COMPUTER SOFTWARE FOR ASSESSING AND SHAPING MOTOR PERFORMANCE IN VOCATIONAL EVALUATION AND ADJUSTMENT PROGRAMS

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ABSTRACT: This paper presentation demonstrated the Research and Training Center's "Learning Curve Analyzer" software developed by Dr. Thomas Blakemore and Dr. Charles C. Coker. The software has been used in research and in clinical settings, and continues to be refined through research and development.

Introduction

One of the processes in Vocational Evaluation is the administration of work samples to assess the ability of an individual to perform a specific task or similar tasks. Work samples normally represent the actual tasks that the individual is expected to do on the job. Interpretation of performance would appear to be a simple yes-no dichotomous decision, based on the face validity of the work sample and comparison of task performance to an appropriate norm. There are three potential fundamental errors in drawing conclusions from this simple comparison to normative criteria.

First, the norms (industrial standards, method-time-motions (MTM) measures, or locally developed client norms) to which the client's performance measures are compared are based on individuals whose amount of prior training or experience on the task(s) typically far exceeds that of the client. The usual result is an under-estimation of the skill level of the client. Industrial and MTM measures are norms for practiced workers or the well-practiced motions of practiced workers, while client norms yield performance norms based on individuals with an unknown amount of practice on the task or motions. The most important point of this criticism is not so much what the normative criteria should be, but how to measure the amount of prior training or practice the client has had, so that practiced performance levels are compared to similar practiced performance levels. It has been shown by Dunn (1976), Chyatee (1976), and Blakemore and Coker (1982) that traditional work sample administration procedures involving industrial standards or MTM will seriously underestimate a client's ability. Client norms may vary in terms of over- or under-estimation of the client's ability.

Secondly, traditional work sample administration loses valuable data that could better determine the client's real potential. Clients with the same performance level on a work sample may not have the same potential. One client may have started out slow, but steadily acquired higher skill levels over repetition of the tasks in the work sample. Another may have performed at a steady pace over all repetitions. Obviously, the problem is to determine if learning has been completed or not, and whether any significant increases in performance could be expected. Traditional work sample administration fails to examine performance on each repetition of the tasks within a work sample.

Third, work samples may not be used just to measure current functional ability, but also as predictive measures of an individual's future potential. Work sample theory does not include valid criteria for prediction of future skill level performance. Instead, work samples are just that, and the appropriate conclusion is whether the individual can now perform those tasks assessed. When used in a predictive mode, work samples become psychometric measures and are subject to some questions of reliability and validity as those measures which they were once taunted to replace.

There is a technique which addresses the three fundamental errors of traditional work sample assessment. This technique involves the measurement of performance changes over several repeated trials on a task and uses statistical measures to predict the "learning curve" of the individual. Recommendations would be more concerned with how long it would take to reach criteria, rather than judging the presence of absence of the skill. The use of learning curve analysis could be a valuable tool in the vocational evaluator's repertoire.

Such a recommendation is not new and has long been advocated (Tillman, 1971; Dunn, 1976; and Blakemore and Coker, 1982.), but very few have utilized learning curves to estimate whether the measured performance is nearer to the tip or bottom of their learning curve. The application of learning curve techniques has not grown simply because they have been too time consuming and cumbersome to apply. With the recent availability of low cost, yet high powered microcomputers, the techniques of learning curve analysis could be used rather easily in Vocational Evaluation and Adjustment programs, at least for repetitive motor tasks.

