A STUDY OF AUTOCORRELATIONS FOR PERFORMANCE CONSISTENCY

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CHAPTER I

REVIEW OF THE LITERATURE

Introduction

Productivity, although a broad, ill-defined term, has been singled out as a key factor in a stable economy. There exists a multitude of definitions for productivity, however, the American Productivity Center (1979) has put forth one which shall be used here. They define productivity as ". . . the ratio of quantities of outputs to quantities of inputs" (p 1).

Concern with this concept has been constantly increasing and even though the problem appears to be paramount today, for many years both psychologists and industrial engineers as well as many other professionals have devoted a tremendous amount of effort to increasing productivity. Productivity encompasses many facets including salesmanship and economic conditions. However, psychologists typically focus on improving the performance of the employee. Their methods have included a variety which range from improved selection and placement techniques, different testing procedures and changes in the work environment to devising more comprehensive compensation benefits and various performance incentives. Zenger (1976) stated,

> of the major factors affecting the productivity of organizations, the amount of capital investment, the quality of technology, invention of new products and services, and performance of employees, only employee behavior can be changed without large

expenditures of money" (p 513).

He listed ten areas in which behavioral scientists could help organizations increase their productivity including job design and work group norms. Invariably, whether validating selection tests or analyzing the effects of wage systems, the actual output rate of the employee, the number of units produced as defined by the job analysis, in other words the job performance is used as the criterion.

Most researchers are aware of the importance of a reliable criterion, however, few studies have been conducted regarding the reliability of industry's most utilized criterion - performance (Ronan and Prien, 1971). If the output rate (performance) on a job is an unreliable criterion, then many hypotheses may be supported by mere chance and personnel testing devices, etc., could become invalid (Rothe, 1978).

The following reviews selected literature which examine the consistency of performance and its implications.

Selected Literature Review

In 1944, Tiffin cited a study of 203 hosiery "loopers", who were paid on an incentive wage system, and their production records. He presented a correlation coefficient of .96 between the production of the first and second weeks which were studied. From this he concluded that production "is a relatively fixed and permanent characteristic" (p 7). Thus, psychologists and industrial engineers had reason to believe that production or output records were reliable criteria by which to measure work performance.

Ghiselli and Brown (1948) devoted a major section of their Personnel and Industrial Psychology text to the reliability of a measure of proficiency on the job as a criterion. They also regarded output, the number of units of work turned out by an employee, as the most common measure of proficiency. The authors pointed out that reliability should be statistically determined rather than assumed. However, that was the extent of the warning. Ghiselli and Haire (1960) later studied the reliability of job performance. Production records from the first 18 weeks of employment for a group of new taxicab drivers were used for data. Criticism was directed toward the practice of validating selection tests with job performance measures obtained early in employment. Suggestion was offered that performance changes considerably during employment and if the purpose of selection tests is to hire individuals who will successfully perform, then the validation procedure should include job performance measures obtained over a long period of employment. In addition, correlations between production on the various weeks were a little lower for distant than closer weeks but they reported that all were substantial. The actual figures were not given.

Ronan and Prien's books of 1971 presented evidence which questions the reliability of job performance in psychological studies performed outside the sterile environment of the laboratory. Included was an article by Rothe and Nye (1958) which will be discussed later. The authors reviewed literature in such areas as developing a criterion for testing variables especially in applied research, the reliability of performance, and the reliability of performance observation. The articles ranged from analyzing individuals to groups to whole organizations. Ronan and Prien introduced the section on reliability of performance stating that human performance must be reliable in order to predict and few studies have been done in this area. They surmised that those studies which have been done "tended toward the conclusion that performance is <u>not</u> reliable. . ." (p. 91).

Coinciding with the publication of the Ronan and Prien text were two articles which exemplify the importance of a thorough understanding of worker output rates in applied research. Groff's (1970) major concern was the establishment of optimal standard rates which would maximize output. These rates might differ from the "universal standard" that many firms have accepted which enables workers to exceed the standard or quota by 25 to 30% on the average. Fundamental to ascertaining this "optimal standard" is the output rate of the employee. If this performance is not consistent the search for the most advantageous standard may be futile.

