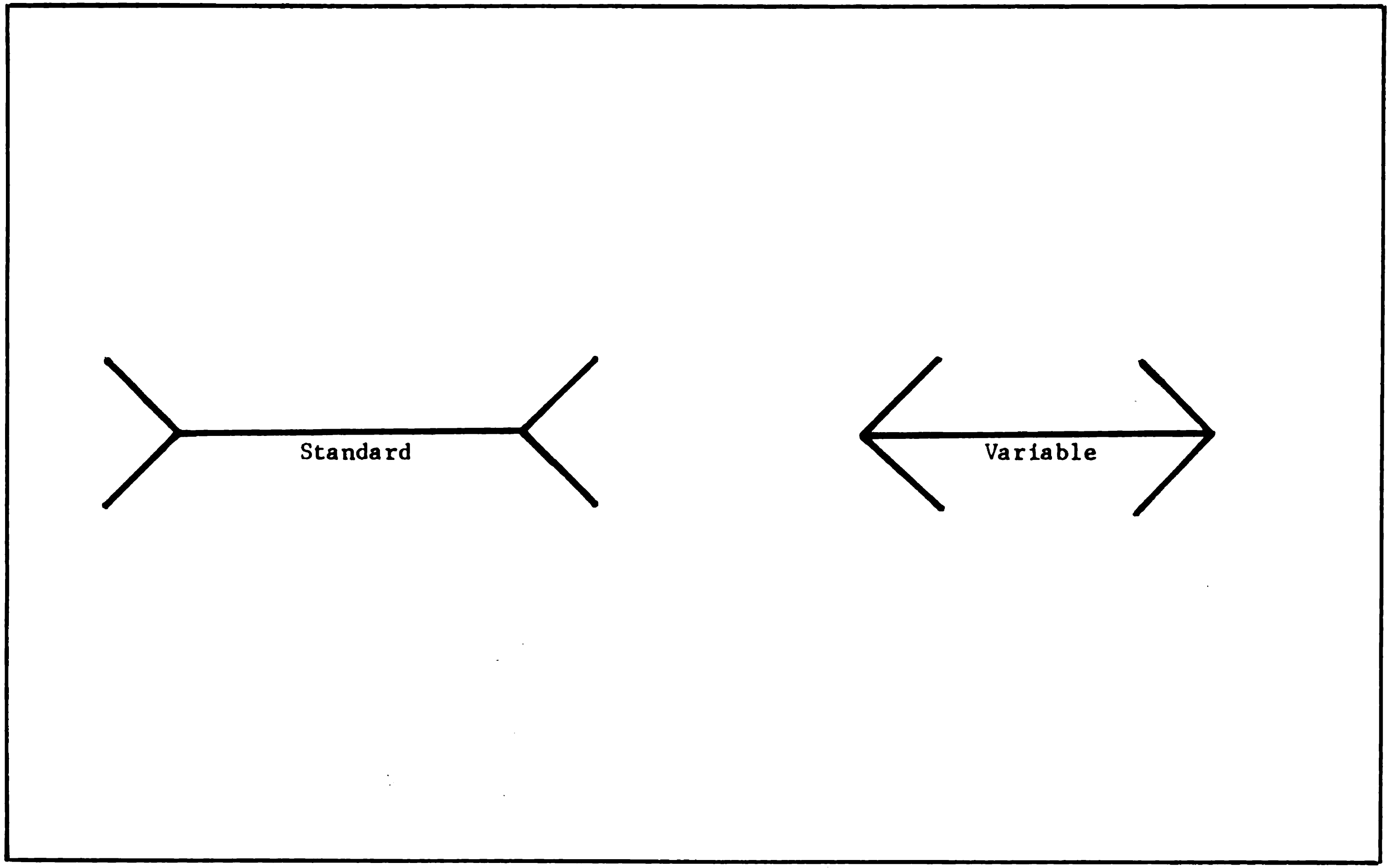

FIGURE 5. The Muller-Lyer Illusion. Size and axial orientation are the same as presented to the subjects. In the actual drawings, the variable and standard lines are drawn in blue india ink. The standard and variable lines are each 8 "d" units long in this example.

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and served the same function as the differing heights of the dynamite cap example. The range of "variable line" values for each illusion was great enough to accommodate all responses. The number of cards and the interval between cards of the same illusion were not the same for all illusions. The interval, number of cards, range, and length of standard for each illusion series appear in Table 1.

TABLE 1. The interval between cards in the series used, the number of cards, the range of the variable line, and the length of the standard for each illusion. All lengths are in inches.

Illusion	Interval (d)	Number of Cards	Range	Length of Standard
Ponzo	.125	6	.875-1.50	1.00
Modified Ponzo	.125	7	.75-1.50	1.00
H-V w/Intersect	.25	8	2.50-4.25	4.00
H-V w/out Intersect	.125	8	1.75-2.625	2.00
Muller-Lyer	.25	7	1.75-3.25	2.00

All lines were drawn with a Speed-Ball C-5 lettering nib, except for the wide horizon line in the Modified Ponzo. This line was drawn with a Speed-Ball C-1 nib.

Two colors of ink were used to facilitate the subject's identification of the lines to be compared. The Ponzo, Modified Ponzo, and Muller-Lyer illusions had the standard and variable lines drawn in blue with the rest of the illusion in black. The two Horizontal-Vertical illusions had the standard line black and the variable line blue. This use of color was especially advantageous during the testing of the younger subjects for they could readily identify the comparison lines by color.

All cards were presented in clear plastic frames. Two frames, one for horizontal and one for vertical presentation, were constructed of 1/8-inch clear plastic stock. Two pieces of plastic, 6" x 9", were separated by 1/16-inch plastic strips forming a 5-1/2" x 8-1/2" x 1/16" pocket between them. For presentation, each stimulus card was slipped into the appropriate frame. This limited the bow of the cards from edge to edge at 1/16-inch and insured equally flat viewing of all cards for all subjects. A 1" x 1" thumb hold was cut from the top of the back piece of each frame to allow removal of the cards after presentation.

Each frame was held in an upright position by wood stands at 5 degrees from vertical, tilted away from the subject. A 100-watt lamp was placed between the subject and the frame to reduce any glare or reflection on the surface of the frames from surrounding light sources. A lamp shade shielded the bulb from the direct line of the subject's viewing. When the subject pointed to his choice of line, a shadow was cast on the surface of the frame. This shadow was observable through the frame and enabled the experimenter to quickly identify the subject's choice.

Subjects

All elementary school subjects were recruited from public schools in Ingham County. The adult samples were obtained at Fall 1962 registration at Michigan State University.

The adult subjects were individually asked their ages. The range of ages for the adult samples was kept constant across

sexes (17-27). Since the age of each adult was available, the mean and the median ages for these samples are presented (Table 2).

The ages of the elementary school samples are presented as age ranges. The maximum and minimum age for each sample and sex is given. Although there is some overlap, these groups differ by roughly one year (See Table 2).

TABLE 2. Age ranges for each sample. (The superscript in the elementary school samples represents months.)

Sample	Age Range Males	Age Range Females
Kindergarten	5^{5}-6^{7}	5^{4}-6^{11}
Grade 1	6^{4}-7^{5}	6^{4}-7^{5}
Grade 2	7^{1}-8^{9}	7^{4}-8^{8}
Grade 3	8^{2}-9^{4}	8^{2}-9^{5}
Grade 4	9^{3}-10^{8}	9^{2}-10^{7}
Grade 5	10^{3}-11^{10}	10^{3}-11^{8}
Adults	17-27	17-27
Adult Median	19	19
Adult Mean	19.47	19.06

The only restriction placed on the elementary school samples was that no child who had been retained in grade was included in the study. Elementary school classes were tested as units. Prior to the testing of the class, the teacher provided: (1) the age range for both sexes excluding retainees, and (2) the names of the retainees. The maximum and minimum age over all classes for a given grade and sex defines the age range for that grade.

While samples of approximately 100 subjects of each sex at each age level were obtained, the effective sample sizes are approximately one-half of this number for each group. The effective sample size for each group appears in Table 3 of the Results section.