It is for these fundamental errors of traditional work sample administration that the microcomputer software was developed. The program does a number of things, such as gather data, store data, compute learning curves, present simple and complex feedback and pacing stimuli, and provide a hard copy of the performance information and task conditions. The primary function, however, is to give evaluators and adjustment specialists with a tool to increase their effectiveness in assessing and changing task performance. One of the most prominent aspects of vocational evaluation is the administration of work samples. After a client has been assessed using work samples, their performance is compared to some norm to determine how well they performed a task relative to other individuals. There is a widespread belief among many vocational evaluators and consumers of these services that competitive norms or industrial norms are the best basis for judging client performance on a work sample (Larsen & Curtin, 1973). In fact, the Commission on Accreditation of Rehabilitation Facilities regulations state that ". . . if work samples are used, competitive norms or industrial standards shall be established and used." (CARF, 1982). There are three ways in which competitive norms can be established: (1) by using the performance of a group of workers employed in a particular occupation; (2) by using a predetermined motion-time system, such as MTM or MODAPTS; or (3) by using piece rates established by a time-study, if the work sample is taken directly from an industrial setting. With all of these methods of calculating norms, the individuals upon whom the norms are based tend to have experience and considerable practice with the tasks included in the work sample. The workers whose performance is used to establish competitive norms and those represented in time studies have obviously had experience performing the task. Similarly, the workers upon whom predetermined motion-time studies are computed are also experienced at the task (Schwab, 1963). Another normative criterion is the development of local client norms. In this case the amount of previous experience on the task is unknown.

There are a large number of studies demonstrating that performance on work tasks involving motor skills shows marked improvement with practice (e.g., Fitts & Posner, 1967; Schmidt, 1975). In addition, further research demonstrates that improvement continues to occur for many thousands (Cochran, 1968) and, in some cases, even millions (Crossman, 1959) of practice trials. The basic conclusion to be reached from studies of motor and industrial work skills, is that these generally show progressive improvement with practice over a large number of trials and, perhaps, many years (Peterson, 1975).

These findings cast doubt upon the validity of competitive norms and industrial standards with simulated work tasks. Competitive norms (such as those derived from a group of employed workers in an occupation) and industrial standards (such as those derived from a pre-determined motion-time study system such as MTM) reflect the performance of experienced workers: those who have had Vocational Evaluation programs, however, tend to be inexperienced workers: they have had only limited work histories and are unemployed at the time they are receiving services (Dunn, 1975). Comparing the performance of an inexperienced persons to norms and standards developed from the performance of experienced persons tends to underestimate the functioning level of the inexperienced person (i.e., that level at which the inexperienced person would perform if provided with practice equivalent to that possessed by the experienced person). In other words, when competitive norms and industrial standards are used with work task time scores, and provision is not made for the individuals to have practice equivalent to that enjoyed by the norm or standardization group, the result is underestimation of the client's potential performance level. If this underestimation occurs early in the Vocational Evaluation process, the result would be to exclude broad occupational areas from further consideration for the client. Error later in the process would tend to exclude specific occupational areas and/or jobs.

The ability of people (both disabled and nondisabled) to reach an industrial standard criterion within a single administration of a simulated task appears to be quite limited. Research by Dunn (1976) suggests that the ability of nondisabled persons to reach the 100% of standard level in a single administration of a work sample appears to be similarly limited. In this study, normative criteria were applied to the work sample performance of 54 college undergraduates and found that only 15% of the males and 6% of the females reached the industrial standard during the first administration (50 trials). When provided with an additional three administrations (150 trials) or practice, however, 55% of the males and 42% of the females met the industrial standard. Individualized prediction equations, based on the times for the four administrations, were developed and used to predict practiced ("peak") levels of performance for these subjects. Those predictions indicated that, after 20 administrations of the work sample, 70% of the males would have attained the industrial standard, while 70% of the females would have attained the standard after 25 administrations. In other words, these data suggest that about 20 administrations for males and 25 administrations for females would be required to clearly differentiate those individuals who could readily attain the industrial standard from those who could not. Thus, in the traditional approach to Vocational Evaluation utilizing one administration, 55% of the males and 71% of the females would have been misclassified in Dunn's study.

Research conducted at Emory University Research and Training Center (Chyatte 1976) provided a client time score distribution and industrial standards based on MTM-3 for two JEVS work samples; union clients who took the union assembly and 1.2% of those who took hardware assembly reached 100% of the industrial standard with one administration of the work sample. Results of research by Blakemore and Coker (1982) were similar to those found by Chyatte. On the first administration of the Stout-Eye-Hand-Foot Coordination work sample only 5% of the clients performed well enough to exceed the industrial standard for the task. However, after four additional administrations of the work sample, 55% of the clients exceeding the industrial standard and individualized prediction equations indicated that most of the remaining clients could have eventually exceeded the industrial norm.

