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The effect of vertical angular subtense on accuracy of response to a tachistoscopic recognition task

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Introduction

Tachistoscopic testing and training procedures have geen used in clinical optometry since the late 1930's. Optometric interest in tachistoscopic testing and training was probably started by Professor Samuel Renshaw* in his series of papers and lectures from the 1930's onward through two decades for the Optometric Extension Program. In a review of the clinical literature digit recognition is one of the specific forms of tachistoscopic testing and training that is described. The object of tachistoscopic digit training has been to increase the number of digits a subject could accurately reproduce per exposure.

Our review of the clinical literature reveals that the variables known to affect accuracy of digit recognition have not been systematically controlled in clinical testing. Among the known variables affecting tachistoscopic performance are angular size, style of optotype, illumination, duration of exposure, the subject's refractive state, previous training and the instructional set. Without standardized testing which controls the known variables, any reported improvements are open to question and varied interpretation. Investigation of the effect due to each of the variables is desirable if a standardized test is to be developed.

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We failed in our review of the literature to find any specific studies showing the effect of angular size on tachistoscopic digit recognition. Instead, the literature possesses a wealth of documentation concerning reaction time per number of stimuli -- Hunter (1942)[1], Oberly (1924)[2], Saltzman and Garner (1948)[3], Von Szeliski (1924)[4] and Warren (1897)[5]; number estimates of visual displays -- Fernberger (1921)[6], Jensen, Reese and Reese (1950)[7], Kaufman, Lord, Reese and Volkmann (1949)[8], Minturn and Reese (1951)[9]; number span for successive visual stimuli -- Taubman (1950)[10], and Cheatham and White (1952)[11]; visual span for words and letters -- Gates (1947)[12], Glanville and Dallenbach (1920)[13], Paterson and Tinker (1929)[14], Pillsbury (1897)[15], Renshaw (1945)[16], Sutherland (1946)[17], Weber (1942)[18], and Woodrow (1938)[19]; reading span as a function of interest -- McGinnes (1949)[20], Postman Bruner, and McGinnes (1948)[21], and Solomon and Howes (1951)[22].

This investigation was suggested by Professor Haynes as a necessary first step in developing a standardized testing procedure. A standardized test is necessary if clinicians are to communicate their results on individual patients and to evaluate the results of different forms of visual training.

Problem

This investigation was designed to determine the effects of subtended visual angle on the accuracy of reproducing a five-digit number displayed tachistoscopically. Appraisal of accuracy includes correctness of both content and sequence. The data required analysis in terms of the percent correct per number of exposures as well as a detailed error analysis.

Experimental Design

In order to determine the effect of subtended angular size in tachistopic testing it was necessary to design an experiment which controlled a number of variables known to affect performance under tachistopic conditions. These variables include exposure time, luminance, instruction, optotype, differential letter legibility, stimulus size, preset and practice effect.

The experimental digit span task consisted of four sets of five-digit numbers each of different angular size. The four sizes in Snellen notation were 20/40, 20/80, 20/160, and 20/320. Using a table of random numbers, the four sizes of five-digit displays were assigned a random presentation order. Each set of the four different angular sizes consisted of ten five-digit numbers. The same numerals were used in each of the four sets but were randomized in sequence for each five-digit display. This procedure was used to assure that the task was equally complex for the four different angular sizes, as certain digits are known to be more or less legible than others. Written responses for each exposure were obtained from each subject for the forty displays.

A Keystone tachistoscope serial number 4014 and a Keystone flash-meter number 59243 were used to expose the digital display. The exposure time was controlled by keeping constant the shutter speed on the tachistoscope. A shutter speed of one twenty-fifth (1/25) second was used.

The projection room was open-ended behind the subject with a distant hall light enabling him to see his recording form. Glare from direct lighting was absent. A black shield on the desk eliminated stray light from the projector. The subject was seated three meters from the screen with the projector mounted directly in front of the subject but below his field of view.