Procedure

The Experimenter entered the classroom, introduced himself and told the class that they were to see a series of line drawings and answer a few questions about them. Then, a group of four or five like-sexed class members were taken to the testing room. All but one of this group were seated outside the testing room. The remaining subject was brought into the room and seated in front of the plastic frames. The distance between the subject's head and the frames varied between 2-1/2 to 4 feet. All subjects were asked to sit upright to control this distance, though no other restriction was imposed. Subjects who tilted their heads or attempted to use their fingers to measure the lines were asked to refrain from doing so. As each subject finished, he returned to his classroom and another subject entered from those waiting outside. The waiting group was constantly replenished in small groups of twos or threes from the class being tested. In this way, a fairly rapid rate was maintained until the total class had been tested. At this point, the Experimenter entered another class and the whole cycle was repeated.

Prior to testing each individual, the Experimenter asked the subject his name. If it appeared on the list of retainees for that

class, his responses were not recorded. Barring this, all other treatment was the same as any other member of the class.

The second step in testing was to present the subject with two different-sized weights. The subject was told:

> "Pick up these weights, one in each hand, and tell me which one feels heaviest to you."

Systematic collection of data for the Size-Weight Illusion was originally planned and collected over the first 200 subjects. After these first subjects, systematic collection was stopped but a pair of weights similar to those used with the first 200 subjects was used to keep the test sequence identical for all subjects.

When the weights had been returned to the Experimenter, the Kindergarten, grade 1, and grade 2 subjects were shown two test cards (Figures 6 and 7) to determine their ability to distinguish between the colors used and to ascertain if they understood the concept of "longest". The presentation order and axial orientation of these cards was alternated for each subject. One card had a black and a blue line; the other, two blue lines. Regardless of which card was presented, subjects were asked:

> "Do you see the two lines on this card? Which one looks longest to you? Point to that line for me."

All instructions requesting the comparison of two lines asked for the identification of the "longest" rather than the "longer" of the two. The youngest subjects seemed to understand the instructions better with this usage, therefore, it was retained for all subjects.

After the subject had chosen one of the lines, he was asked:

> "What is the color of that line? What is the color of the other line?"

The same process was repeated with the second test card.

For his responses to be recorded, each subject had to identify the longest line on both cards and be able to discriminate between the two colors, black and blue. Correct naming of the colors was not required although discriminating between them was. It is of interest to note that several boys at the Kindergarten and first grade levels did not correctly name the blue line. When this occurred, the name the subject had applied to that color was used through the rest of the session. For example, if the subject called the blue line "purple", he was later asked, "Do you see the two purple (instead of blue) lines?" No such problem was found with girls.

At this point, the first illusion was placed in the appropriate plastic frame. The length of the variable line of each illusion was determined in advance by the choice of the preceding subject. If the preceding subject had chosen the variable line, the card shown to the present subject had the variable one "d" unit smaller. If the preceding subject had chosen the standard line, the present subject was shown the card with the variable one "d" unit larger. The illusion shown to the first subject of a sample was one

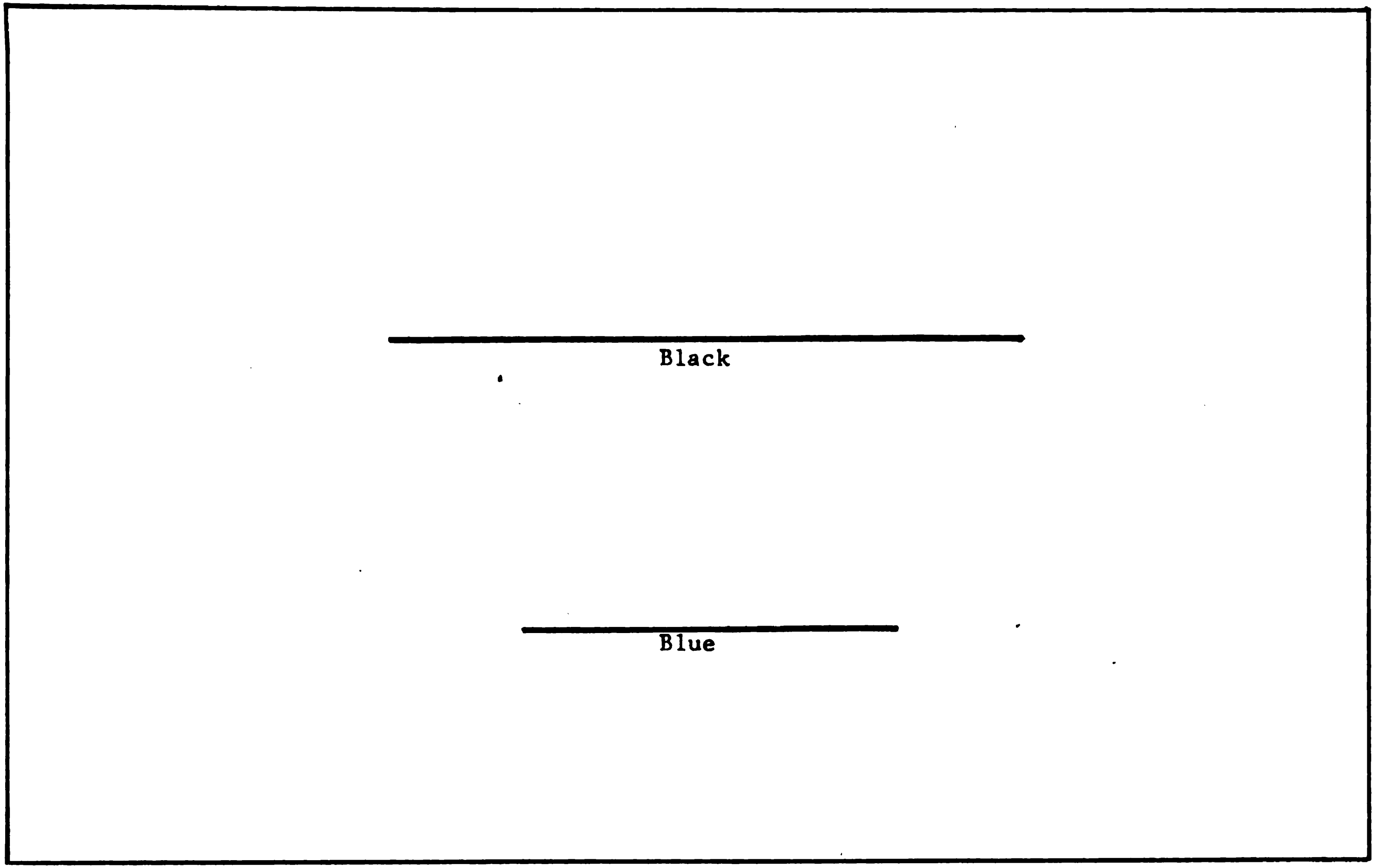

FIGURE 6. Test card No. 1. The colors indicated are as they appear on the actual test card. The size is the same as the actual card. The axial orientation of this card was changed at each presentation.

