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DEVELOPMENT OF MARKETABLE TYPING SKILL--SENSORY PROCESSES UNDERLYING ACQUISITION.
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THE PROJECT ATTEMPTED TO PROVIDE FURTHER DATA ON THE DOMINANT HYPOTHESIS ABOUT THE SENSORY MECHANISMS UNDERLYING SKILL ACQUISITION IN TYPEWRITING. IN SO DOING, IT PROPOSED TO FURNISH A BASIS FOR IMPORTANT CORRECTIVES TO SUCH CONVENTIONAL INSTRUCTIONAL PROCEDURES AS TOUCH TYPING. SPECIFICALLY, THE HYPOTHESIS HAS BEEN THAT KINESTHESIS IS NOT AVAILABLE FOR USE AT THE START OF LEARNING SUCH A PERCEPTUAL-MOTOR SKILL AS TYPING, BUT THAT IS OCCURS AFTER SOME LEARNING ON THE BASIS OF VISUAL CUES HAS TAKEN PLACE. THIS INFERENCE IS CONFIRMED BY THE RESULTS OF THIS INVESTIGATION IN WHICH 266 SUBJECTS AT 9 WPM TO 108 WPM TYPING SKILL LEVELS, TYPED UNDER VISUAL AND NONVISUAL CONDITIONS. DEPRIVATION OF VISION RESULTED IN SIGNIFICANT AND LARGE INCREASES IN NUMBER OF ERRORS. THE RESULTS UNDERCUT CONVENTIONAL INSTRUCTIONAL INSISTENCE ON TOUCH TYPING AND SUGGEST THE DESIRABILITY OF FREE USE OF VISION EARLY IN LEARNING--(1) AS GUIDANCE FOR MAKING RESPONSES, (2) AS A SOURCE OF CORRECTIVE INFORMATION FOR WRONG RESPONSES AND OF IMMEDIATE REINFORCEMENT FOR CORRECT RESPONSES, AND (3) AS A REDUCER OF THE ANXIETIES AND TENSIONS THAT REPORTEDLY COMMONLY ACCOMPANY EARLY INSISTENCE ON NONVISUAL WORK. THE EXTENT TO WHICH THESE FINDINGS MAY BE PARALLELED FOR OTHER PERCEPTUAL-MOTOR SKILLS REMAINS TO BE INVESTIGATED. (GD)

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DEVELOPMENT OF MARKETABLE TYPING SKILL: SENSORY PROCESSES UNDERLYING ACQUISITION

Division of Adult and Vocational Education Project
No. 5-8434

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A REPORT OF THE OFFICE OF RESEARCH AND EVALUATION

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PROBLEM

Concerning the sensory processes that underlie the acquisition of perceptual-motor skills, there is thought to be decreasing reliance on exteroceptive stimuli (i.e., vision) and increasing utilization of kinesthetic cues (muscular sensations) as skill is acquired. Specifically, the hypothesis has been that kinesthesis is not available for use at the start of learning a new perceptual-motor skill but that it comes into play after some learning on the basis of visual cues has taken place.

On the one hand, while a number of earlier studies have furnished support for the existing hypothesis, nothing is yet known about the extent of utilization of kinesthetic cues at progressive stages of skill. If, as performance becomes habitual, proprioceptive feedback or "feel" becomes more important than vision, then estimates of kinesthetic dependability at various skill levels should show kinesthesis to be at low levels among beginners, but rising thereafter--thus furnishing a test of the hypothesis.

On the other hand, the particular skill selected for investigation--ordinary copying at the typewriter--happens to be one in which conventional instructional procedures, consisting of a heavy insistence on so-called "touch" typewriting from the start of learning, flatly contradict the existing hypothesis and the accumulation of evidence from earlier studies, which show slow acquisition and high error rates when working without visual guidance. If kinesthetic sensations have little dependability at the start of learning, then the beginning typist who is asked to work without vision is denied guidance for making responses, corrective information about wrong responses, and sufficiently prompt reinforcement for correct responses. The consequence is to slow the rate of acquisition in a skill for which there is widespread occupational and personal use.

The problem, therefore, is the twofold one of providing further data on the dominant hypothesis about the sensory mechanisms underlying skill acquisition and, in so doing, to furnish a basis for important correctives to conventional instructional procedures for a skill in widespread use. In addition, insofar as typewriting may be taken as a sample from a class of perceptual-motor skills (ones involving serial action, ballistic movements, self-paced responses, and chaining of responses), findings should have general applicability to skills of that class.

OBJECTIVES

The major objectives of the present study bear on (a) the sensory processes involved in the acquisition of perceptual-motor skills and, in turn, on (b) the derivation of instructional procedures for a particular skill in widespread use. Specifically, the intent was:

1. To estimate the extent of dependability of kinesthetic cues at successive levels of typing skill and, with the resulting data,

   a. To test the hypothesis of increasing dependability of kinesthetic cues as skill is acquired, and

   b. To estimate the relationship between skill level and extent of dependable kinesthetic feedback.

2. To estimate the extent of dependable all-senses feedback at successive levels of typing skill and to assess the differences between extent of dependable all-senses feedback and extent of dependable kinesthetic feedback.

3. To estimate the effects on performance (speed and errors), at successive levels of typing skill, of visual deprivation.

Several ancillary purposes were served by the data generated by the major purposes, namely,

4. To estimate relationships among performance variables and between performance variables and work conditions.

5. To determine what, if any, types of typing errors vary with skill level under visual and nonvisual work conditions.

RELATED RESEARCH

The related literature bears on three issues: (a) analysis of the skill acquisition process in typewriting, (b) psychological data on visual and kinesthetic cues in perceptual-motor skills, and (c) correlational data on performance variables and error-analysis data that have implications for training and for testing ordinary copying skills.