Luminance characteristics were measured by a United Detector Technology telephotometer, model 10A with a digital display accessory attached. Using a barium sulfate standard, with reflectance close to unity, the reflectance of the screen was found to be fifty-nine foot-candles. The screen was a poor diffusor due to its glossy surface. Three numerals of the 20/320 Snellen size (from three meters) had the following luminances: The numeral one was one-hundred-six foot lamberts (fL) with a surround of one and four-tenths fL. Detail of the numeral seven was one-hundred-fourteen with a surround of four and one-tenth fL. Luminance of the numeral six was one-hundred-nine with a surround of two foot lamberts. Two numerals of the 20/80 Snellen size (from three meters) were measured. The detail of the numeral eight was measured at ninety-five fL with a surround luminance of six-tenths fL. The numeral three had detail luminance of one-hundred-nineteen fL with a surround of nine-tenths fL.

The following written instruction was read to each subject:

> I will present some groups of four or five digits on the screen in front of you for a short time. You will see them above the line like the examples we will show you. The digits may be of different sizes with each presentation. The presentation will be preceded by the words 'ready' and 'now'. Look at the line as I say 'ready'. Secondly, wait as I call 'now'. The presentation will occur thirdly as a click. After the presentation, write the numerals in the spaces on the sheet provided. If you are not sure, or if you didn't see all of the numbers in the exposure, then write down as many as you can. You are encouraged to guess.

Some of the numbers will be more difficult than others.
Here are some practice numerals you need not record.
Call them aloud.

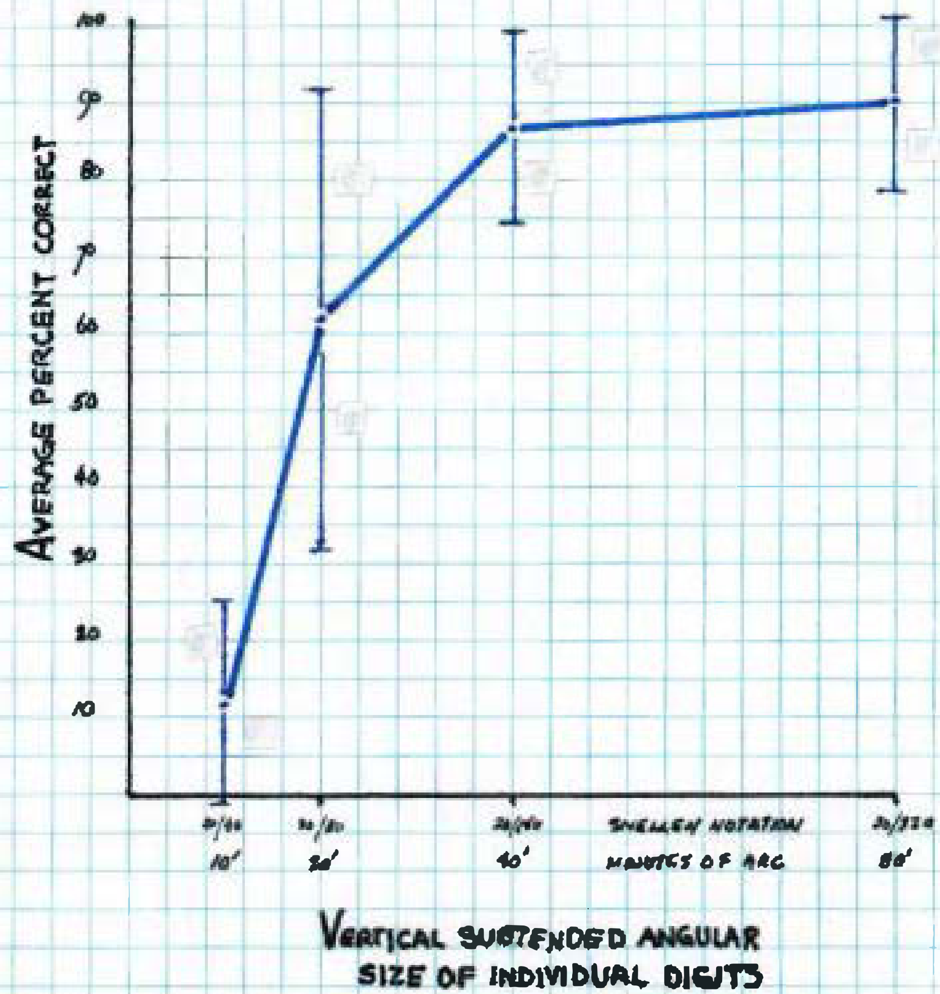
The instruction "You are encouraged to guess" was not used for the first seven subjects. It was inserted to try to reduce the frequency of omissions. This created two groups, Group I and Group II.