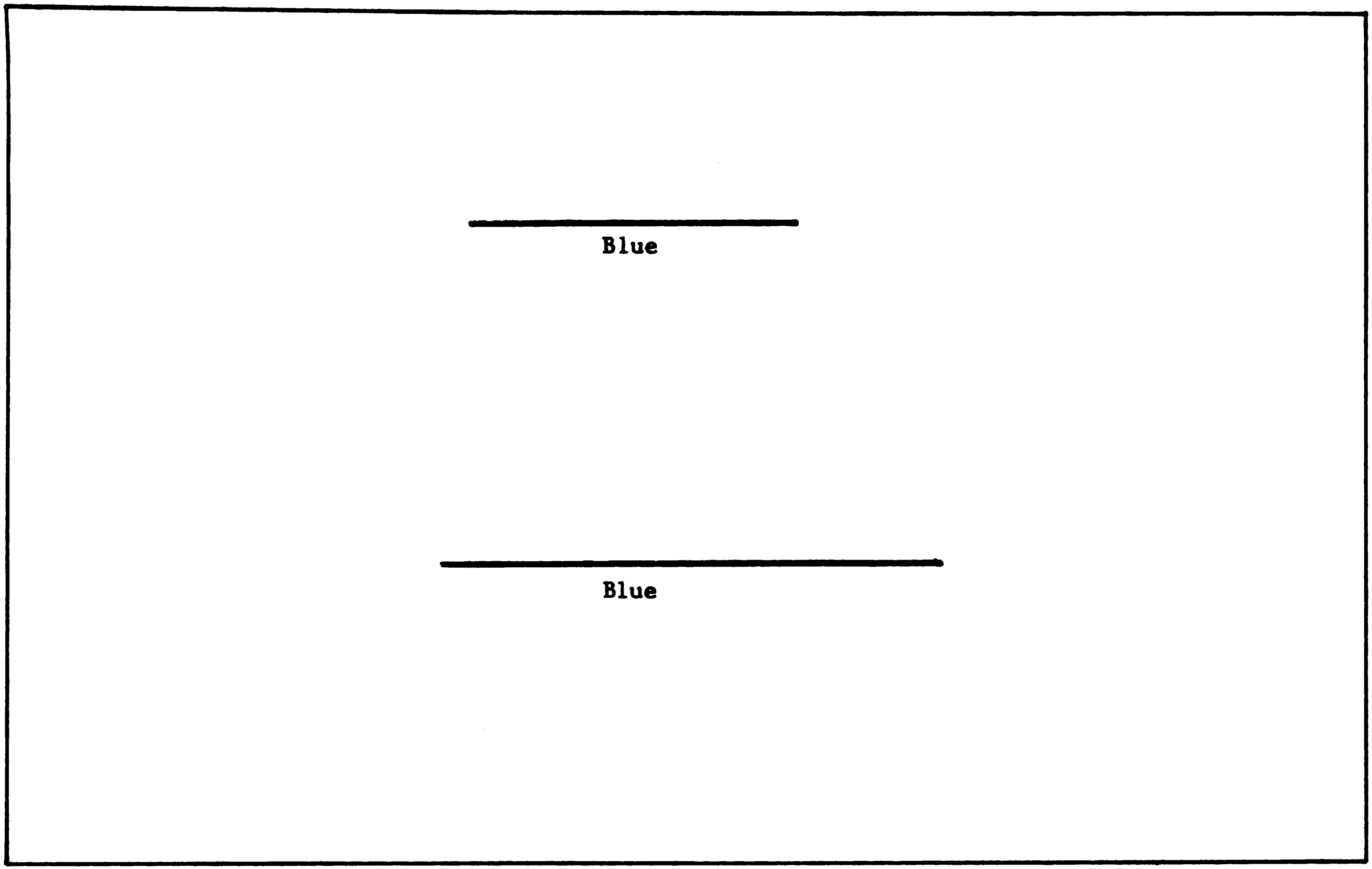

FIGURE 7. Test card No. 2. The colors indicated are as they appear on the actual test card. The size is the same as the actual card. The axial orientation of this card was changed at each presentation.

representing the middle of the illusional series. The sequence of presentation and axial placement of the cards was the same for all subjects. This sequence was:

1. Modified Ponzo (Vertical)
2. Horizontal-Vertical with Intersect (Vertical)
3. Muller-Lyer (Horizontal)
4. Ponzo (Horizontal)
5. Horizontal-Vertical without Intersect (Horizontal)

The cards were placed vertically (5" side parallel to table top) or horizontally (8" side parallel to table top) in the appropriate frame.

With the Modified Ponzo before him, the subject was asked:

> "Do you see the two blue lines? Which one looks longest to you? Point to that line for me."

These same questions were asked upon presentation of the Muller-Lyer and Ponzo illusions.

After the subject had pointed to his choice, it was recorded, the illusion removed, and the next illusion in the sequence placed in its appropriate frame. For the two horizontal-vertical illusions, subjects were asked:

> "Do you see the black and blue lines? Which line, black or blue, looks longest to you? Point to that line for me."

Verbal identification of the line was not accepted in the illusions where the standard and variable lines were the same color. Subjects were allowed to identify their choice by color in the two Horizontal-Vertical illusions.

Each subject saw just one drawing of each illusion.

Scoring

Responses were recorded on special scoring sheets (see appendix). If the subject chose the variable line as longest, a + (plus) was entered in the appropriate place. If the standard was chosen, a 0 (zero) was entered. When a + was entered for a subject, the next subject saw a card on which the variable was one "d" unit smaller. If a zero was entered for the subject, the next subject saw a card with the variable one "d" unit larger.

RESULTS

Fourteen groups, both sexes for each of seven age levels, were defined by the experimental procedure for each of five illusions. The normality of the distribution of the variable in all seventy groups was checked by plotting each distribution on normal probability graph paper. With one exception, all plots yielded straight or nearly straight lines of three or more points. The exception is the kindergarten Ponzo female group which had only two points on the graph.

The n, $\bar{X}$, and SD for each group was determined by techniques appropriate to the Up-and-Down Method. All $\bar{X}$s, and SDs were originally determined by the method in Dixon and Massey (1957, pp 318-327). The kindergarten and grade 2 Ponzo female groups yielded d/SD ratios greater than 2.00, necessitating the use of the alternative technique (Dixon and Mood, 1948). Dixon and Mood also point out that in comparisons of $\bar{X}$s, the standard error of the mean determined must be corrected by a factor "G" which is related to the size of the d/SD ratio. This correction is listed in tabular form in their article. The correction, G x SD, is less than $\pm$ 5 per cent in most cases. All SDs used were so corrected for use in analysis of variance. Table 3 shows the $\bar{X}$, corrected SD, and effective n, for each group. Figures 8 through 12 graphically show the means in terms of "d" units by sex and grade level for each of the five illusions.

TABLE 3. The mean, standard deviation (corrected according to the d/SD ratio), and effective sample size for each grade and sex of each illusion. Means and standard deviations are in terms of "d" units.

		Grade Level						
Illusion		K	1	2	3	4	5	A
PONZO								
Males	$\bar{X}$	8.956	9.066	9.231	9.229	9.100	9.347	9.180
	SD	.6188	.6239	.6079	.6877	.7902	.5730	.7048
	n	57	53	52	48	50	52	50
Females	$\bar{X}$	8.885	9.198	9.265	9.420	9.324	9.352	9.180
	SD	.6307	.6291	.6273	.7869	.5955	.6603	.6474
	n	52	53	51	50	51	54	50
MODIFIED PONZO								
Males	$\bar{X}$	9.710	9.944	9.577	9.542	9.520	9 519	9.340
	SD	1.0147	.8311	.7067	.7551	.7090	.7357	.8066
	n	57	54	52	48	50	52	50
Females	$\bar{X}$	10.019	10.085	10.029	9.680	9.637	9.783	9.342
	SD	.9940	.6736	.8483	.7151	.8912	1.0376	.7009
	n	52	53	51	50	51	53	50
HORIZONTAL-VERTICAL WITH INTERSECT								
Males	$\bar{X}$	13.219	13.593	13.443	13.542	13.700	13.519	12.420
	SD	1.4355	1.0128	1.1492	1.3384	1.4137	1.5326	1.2298
	n	57	54	53	48	50	52	50
Females	$\bar{X}$	13.538	13.934	13.637	13.378	13.657	13.310	13.280
	SD	1.1915	1.1550	1.1560	1.1239	1.2394	1.0285	1.3073
	n	52	53	51	49	51	53	50
HORIZONTAL-VERTICAL WITHOUT INTERSECT								
Males	$\bar{X}$	17.607	17.462	17.231	17.543	17.745	17.615	18.235
	SD	1.0591	1.4253	.9887	1.0193	.8929	.8520	1.1215
	n	56	54	52	48	49	52	49
Females	$\bar{X}$	17.365	17.613	17.637	17.420	18.186	18.037	17.800
	SD	1.3626	1.1712	1.0541	.7794	.9130	.8870	1.0890
	n	52	53	51	50	51	54	50
MULLER-LYER								
Males	$\bar{X}$	10.589	11.037	11.104	10.646	10.720	10.673	10.700
	SD	.9402	.8872	.7698	.8125	.6426	.6984	.7826
	n	56	54	53	48	50	52	50
Females	$\bar{X}$	10.692	11.123	11.010	10.940	10.892	10.821	10.820
	SD	.8210	.7142	.7926	.6853	.7284	.7406	.7048
	n	52	53	51	50	51	53	50

Separate analyses were performed on each illusion. The general sequence of steps follow:

1. F-max test over all fourteen groups of each illusion to determine homeogeneity of variance (Walker and Lev, 1953).

2. A two-way analysis of variance using sex and age level. (Linquist, 1953). Since the Up-and-Down Method yields only $\bar{X}$s and SDs, the following relationships were used to obtain the needed sums of squares:

$$\sum X = \bar{X} n$$
$$\sum X^2 = SD^2 (n-1) + (\sum X)^2/n$$

Any error incurred due to the slightly unequal sample sizes is Type II error (Dixon and Massey, 1957, pp 181-182).