Skill Acquisition Process in Typewriting

Following the lead of the classic Bryan and Harter studies of the acquisition of the telegraphic language (1897, 1899), Book (1908), in his pioneering inquiry into the acquisition of typing skill, hypothesized a hierarchy of stroking habits corresponding to language units. Book mentioned the introspective reports of his very few subjects to the effect that they often "felt" that a motion was right or wrong as the case may be --thus recognizing the operation of kinesthetic cues. But no empirical evidence was offered about the extent or accuracy of use of kinesthetic cues as skill was acquired. Book dealt with the size of the perceptual and response units as skill was acquired, but not with the sensory processes underlying acquisition. Continuously since then, such writers on typewriting as Blackstone (1949), Dvorak, et al. (1936), Russon and Wanous (1960), West (1957), et al. have referred to the "feel of the motion," but they offered no specific data because none was available.

Psychological Data on Sensory Mechanisms

In the meantime, psychological research on sensory mechanisms in "place learning," in learning one's way about a novel environment, has been furnishing pertinent data. Representative studies (Carr, 1927; Koch and Ufkess, 1926; Zigler, 1932) are among many which showed great difficulty, high error rates, and slow acquisition rates among the blind and among sighted subjects working with the eyes closed--mostly on maze learning tasks. Most pertinently, Carr (1927) reported 30-95 errors in a maze learning task by subjects who were allowed various numbers of visually guided trials before nonvisual trials, but a mean of 201 errors by a group with no earlier visually guided trials.

In a direct attempt to assess the role of kinesthesis (but not to measure its extent during the course of acquisition), Honzik, through surgical procedures cumulatively deprived groups of rats of vision, hearing, and smell (singly and in combination)--leaving kinesthetic-tactile cues intact --and concluded from their maze running performance "not that kinesthesis has no function in learning, but that an act cannot be learned by kinesthesis alone. It is probable that only after learning on the basis of exteroceptive stimuli [i.e., vision] has begun can kinesthetic impulses begin to take some part in the perfecting of the habit" (Honzik, 1936, p. 56).

Fitts later stated the hypothesis under investigation here, namely: "Visual control is very important while an individual is learning a new perceptual-motor task. As performance becomes habitual, however, it is likely that proprioceptive feedback or 'feel' becomes the more important" (Fitts, 1951, pp. 1323-1324). As an indication of the paucity of direct data on this issue, Fitts did not accompany this hypothesis with citation of specific data.

Fleishman and Rich (1963) also pointed to the general paucity of relevant data and quoted Fitts' hypothesis. Working within the framework of their "ability-skill paradigm," Fleishman and Rich showed that subjects who have superior sensitivity to kinesthetic cues (as measured by a kinesthetic sensitivity test developed by them) were superior to other subjects at advanced stages of learning a two-hand coordination task, but not at initial stages of learning this task. Conversely, significant superiority on the criterion task was found early, but not late, in learning for those high on an earlier measure of spatial sensitivity. While these findings furnish suggestive support for Fitts' hypothesis, the Fleishman-Rich rationale was that of correlating different aptitudes (spatial and kinesthetic) with performance on a pursuit task involving an irregularly moving target. The specificity of fine motor skills has been well established (Seashore, 1951), and the typewriting task selected for present investigation is, as contrasted with the two-hand coordination task, a serial action task involving ballistic motions. Further, it is self-paced rather than externally paced. In any event, the present investigation is directed at a different question: the extent of the hypothesized shift from dependence on exteroceptive toward dependence on proprioceptive stimuli as skill is acquired.

Typewriting Performance Variables

As represented in a number of current typewriting textbooks, there are two opposed rationales for building ordinary copying skill: concurrent versus separate development of increasing speed and higher accuracy. Existing speed-accuracy correlational data, as summarized by West (1957), show typically near-zero correlations between speed and errors. This suggests that the factors underlying speed and accuracy at the typewriter have little overlap and, therefore, that separate training must be offered. However, each of these earlier studies was confined to a fairly narrow range of skill, whereas the present investigation is the first to provide data across the entire range of skill, holding test content and conditions constant.

Earlier studies, summarized by West (1957), also show very high reliability for measures of stroking speed, but low to moderate reliabilities for measures of stroking errors: the latter varying with skill level, test length, test content, intertest interval, and conditions of administration. Again, the present investigation provides reliability data across the entire range of skill for quite novel conditions of work, thus adding to the body of information on score reliability.

Tactics for improving stroking accuracy have largely been based on numerous error analyses (summarized by West, 1957) and have been predicated on the supposition that there exist appropriate preventive and remedial exercises for each kind of error. The fact that nearly nothing that has been tried by way of error reduction has proven successful (West, 1957) suggests that the supposition underlying conventional accuracy improvement practices is unsound and/or that the real causes (and relevant cures) for inaccuracy have yet to be identified. In any event, the present investigation provided data on one kind of error that furnishes a test of the conventional supposition.

PROCEDURES

Subjects. Of a total N of 266 typists, ranging in skill from 9 through 108 wpm (words per minute), all but 10 of the 224 Ss at skill levels between 9 and 74 wpm were students in 11 intact typing classes, taught by 8 different instructors, in 4 different high schools and colleges. Of the remaining 42 Ss (at 75-108 wpm skill levels), most were employed typists, a few were typing teachers, and a few were finalists in a national contest for high school typing champions. The relevant population is one of levels of typing skill (as measured by gross stroking speed in ordinary copy work under normal conditions); and the sample data are in terms of skill level and not in terms of stage of training or amount of work experience.

Design. All Ss typed under each of three conditions, in turn:

Condition 1: Normal, i.e., under the conventional and familiar instructions to follow the copy word by word. This condition provided the basis for classification of Ss according to skill level.

Condition 2: Under instructions to space once and retype instantly any word thought to have been mistyped, before continuing with the next word.

