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The project gathered data on a number of experiments using a variety of tasks. The purpose was to show that there are conditions relevant to the differential composition o f a task and other conditions which are irrelevant. Invariances in level, slope, and regularing of pattern of intertrial correlations were found for cranking, a repetitive work task. Learning trials with very simple rotary or linear positioning tasks did not show the superdiagonal form of intertrial correlation matrix found with complex tracking tasks. Experimental variables such as the precision required and the directions given to the subject did affect the differential composition of a task. The general conclusions are that some experimental variables do alter an individual's performance and the processes involved in learning can be manipulated and analyzed. Implications of this study for standardized tests and education programs are discussed. (NS)

FINAL REPORT
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Individual Differences in Motor and Verbal Skills

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Marshall B. Jones

1968

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Problem. Knowledge of the role that individual differences play in learning and recall will permit the instructor to adjust techniques and programs to specific groups of individuals.

(a) For example, some experimental variations may not affect the differential composition of a task; knowledge of this invariance can be of major importance in the design and use of psychological or educational tasks. Consider a test which is being used to predict scholastic success. In the absence of established invariances we must assume that the validity of the test may be weakened by any change in the test's construction or administration. The consequence is a rigidity of design and procedure which is very burdensome. It would be distinctly advantageous to know that specific features of the task could be altered without affecting its differential composition. To the extent that invariance can be established for important classes of experimental manipulations, the design and construction of psychological tests for educational or other purposes becomes more flexible and relaxed. Adherence to rigid protocol is not necessary with respect to variations which leave the differential composition of the task and, hence, its validity invariant. These variations can be adjusted at will to maximize other desiderata in the testing situation, for example, ease or economy of administration.

(b) In dealing with variations which do affect the differential composition of a task, it is vital to know the ways in which composition is affected. Correlations among trials of practice are generally structured into a superdiagonal form. We need to know under what conditions this generality holds or, to put it oppositely, the kinds of variations that weaken or abolish superdiagonal form. Some tasks involve the same abilities at all stages of practice while others, though they remain outwardly unchanging, involve different abilities early in practice than later on. For many educational purposes it matters which situation obtains. It also matters that we know what to do by way of altering the conditions of learning so as to move a task in one direction or the other. We do not want to change task composition by accident, though we may want to do it deliberately.

Related literature. Throughout its history the study of skills acquisition has been predominantly a nomothetic area. Research has centered on regularities which hold on the average, for groups of subjects. At the same time, there has also been a persistent interest in individual differences. Experimental manipulations upon groups of subjects account for a fraction of the total variance typically observed in skilled performance. The remainder derives from differences in the natural equipment and previous experience of the subjects. In consequence, nomothetic accounts of skilled performance are fragmentary to partial in extent, and distinctly unreliable in their application to any one of even a small number of people. These limitations are particularly restrictive in applied work, where variations in individual performance are often critical, in the selection and classification of students, the design of aids, establishing training programs, etc..

Early work on individual differences in skill acquisition was dominated by Herbert Woodrow (1938, 1939a, 1939b). This pioneer addressed himself to a host of essential questions: whether variability increases or decreases with practice, the possible existence of general factors in improvement scores, the relations of external measures to initial and final performance, and others. Kientzle (1946 and 1949), working with Woodrow, hypothesized that correlation patterns among trials of acquisition are not influenced by fatigue effects. Her theory indicated that correlation patterns in motor-skill acquisition are determined by learning phenomena only, to the exclusion of performance variables.

In the 1950's Woodrow's work was extended by several investigators -- most prominently by B. Reynolds (1952a, 1952b), J. A. Adams (1953), E. A. Fleishman (1953a, 1953b, 1960) and D. Lewis (1953) -- to apparatus studies of psychomotor performance. The principal issue of their work was a definitive recognition of the superdiagonal forms of practice and an appreciation of their centrality both for theory and for further experimental work.