Hershauer's (1971) article in <u>Industrial Engineering</u> asked, "Optimal incentive standards: Are they possible?" In order for these desired standards to be determined three steps must be taken. First, maximum sustainable output must be determined. Second, the worker-output response curve must be determined. That is where the greatest difficulties are encountered. Third, the cost model Groff put forth could be used. Again, the importance of understanding worker output trends was discussed as the weak link in the system.

The preceding articles indicate that the use of worker performance in the form of output rates as a criterion should be questioned. Nevertheless, as of 1978, only one series of studies has concentrated directly on the consistency of individual output. This series, which is summarized below, was conducted by Rothe and Rothe and Nye beginning in 1946.

The first study (1946a) examined the output rates of 16 butter wrappers for 8 days. These women were paid by straight time plus overtime. Daily work curves for each wrapper were developed as well as group daily curves based on readings, taken every fifteen minutes, of the number of pounds wrapped. In addition, individual and group trend lines were constructed over the 8 days. It was concluded that individual daily work curves did not indicate "any characteristic, predictable pattern" (p. 209). The median intercorrelation between the work curves of each day for each operator was near zero. The range of rhos for group daily work curves over a five day period were from -.22 to .53 and the median was .30. Rothe reasoned, among other things, that group trend lines represented a "stable phenomenon" within the context of this study. It was here that Rothe first suggested that in studying the effects of music, lighting, rest periods, etc. the researcher should gather data which covers more than one employee over a long period of time.

The second article by Rothe (1946b) was concerned with further analyses of the same data. Individual and group frequency distribution of output rates for the wrappers were investigated and tested for normality. The employees were paid straight time wage plus overtime and there was no incentive pay system in effect. In addition, Rothe stated that each worker showed a large range of output rates and this lead to the hypothesis "that the incentives to work may be considered ineffective when the ratio of the range of intra-individual differences is greater than the ratio of the range of inter-individual differences" (p 326). In other words, when the within subjects variability of output rate is greater than the variability of output between subjects, the incentive to produce may not be properly defined and/or implemented by management. By the final study in the series the author admits that this hypothesis had very little support. According to Rothe, if there is a high consistency in performance, it reflects a motivated worker. Thus, it is important to acknowledge the pay system used by the organization under study.

The next year, Rothe (1947) examined the output rates of 130 machine operators at an auto company. The data consisted of 3 bi-weekly sets of production records. There was no incentive system present. However, the employees were paid by standard time determined by time studies. That is the time required to do a job by an "average" operator under typical conditions. An important point that the author made was that with the use of standards the outputs of employees from different jobs may be combined.

> It is unfair to compare the number of gears one man makes with the number of pieces another man blanks out on a punch press, but we can compare the relative efficiency of performance of these two men if a standard of performance has been established for each (p. 485).

Of importance to the present study were the intercorrelations of the 3 two week time periods. The correlations between periods 1 and 2, 2 and 3, and 1 and 3 were .57, .68, and 172 respectively. These correlations are lower than the .96 reported by Tiffin earlier and it was hypothesized that the difference might be due to the lack of incentive in the Rothe study. Finally, Rothe amended an hypothesis which is important to the present study. It read "if the intercorrelation of group output rates for two periods closely related in time is less than .80 the incentivation is not highly effective, while intercorrelations higher than .90 indicates effective incentivation" (p 488). These figures are based on Tiffin's results and his own. It should be noted that this hypothesis was continuously revised throughout the series of studies.

Rothe's fourth such publication came in 1951. The output rates of 18 chocolate dippers were studied for 16 weeks. These employees were all experienced and were paid a one-to-one ratio for performance over standard. Correlations between successive weeks' performance were obtained on an individual basis. The median inter-weekly correlation was determined to be .85. Of significance was the writer's statement regarding the idea that the level of consistency in performance may be more than an indication of a reliable or unreliable criterion. He suggested that output rates in and of themselves are important sources of information. The consistency of output might indicate the effectiveness of incentive systems.

The output rates of 27 coil winders over 38 weeks were investigated next (Rothe and Nye, 1958). There was no incentive system present. Of the findings the most relevant to the present study concern the correlations of the workers' output between successive weeks. The range was from -.03 to .91 with the medium at .64 and the range with the highest frequency was .71 to .80.

According to Rothe (1959) field studies are superior to laboratory experiments when testing hypotheses concerning performance consistency. Further, he contends that the validity of the hypotheses is best examined through observations taken on the job where realistic conditions prevail. The subjects of this study were 36 machine operators working under an incentive plan. The study covered 10 weeks. The median correlation between adjacent weeks over all subjects was found to be .78. This approximates the hypothesized criterion for indication of the presence of effective incentives.