Learning Curves: A Potential Solution

A number of researchers (e.g., Tillman, 1971; Dunn, 1976; Blakemore and Coker, 1982) have suggested that one way to overcome the problems of underestimating client potential on work samples is to plot the client's performance data in the form of a learning curve (or equation) and to extrapolate client potential using this data. For instance, Tillman suggested that the client's performance on a task should be graphed with the number of practice trials on the horizontal axis and some measure of performance, such as production rate, on the vertical axis. Such graphic representations, called learning or performance curves, typically show increases in performance with increases in practice. The law of diminishing returns sets in on such tasks, however. That is, the slope of the curve, which represents the rate of learning or improvement, is usually very steep on the initial practice trials but tends to level off as the amount of practice increases. Tillman suggested that clients should be allowed to practice a work sample until their performance curve becomes almost horizontal, that is, until performance is no longer improving and that this level of performance would be used to gauge client potential. As mentioned above, however, improvement can continue for many thousands and even millions of trials. For this reason, Dunn (1976) has suggested that Tillman's technique might require an exorbitant amount of practice before performance levels off. Dunn proposed, instead, that the data on the performance of a limited number of trials could be fitted to a regression (or learning curve) equation and that this method could be used to accurately predict client potential.

The term "learning curve" usually refers to a graph representing changes in performance over time or trials. Though the changes in performance can be attributed, in part, to learning, variations in the curve also reflect variables other than learning which affect performance (e.g., environmental variables, motivation). Though these graphs of performance do not necessarily reflect the actual amount of learning that occurs, they do reflect how an individual actually performs, which is the most important aspect. Since the term learning curve is widely used in literature this study referred to the graphing of performance (and equations which describe such performance) as a learning curve, with the realization that such curves reflect the effects of many variables.

The research by Blakemore and Coker (1982) also indicated that the use of the learning curve technique does have great potential for providing accurate estimates of the level of performance that someone can attain at a task following practice. Blakemore and Coker had Vocational Evaluation clients perform on the same work sample for five consecutive work days. On the average, performance was 30.68% better on the final day of practice (Day 5) than on the first day of practice (Day 1). Thus if the performance level (total time score or average score) for Day 1 had been used as the estimate of the client's capacity to perform this task, their potential would have been underestimated by an average of 30.68%. Blakemore and Coker's analysis demonstrated that learning curves could produce significantly more accurate predictions on Day 5 performance. They found that predicting Day 5 performance using the total performance scores from Days 1-4 produced predictions that differed from the obtained level of performance by only 6.78%, on the average. They also predicted that Day 5 performance level using only the time scores for the first 50 Repetitions of the task (Day 1) and found that these predictions differed from the obtained level of performance by 17.15%. Both of these estimates were significantly better than the 30.68% average error made when using the total time score for Day 1 to estimate Day 5 performance level. Thus Blakemore and Coker's results clearly indicate that learning curves can be used to produce significantly more accurate estimates of someone's capacity to perform a task than is typically obtained when the total time score for a single administration of work samples is used to estimate that capacity. The findings of the study by Dunn (1976) closely paralleled Blakemore and Coker's findings.

The advantage of the learning curve approach to evaluating work sample performance is that this method reflects what changes occur in the client's work sample performance during testing. A static process of evaluating the level of functioning, such as using the mean or total production rate, fails to account for differential performance during the repetitions of the tasks within the work sample and the potential for further learning. Individuals functioning at the same average level on a work sample involving several repetitions are not necessarily performing comparably during the entire session. Figure 1 illustrates this point. In Situation A, the idealized learning curve is presented where skill acquisition increase consistently over time. In Situation B, performance deteriorates over time rather than steady improvement. It is clear that the client initially performed well, but performance deteri-

FIGURE 1:

Examples of differential performance during a work sample with the same normative score of 67%.