Table 1 presents correlations between trials of practice on the Two-Hand Coordination Test in a sample of 152 adult males; the matrix is a superdiagonal form. The largest correlations are in the superdiagonal (the lowermost down-slanting array of correlations) and correlations decrease as they succeed one another up the columns or across the rows to the right, so that the smallest correlation is in the upper-right-hand corner of the matrix. This pattern appears in every known matrix of intertrial correlations on a motor skill. (Bilodeau, Jones, and Levy, 1964, have also found the same phenomenon in the retention of verbal instructions.) In most instances, as in Table 1, the pattern also submits to an exact metric regularity, the law of single tetrad differences.

The recognition of these generalities in the differential patterning of skill acquisition has led to a radical reformulation in theory and approach (Jones, 1962 and 1966). Substantively, the superdiagonal forms of practice lend themselves to interpretation as a process of simplification. This interpretation concords nicely with known regularities concerning the correlations of external tests with early and late trials of practice; it also concords well with nomothetic accounts of the acquisition process.

Methodologically, the recognition of pattern has provoked a sharp break with the factor-analytic tradition (Jones, 1959 and 1960). Factor analysis decomposes a correlation matrix into a more or less arbitrary array of structural factors. Unfortunately, it also decomposes the time-ordered correlation patterns in

Table 1

Intertrial Correlations for the Two-Hand Coordination Test (from Jones, 1962)

Trial	1	2	3	4	5	6	7	8
1		.79	.77	.74	.73	.71	.71	.70
2			.87	.87	.84	.82	.82	.82
3				.91	.89	.87	.85	.86
4					.91	.88	.86	.88
5						.89	.90	.90
6							.93	.93
7								.94
8								

(n = 152)

which generality and regularity of result seem principally to inhere. It is the pattern itself which appears time and again, from one apparatus to another, from one population of subjects to another. These patterns are time-ordered; they have to do with process and change. Structural contents are relevant, but not apart from the process of orderly change in which they participate.

More important is the realization that correlation patterns and variations in them are dependent variables. Superdiagonal forms vary in their regularity, level, and various other features. And these variations may be attributable to the tasks and circumstances of acquisition.

Purposes and Objectives. The purpose of the program of which the present work is a part is to extend our limited knowledge of the patterning of individual differences in skills acquisition and retention as functions of practice, feedback, transfer of training, and work variables. A long-term objective in the longitudinal study of individual differences is to find more effective means of scheduling stages of practice. The present small-contract proposal was initiated as very nearly a first step toward this objective.

The more immediate, specific purposes were (a) to determine how a variety of task and experimental manipulations affect (or fail to affect) the pattern and level of intertrial correlations during skill learning, (b) to compare the usual mean and variance effects of experimental manipulations with correlational indices of the effects of the same variables, and (c) to provide further tests of the theoretical formulation, based on earlier differential studies, that practice is a process of simplification.

Method

Experimental Procedures. From an available pool of data collected and analyzed previously for mean and variance trends, but not for differential patterning, a number of experiments were selected. The procedures of the individual experiments are briefly summarized in the Results and Discussion section of this report; more detailed descriptions are available in the previously published experimental reports, as referenced.

The experiments all involved repeated testing of large numbers of subjects, different subjects in different experiments. The several experiments together covered a range of task categories: work and learning tasks; and repetitive, rotary- and linear-positioning, and tracking tasks. Within experiments there was variation in work loading, distribution of practice, and target size, as well as transfer shifts from one level of loading to another. Over experiments, then, both a fair range of experimental variables and kinds of motor tasks were examined.

Data analysis. Trial scores from the original data records on file in the Skills Laboratory of the Tulane University Psychology Department were punched on cards. Intercorrelation matrices were obtained by computer and studied for temporal patterning by molar correlational analysis (Jones, 1959, 1960, 1962). Trends in central tendency, treated in the original reports of the data, and their implications for differential structure were included for comparison with the implications of correlational analysis.

Results and Discussion

The primary empirical base of the project lay in the data collected by E. A. Bilodeau and his associates, data on thousands of subjects evaluating transfer of training, schedules of practice, feedback, and retention experiments. These data were punched, intercorrelated by computer methods, and examined for time-ordered structures.