Condition 3: Under the same special instructions as for Condition 2, but deprived of visual reference to the typewriter or to the typescript produced.

These three work conditions are referred to hereafter as Condition 1 (normal), Condition 2 (Visual, i.e., all-senses), and Condition 3 (Non-visual, i.e., kinesthetic). The design is not orthogonal. The absence of a fourth condition (visual deprivation, but without instructions to retype in the case of sensed error) was due to the inability of teachers to make sufficient class time available to the investigator. Accordingly, this study does not provide a pure measure of the effects on performance of visual deprivation. Instead, Condition 2 furnished a measure of all-senses feedback and a means of accounting for that part of Condition 3 behavior attributable to the novel instructions to retype in the case of error. That is, Conditions 2 and 3 provided estimates of the effects of visual deprivation, holding constant the novel instructions to retype.

Test Content and Administration. Test copy consisted of three different sets of ordinary prose (approximately 875 words in each set), composed so as to be of equivalent difficulty as measured by syllabic intensity (mean number of syllables per word). Specifically, since a syllabic intensity of 1.40 is conventionally taken to represent average difficulty of copy materials for vocational typists, each successive 100 dictionary words of copy contained 140 syllables. Test copy was used in counterbalanced order across conditions within typing skill levels. Instructions to Ss under all three conditions were to type at their ordinary rates, aiming at their best overall performance, giving due account to speed and accuracy. Under Conditions 2 and 3, Ss were in addition urged to "try to 'catch' (as demonstrated by retyping) as many of the errors you do happen to make as you possibly can." Further, a sample of typescript containing every class of typing error, with appropriate retyping, was examined by Ss before the work session, as an illustrative model. Also, to reduce novelty effects, Ss were given a minute or two of unscored practice just before formal work under Conditions 2 and 3. Finally, with 10 exceptions, each S worked at his own accustomed typewriter.

For those Ss who were students in training, Conditions 1 and 2 were administered in that order during one class period, with appropriate rest between the two. Condition 3 was administered in class the next day. For those Ss who were employed typists, all three work conditions were administered the same day, in 1-2-3 order, and with appropriate rest between work sessions. Test-condition order was deliberately not counterbalanced in order (1) to maximize the reliability of the basis for classification of Ss according to skill level and (2) to provide maximum experience with retyping of errors prior to working under nonvisual conditions. Each of the three work conditions involved 12 continuous minutes of typing. To preclude interruption during the work session for changing paper in the machine, paper of sufficient length was cut from teletype rolls.

Apparatus.--Deprivation of vision (under Condition 3) was accomplished by means of a paperboard shield, weighing 9-1/2 ounces. An adjustable neck halter and waist strap provided for individual differences in body build and in visual acuity, while holding the shield stably in place, yet entirely blocking Ss' view of the typewriter and of the typescript, but permitting free movement of the hands beneath the shield for operating the typewriter. Stimulus materials (printed in double column on an 8-1/2" x 11" page) were tacked to the upper surface of the shield in any position desired by the typist. Routine inquiry of all Ss as routinely elicited their report that the shield was comfortable and stable and freely permitted operation of the typewriter.

Data and Analysis.--Data consist of measures of speed (gross wpm) and of total errors under each of the three work conditions, as well as--under Conditions 2 and 3--of "applicable errors" (those amenable to kinesthetic feedback, excluding, for example, incorrect word divisions or the omission of words or lines in the copy). Level of dependable feedback under Visual (all-senses) and Nonvisual (kinesthetic) conditions is defined as the per cent of "applicable errors" followed by immediate retyping, including the very occasional retyping of words that had not originally been mistyped. The 266 Ss were classified (on the basis of their speed under the normal work procedures of Condition 1) into ten 10-wpm skill ranges, but with unequal Ns in each skill range. To permit finer analysis and the drawing of inferences about the entire range of typing skill, two equal-frequency samples were drawn at random from the original pool of 266 Ss: one for N = 189 (21 from each of nine 10-wpm skill ranges--combining the top two ranges into one); the other, for N = 168 (42 from each of four 25-wpm skill ranges).

RESULTS AND DISCUSSION

Results are presented, in turn, for (a) the hypotheses concerning kinesthetic feedback (and in relation to all-senses feedback), (b) effects of visual deprivation on typewriting performance, and (c) correlational data on performance variables plus error-analysis information.

Sensory Feedback

Results on the separable issues of the hypothesized increase in dependability of kinesthetic cues as skill is acquired and on differences between kinesthetic and all-senses feedback are presented in turn.

Increase in Kinesthetic Dependability. With dependable kinesthetic feedback defined as the proportion of "applicable errors" (those amenable to muscular sensations) in fact followed by immediate retyping under visual and nonvisual conditions, means, standard deviations (in parentheses), and Ns (circled) for N = 266 (distributed unequally among ten 10-wpm skill ranges, are displayed in Figure 1, page 11.

Descriptively, it is apparent from the solid line of Figure 1 that there was a sharp rise from low levels of kinesthetic feedback among novices. However, the long plateau thereafter was not anticipated and may or may not be characteristic of other skills. The surprisingly low (50 per cent) levels of dependable kinesthetic feedback among extremely skillful (100-wpm) typists contradicts and shows to be a delusion the common self-report by such typists that they "nearly always" know when they make an error because it "feels" wrong. The skillful typist is apparently simply not aware of the frequency with which he steals corner-of-the-eye glances at keyboard and/or typescript as guidance for responses and for ascertaining their correctness or incorrectness.

Stratification into ten 10-wpm skill ranges was arbitrary; there was no basis for anticipating increases in dependable kinesthetic feedback accompanying 10-wpm increments in typing skill. A less molecular treatment of the data is displayed in Figure 2, page 12, which is for 168 typists (drawn at random from the original 266 Ss), distributed equally among four 25-wpm skill ranges.