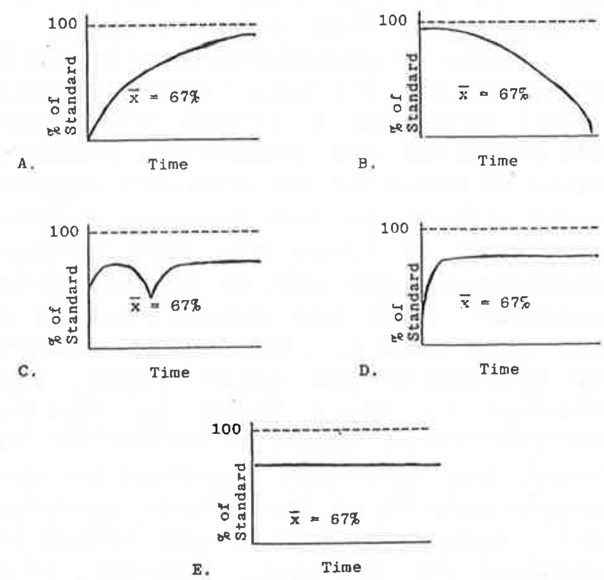
A. Normal acquisition under an idealized learning curve.

B. Decline in performance due to fatique or lack of motivation.

C. Acquisition and reacquisition due to temporarily forgetting tasks, disruption, lack of attention, etc.

D. Rapid reacquisition to steady state indicating the relearning of a previously mastered task.

E. Idealized practiced worker performance assumed under traditional work sample administration.



orated; and may have been caused by fatigue, boredom, confusion, etc. In Situation C, performance is relatively stable except that there is a momentary decline in task performance due to distraction, forgetting of instruction, or perhaps lack of parts. In Situation D, there is a rapid requisition of the task. It is indicative of having had previously mastered the task and of the ability to rapidly return to that level. Finally, steady level task performance from first to last repetition is graphed as is assumed under traditional work sample administration. Only in Situation E is the true current and potential level of task performance of 67% of the normative criterion accurate. In the other situations, current and potential task performance is underestimated and additional valuable information about the client is lost. It would not be lost, however, if a learning curve analysis was used.

The Microcomputer Solution to Learning Curve Analysis

The major drawback to the use of learning curve is the fact that the use of this approach could increase the work load of vocational evaluators beyond reason. In the traditional approach, the total number of pieces, the total time to complete a set number of pieces, or mean production rate are relatively simple to obtain. It is also very easy for evaluators to administer the work sample and obtain the data in such cases. A timer is started when the client begins the task and is stopped when the client is finished. In the interim, the evaluator can be busy with other tasks.

This would not be the case, however, if an evaluator were to collect data to be used in calculating a learning curve for a client. In this case, the evaluator would have to constantly monitor the client's performance, recording the amount of time taken to complete each item. Furthermore, the evaluator would then have a more complex analysis of the data to perform. This procedure would, of course, reduce the amount of time evaluators could spend on other aspects of their work or with other clients. Thus, though analysis of performance through generation of learning curves has been advocated for a number of years, few evaluators consistently employ them.

One of the primary purposes of the previous research project by Blakemore and Coker (1982) was the development of a microprocessing (microcomputer) system that automatically collects data on work sample performance and calculates a learning curve using the data which was collected. That device has the advantage for applied use of learning curves, in that it can be used to accurately reflect a client's present level of functioning and potential. At the same time, it does not have the disadvantage of increasing the work load for an evaluator. One purpose of this project involved determining the feasibility and utility of making the learning curve theory a routine procedure for evaluating client potential through the development and testing of software for microcomputers.

Learning Curve Analysis Software

The software that was developed involved the use of three concepts: Learning curve analysis, performance feedback, and pacing of performance. For all three concepts, the recording of the time it takes for a client to complete each repetition of a task on a work sample is required. The computer provides the timer, but the task must include switch closure to start and stop the timer. The closure can be obtained by including pressing a switch as part of the task elements, or an element could start and stop the timer. In the latter case, a completed piece could be dropped into a box which closes the switch or breaks a photocell beam. There are a number of more creative and exotic ways that switch closure or opening could result in control of the timer that is part of the software program or computer. Once the task is appropriately tied to the computer, an evaluator or client can utilize the software.