The slides were prepared using Letraset (TM) black Futura Bold numerals sizes twelve, twenty-four, forty-eight and ninety-six point. This progression of sizes provided the proper sequence for the finished projection slides. Letraset (TM) is a brand of transfer lettering. Space bars were used to keep spacing constant. The digits were pressed on white printers' proof paper while it was mounted on a prepared easel so that the center digit of the five-digit number would be in the center of the paper and the horizontal center-lines would be equidistant from the adjacent center-lines.

The volunteer subjects were thirty-six male optometry students whose ages ranged from twenty-one to forty-four years. Subjects with less than 20/40 visual acuity at twenty feet were rejected. Visual acuity for the subjects accepted ranged from 20/15 to 20/30- at twenty feet. No subject used in the study had received tachistoscopic training in the past year.

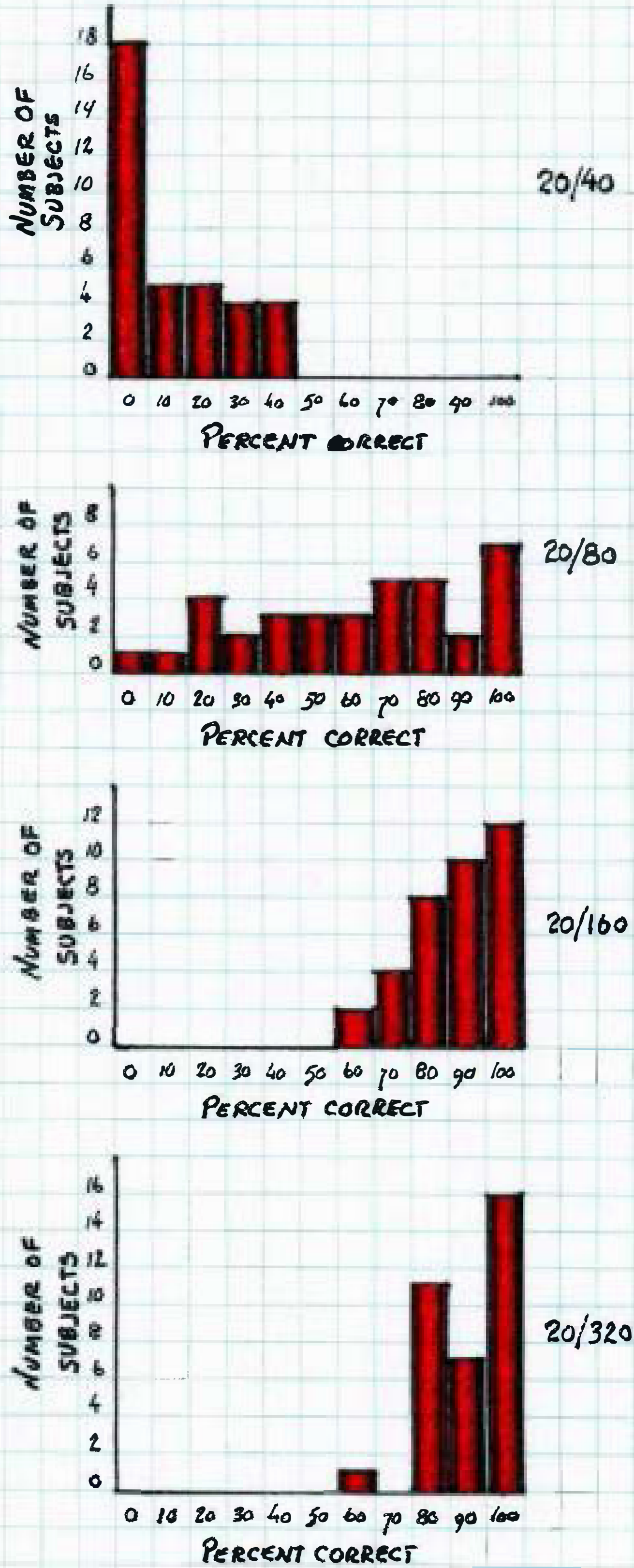
Visual acuity measurements were taken in an adjoining examining room. Acceptable subjects were then brought into the tachistoscopic testing room for the experiment.