Invariance. Several years ago Kientzle (1946, 1949) reported that intertrial correlations were invariant under different distributions of practice. "Correlations between scores on specific trials," said Kientzle (1949, p. 532) in retrospect, "were associated with the ordinal numbers of the trials, but not with the amount of rest between them. In other words, intertrial correlations were invariant under spacing."

In a second study Kientzle (1949) addressed herself to the invariance of the intertrial correlations under different distributions of practice. Two groups of college students practiced writing the inverted alphabet for 15 one-minute trials with no rest between trials. One group continued practice without rest, while the other received 60 seconds of rest before each of the last five trials, i.e., Trials 16 through 20. Two additional groups practiced the first 15 trials with 60 seconds of rest before each trial. One group continued on this schedule, while the other completed practice without rest. Kientzle calculated the correlations between Trial 15 and Trials 16 and 20. Both correlations, i.e., $r_{15,16}$ and $r_{15,20}$, took substantially the same values in all four groups. "Although changing conditions of spacing late in practice materially affected mean scores and standard deviations," Kientzle concluded, "it did not affect correlations with the 15th trial" (Kientzle 1949, p. 536).

Effects upon mean performance produced by distributing practice in different ways are mediated by reactive inhibition or, more generally, fatigue effects, at least, so it is that the psychological consensus has it. Kientzle's findings suggested that intertrial correlations might be independent of experimental variations other than distribution of practice which affect performance through fatigue. A main result of this project was a test of this suggestion, using the force required to make a response on the Manual Crank (Jones, 1968).

Two identical experiments were performed on the Manual Crank, a work task in which practice leads to decrement (Bilodeau, 1951, 1952). Each experiment involved a total of 160 basic airmen who were divided into four groups of 40 subjects each. In all four groups the subjects stood before the crank handle and rotated it as fast as they could for a continuous practice period of 5 minutes. Group 1 practiced with minimum, Group 4 with maximum work loading (horsepower requirement); Groups 2 and 3 were alternated between minimum and maximum loadings after each minute of practice, Group 2 beginning with minimum and Group 3 with maximum loading. The number of crank revolutions in each 20-second period was recorded.

Each group generated a 15-variable correlation matrix, and the average correlation in each matrix was calculated. In the original experiment the difference between the largest and the smallest average correlation was .08; in the repeat experiment this difference was .10. However, the largest difference for a single group between experiments was of the same order, .08. The differences between experiments were as large as the differences between groups within an experiment.

Variations in effort had no effect on the level of intertrial correlation. Nor were there any differences in pattern. Table 2 sets forth the correlations between each period and every other, averaged over all four groups in both experiments; the correlations are patterned into a rough superdiagonal form. The pattern in Table 2 is not perfect; it was still less so in the eight matrices which were averaged to produce Table 2. Nevertheless, in all eight matrices this same pattern

Table 2

Correlations among 20-Second Periods on the Manual Crank Averaged over the Four Groups and Two Experiments (from data of E. A. Bilodeau, 1951, 1952)

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1		.65	.51	.47	.47	.44	.51	.48	.44	.43	.42	.39	.44	.42	.39
2			.83	.69	.69	.63	.61	.63	.58	.55	.56	.52	.53	.55	.51
3				.85	.78	.76	.72	.73	.71	.66	.63	.64	.61	.64	.61
4					.88	.84	.77	.74	.70	.77	.73	.70	.66	.64	.50
5						.91	.80	.83	.78	.81	.82	.76	.68	.72	.72
6							.84	.84	.80	.83	.82	.81	.72	.73	.75
7								.88	.85	.81	.79	.79	.84	.79	.78
8									.89	.81	.83	.80	.81	.83	.80
9										.80	.82	.81	.80	.82	.81
10											.84	.85	.77	.75	.77
11												.89	.77	.82	.82
12													.77	.78	.81
13														.83	.80
14															.88

(n = 320)

appeared and with comparable degrees of roughness.

A detail of patterning which suggested itself for particular attention was the contrast, in the two alternating groups, of correlations among periods in which the subjects were working against the same load and correlations between periods in which they worked against different loads. The correlations between periods with different loads were fully as large as those between periods with the same load.