The accompanying manual explains how the user can select and interact with the various programs. In Appendix A, selections within the Main Menu (M), Learning Curve Analyzer Program (L), Performance Enhancer Program (E), Feedback Menu (F), Pacer Menu (P), Data Analysis Program (D), and Learning Curve Analysis Menu (C) are given. The presentation demonstrated the operation of the various sub-routines of the software. In addition to these relatively well known learning theory techniques, the "vest 20% method" developed by the Research and Training Center (Blakemore and Coker, 1982) and the demonstration of confidence intervals or error of measurement associated with the learning curves were discussed.

The "Performance Analyzer and Performance Enhancer" software were developed as part of the objectives of the Research and Training Center grant awarded to the Stout Vocational Rehabilitation Institute by the National Institute of Handicapped Research, Officer of Special Education and Rehabilitation, Department of Education. Currently, this software is undergoing field testing in three different rehabilitation facilities and will be made available for use on the Commodore 64 computer with disk drive upon completion. The software may be made available for other computers. The Commodore, however, does provide a relatively sophisticated computer at a reasonable price. The Commodore was chosen to increase the likelihood of the purchase of a computer dedicated to applications within the rehabilitation services such as Vocational evaluation, work adjustment, skill training, and job placement.

APPENDIX A

Software Program Selections

PERFORMANCE ANALYZER AND PERFORMANCE ENHANCER

Copyrighted Computer Program

Research and Training Center
University of Wisconsin-Stout

M

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***********************************
          WELCOME TO THE MAIN MENU
***********************************

SELECT ONE OF THE FOLLOWING:

    L = LEARNING CURVE ANALYSIS

    E = PERFORMANCE ENHANCEMENT PROGRAM

    D = DATA ANALYSIS OF RECORDED DATA

    Q = QUIT

ENTER THE SYMBOL OF YOUR CHOICE
AND PRESS RETURN
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L

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****************************************
          WELCOME TO THE LEARNING CURVE
                 ANALYZER PROGRAM
****************************************

SELECT ONE OF THE FOLLOWING:

    C = DATA COLLECTION

    D = DATA ANALYSIS

    R = REPORT

    ← = RETURN TO MAIN MENU

ENTER THE SYMBOL OF YOUR CHOICE
AND PRESS RETURN
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E

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*******************************************
              WELCOME TO THE PERFORMANCE
                   ENHANCER PROGRAM
*******************************************

SELECT ONE OF THE FOLLOWING:

    F = FEEDBACK PROGRAMS

    P = PACER PROGRAMS

    D = DATA ANALYSIS

    R = REPORT

    ← = RETURN TO MAIN MENU

ENTER THE SYMBOL OF YOUR CHOICE
AND PRESS RETURN
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F

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**********************************************
               WELCOME TO THE FEEDBACK MENU
**********************************************

SELECT ONE OF THE FOLLOWING:

    1 = BARGRAPH

    2 = BASKETBALL

    3 = HOPPER

    4 = PERCENTAGE OF STANDARD

    ← = RETURN TO PERFORM. ENHANCER MENU

ENTER THE SYMBOL OF YOUR CHOICE
AND PRESS RETURN
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P

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********************************************
                WELCOME TO THE PACER MENU
********************************************

SELECT ONE OF THE FOLLOWING:

    1 = SHARK CHASE

    2 = CLOCK

    ← = RETURN TO PERFORM. ENHANCER MENU

ENTER THE SYMBOL OF YOUR CHOICE
AND PRESS RETURN
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D

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*******************************************
                   WELCOME TO THE DATA
                     ANALYSIS PROGRAM
*******************************************

SELECT ONE OF THE FOLLOWING:

    B = BEST 20% METHOD

    C = LEARNING CURVES

    S = DATA SUMMARY

    ← = RETURN TO MENU

ENTER THE SYMBOL OF YOUR CHOICE
AND PRESS RETURN
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C

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******************************************
                WELCOME TO THE LEARNING
                      CURVES MENU
******************************************

SELECT ONE OF THE FOLLOWING:

    1 = Y=A*X^B          POWER

    2 = Y=A+B*C^X        MODIFIED EXPONENTIAL

    3 = Y=B*X/X+A        LEARNING CURVE

    ← = RETURN TO DATA ANALYSIS MENU

ENTER THE SYMBOL OF YOUR CHOICE
AND PRESS RETURN
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