GRAPH I



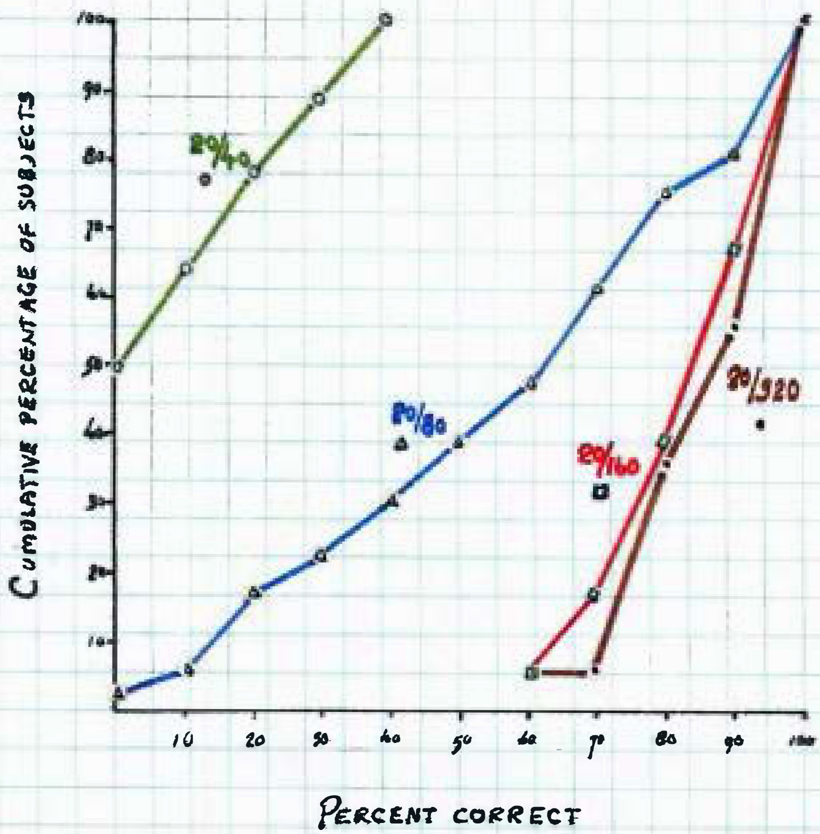
Graph I shows the mean percent correct (---) for each of the four tested vertical angular subtenses (ordinate) plotted against the four angular sizes arranged in a manner proportional to the subtended angle along the abscissa. One standard deviation is shown for each size.

Graph II



Graph II is a frequency distribution of subjects' scores plotted by number of subjects (ordinate) against the percent correct (abscissa) for each of the vertical subtended angular sizes. The distribution of scores for each size digit display is shown in the respective graphs.

GRAPH III



Graph III is a cumulative frequency distribution by percentage (ordinate) plotted against percentage of correct responses (on the abscissa). The effect of vertical subtended angular size on the digit recognition is shown in the four curves respectively.

Table I

	20/40	20/80	20/160	20/320
Average number correct responses per subject	1.2	6.2	8.7	9.0
Total correct digits	43	223	314	323
Mode	0	10	10	10
Median	0.5	7	9	9
Standard deviation	1.31	2.98	1.21	1.14
Total gross errors	327	137	46	38
Percent of exposures (360)	90.7	38.0	12.8	10.5
Total omissions	468	73	13	6
Omissions per exposure (360)	1.30	0.202	0.036	0.017
Percent of possible omissions (1800)	26.0	4.05	0.72	0.33
Total random substitutions	228	83	19	18
Substitutions per exposure (360)	0.64	0.23	0.05	0.05
Percent possible substitutions (1800)	12.7	4.61	1.06	1.00
Total sequence errors	189	101	33	37
Sequence errors per exposure (360)	0.53	0.28	0.09	0.11
Total rotational errors	12	5	3	0
Percent possible rotational errors (468)	2.57	1.07	0.64	0
Total configurational errors	71	23	5	6
Configurational errors per exposure (360)	0.19	0.06	0.01	0.02
Percent possible configurational errors(1656)	4.29	1.39	0.30	0.36
Total elaborations	0	2	0	0