As compared with the Figure-1 curve for feedback under nonvisual conditions, the Figure-2 curve for the same variable is, inevitably, smoother; but it displays the same sharp early rise from a low level, the same small increments thereafter, and the same low levels (in an absolute sense) even among very skillful typists.

The losses in dependable feedback when typists were deprived of vision are directly observable in the differences between visual and nonvisual feedback percentages in Figures 1 and 2, namely, (Figure 1) about a one-third loss for 9-14 wpm typists, about a one-fourth loss for 15-84 wpm typists, and about a one-sixth loss for 85-108 wpm typists.

Turning now to analyses of these descriptive data, on the question of the hypothesized rise in dependable kinesthetic feedback with increases in

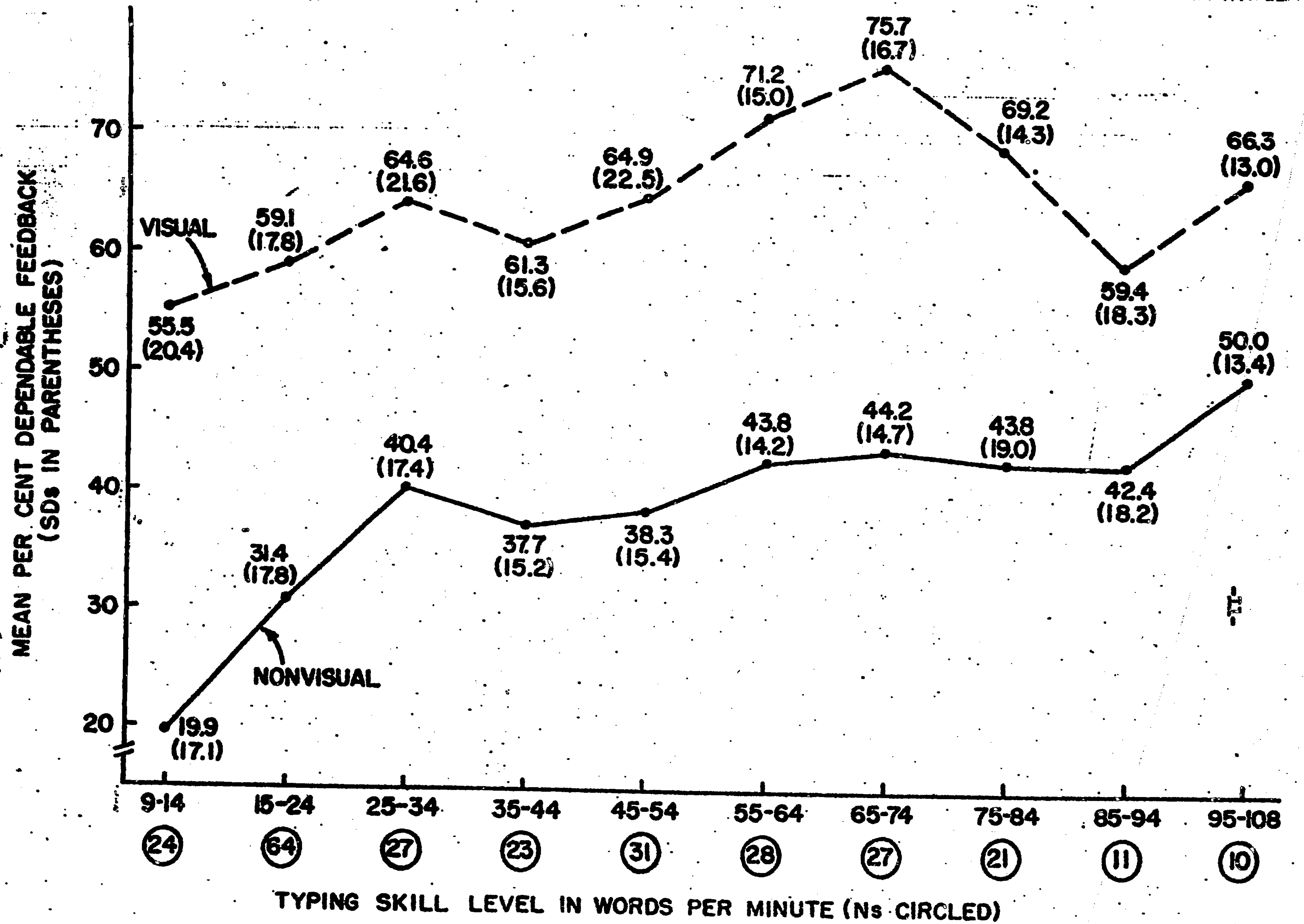

Figure I. Per Cent Dependable Visual and Nonvisual Feedback (Means and SDs) By Level of Typing Skill for 10-wpm Skill Ranges