3. If the Analysis of Variance did not indicate significant sex or interaction effects, the sexes at each age level were pooled, leaving seven age groups. These combined groups were then tested for homeogeneity of variance using the F-max procedure. Finally, all possible comparisons were made between these seven age groups using a range or critical difference technique (Dixon and Massey, 1957, pp 152-153). This technique does not increase the Type I error level and, if anything, is conservative.

4. If the Analysis of Variance did indicate sex and/or interaction effects, the sex groups at age levels were not combined. First, an F-max was calculated over age levels for each sex separately. Then all comparisons between like-sexed age groups were made using the critical difference technique. Lastly, differences between sexes at each age level were tested using t-tests.

Ponzo

The F-max test over the fourteen groups of the Ponzo illusion is not significant ($P > .05$) indicating homeogeneity of variance. Table 4 shows the Analysis of Variance for the Ponzo data.

TABLE 4. Analysis of Variance for the Ponzo Illusion

Source	SS	df	MS	F
Age	13.1024	6	2.1837	5.0479**
Sex	1.0624	1	1.0624	2.4558
Age x Sex	1.7265	6	.2878	.6653
Within	306.6931	709	.4326	-
Total	322.5844	722	-	-

**Significant at the .01 level

Since no sex and/or interaction effects appear in Table 4, sexes at each age level were pooled. The means for these combined groups appear in Table A, in the Appendix. An F-max test over these seven combined groups indicates homeogeneity of variance ($P > .05$). All possible comparisons between these combined groups, listed in

Table B of the Appendix, show that the amount of illusion displayed by the kindergarten group is less than that shown by the grade 2, 3, 4, and 5 age levels. There is also a decrease in the magnitude of the illusion at the adult level (Figure 8) but this difference is not statistically significant.

Modified Ponzo

The F-max test over the fourteen groups of the Modified Ponzo indicates homeogeneity of variance ($P > .05$). The Analysis of Variance for this illusion (Table 5) shows sex differences, precluding pooling of sexes at each age level.

TABLE 5. Analysis of Variance for the Modified Ponzo Illusion

Source	SS	df	MS	F
Age	29.7140	6	4.9523	7.2254**
Sex	7.2904	1	7.2904	10.6367**
Age x Sex	3.7394	6	.6232	.9093
Within	485.9325	709	.6854	-
Total	526.6763	722		-

**Significant at the .01 level.

F-max tests over the seven age levels of each sex are not significant, indicating homeogeneity of variance ($P > .05$). All possible comparisons between the age levels of each sex separately appear in Tables C and D in the Appendix. Table C indicates that adult males have less illusion than kindergarten level males. Table D indicates that female adults have less illusion than kindergarten, grade 1, and grade 2 females. Differences between sexes at each age level show that kindergarten, grade 2, and grade 5 females see more illusion than males at the same ages (Appendix, Table E).

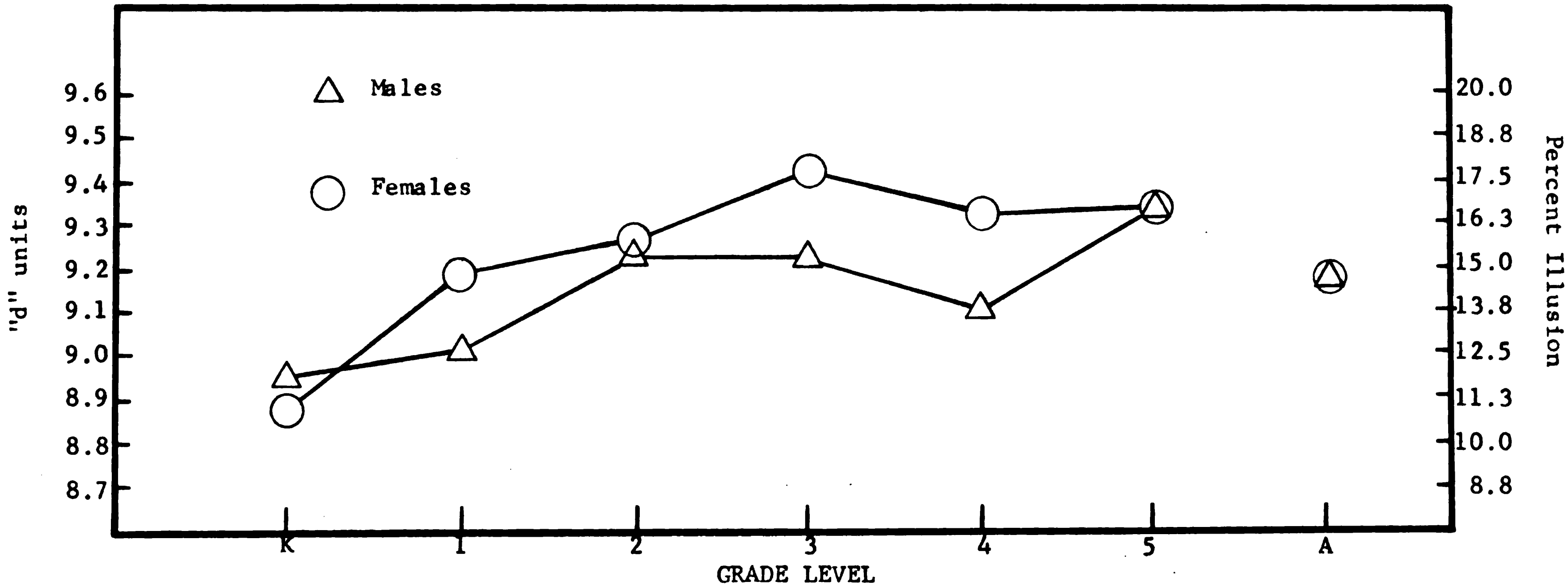

FIGURE 8. The means for the Ponzo Illusion. All means are expressed in terms of "d" units, the interval between test cards. For the Ponzo, the variable line series runs from 7d (.875 inches) to 12d (1.50 inches). The standard line is 8 "d" units long.

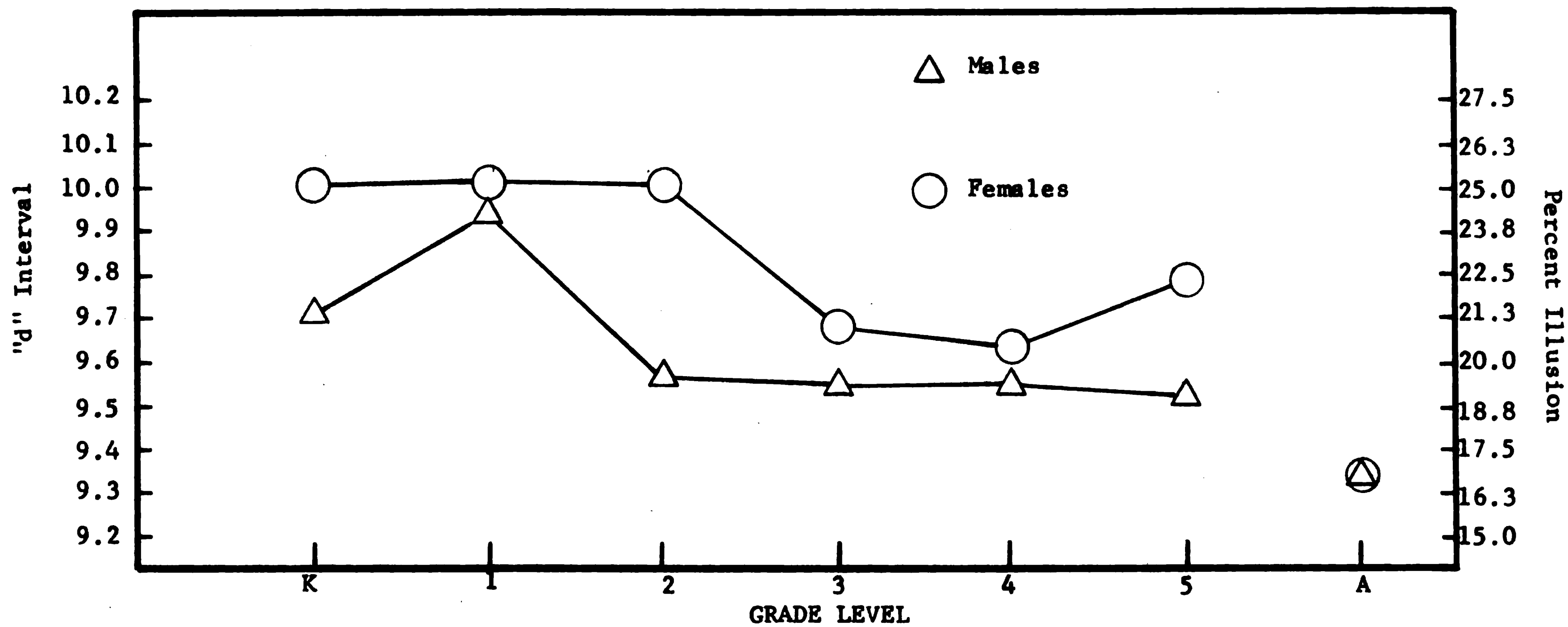

FIGURE 9. The means for the Modified Ponzo Illusion. All means are expressed in terms of "d" units, the interval between test cards. For the Modified Ponzo, the variable line series runs from 7d (.875 inches) to 12d (1.50 inches). The standard line is 8 "d" units long.