In discussing her findings on distributed practice, Kientzle (1949, p.537) wrote, "If intertrial correlations depend on number of trials, but not on the amount of intervening rest, and if the invariance of correlations means an invariance of component abilities, then rest does not change a subject's standard score on a specified trial. That is, if it were possible to observe, say, two 15th trials from the same group of subjects, the one trial under massed conditions and the other under spaced, each subject's standard score would be the same on both trials. He might earn a higher score with rest, but he would keep the same standing on both trials."

The same language applies to the Manual Crank study. The evidence suggests that a subject's standard score in the kth period would not have been different, if he had been assigned to a different experimental group. If we imagine an (obviously hypothetical) analysis of variance in which each subject works the Manual Crank under all four conditions but the ordering of the conditions is irrelevant, then individuals and trials interact, to produce a nonunitary correlation matrix, but individuals and conditions do not.

Another way to make the same point is to say that loading on the Manual Crank does not affect the differential structure of the task. Insofar as individual differences are concerned, the task remains the same no matter what the loading is. Mean performance changes with loading, while the subjects' relative standing remains invariant.

This last implication is present in correlational analysis based on simple, single-session design for either work variable--loading or distribution of practice: the pattern and level of intertrial correlation are not influenced by value of loading or distribution, i.e., they are not effective differential variables. For even a hint of this to appear in central-tendency analysis requires a more complicated, two-session experiment with a transfer-shift between sessions. That is, mean output (in a single-variable design without transfer test) decreases regularly the heavier the loading or the briefer the between-trial rests; in this sense, the variables are effective. If, however, a group has a first practice session at one level of loading or distribution and then transfers to another level for a second session, output in the second session is about what it would have been had the new level been used in both sessions. The variables are no more effective in producing residuals than in changing patterns, and the central-tendency outcome agrees that what performance requires of a subject is the same regardless of the particular values of work variables.

Breakdown conditions. The meaning of any generalization is best determined by examining the conditions under which it breaks down. A regularity is itself a variation like any other, and holds or does not hold according as the conditions which sustain it are present or absent. In the case at hand we need to discover tasks which do not show superdiagonal form or, better yet, learn how to modify tasks so that superdiagonal form is abolished.

Exceptions to superdiagonal form are not easy to come by, but they do exist. Bilodeau (1953) had subjects practice a task in which turning the knob of a micrometer was translated into a linear scale, 25 points for each full turn of the knob. The subjects, 40 basic airmen, were told after each trial how many scale points one way or the other they were from target, which was eight full turns of the knob or 200 points on the linear scale. The knob was shielded from visual contact and the subjects were unaware of the conversion formula. The results for the 16 trials of practice appear in Table 3.

In some tasks the effect of practice may be to eliminate reliable individual differences. All subjects approach a common level of performance except for random departures. In tasks of this sort the intertrial correlations should show superdiagonal form early in practice. As practice continues, however, reliable differences among subjects at any one trial are eroded away until little or nothing is left but error. As this point is reached, correlation level falls close to zero and patterning all but disappears.

The results for the micrometer task conform closely to this description. The average absolute error is high initially, falls sharply in the next three trials, and approaches asymptotic values around the 9th trial. The standard deviations are maximal at the second trial --the first trial, it should be remembered, is "free" in the sense that the subjects have no knowledge of previous results; thereafter, they drop sharply and also reach asymptotic values at or about the 9th trial. Meanwhile, the correlations start off in an unmistakably superdiagonal pattern. The correlations among Trials 2 through 7 are almost perfectly regular. However, at the 8th trial, correlation level drops precipitously and the matrix becomes completely disorganized.

Line drawing is another exception to superdiagonal form. Bilodeau and Ryan (1960) taught 48 blindfolded undergraduates to draw a 3-inch line. Errors were reported back to the subjects in sixteenths of an inch "long" or "short" of the target. Altogether, the subjects received 35 trials. However, both means and standard deviations reached asymptotic values by the 16th trial. Table 4 contains the results.