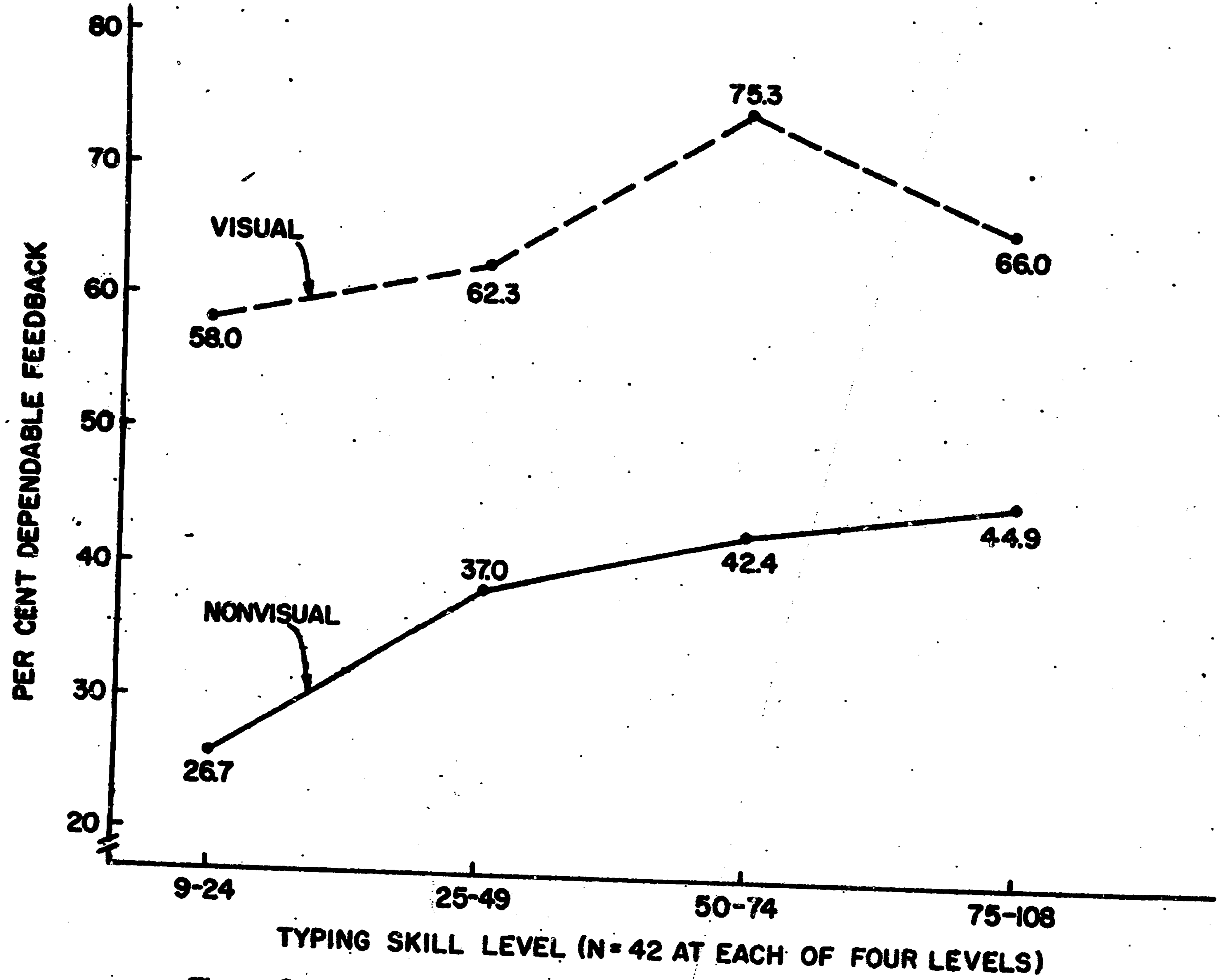

Figure 2. Per Cent of Dependable Visual and Nonvisual Feedback By Level of Typing Skill for 25-wpm Skill Ranges

skill, analyses of variance for N = 189 (21 Ss from each of nine 10-wpm skill ranges, combining 85-108 wpm in one range) and for N = 168 (42 Ss from each of four 25-wpm skill ranges) are shown in Table 1.

Table 1

Analyses of Variance for Extent of Dependable Kinesthetic Feedback Among Nine and Four Typing Skill Ranges

(Ns per range = 21 and 42)

Source	Nine Ranges			Four Ranges		
	df	MS	F	df	MS	F
Between skill ranges	8	1468.47	5.283[a]	3	2718.71	10.735[a]
Within skill ranges	180	277.97		164	253.25	
Total	188			167		

[a] $p < .001$.

Following the significant F for dependable kinesthetic feedback (Table 1) and confirming what is more or less apparent from the nonvisual feedback data of Figure 1 (for N = 266)--but for the subsample of 189 Ss--Tukey's significant gap test showed the differences in dependable feedback to lie between the 9-14 wpm typists and each of the other more advanced skill levels and between 15-24 wpm typists and those above 55-wpm levels ($p < .05$). No other significant inter-skill level differences were found. Similarly, for the subsample of 168 Ss, 9-24 wpm typists differed from each of the more advanced groups, while 25-49 wpm typists differed significantly from those above 75-wpm levels ($p < .05$). The hypothesis of a significant rise in dependability of kinesthetic feedback from low levels among beginners is thus confirmed; but it is equally clear that there is no further significant rise in utilization of kinesthetic cues once moderate levels of typing skill have been reached. The curve for utilization of kinesthetic cues as a function of typing skill level is essentially negatively accelerated.

Kinesthetic versus All-Senses Feedback. For the data of Figures 1 and 2 (Ns of 266 and 168), analyses of variance are shown in the lower and upper halves, respectively, of Section I of Table 2, page 14.

Table 2

Analyses of Variance for I. Visual and Nonvisual Feedback, II. Applicable Errors, III. Total Errors, and IV. Speed: Among Four Equal-Frequency and Ten Unequal-Frequency Typing Skill Ranges

(Ns = 168 for four ranges and 266 for ten ranges)

Source	Conditions 2 and 3					Conditions 1, 2, and 3				
		I Feedback		II Applic. Err.			III Total Err.		IV Speed	
(N=168)	df	MS	F	MS	F	df	MS	F	MS	F
Conditions (C)	1	64186.71	287.28[c]	18990.11	93.22[c]	2	12305.82	62.25[c]	1783.76	185.92[c]
Range (R)	3	4352.67	11.02[c]	565.05	1.19	3	2138.65	2.31	105874.20	648.22[c]
Ss within R	164	395.04		475.51		164	925.50		163.33	
C x R	3	626.57	2.81[a]	325.54	1.60	328	644.25	3.26[b]	106.05	11.05[c]
C x Ss within R	164	223.43		203.71		6	197.67		9.59	
Total	335					503				
(N=266)										
Conditions (C)	1	3262.48	187.22[c]	937.63	62.14[c]	2	682.27	31.08[c]	105.75	131.69[c]
Range (R)	9	90.68	5.22[c]	19.28	1.28	9	28.96	1.32	2515.66	3132.83[c]
C x R	9	17.13		14.45		18	23.13		2.18	
Error	512	17.37		15.09		768	21.95		.80	
Total	531					797				

Note.--For the analyses for N = 168 (top half of table) the error term for Conditions and for C x R is C x Ss within R. For Range, the error term is Ss within R. For the analyses for N = 266 the residual variance (Error) is the error term for Conditions and for Range.