Horizontal-Vertical with Intersect

The F-max test over the fourteen groups of this illusion is not significant, indicating homeogeneity of variance ($P > .05$). The Analysis of Variance (Table 6) shows both sex and interaction effects at the .05 level, precluding combining sexes.

TABLE 6. Analysis of Variance for the Horizontal-Vertical with Intersect Illusion

Source	SS	df	MS	F
Age	53.2572	6	8.8762	5.7251**
Sex	6.3292	1	6.3292	4.0823*
Age x Sex	20.8619	6	3.4770	2.2426*
Within	1099.2350	709	1.5504	-
Total	1179.6833	722	-	-

*Significant at the .05 level
**Significant at the .01 level

F-max tests over the seven age levels of each sex are not significant ($P > .05$). All possible comparisons between male groups show the adults displaying a greater magnitude of illusion than the children in grades 1 through 5. (Appendix, Table F). No significant differences occur between female groups (Appendix, Table G). Differences between sexes at each age level show males to have a greater amount of illusion than females at grade 1 and adult levels (Appendix, Table H).

Horizontal-Vertical without Intersect

The F-max test over all fourteen groups of this illusion is not significant ($P > .05$), indicating homeogeneity of variance.

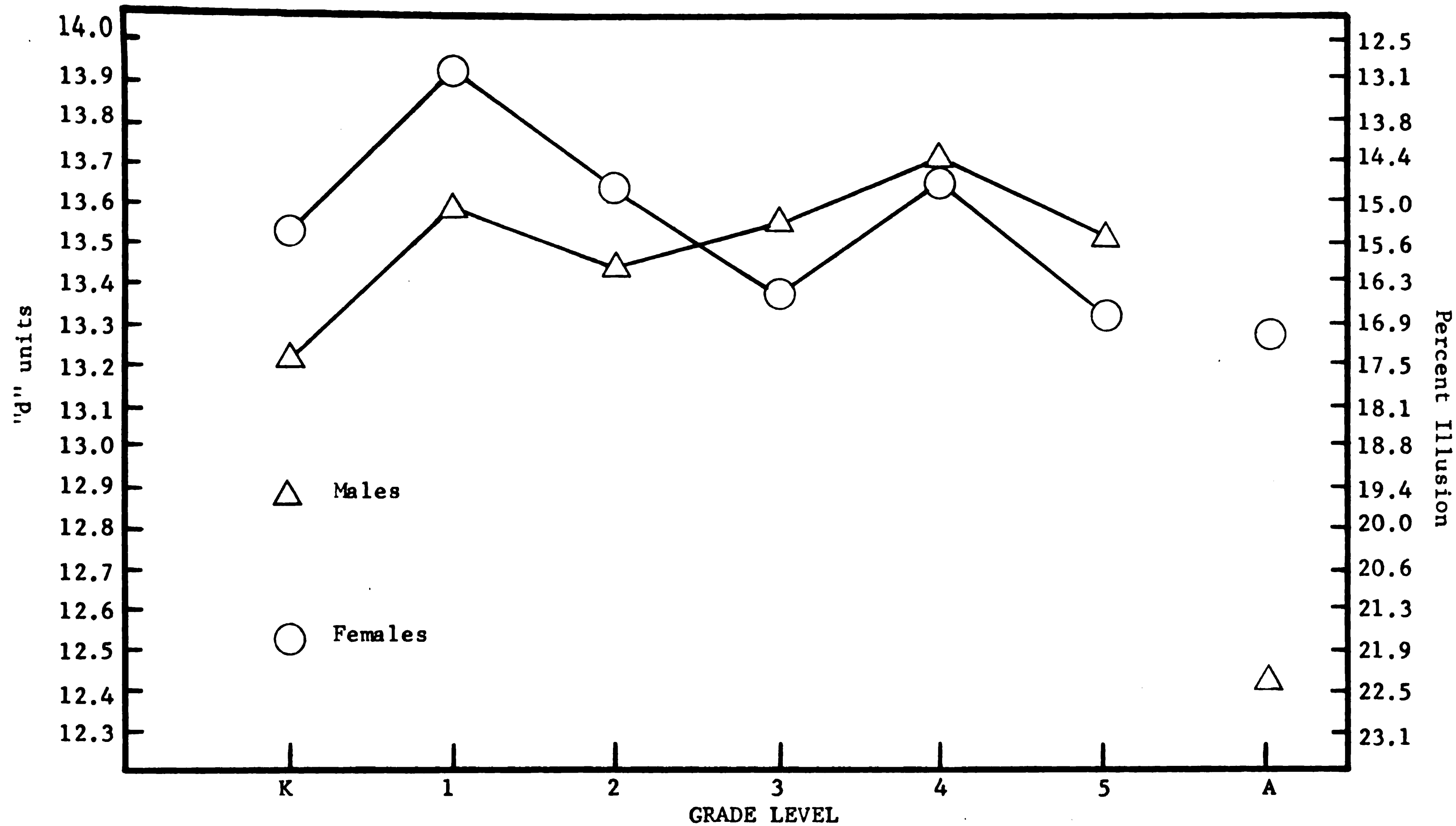

FIGURE 10. The means for the Horizontal-Vertical with Intersect Illusion. All means are expressed in terms of "d" units, the interval between test cards. For the Horizontal-Vertical with intersect, the variable line series runs from 10d (2.50 inches) to 17d (4.25 inches). The standard line is 16 "d" units long.

The Analysis of Variance (Table 7) shows interaction effects at the .05 level, precluding combining of sexes.

TABLE 7. Analysis of Variance for the Horizontal-Vertical without Intersect Illusion

Source	SS	df	MS	F
Age	38.5934	6	6.4322	5.7089**
Sex	2.0423	1	2.0423	1.8126
Age x Sex	19.0217	6	3.1703	2.8138*
Within	796.5463	707	1.1267	-
Total	856.2037	720	-	-

*Significant at the .05 level
**Significant at the .01 level

F-max tests between the seven groups of each sex indicates homeogeneity of variance for the males ($P > .05$), but the females yield a ratio of 3.06 (3.02 is the .05 level) suggesting heterogeneity of variance. In spite of this finding of statistical heterogeneity of variance, the critical difference technique was used to compare age levels for the female groups. Comparisons among the male groups indicate that the adult males see more illusion than the grade 1, 2, and 3 boys (Appendix, Table I). Grade 4 and 5 girls show more illusion than the kindergarten level girls, and the grade 4 girls show more illusion than those in grade 3. (Appendix, Table J). Comparisons between sexes at each age level indicate that females have more illusion than males at grades 2, 4, and 5, with a reversal, males greater than females, at the adult level.