Table 3

Means, Standard Deviations, and Intertrial Correlations for Micrometer Reading (from data of E. A. Bilodeau, 1953)

Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		.30	.33	.29	.12	.14	-.16	.07	.05	.10	-.00	.04	.03	-.16	-.06	.05
2			.72	.56	.43	.20	-.10	.34	.11	.15	.22	.08	.01	-.02	.13	.06
3				.72	.66	.47	.15	.34	.17	.31	.20	.03	-.08	.06	.03	.18
4					.57	.57	.26	.08	.06	.29	.20	.10	.13	.13	-.05	.20
5						.77	.44	.14	.23	.48	.09	-.10	-.04	-.05	.00	-.04
6							.65	.15	.30	.62	-.01	.11	.01	.02	-.09	.14
7								.19	.36	.60	-.08	.22	.17	.13	.09	.23
8									.19	.09	-.04	.28	.33	.27	.27	.42
9										.47	.14	-.08	.20	.04	.12	.05
10											.08	-.00	.19	.20	.27	.20
11												-.16	.17	.09	.19	-.03
12													.09	.38	.20	.41
13														.09	.06	.12
14															.52	.31
15																.22
16																--
$\bar{X}$	178	73	41	32	26	23	18	20	13	15	14	11	13	14	12	11
σ	6.8	53.9	42.2	44.4	31.6	29.7	17.2	18.2	11.0	15.4	8.9	8.6	11.7	11.0	9.4	9.2

(n = 40)

Table 4

Means, Standard Deviations, and Intertrial Correlations for Line Drawing (from data of E. A. Bilodeau and Ryan, 1960)

Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		.68	.34	.24	-.14	.21	.25	-.05	.07	.17	.28	.23	.06	.08	.10	.11
2			.21	.03	-.13	.04	.20	.07	.13	.24	.09	.17	.22	.19	.06	.09
3				.39	.10	.41	.13	-.22	.24	-.08	.03	.18	-.22	.03	-.05	.08
4					.21	.42	.31	-.00	-.08	-.10	.14	-.03	-.22	-.15	-.25	-.06
5						.46	.16	.33	.34	-.04	.07	.12	-.09	-.08	-.04	-.11
6							.33	.05	.08	-.02	.04	.25	-.21	-.09	.05	.09
7								.01	.23	.23	.09	.04	-.27	-.11	.07	.04
8									.26	.04	.21	.15	.07	-.06	.18	.03
9										.34	.39	.36	.13	.13	.18	.23
10											.43	.13	-.08	.10	.26	.34
11												.51	.24	.23	.10	.38
12													.26	.14	.16	.07
13														.47	.25	.19
14															.20	.44
15																.43
16																--
$\bar{X}$	16.4	11.3	9.8	6.8	6.9	4.1	5.3	4.7	5.2	4.9	5.1	5.0	4.5	3.6	4.8	4.6
σ	8.2	7.4	6.5	5.5	4.9	3.9	4.2	4.1	3.9	3.6	4.1	3.9	3.2	2.9	3.7	3.2

(n = 48)

The correlations in Table 4 are generally low and their pattern is extremely ragged. Nevertheless, some elements of superdiagonal form are present. The average correlation in the superdiagonal is .346. In the next diagonal over the average correlation is .211; in the third diagonal it is .195. In succeeding diagonals the average is .195, .032, .090 and continues to follow a generally decreasing course. In short, there is a tendency for the correlations to become weaker as the trials are more and more separated in practice, but it is only a tendency. In a developed superdiagonal form this regularity appears in each row and column. Here it appears only on the average. Reading across the rows or up the columns there are many departures from the superdiagonal rule.

All in all, the correlation pattern in Table 4 is vestigial. This description, moreover, applies to the last 19 as well as to the first 16 trials of practice. Correlation level remains at the same level throughout; and there are traces of superdiagonal form through all 35 trials, but these traces are no more or less apparent later than early in practice. Superdiagonal pattern does not disappear in Table 4 because it never appears, except in vestigial forms which are equally distributed at all stages of practice.