[a] $p < .05$.

[b] $p < .01$.

[c] $p < .001$.

As shown for level of dependable feedback under visual (i.e., all-senses) and nonvisual (i.e., kinesthetic) work conditions, condition effects were highly significant, and for each of the ten (and four) skill ranges. Significant interaction between work conditions and skill range was also found for the 4-range, but not for the 10-range sample. The general trend toward narrowing of visual-nonvisual feedback differences appears with broad, but not with narrow, grouping according to skill.

Effects of Visual Deprivation on Typewriting Performance

Effects of visual deprivation on applicable errors (those amenable to kinesthetic feedback), total errors, and speed are discussed in turn.

Applicable Errors. Applicable-error means for each skill range and differences in means as between visual and nonvisual conditions are shown in Table 3.

Table 3

Mean Number of Applicable Errors Under Visual and Nonvisual Work Conditions (By Skill Level)

Skill Level (Gross wpm)	N	Mean Number of Errors: Condition 2 Visual w/Retyping	Mean Number of Errors: Condition 3 Nonvisual w/Retyping	Increase Nonvis. - Visual: No.	Increase Nonvis. - Visual: %
9- 14	24	18.17	41.38	23.22	127.9
15- 24	64	18.89	34.27	15.38	81.4
25- 34	27	26.26	39.26	13.00	49.5
35- 44	23	26.22	41.17	14.95	57.0
45- 54	31	23.55	43.19	19.64	83.4
55- 64	28	23.86	32.14	8.28	34.7
65- 74	27	22.59	37.67	15.08	66.8
75- 84	21	21.91	35.91	14.00	63.9
85- 94	11	21.27	28.27	7.00	32.3
95-108	10	23.20	29.60	6.40	27.6
	266				
Grand Mean[1]	189	23.27	37.28	14.02	60.25

[1] These are based on a randomly selected 21 persons from each of 9 skill levels, combining 85-108 wpm into one cell.

Applicable errors, as is apparent from comparison with total-error data (Table 4), made up more than 90 per cent of all errors; most typing errors are amenable to kinesthetic feedback. As shown in Table 3, visual deprivation was accompanied by very substantial (60 per cent) increases in such errors. Specifically, the extreme right-hand column of Table 3 suggests classification of typists into three groups with respect to effects of visual deprivation on the frequency of errors amenable to kinesthetic feedback: very large effects on typists at 9-24 wpm levels, intermediate effects on 25-84 wpm typists, and markedly smaller (but decidedly nontrivial) effects on 85-108 wpm typists.

Analyses of variance for applicable errors are shown in Section II of Table 2, page 14. As with the feedback analyses of Section I, condition differences for applicable errors were highly significant. The absence of significant range effects (and of interaction) is implicit in the essentially "plateau-ish" character of the differences in condition means for those across the broad 25-84 wpm range mentioned earlier (extreme right-hand column of Table 3).

<u>Total Errors</u>. Means for total errors under each of the work conditions, by skill range, and differences between total-error means for Conditions 2 and 3, are shown in Table 4, page 17.

The inferences to be drawn from Table 4 parallel those for applicable errors, namely, the approximate classification of typists into three groups: large effects for those at the lowest levels of skill (9-14 wpm), intermediate effects for those at 15-84 wpm levels, and smaller (but nontrivial) effects on 85-108 wpm typists. Averaged for all <u>S</u>s, instructions to retype in the case of error (Condition 2) brought about a 34 per cent reduction in errors from those made under normal conditions. The effect of the novel instructions to retype (as suggested by the data of Table 5) was to bring about a slight reduction in speed, resulting in lower error frequencies. Visual deprivation, on the other hand, led to a 56 per cent increase in errors over visual typing--holding retyping instructions constant--while not significantly affecting speed.

Analyses of variance for total errors are shown in Section III of Table 2, page 14. Although there was no significant interaction between work condition and range for the 10-range sample, for the 4-range sample, interaction was significant ($p < .01$). That is, differential effects of the work conditions on errors made by those at various skill levels did

Table 4

Total-Error Means Under Each of Three Work Conditions and Gain in Mean Errors Between Visual and Nonvisual Conditions, by Skill Level

Skill Level (Gross wpm)	N	Mean Number of Errors			Increase Nonvis.-Visual	
		Condition 1 Normal	Condition 2 Visual w/Retyping	Condition 3 Nonvisual w/Retyping	No.	%
9- 14	24	26.79	20.12	43.08	22.96	114.1
15- 24	64	32.98	20.80	35.78	14.98	72.0
25- 34	27	43.78	28.00	40.78	12.78	45.6
35- 44	23	42.65	28.78	44.08	15.30	53.2
45- 54	31	40.42	26.64	46.26	19.62	73.6
55- 64	28	36.89	26.61	46.79	20.18	75.8
65- 74	27	41.07	25.30	41.11	15.81	62.5
75- 84	21	38.33	24.10	40.19	16.09	66.8
85- 94	11	51.27	24.18	32.18	8.00	33.1
95-108	10	41.00	25.40	32.60	7.20	28.3
	266					
Grand Mean[1]	189	39.27	25.74	40.10	14.36	55.8

[1] These are based on a randomly selected 21 persons from each of 9 skill levels, combining 85-108 wpm into one cell.

not vary with the finer 10-wpm grouping according to skill level, but were revealed in the broader 25-wpm grouping. The highly significant condition effects, on the other hand, were followed by application of Tukey's significant gap test for pairs of treatment differences. Differences significant at the .001 level were found between Conditions 1 and 2 and between Conditions 2 and 3. The reduction in errors brought about by instructions to retype was nearly equal to the increase in errors accompanying subsequent deprivation of vision; accordingly, Conditions 1 and 3 did not differ significantly.