Table I is a distribution of the various types of errors that contributed to an incorrect response. The total of each type, frequency per exposure and percentage per opportunity to err are shown.

Results

Analysis of the data for Group I and Group II containing seven and twenty-nine subjects respectively showed that the change in instruction made no difference in performance. Since no difference was found, the groups' data were combined for all subsequent analyses.

Graph I displays the mean percentage of correct responses plotted as a function of angular size using Snellen notations. Standard deviations are shown at the horizontal marks. The average percentage of correct responses increases sharply up to nearly ninety percent at the 20/160 Snellen size after which point increased size produced a lesser rate of increase in the accuracy of responses. Approximately two-thirds of the population tested were accurate seventy-five percent of the time on the 20/160 Snellen size digits. By contrast, approximately seventy-five percent of the subjects were accurate thirty percent or less of the time on 20/40 size presentations.

Graph II shows the distribution of scores by Snellen size. It is easily seen in the graph that the distribution of scores for the 20/80 size is widely spread. The variance in scores of the 20/80 size from the other angular sizes is statistically significant at the .01 level of confidence.

Graph III was constructed by summing the population frequency percentages from Graph II. The percentage of the population (on the ordinate) who scored a given percent or less (on the adscissa) is shown. For example, one hundred percent of the population scored forty percent or less on the 20/40 size presentations. The nearly straight line with the 20/80 size digits is the result of summing nearly equal increments.

The 20/160 and 20/320 curves are similar in shape and location, demonstrating little difference in performance.

An error analysis of the data is seen in Table I. Any written response not accurate in sequence and content was scored as a gross error. Every numeral within each response was considered and graded as to the type of error. The errors considered were omissions, random substitutions, sequence errors, rotation errors (6-9 and 5-2), configuration errors (5-3, 7-1, 9-0, 3-8, 7-9, 2-7, 6-0, or 2-9) and elaboration (the adding on of digits).

Table I displays the total correct responses (exposures less gross errors), average correct responses per subject, mode, median and standard deviation for each of the sizes used in the testing. The total gross errors is the total of errors for each angular size.

The effect of angular subtense is clearly demonstrated on the rate of omission. The larger angular subtenses had fewer omissions per exposure.

The random substitutions totals for each size decreased with an increase in size as did omissions and gross errors. The total sequence errors also decreased with an increase in size up to the 20/160 size. The 20/320 size showed a slight increase.

In determining the number of rotational errors per possible errors, the total frequency of appearance for the digits six, nine, five and two was counted and used as the number of possible rotational errors. Such errors also decreased with an increase in size.

All the digits could be involved in configurational errors except the digit four. Therefore, five digits times ten exposures less the frequency of appearance of the digit four provides forty-six opportunities for each subject to make a configurational error on each size presentation. The configurational errors also decreased as size increased except that there was a slight increase at the 20/320 size.

Errors of elaboration were interesting. Of three-hundred-sixty exposures, only two elaborations occurred, both on the 20/80 Snellen size, both on the same digit of the same exposure.

Discussion of the Results

Analysis of the data shows that generally all types of errors decreased with an increase in vertical angular subtense. The greatest rate of increase in correct responses occurred at the 20/80 size. Displays of that size also had a significantly greater variance of correct response, indicating a greater spread of scores. It can be concluded from this data that the 20/80 size is most appropriate for testing, as any given subject has an almost equal opportunity for a zero to a one-hundred percent correct score.

The 20/40 size appears to be too small to use for a standardized test. The 20/160 and 20/320 sizes, by contrast, elicited results similar enough that both sizes might be said to be "too big" to spread out the performances. Subtended angular size makes a significant difference in the performances.