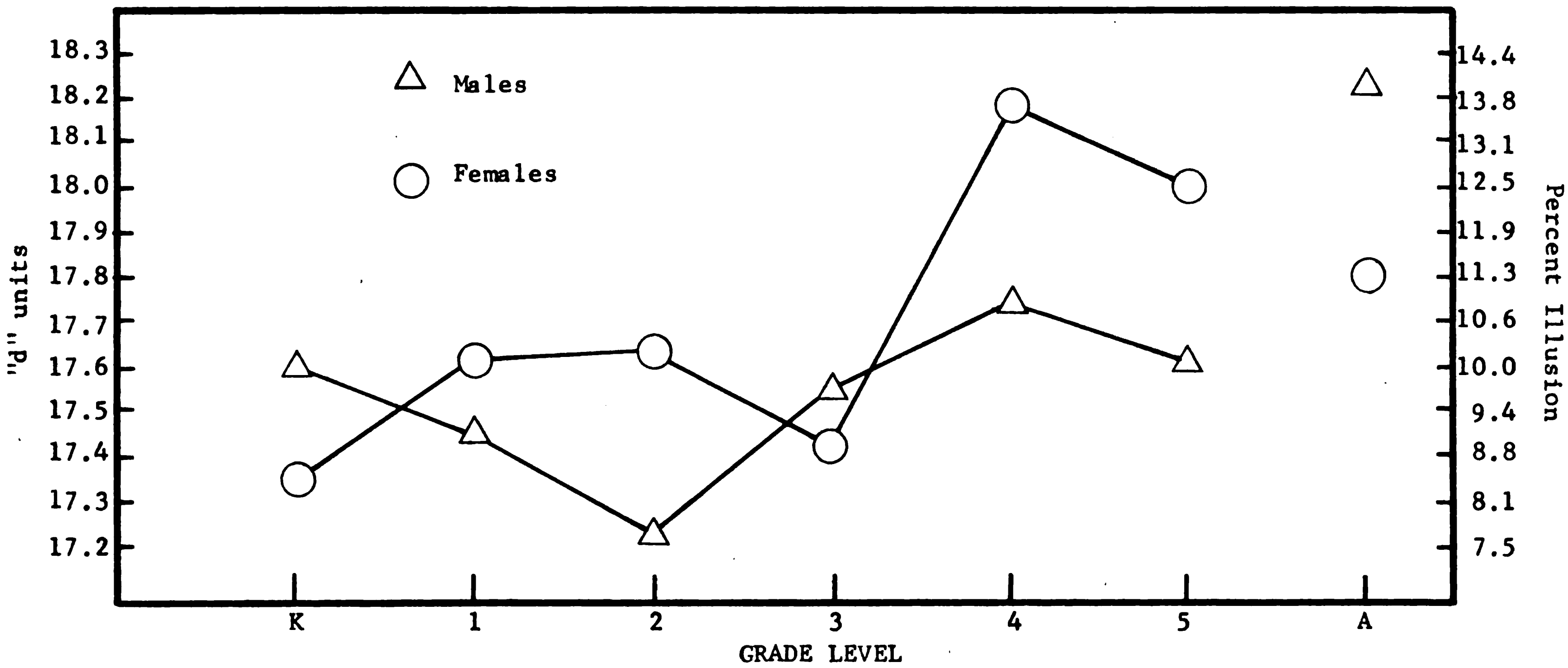

FIGURE 11. The means for the Horizontal-Vertical without Intersect Illusion. All means are expressed in terms of "d" units, the interval between test cards. For the Horizontal-Vertical without Intersect, the variable line series runs from 14d (1.75 inches) to 21d (2.625 inches). The standard line is 16 "d" units long.

Muller-Lyer

The F-max test over the fourteen groups of this illusion is not significant ($P > .05$) indicating homeogeneity of variance. The Analysis of Variance (Table 8) shows significant sex differences, precluding the combining of sexes at age levels.

TABLE 8. Analysis of Variance for the Muller-Lyer Illusion

Source	SS	df	MS	F
Age	17.2949	6	2.8825	4.8429**
Sex	2.4451	1	2.4451	4.1080*
Age x Sex	2.0670	6	.3445	.5788
Within	422.0132	709	.5952	-
Total	443.8202	722	-	-

*Significant at the .05 level
**Significant at the .01 level

F-max tests over the seven age-level groups of each sex indicate homeogeneity of variance ($P > .05$). All possible comparisons between males show that the grade 2 males have a greater illusion than the kindergarten level males (Appendix, Table L). No significant differences are found between female groups (Appendix, Table M). Comparisons between sexes at each age level find the grade 3 females with a larger illusion than the grade 3 males (Appendix, Table N).

All Possible Comparisons

The use of the All Possible Comparisons technique for testing differences between individual groups seems to find very few such differences significant. This seems especially contradictory considering that all Analysis of Variance tests indicate differences

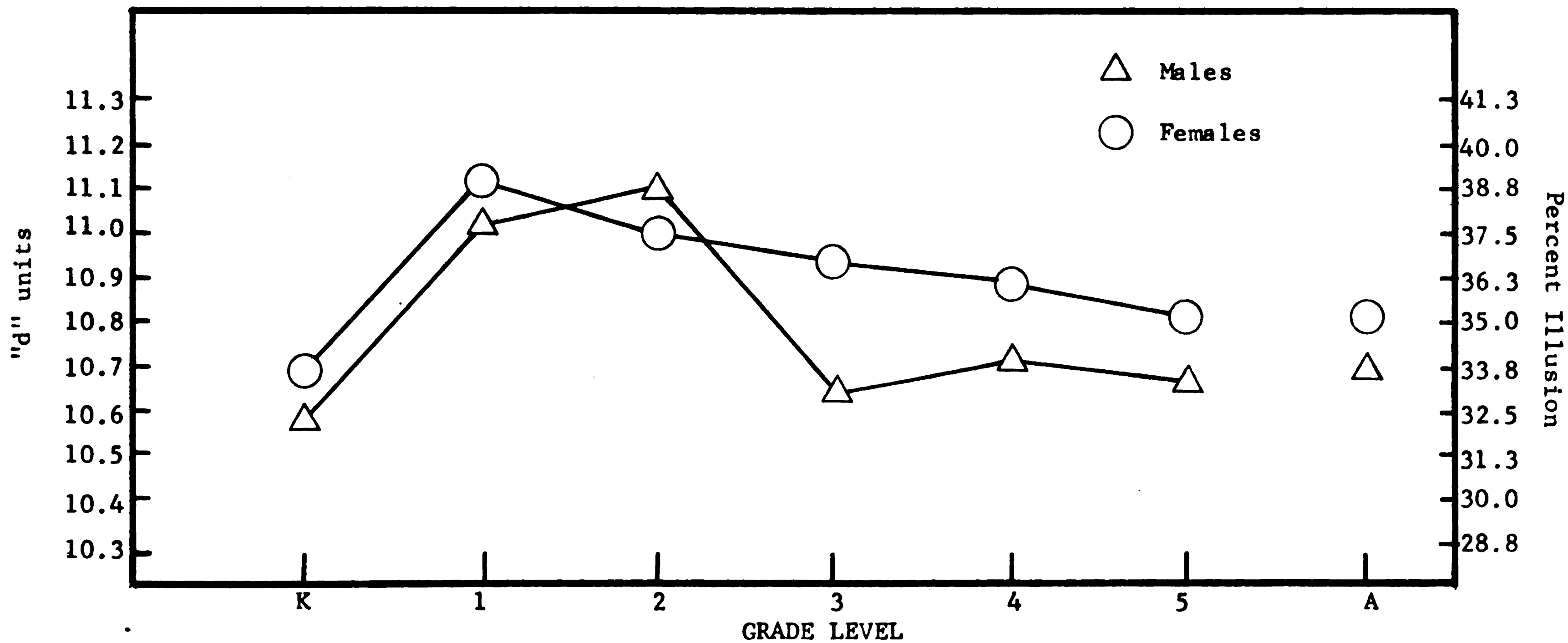

FIGURE 12. The means for the Muller-Lyer Illusion. All means are expressed in terms of "d" units, the interval between test cards. For the Muller-Lyer, the variable line series runs from 7d (1.75 inches) to 13d (3.25 inches). The standard line is 8 "d" units long.

between age levels exceeding the .01 level. The most extreme case is the Muller-Lyer Illusion where although age level differences by the Analysis of Variance test exceed the .01 level, the Individual Comparison tests show only one significant difference. This seems contradictory, but in fact is due to the extreme conservatism of the All Possible Comparisons technique. This test, in order to allow ad hoc all possible comparisons, increases the size of the statistic necessary to reach a given level of significance. Although this keeps the Type I error level at or below the value stated, it increases the Type II error considerably. This results in an extremely conservative test which may overlook many true differences which would be found with less conservative methods. These less conservative techniques might also violate the Type I error level set. In line with the exploratory nature of this research, the Experimenter feels that the All Possible Comparison technique is warranted, although it may overlook some significant comparisons, and serves the primary purpose of this research; to ascertain if the Up-and-Down Method can be used to assess psychophysical variables.