Speed. Speed means for each of the three work conditions and differences between visual and nonvisual treatment means are displayed in Table 5, page 18.

Table 5

Mean Gross Words Per Minute Under Each of Three Work Conditions and Difference Between Conditions 2 and 3, by Skill Level

Skill Level (Gross wpm)	N	Mean Gross Words Per Minute: Condition 1 Normal	Condition 2 Visual w/Retyping	Condition 3 Nonvisual w/Retyping	Difference Betw. Means Conds. 2-3
9- 14	24	12.12	11.25	11.54	- .29
15- 24	64	18.95	16.56	15.80	.24
25- 34	27	28.85	23.78	24.26	- .48
35- 44	23	39.44	34.83	33.78	1.05
45- 54	31	48.87	43.45	41.87	1.58
55- 64	28	59.36	53.29	52.14	1.15
65- 74	27	70.96	63.63	61.63	2.00
75- 84	21	79.71	74.43	71.00	3.43
85- 94	11	88.18	82.00	79.82	2.18
95-108	10	100.70	96.60	93.00	3.60
	266				
Grand Mean[1]	189	50.30	45.50	44.46	1.04

[1] These are based on a randomly selected 21 persons from each of 9 skill levels, combining 85-108 wpm into one level.

It is apparent (from the grand means shown in Table 5) that instructions to retype had a larger (negative) effect on speed than did deprivation of vision. This inference was substantiated by Tukey's significant gap test for pair differences, following the finding of highly significant condition effects in variance analysis (Table 2, Section IV). Significant pair differences (at the .001 level) were found between Conditions 1 and 2 and between Conditions 1 and 3, but not between Conditions 2 and 3.

Feedback and Performance Data Summarized

Table 6 furnishes a convenient summary of the data thus far presented. As contrasted with the earlier tables of means and differences between means, the data of Table 6 are means of differences. For example, for each

Table 6

Mean Performance Differences Among Three Work Conditions, by Skill Level

(Work Conditions: 1 = Normal; 2 = Visual, w/Retyping; 3 = Nonvisual, w/Retyping)

Skill Level (Gross wpm)	N	Means of Difference Scores Between Pairs of Work Conditions								
		Speed			Total Errors			Applicable Errors	Uncorrected Errors	Per Cent Feedback
		1-2	1-3	2-3	1-2	3-1	3-2	3-2	3-2	2-3
9 - 14	24	1.0	.8	- .3	6.7	16.3	23.0	23.2	25.7	35.6
10 - 24	64	2.4	3.1	.6	12.2	2.8	15.0	15.4	15.2	27.7
25 - 34	27	5.1	4.6	- .4	15.8	- 3.0	12.8	13.0	11.6	24.2
35 - 44	23	4.6	5.5	1.0	13.9	1.5	15.3	15.0	14.2	23.6
45 - 54	31	5.4	6.9	1.5	13.8	5.8	19.6	19.6	15.7	26.6
55 - 64	28	6.1	7.3	1.1	10.3	- 2.2	8.1	8.3	7.8	27.4
65 - 74	27	7.5	9.6	2.0	15.8	.0	15.7	15.1	12.2	31.6
75 - 84	21	5.4	8.2	3.5	14.2	1.9	16.1	14.0	10.2	25.4
85 - 94	11	6.3	8.3	-2.0	27.1	19.1	8.0	7.0	5.1	17.1
95 - 108	10	4.0	7.6	3.5	15.6	- 8.4	7.2	6.4	4.5	16.3
	266									
Mean of Means		4.8	6.2	1.0	14.5	3.4	14.1	13.7	12.2	25.6

of the 24 typists in the 9-14 skill range, his speed under Condition 2 was subtracted from his speed under Condition 1, and the mean of these 24 difference scores was taken and found to be 1.0 wpm. All of the data of Table 6, page 19, were computed in that fashion, with results and implications that match those for the earlier tables.

Correlational Data

Correlational evidence for the feedback and performance variables confirm the earlier findings about means. For the equal-frequency subsample of 189 typists (21 from each of nine skill ranges), the data are shown in Table 7, page 21, for the nine ranges individually and for the entire 189 typists.

As shown in Table 7 (row 4b), r = .36 was found between typing skill (gross wpm under normal conditions) and per cent of dependable nonvisual feedback (Condition 3). There was not any strong tendency for continuous increases in dependable kinesthetic feedback as typing skill increased. The sharp effects of visual deprivation at very low skill levels and the modest increase in kinesthetic dependability among the very fastest typists were swamped by the general absence of differences in effects of visual deprivation among typists in the great middle range of 25-94 wpm speeds. Another factor (as shown by the SDs in Figure 1) was the overlap in levels of dependable feedback between skill levels. Finally, as shown in row 6a of Table 7, r = .39 was found for per cent dependable feedback between Conditions 2 and 3. The modest size of that r (in terms of r^2) suggests the substantial independence of kinesthetic feedback from the other components of all-senses feedback (mainly visual, but occasionally tactile and auditory).

Turning next to data bearing on speed and accuracy training, row 2a of Table 7 shows r = .14 between speed and number of errors under normal work conditions. This statistic for the entire range of typing skill agrees with earlier findings for particular portions of the range of skill and demonstrates the substantial independence of speed from error factors. This independence calls into question those training programs that attempt to build higher speeds and better accuracy at the same time and suggests, instead, that separate training be offered. That is, speed practice should apparently be carried out with very tolerant error limits; while separate accuracy practice should not include insistence on maintenance of normal speed.