Still another exception to superdiagonal form is lever positioning. Bilodeau (1953b) trained his subjects, 41 basic airmen, to move a lever through 26 degrees of arc. The maximal arc through which the lever could be moved was 42 degrees, and the subjects had no visual contact with the lever. Information was fed back to the subjects in degrees of arc past or short of the target. The results were virtually the same as in line drawing, a vestigial superdiagonal pattern that showed no tendency to weaken or strengthen with practice.

In 1962 Jones pointed out that if practice were understood as a process of simplification, the superdiagonal pattern of intertrial correlations could be explained. According to Jones, any ability or other differential element which was active at any point in practice was active at the outset, at the first trial. With each new trial some of these elements dropped out, not to return. As practice progressed fewer and fewer abilities, fewer and fewer differential elements remained; and those that did, tended to be peculiar to the task being practiced. Differentially, practice was a process of simplification. From this hypothesis, Jones was able to derive the superdiagonal forms of practice and, more particularly, the single-tetrad law. The theory was also congruent with the common observation that the later trials of practice are more specific to the particular task than those at the beginning.

The results with the micrometer task are congruent with Jones' theory. It is only necessary to suppose that in some tasks the process of simplification converges on pure error. The only differential elements which are present at the beginning and which remain throughout practice are errorful; all of the reliable elements drop out sooner or later. As they do, correlation level drops toward zero and correlation pattern degenerates into disorganization. Line-drawing and lever-positioning are not so easily explained.

The most obvious feature of these two tasks is their extreme simplicity; in both cases a trial consists of a single, self-contained motion. It is possible to argue that superdiagonal form is lost or almost lost under these conditions because the task is already so simple that there is nothing to simplify. The process of simplification aborts because it is required to begin at its end.

There is, however, an alternative, in fact, an antithetical explanation. The tasks which show strong superdiagonal patterning are all of them fairly complex. Tasks like Two-Hand Coordination and the Complex Coordination Test require many, continuous and coordinated behaviors. It may be, therefore, that line-drawing and lever-positioning lack superdiagonal form because they require a single discrete motion which, though it may be perfected, cannot substitute for a gathering complex of inter-related behaviors. In this view, the superdiagonal forms of practice reflect the assembly and organization of a complex skill. Practice, so far from being a process of simplification, is a process of complication. This view of the matter is equally competent to explain the failure of patterning in line-drawing and lever-positioning. And it can explain the usual finding that later trials are more specific, less related to external tests and variations, than earlier ones; the specificity lies in the particular organization that characterizes an accomplished skill.

On the existing evidence it seems most adequate to regard practice as a process of both simplification and complication. In a typically complex task the earlier stages are given over mainly to simplification as pre-existing habits and understandings give way before the demands of practice; at the same time, however, the skill itself is cumulating and coming together and in the later stages of practice complication predominates. In some tasks, for example, the micrometer, there is no complication, no complex assembly that can, according as the subjects build it well or poorly, spread them out into reliably different levels of performance. Learning is a matter of settling into the task, but the task once learned is everywhere the same because it isn't so much built as it is freed from proactive effects.

Differential definition. Beyond differential invariance lie all those experimental manipulations which affect the intertrial correlations. Fortunately, these outer regions are not as uncharted as they might seem at the outset. If the correlations fall into a superdiagonal form, at least roughly -- and this limitation excludes only a small number of very simple tasks -- the number of ways in which the correlations can be affected is sharply limited. The correlations may differ in the precision with which they obey the single tetrad law. They may differ in level, i.e., whether the correlations are generally large or small. And they may differ in the slope of the pattern as it falls away from the superdiagonal. Two matrices may be equally regular and have the same level yet differ markedly in pattern-slope. One matrix may be almost flat while the other has larger correlations in the superdiagonal and smaller ones in the upper righthand corner with a steep gradient between the two extremes. If two superdiagonal patterns are alike in level, slope, and regularity they may still differ but only in relatively subtle ways, of which the most important is the course of differential change.