DISCUSSION

Because the major purpose of this research was to explore the utility of the Up-and-Down Method as a technique for obtaining psychophysical data, especially from children, this discussion will be limited to the measurement aspects of the technique. Comparisons will be drawn between developmental trends as measured by earlier techniques and by the present method, and arguments presented for both in detail under each illusion.

The Ponzo Illusion

For a different form of the Ponzo Illusion, Leibowitz and Heisel (1958) report an increase in the magnitude of illusion between the ages of four and seven years, with no later change. Since no statistical analysis is presented, their conclusions appear to be drawn from inspection of their empirical developmental curve. They used small samples of two to 12 subjects over nine age levels from four to 12 years. There appears to be no exploration of sex differences in their report. Their method is an adaption of the method of constant stimuli with each subject exposed several times to the illusion. The trend found in the present study is generally the same as they report. There is a statistical increase in magnitude of illusion between the kindergarten group and the grade 2, 3, 4, and 5 levels. There are no statistical differences among grade 1, 2, 3, 4, 5, and adult levels. However, inspection of Figure 8 reveals a drop in amount of illusion between these elementary school levels and the adult level although this decrease is not statistically significant.

One more point deserves mention. The difficulty in analyzing the results of the Ponzo results, i.e., the indeterminacy of normality for the kindergarten girls and the necessity of using the alternative SD approximation technique, stems from the choice of "d". Although a preliminary study indicated that a "d" unit of 1/8-inch would yield a d/SD ratio within the tolerance limits of the easier SD approximation technique, this interval proved too large. Using a smaller "d" unit, say of 1/10 or 1/12-inch, would have decreased the d/SD ratio to less than 2.00 and enabled the use of the less tedious SD estimation technique. This would also increase the number of points to be plotted, therefore allowing an adequate check of normality.

Modified Ponzo Illusion

Since this illusion was introduced in this study, there are no prior citations concerning it in the literature. Although the illusion is basically the Ponzo rotated 90 degrees and given a horizontal line, the resultant developmental curve is very different. Tests between age levels suggest a decreasing magnitude of illusion with an increase in age although the trend is much more marked with the females insofar as the statistical results. Sex differences are found at several levels indicating, as does inspection of Figure 9, that the females generally see more illusion than the males until the adult levels are reached. However, absolute empirical equality of magnitude of illusion at the adult level does not necessarily insure real equality.

Considering the similarity of the Ponzo and Modified Ponzo as used, the effect of the horizontal cue on the empirical developmental curve, could possibly be assessed by matching the axial orientation of these illusions and comparing the two resulting curves.

The Horizontal-Vertical Illusion

Wohlwill (1960) indicates that the age trends found in earlier studies of this illusion are confusing. The shape of the developmental trend seems to depend on the form of the illusion used, i.e., whether or not the lines intersect. Kunnapas (1955) suggests there are two factors involved: first, the vertical line tends to be overestimated; second, the intersecting line is overestimated. When the vertical line is also the intersecting line, the illusion should be at its maximum. Any other configuration will reduce the amount of illusion. Kunnapas does not, however, discuss what this implies for developmental trends. Wohlwill (1960) tentatively concludes that when the lines intersect, the magnitude of illusion decreases with age (Walters, 1942). The Walters study also indicates consistant sex differences, males having more illusion, although the trends are the same. Wohlwill's second tentative conclusion is that when the lines do not intersect, there is an increase in the amount of illusion to age ten followed by a decrease to the adult level (Wursten, 1947).

For the form of the illusion with intersecting lines, the present study finds sex differences only at the grade 1 and adult levels. With the male groups, there are no age differences from kindergarten to the grade 5 level, but a sharp increase in magnitude of illusion at the adult level (see Figure 10). Examination of the age levels between grade 5 and adult levels would be necessary

to clarify the nature of this increase. No differences are found between the female groups. The trends found in this research differ both in direction and detail from those found by Walters.

The non-intersecting form of the Horizontal-Vertical used in the present study yields highly variable trends. Inspection of Figure 11 shows a relatively small decrease to grade 2 followed by a rise to the adult level for males. The statistical comparisons support the increase from the grade 2 to adult level, but do not corroborate the decrease from the kindergarten to grade 2 level. For the females, the largest amount of illusion is shown for the grade 4 level which is statistically different from the kindergarten, and grade 3 females. There is a decrease from this peak to the adult level. If there is an increase from kindergarten to grade 4 with a subsequent decrease for the females although the former is not indicated in the present study, then the developmental trend is comparable to Wursten's work. However, there is no agreement between Wursten's data and the present curve for males.

A comparison between per cent illusion at each age level and sex shows the form with the intersecting lines displaying a greater relative magnitude of illusion than the non-intersecting form (Appendix, Table O). This supports Kunnapas's contention about the function of the intersect. However, since the sizes of the lines used in the two forms used are not equal, this conclusion is tentative.

The Muller-Lyer Illusion

Probably more work has been completed on the Muller-Lyer illusion than any other illusion employed in this study. Walters (1942) finds that increasing age is accompanied by a decrease in the magnitude of illusion. Most other studies report substantially the same result (Wohlwill, 1960). Walters also reports that the variability of her young subjects is statistically greater than other subjects. The results of the present study disagree. First, there is no statistical evidence indicating differences in variability between the age levels tested. Second, the youngest subjects show the least amount of illusion. Inspection of Figure 12 shows an increase in illusion from kindergarten to grade 2 for males, and from kindergarten to grade 1 for the females. The difference between the kindergarten and grade 2 males is significant. Each sex drops from these peaks. The males reach their smallest illusion at grade 3 and remain lower than the females through the adult levels though not significantly so. Fairly stable levels are reached by both groups by grade 3. They appear to slowly converge, males increasing slightly and females decreasing slightly. The only significant sex difference appears at grade 3.

Although different forms and sizes of the illusions used in this study produce differing amounts of illusion (Kunnapas, 1955, Abshire, 1962), rough comparisons of the magnitude of illusion as measured by psychophysical and Up-and-Down Method techniques can be made. Psychophysical data indicate that different illusions produce different relative magnitudes of illusion. This order in terms of decreasing magnitude, is the Muller-Lyer, the Horizontal-Vertical with Intersect, the Horizontal-Vertical without Intersect, and the Ponzo. The Up-and-Down Method gives the same relative order of magnitude. Also, the percentage of illusion reported for adult subjects using psychophysical measurement techniques (Kunnapas, 1955; Leibowitz and Heisel, 1958; Kohler and Fishback, 1950) are comparable to those shown in the present study, although Up-and-Down Method data seem to indicate slightly more illusion. The major discrepancies between psychophysical and Up-and-Down Method data are at the youngest age levels. Typically, psychophysical data indicate that young subjects have considerably more illusion than is shown by the Up-and-Down Method. This is not surprising considering that the largest effect of the unwanted age-related variables not controlled by psychophysical techniques should occur at the younger ages.

The Up-and-Down Method appears reliable, that is, relatively free from random error. If the subjects had chosen the "longest" line by guesswork, their responses would have generated a "random walk series". A random walk series is characterized by a rectangular distribution with a large variance (Feller, 1950). All the distributions in the present study with the exception of the Ponzo for kindergarten females, appear normal, and all distributions without exception, have variances much smaller than would be expected if they had been much affected by random factors. Also related to the reliability of the data is the fact that small differences in magnitude of illusion between age levels were found to be significant despite the extreme conservatism of the All Possible Comparisons technique. In the case of the Ponzo, differences between age levels of less than five per cent illusion reached significance. The reliability of the means measured by the Up-and-Down Method is demonstrated by their small standard errors.

Although both psychophysical and Up-and-Down Method techniques find age-related differences, the discrepancies between them, especially at the young ages, raise the question of which technique best assesses 'true' developmental trends. This decision might be easier if data over all age levels using the same size and form of illusion for both measurement techniques were available. However, lack of complete data does not preclude a choice on logical grounds. The criticisms Wohlwill makes of psychophysical techniques do not apply to the Up-and-Down Method. There can be no Error of the Standard because for the individual subject there is no identifiable standard. There can be no Starting Position Effect because the subject sees the stimulus card in only one position. A Context or Central Tendency Effect cannot exist with only one stimulus element.