A further study was conducted in a third plant of machine operators (Rothe and Nye, 1961). The data collected was taken from two different time periods with a maximum of 55 employees examined in 1958 for 11 weeks and 68 in 1960 over a 12 week period. All were paid by a standard-hour rate. As stated in the article, "the median rho was .48 with a range of .29 to .80 for 1958. The median rho for 1960 was .53 with a range of .17 to .72." This supported the hypothesis which was stated above.

A deviation from the usual situation was found in Rothe's 1970 study. It was conducted immediately after an incentive system was removed at the request of the union. This resulted in a decrease in the take home pay and, in general, a 25% drop in the output of the group of welders was experienced. It should be noted that this drop was temporary and performance soon showed an upward trend and by the end of the study, the rate was as high as it was prior to the elimination of the incentive. The median rho for successive weeks was .52 and the range was from .11 to .90. Rothe concluded that since the intercorrelations were low and there was no longer an incentive program in existence, there was support for his hypothesis which in part stated that if the intercorrelation is less than .70, the incentivation is not highly effective. Further support for the hypothesis concerning week to week consistency and incentive effectiveness was gathered.

Rothe's latest study (1978), analyzed the output rates of 4 departments of foundry workers. Two of the groups were paid individual incentive rates and the other two were on a group incentive plan. It should be noted that the individual incentive plan was only just being adopted in one of the two groups. In addition, the group incentive plans depended on two different size groups. The resulting median intercorrelations were .68 and .82 for the individual incentive groups and .67 and .72 for the group incentive departments. This led Rothe to revise downward his standard for inferring the presence of an effected monetary incentive. The result was a hypothesis which states "a week-to-week correlation of .65 indicates the presence of some effective (monetary) incentive" (p 44). He concluded that output in an industrial setting is inconsistent and consistency, where the correlation is greater than .65, may suggest an effective incentive system. Finally, it was emphasized that objective data had been used. The author felt that questionnaires, etc. might have contributed information but certainly would have added controversy.

It should be noted that Tiffin (1952) in the third edition of his Industrial Psychology text revised his statement concerning the .96 inter-week correlation mentioned earlier. A statistical adjustment was made in order to remove the effect of experience. This reduced the correlation of performance between successive weeks to .85 which was high enough for Tiffin to still conclude that an employees production level is "rather a relatively fixed and permanent characteristic." It is believed that he used production level as output rate has been used here. By the fifth edition (Tiffin and McCormick, 1965) the variability in performance was finally acknowledged.

Today, concern with increasing performance on the job and productivity is as high as ever. The Labor Department announced in July, 1980 that "productivity during the April-June period fell at an annual rate of 12.5 percent, the largest quarterly drive since the department began issuing productivity reports 33 years ago" (p 2). This drop resulted in a 3.1 percent annual drop in the productivity of the U.S. economy during the spring of 1980. The article, entitled Productivity Down, defined productivity as a "measure of goods and services produced by the eocnomy in each hour of paid working time" (p 2). More needs to be known about the consistency of job performance which is the criterion for most on-the-job experiments conducted to increase output.

Below in Table I is a summary of the findings of the studies conducted by Rothe, Tiffin, and Rothe and Nye.

The purpose of the present exploratory field study is to test Rothe's contention that output rates are inconsistent. The present study is descriptive and longitudinal. The data cover a 179 week period whereas Rothe's longest sudy examined 48 weeks.

Furthermore, although Rothe emphasized that a high correlation between weekly output rates may indicate an effective incentive system, he only conducted one study in which more than one group from the same plant were on an individual incentive plan. But since the second group was only beginning to adopt the plan when the study began, comparisons may not have been appropriate and certainly the actual effect of the plan on worker output consistency could not be fully assessed. The