The idea of differential definition is composed of these three variations: level, pattern-slope, and regularity. The better defined a task is, the higher the level of correlation, the flatter the pattern-slope, and the more regular it is. In the extreme case all correlations equal unity; every trial is differentially identical with every other. A poorly defined task shows a low order of correlation and falls off steeply from the superdiagonal or is highly irregular. In a well-defined task, every trial is roughly equivalent with every other, while in a poorly defined task the trials are various in their differential contents.

The three components of differential definition are all capable of precise formulation. In order to formulate slope and regularity with precision, we must first fit a theoretical superdiagonal pattern, i.e., one which obeys the single tetrad law exactly, to the empirical correlations. The differences between corresponding empirical and best-fitting theoretical correlations are irregularities in the superdiagonal pattern. Unfortunately, the residual correlations, as these differences are called, are partly determined by correlation level; the higher the level, the smaller the residuals are likely to be. The best way to correct for this interaction is to express the residuals in terms of Fisher's z transformation. The root mean square of the transformed residuals may then be taken as an inverse measure of regularity, the smaller the root mean square the more regular the superdiagonal pattern.

In principle, it is possible for intertrial correlations to take some pattern other than superdiagonal form but, as a matter of fact, they never do. If an intertrial matrix has any pattern at all, it is superdiagonal. Hence, absence of superdiagonal pattern is materially synonymous with little or no definition. Tasks like lever-positioning and line-drawing lack definition. Absence of superdiagonal pattern is a qualitative extreme of poor definition. At the other extreme is perfect definition, in which all intertrial correlations equal unity. In between lie moderate levels of correlation with greater or lesser degrees of regularity and widely varying pattern-slopes.

The Two-Hand Track, a modified version of the Two-Hand Coordination Test, measures a subject's ability to guide a pin around a track by manipulating control handles. Turning the right-hand control moves the pin away from or toward the operator; turning the left-hand control moves the pin left and right. The object is to drive the pin over the pathway as quickly as possible.

I. McD. Bilodeau (1965) divided 114 basic airmen into three groups of 38 subjects each. All three groups worked on a clover-shaped track that was flush with the plate in which it was set. The differences among the groups concerned the play that was tolerated in the control handles. Group P (precise) was the standard condition; the handles could be turned 187.5 degrees before the pin went off the track; in Group M (moderate) the play was 865 degrees; and in Group F (free) it was 1626 degrees. In Groups P and M the contacts had to be made consecutively; in Group F a subject who jumped the track was permitted to bring the pin back further along the track. Each subject practiced five one-minute trials a day for six days. Performance was analyzed in number of contacts made per day, so that the analysis rests on a six-variable matrix.

Table 5 contains the results for Group P and Table 6 the results for Group F. The results for Group M are not presented. However, Groups P and M were much alike. Correlation levels in the two groups were .84 and .86 respectively. Pattern slope in Group P was slightly shallower than in Group M, while root mean errors in Groups P and M were .05 and .08 respectively.

Group F, in contrast, is plainly less well defined than either of the other two groups. Pattern slope is very steep, with correlations ranging from the low .90s in the superdiagonal to .23 in the upper right-hand corner. Correlation level is .67, and root mean error .09.

In this experiment, enlarging target size by allowing more play in the control handles and permitting the subjects to come back on the track as best they could greatly weakened differential definition. It permitted the subjects to register many more contacts per day than in either of the other two groups, but it also modified the task in a way which called for much greater differential change over the six-day period.

Comparing the last two columns in Table 5 with those of Table 6 shows that the precision requirement had a sizable effect on mean and variance as well as on pattern definition. The subjects covered more ground under sloppy than strict requirements. The transfer-test results treated in the original central-tendency report of the data agree that precision requirements are effective variables, not only in the sense of producing different mean outputs for different present levels of precision tolerance, but in the residual sense. Though transfer of training was positive between all pairs and directions of transfer shift, the amount of transfer was related to the amount of change in the precision requirements from training to test. That is,

Table 5

Means, Standard Deviations, and Correlations in the Target-size Experiment, Group P (from data of I. McD. Bilodeau, 1965)