The other criticisms offered in this paper are also overcome or minimized by the use of the Up-and-Down Method. The five-minute total test duration minimizes attention span differences between young and old subjects. The one-exposure-per-subject-per-illusion method of presentation completely circumvents criticisms involving change in amount of illusion through repeated exposure to the same material. The simplicity of choosing one of two fixed lines minimizes the complexity of the procedure, maximizing the comparability of responses over age groups. The greater variability of the responses of children reported by Walters (1942) could easily be due to the effect of any or all of these criticisms. It seems reasonable to assume that the differences between trends reported earlier and those of the present study are because of the effects of these unwanted age-related components.

In conclusion, it has been demonstrated that the Up-and-Down Method is capable of assessing the perceptual development levels of different age groups. Logical considerations suggest that it minimizes or circumvents the criticisms made of standard psychophysical measurement techniques and therefore is a superior assessment tool Although this research has limited the use of the Up-and-Down Method to visual illusions, with a little ingenuity, it should be applicable to many other developmental and psychophysical measurement problems.

SUMMARY

Standard psychophysical techniques, when used to assess Points of Subjective Equality in visual illusions for different age levels, suffer from inherent flaws such as Error of the Standard, Central Tendency or Context Effect and Starting Position Effects. Other criticisms due to the effects of changes in the amount of illusion with repeated exposure and differences in attention span between young and older subjects are applicable to these older techniques. Most of these effects may be related to age and thus confound measurement of Perceptual Development. The Up-and-Down Method minimizes or circumvents these criticisms by using a one-exposure-per-subject technique. Data are presented for five visual illusions and compared to developmental curves found using standard procedures. Reasons for preferring the Up-and-Down Method are discussed.

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APPENDIX

TABLE A. Means and sample sizes for combined sexes at each grade level for the Ponzo Illusion

	Grade Level K	1	2	3	4	5	A
$\bar{X}$	8.922	9.132	9.248	9.326	9.213	9.350	9.180
n	109	106	103	98	101	106	100

TABLE B. The individual comparisons for the composite grade level groups of the Ponzo Illusion. All possible comparisons are indicated. Significance is obtained when the absolute difference between two means equals or exceeds a calculated value. To determine the direction of the difference, refer to Appendix, Table A.

GRADE LEVEL	Grade Level 1	2	3	4	5	A
K	.210	.326*	.404**	.291*	.428**	.258
1	-	.116	.194	.081	.218	.048
2	-	-	.078	.035	.102	.068
3	-	-	-	.113	.024	.146
4	-	-	-	-	.137	.033
5	-	-	-	-	-	.170

TABLE C. The individual comparisons for the Modified Ponzo males. All possible comparisons are indicated. All differences are absolute values. To determine the direction of difference, refer to Table 3.

GRADE LEVEL	Grade Level 1	2	3	4	5	A
K	.230	.133	.168	.190	.191	.370
1	-	.367	.402	.424	.425	.604**
2	-	-	.035	.057	.058	.237
3	-	-	-	.022	.023	.202
4	-	-	-	-	.001	.180
5	-	-	-	-	-	.179

*Significant at the .05 level
**Significant at the .01 level

TABLE D. The individual comparisons for the Modified Ponzo females. All possible comparisons are indicated. All differences are absolute values. To determine the direction of the difference, refer to Table 3.

GRADE LEVEL	Grade Level 1	2	3	4	5	A
K	.066	.010	.339	.382	.236	.679**
1	-	.056	.405	.448	.302	.745**
2	-	-	.349	.392	.246	.689**
3	-	-	-	.043	.103	.340
4	-	-	-	-	.146	.297
5	-	-	-	-	-	.443

TABLE E. The differences between sexes at all age levels for the Modified Ponzo.

	Grade Level K	1	2	3	4	5	A
t	2.247*	1.351	4.109**	1.292	1.022	2.107*	.000
df	51	52	50	47	49	51	49

TABLE F. The individual comparisons for the Horizontal-Vertical with Intersect Illusion males. All possible comparisons are indicated. All differences are absolute values. To determine the direction, refer to Table 3.

GRADE LEVEL	Grade Level 1	2	3	4	5	A
K	.374	.224	.323	.481	.300	.799
1	-	.150	.052	.107	.074	1.173**
2	-	-	.099	.257	.076	1.023**
3	-	-	-	.158	.023	1.122**
4	-	-	-	-	.181	1.280**
5	-	-	-	-	-	1.099**

*Significant at the .05 level
**Significant at the .01 level

TABLE G. The individual comparisons for the Horizontal-Vertical with Intersect Illusion females. All possible comparisons are indicated. All differences are absolute values To determine the direction, refer to Table 3.

GRADE LEVEL	Grade Level 1	2	3	4	5	A
K	.396	.099	.160	.119	.228	.258
1	-	.297	.556	.277	.624	.654
2	-	-	.259	.020	.327	.357
3	-	-	-	.279	.068	.098
4	-	-	-	-	.347	.377
5	-	-	-	-	-	.030

TABLE H. The differences between sexes at all age levels for the Horizontal-Vertical with Intersect Illusion

	Grade Level K	1	2	3	4	5	A
t	1.769	2.273*	1.204	.914	.228	1.148	4.741**
df	51	52	50	47	49	51	49

TABLE I. The individual comparisons for the Horizontal-Vertical without Intersect Illusion males. All possible comparisons are indicated. All differences are absolute values. To determine direction, refer to Table 3.

GRADE LEVEL	Grade Level 1	2	3	4	5	A
K	.145	.376	.064	.138	.008	.628
1	-	.231	.081	.283	.153	.773*
2	-	-	.312	.514	.384	1.004**
3	-	-	-	.202	.072	.692*
4	-	-	-	-	.130	.490
5	-	-	-	-	-	.620

*Significant at the .05 level
**Significant at the .01 level

TABLE J. The individual comparisons for the Horizontal-Vertical without Intersect Illusion females. All possible comparisons are indicated. All differences are absolute values. To determine direction, refer to Table 3.

GRADE LEVEL	1	2	3	4	5	A
K	.248	.520	.055	.821**	.672*	.435
1	-	.024	.193	.573	.424	.187
2	-	-	.217	.549	.400	.163
3	-	-	-	.766**	.617	.380
4	-	-	-	-	.149	.386
5	-	-	-	-	-	.237

TABLE K. The differences between sexes at all grade levels for the Horizontal-Vertical without Intersect Illusion.

	K	1	2	3	4	5	A
t	1.444	.839	2.821*	.938	3.421**	3.505**	2.739*
df	55	52	50	47	48	51	48

TABLE L. The individual comparisons for the Muller-Lyer Illusion males. All possible comparisons are indicated. All differences are absolute values. To determine direction, refer to Table 3.

GRADE LEVEL	1	2	3	4	5	A
K	.448	.515*	.057	.131	.084	.111
1	-	.067	.391	.317	.364	.337
2	-	-	.458	.384	.431	.404
3	-	-	-	.074	.027	.054
4	-	-	-	-	.047	.020
5	-	-	-	-	-	.027

*Significant at the .05 level
**Significant at the .01 level

TABLE M. The individual comparisons for the Muller-Lyer Illusion females. All possible comparisons are indicated. All differences are absolute values. To determine direction, refer to Table 3.

GRADE LEVEL	Grade Level 1	2	3	4	5	A
K	.431	.318	.248	.200	.129	.128
1	-	.113	.183	.231	.302	.303
2	-	-	.070	.118	.182	.190
3	-	-	-	.048	.119	.120
4	-	-	-	-	.071	.072
5	-	-	-	-	-	.001

TABLE N. The differences between sexes at all grade levels for the Muller-Lyer Illusion.

	Grade Level K	1	2	3	4	5	A
t	.850	.772	.858	2.670*	1.764	1.473	1.712
df	51	52	50	47	49	51	49

TABLE O. The comparison between percentages of illusion for each age level and sex of the Horizontal-Vertical with and without Intersect Illusions. The intersecting form of the illusion has a greater percentage of illusion in all fourteen cases.

	Grade Level K	1	2	3	4	5	A
With Intersect Males	17.4	15.0	16.0	15.4	14.4	15.5	22.4
W/out Intersect Males	10.0	9.1	7.7	9.6	10.9	10.1	14.0
With Intersect Females	15.4	12.9	14.8	16.4	14.6	16.8	17.0
W/out Intersect Females	8.5	10.1	10.2	8.9	13.7	12.7	11.3

*Significant at the .05 level
**Significant at the .01 level

INTERVALS | School | Date | Age Range | Testor

ILLUSION

SEX

TOT

TOT