TABLE I

SUMMARY OF OUTPUT RATES STUDIES

Study	Type of Job	# of Weeks	Incentive	Median Correlation Lag=1
Tiffin (1944)	hosiery loopers	2	yes	.96
Tiffin (1952) (revised findings of 1944 study)	hosiery loopers	2	yes	.85
Rothe (1946a)	butter wrappers	8 days	no - straight time plus over-time	.30
Rothe (1947)	machine operators	3 successive bi-weekly periods	no - standard time	r_{12} =.57 r_{13} =.72 r_{23} =.68
Rothe (1951)	chocolate dippers	16	yes - 1-to-1 ratio over standard	.85
Rothe (1958)	coil winders	38	no	.64
Rothe (1959)	machine operators	10	yes	.78
Rothe (1961)				
(1958)	machine operators	11	no - standard time	.48
(1960)	machine operators	12	no - standard time	.53
Rothe (1970)	welders	48	no	.52
Rothe (1978)	4 groups of foundry workers	11	yes - 2 groups on individual incentive	.68, .82
			2 groups on group incentive	.67, .72

present study, however, examines two groups of workers whose jobs differ but both come from the same plant and have been on the same incentive plan for an equal length of time.

In addition, while Rothe correlated successive weeks to examine consistency, this study will analyze and summarize the correlations between every one of 179 weeks to seek a trend in the consistency of performance. This may lead to an estimation of how well one might be able to predict performance in a future week based on another week's output. Lastly, in keeping with Rothe's preference for objectivity, the data were obtained from company records which were a reliable source.

CHAPTER II

METHOD

Subjects

The subjects in this study were 46 experienced female sewing macine, etc. operators who had been employed continuously from January, 1977 to June, 1980 in a plant owned by a midwestern manufacturing company. The plant manufactured several garments including T-shirts, briefs, athletic shirts and pajamas. All employees belonged to the International Ladies' Garment Workers' Union.

In this plant, jobs were broken down into two broad categories. Group I jobs consisted of inspecting, folding, and boxing the garments. Also included were all other non-sewing machine jobs such as applying the company's label to the garment. Group II jobs consisted of all sewing machine operations. The inspection and folding jobs are described by 789.687 in the Dictionary of Occupational Titles (U.S. Department of Labor, 1977) and jobs such as the tackers are found under 786.685. Definitions of the various sewing machine operations are under 786.682. A brief description of each operation involved in this study and the groups belonging to each may be found in Appendix A.

As mentioned above, all 46 operators were experienced. Based on their seniority dates, (rounded to the nearest month) which were assigned beginning at the end of the 30 day probationary period for new employees, the Group I workers had experience which ranged from nearly 39 months to

280 months (over 23 years). The average was 126.16 months or 10.5 years. Company job experience for Group II workers ranged from 16 to 205 months (over 17 years). The mean was just under 98 months or 8 years. Clearly these women were familiar with the duties and requirements of the work. Exactly how long each operator had worked with the machine she was on at the time of the study is not known. However, none were trainees.

In keeping with company policy, the women were divided into two groups for the purpose of the analysis.

Group I consisted of 19 employees who:

1) worked throughout the 3½ year period,
2) had missing data for no more than 12 consecutive weeks (only 4 of the entire 46 subjects had more than 7 consecutive weeks missing),
3) were Group I workers,
4) and did not change jobs during the study.

Group II consisted of 27 employees who met the same requirements as stated above but these women were Group II workers.

Several comments should be considered. First, there were 26 additional employees who had worked in the plant throughout the designated time period and had missing data for no more than the required 12 consecutive weeks however, they were not included in the study because they experienced at least one job change which was not clearly documented in the records which were used as data. Furthermore, it was clear that job changes had profound effects on employees with regard to consistency of performance. The time it took to get accustomed to a new job varied with each individual. Thus, the output data of these employees was excluded from analysis in this study. Secondly, missing data does not necessarily indicate the employee was absent during that time period. When missing data was encountered the weekly hourly average from the previous week was substituted. This would tend to increase the week to week correlation, but given the number of subjects and weeks studied, the effect was assumed to be insignificant. Details in relation to the data are presented in the next section.

Company Pay Policy and Employee Records

The standards for all of the jobs were obtained using Method-Time Measurement (MTM) procedures using predetermined times. This method was introduced by Maynard, Stegemerten and Schwab (1948). They defined MTM as

> . . . a procedure which analyses any manual operation or method into the basic motions required to perform it and assigns to each motion a predetermined time standard which is determined by the nature of the motion and the conditions under which it is made (p 12).

Once the motions actually used in a job are determined, the associated predetermined time standards are found. The sum of these times along with a 20% personal fatigue and delay allowance gives the standard for the job. Time studies are conducted when there is an indication that a rate is inappropriate. These standards then make it possible to compare the relative efficiency of performance for all employees.