Table 7

Intercorrelations Between Variables Among Three Work Conditions, By Skill Level

[Work Conditions: 1 = Normal; 2 = Visual, w/Retyping; 3 = Nonvisual, w/Retyping]

[N = 189; 21 from each of nine skill levels]

Variables	Skill Level (Gross wpm Under Condition 1)									Mean[a]	(N=189) 9-108
	9-14	15-24	25.34	35-44	45-54	55-64	65-74	75-84	85-108		
1. Speed-Speed											
a. Cond. 1-2	.60	.63	.34	.65	.71	.72	.43	.71	.90	.66	.99
b. Cond. 1-3	.25	.68	.38	.44	.39	.49	.57	.63	.88	.56	.98
c. Cond. 2-3	.54	.73	.38	.50	.42	.49	.79	.46	.80	.59	.98
2. Speed-Errors											
a. Cond. 1	.07	.21	.19	-.07	-.41	.07	-.22	.06	-.12	-.02	.14
b. Cond. 2	.64	.17	.18	-.00	-.37	.31	-.13	.03	-.08	.10	.03
c. Cond. 3	.43	.27	-.25	.32	-.09	.05	-.25	-.18	-.05	.03	-.09
3. Errors-Errors											
a. Cond. 1-2	.75	.70	.50	.83	.86	.83	.91	.55	.81	.78	.72
b. Cond. 1-3	.55	.60	.60	.85	.80	.74	.85	.56	.70	.71	.63
c. Cond. 2-3	.65	.48	.48	.85	.61	.68	.81	.69	.77	.69	.64
4. Speed (Cond. 1) and											
a. % Feedback, Cond. 2	-.32	.02	.06	.27	.45	-.27	-.10	.21	.17	.06	.22
b. % Feedback, Cond. 3	.10	.20	-.19	.05	.62	-.20	.54	.18	.09	.17	.36
5. Speed-% Feedback											
a. Cond. 2	-.35	.06	-.22	.28	-.04	-.26	-.08	.13	.31	-.02	.20
b. Cond. 3	-.09	.18	.29	-.27	.40	-.20	.42	.53	.05	.16	.36
6. % Feedback-% Feedback											
a. Cond. 2-3	-.21	.44	.63	.64	.41	.09	.30	.39	.35	.36	.39
7. Applic. Err.-Applic. Err.											
a. Cond. 2-3	.62	.39	.47	.78	.60	.61	.82	.63	.78	.65	.60

[a] By z transformation.

Considering, finally, the reliability of speed and error scores under the various work conditions, it is apparent from the near perfect r's (of rows 1a, 1b, and 1c of Table 7) that speed is a highly stable aspect of performance, remarkably resistant to modification by novel work conditions. The parallel error correlations (rows 3a, 3b, and 3c) are substantially lower, suggesting the greater sensitivity to work conditions of stroking accuracy.

Error Analysis

One interesting type of error was finally classified as not "applicable" to kinesthesis, namely, the transposition error (reversal of the order of letters in a word, e.g., inti for initials, singal for signal). It was judged that if the proportion of total transposition errors "corrected" by retyping were found to be highly correlated with the proportion of other, clearly kinesthetic errors that were corrected, transposition errors could properly be deemed to be a phenomenon susceptible to kinesthetic feedback. Since the correlations turned out to be .25 for visual work (among 121 Ss who made transposition errors) and .45 for nonvisual work (among 118 Ss who made such errors), transposition errors were, conservatively, excluded from the applicable-error category. Further support for this decision arises from the finding that the incidence of transposition errors rose regularly with increases in typing skill: from 12 per cent of those in the 9-14 wpm skill range through 76 per cent of those in the 85-108 range. The rank order correlation between skill range and percentage of persons in each range who made at least one transposition error was .98. The transposition error is clearly a direct concomitant of increasing skill that may often perhaps be due to increasing development, as skill is acquired, of chained responses for highly common letter sequences. The overpracticed sequence dominates and replaces the less common letter sequence. The typewriting teacher might well welcome an increase in transposition errors as a sign of increase in skill, which is to say, in the development of response chains. In any event, specific preventive or remedial exercises for the transposition error would appear to be out of the question.

CONCLUSIONS AND IMPLICATIONS

Fitts' hypothesis--that visual control is important early in the learning of new perceptual-motor skills and that proprioceptive cues come into play later on--leads to the inference that kinesthesis should be at low levels among beginners but should rise thereafter. This inference is supported and Fitts' hypothesis is confirmed by the results of the present investigation, in which 266 _S_s at 9-108 wpm typing skill levels, as measured under normal conditions, typed under visual and nonvisual conditions under instructions to retype in the case of sensed error. Level of dependable kinesthetic feedback among beginners was significantly lower than that of more advanced typists. However, there was no continuous rise in utilization of kinesthetic cues accompanying increases in skill; $r = .36$ between skill level and level of dependable kinesthetic feedback. The curve for utilization of kinesthetic cues as a function of typing skill level is negatively accelerated. Further, throughout the range of skill feedback was significantly lower under nonvisual than under visual conditions. The extent to which these findings may be paralleled for other perceptual-motor skills remains to be investigated.

Finally, deprivation of vision resulted in significant and very large increases in number of errors, but had no significant effects on speed of performance. Taken together with the feedback data, these results call into question the conventional instructional insistence on "touch" typewriting from the start of learning and suggest the desirability of free use of vision early in learning: as guidance for making responses, as a source of corrective information for wrong responses and of immediate reinforcement for correct responses, and as a reducer of the anxieties and tensions that reportedly commonly accompany early insistence on nonvisual work. Clearly, the conventional insistence on touch typing from the start of learning is instruction without immediate knowledge of results.

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