Trial	1	2	3	4	5	6	$\overline{X}$	σ
1		.84	.80	.83	.78	.73	69	20.5
2			.90	.86	.81	.75	103	29.5
3				.91	.86	.80	139	43.9
4					.89	.85	171	53.3
5						.93	208	61.7
6							241	68.9

(n = 38)

Table 6

Means, Standard Deviations, and Correlations in the Target-size Experiment, Group F (from data of I. McD. Bilodeau, 1965)

Trial	1	2	3	4	5	6	$\bar{X}$	σ
1		.68	.54	.40	.32	.23	367	89.9
2			.87	.70	.58	.51	553	96.4
3				.89	.82	.74	665	104.1
4					.91	.87	741	94.1
5						.90	790	88.3
6							829	91.4

(n = 38)

any kind of training was better for transfer test output than no training at all; but the extremes (P and F) had more benefit to and from the intermediate treatment (M) than to each other. Transfer and correlational analyses agree that changing the tolerance or precision standard for the two-hand tracking apparatus changed the task for the subject. The correlational analysis adds that the greatest change was made between M and F tolerances.

Conclusions and Implications

The project's central concern was to provide evidence that there are conditions that are relevant to the differential composition of a task and other conditions that are irrelevant. Specifying the class to which a given variable belongs is obviously of long-term pertinence to programs of testing and education than can take advantage of both individual differences and lack of differential effect. Our conclusion is that the analyses support the expectation that conditions of each kind exist.

(1) There are variables that affect a group's average output but are invariant as far as individual differences are concerned: in setting values for this class of variable in training or selecting, the program director need consult only convenience and economy.

(2) There are, however, other variables that do have differential influence, changing not only group mean but individual standard-score status, or differential task composition. In selection and education it clearly matters whether we use the standard test and task or versions that introduce critical variations. These are dangers against which severe warnings are traditionally offered, and quite properly. But the presence of experimental variables that do alter differential composition offers also the promise of their eventual use in controlled variations by which stages of practice can be ordered to take advantage of communalities and differences in component composition.

The promise is offered, however; the project is an initial step in a long-term effort, for which its findings are encouraging.

(3) The findings are also encouraging in their contribution to a theoretical analysis of the processes involved in learning. Correlation pattern is a dependent variable; it can be manipulated. The pattern variations found in the project, with earlier variations obtained by the same investigators, lead to the conclusion that practice is a process of simplification, complication, or both, according to the type of task practiced.

Summary

(1) Intertrial matrices for a number of experiments using a variety of different tasks and experimental variables were obtained and analyzed for temporal patterning.

(2) Invariances in level, slope, and regularity of pattern of intertrial correlations were found for cranking, a repetitive work task, with different amounts of work-loading from group to group and with transfer-shifts in work loading for a single group of subjects from trial to trial. Mean output, analyzed in previous reports, was sensitive to present, but not to past work loading.

(3) Learning trials with very simple rotary or linear positioning tasks did not show the superdiagonal form of intertrial correlation matrix found with complex tracking tasks. The superdiagonal form, though extremely common for learning tasks, is not universal; pattern of correlation, or at least degree of pattern definition, is a dependent variable that can be controlled by task variables.

(4) An experimental variable, target size (precision of movement required to score "on-target") in a

two-hand tracking task influenced the sharpness of definition of the intercorrelation matrix of learning trials. Giving a free or loose definition of the task to the subject weakened differential definition, i.e., increased the slope of the correlation pattern, decreased the overall level of intertrial correlation, and reduced the regularity or smootheness of trends. Experimental variables can affect the differential composition of a task.

(5) Output or performance differences measured by means and variances do not imply a change in differential requirements for different conditions of practice. For variables that do produce mean and variance effects, correlational analysis revealed instances of both influence and lack of influence on differential composition. Output indices (means and variances) in transfer of training tests supported the correlational analyses.

(6) The theoretical alternatives for the process of component composition that takes place during practice, simplification and complication, were considered. These opposite processes are both hypothesized in the theoretical treatment of the project, with the suggestion that the process is determined by task complexity.

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