A prediction of digit span and grouping responses in timed and untimed visual displays would be of questionable value without specification of subtended visual angle of the task. This experiment suggests that letter and word recognition may be similarly affected.

Suggestions for Further Study

To develop a standardized procedure for tachistoscopic testing and training, other variables need to be investigated. Variables to be investigated for standardization include age, quality of proximal image, degradation of distal image focus, contrast, the effect of black numerals on a white background, exposure duration and different instructions.

Summary

The effect of subtended angular size on a five-digit tachistoscopic recognition task was evaluated on thirty-six male optometry students. Vertical angular subtense was shown to significantly affect the accuracy of the response.

Footnotes

1. W. S. Hunter, "Visually Controlled Learning as a Function of Time and Intensity of Stimulation," Journal of Experimental Psychology, XXXI (July, 1942), 423-429.

2. M. S. Oberly, "The Range for Visual Attention, Cognition and Apprehension," American Journal of Psychology, XXXV (July, 1924), 332-352.

3. I. J. Saltzman and W. R. Garner, "Reaction Time as a Measure of Span of Attention," Journal of Psychology, XXV (April, 1948), 227-241.

4. V. Von Szeliski, "Relation Between the Quantity Perceived and the Time of Perception," Journal of Experimental Psychology, VII (March, 1924), 135-147.

5. M. C. Warren, "The Reaction Time of Counting," Psychological Review, IV (December, 1897), 569-591.

6. S. W. Fernberger, "A Preliminary Study of the Range of Visual Apprehension," American Journal of Psychology, XXXII (January, 1921), 121-133.

7. E. M. Jensen, E. P. Reese, and T. W. Reese, "The Subitizing and Counting of Visually Presented Fields of Dots," Journal of Psychology, XXX (October, 1950), 363-392.

8. E. L. Kaufman, M. W. Lord, T. W. Reese, and J. Volkmann, "The Discrimination of Visual Number," American Journal of Psychology, LXII (July, 1949), 498-525.

9. A. L. Minturn and T. W. Reese, "The Effect of Differential Reinforcement on the Discrimination of Visual Number," Journal of Psychology, XXXI (April, 1951), 201-231.

10. R. E. Taubman, "The Judgment of Visual Number," Journal of General Psychology, XLIII (October, 1950), 195-219.

11. P. G. Cheatham and C. T. White, "Perceived Number as a Function of Flash, Number and Rate," Journal of Experimental Psychology, XLIV (December, 1952), 447-451.

12. A. I. Gates, The Improvement of Reading, (3rd ed.; New York: Macmillan, 1947).

13. H. D. Glanville and K. M. Dallenbach, "The Range of Attention," American Journal of Psychology, XLI (April, 1920), 207-236.

14. D. G. Paterson and M. H. Tinker, "Studies of Typographical Factors Influencing Speed of Reading," Journal of Applied Psychology, XIII (April, 1929), 120-130.

15. W. B. Pillsbury, "A Study in Apperception," American Journal of Psychology, VII (October, 1897), 315-393.

16. S. Renshaw, "The Visual Perception and Reproduction of Forms by Tachistoscopic Methods," Journal of Psychology, XX (October, 1945), 217-232.

17. J. Sutherland, "The Relationship Between Perceptual Span and Rate of Reading," Journal of Educational Psychology, XXXVII (September, 1946), 373-380.

18. C. O. Weber, "Effects of Practice on the Perceptual Span for Letters," Journal of General Psychology, XXVI (October, 1942), 347-351.

19. M. Woodrow, "The Effect of Pattern Upon Simultaneous Letter Span," American Journal of Psychology, LI (January, 1938), 83-96.

20. E. McGinnes, "Emotionality and Perceptual Defense," Psychological Review, LVI (September, 1949), 244-251.

21. L. Postman, J. S. Bruner, and E. McGinnes, "Personal Values as Selective Factors in Perception," Journal of Abnormal and Social Psychology, XLIII (January, 1948), 142-154.

22. R. L. Solomon and D. M. Howes, "Word Frequency, Personal Values, and Visual Duration Thresholds," Psychological Review, LVIII (July, 1951), 256-270.

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