The pay system employed at the plant was based on piecework with all operators being guaranteed at least minimum wage. That is, those who produced below quota received a guaranteed minimum wage whose level depended on one's seniority date. This is detailed later. Those employees who produced above quota received wages commensurate with their rate of output. This incentive system is explained to employees during orientation and may be found in the _Reference Book to Company Policy_ which each employee received upon entering the company.

The following information may lead to a better understanding of the financial situation of the subjects. By the end of the study, the expected earnings was $3.92 for Group I employees and $3.98 for Group II employees. Expected earnings are estimates of what the average employee could earn in an average hour based on the pay system in effect. In this case, there is only a six cent difference between the two groups. This amounts to a 1.5% difference. Rate increases of 7% were given annually according to the manager of the plant. However, since the increases applied to all employees they did not disturb the relative earnings.

The guaranteed minimum wages applicable during the study may be seen in Table II. After 30 days of employment, the garment workers were required to join the union and there was a corresponding wage increase. Finally, there was a guaranteed wage increase after 6 months. It may be noted that this particular company has been cited as "one of the better paid apparel companies."

TABLE II

GUARANTEED MINIMUM WAGES

	1977	1978	1979	1980
Starting wage	$ 2.30	$ 2.65	$ 2.90	$ 3.10
After 30 days	2.40	2.70	2.95	3.15
After 6 months	2.70	2.88	3.09	3.30

The data used for the analyses were taken from the Weekly Production Earnings Reports kept by the company. In this sense, it was a retrospective study. However, the data was collected continuously and reliably in the manner of longitudinal studies. Of the 179 weeks there was no data for 7 of them because of vacations, etc. These records included the employee's identification number, name, and seniority date. Also included was the stated quarterly average which was the average amount of money paid per hour to the employee during the previous quarter, in other words, the average earned rate. For example, if in the last quarter of 1978 an employee, of more than 6 months, earned $1.50 per average hour, based on output, the quarterly average shown would be $2.88, the minimum wage that was actually paid. Finally, the records contained the weekly breakdown of the monetary equivalent of the average per-hour output rate of each employee based on the operation's piecerate. In other words, these were records of the number of pieces produced by each employee transformed into dollars and cents according to the rate set for each operation. The monetary figures which appeared were a direct linear function of the units produced by the employees. This section did not indicate the wages paid. In the example above, here is would be appropriate to record $1.50 and not the $2.88 which was the guaranteed minimum wage. This data was sufficient to examine the relative position of an employee's output compared to other employees within the group.

Procedure

The Weekly Production Earnings Reports from January, 1977 to June, 1980 were collected from the company files and the analyses were conducted using a 370/168 IBM computer and modified Statistical Analysis Systems Packages (SAS). An Apple II Plus mini-computer was also used. These programs may be found in Appendix B.

Statistical Analyses

The present study is an attempt to extend Rothe's work. In his studies a main concern was consistency of performance as measured by how well output rates from successive weeks correlated. In other words, Rothe was interested in week to week consistency.

To go a step further, this study examines the trend of output rates over 179 weeks for two groups of workers. It questions how accurately one might be able to predict any particular week's average hourly output rate given another week's rates. Finally, it may give some insight into the relationship between performance as time increases.

Basically, autocorrelations were calculated for various time lags defined as K. A lag is an interval between events and specific to this case it is the number of weeks separating $week_i$ from $week_j$. For example, when K = 1 correlations are found for week 1 vs. week 2, week 2 vs. week 3, etc. When K = 20 correlations are found for week 1 vs. week 21, week 2 vs. week 22, etc. Eventually, one finds the regression of the average correlation on the lags and curve fitting procedures are applied to this data to arrive at an equation for this trend line which indicates how well one may predict worker output rates anytime in the future up to 3½ years in this case.

The following is a step by step summary of the statistical methods which were applied simultaneously to the 179 weeks of data for the group one workers and the group two workers. A sample of the Weekly Production Earnings Report may be found in Appendix C. All steps were repeated for the second group.

First, a matrix containing the intercorrelations (Pearson r) of weekly production data was computed. That is, the output rates of every week were correlated with every other week for each group of employees.

From there, the inter-week correlations were organized into an upper triangular matrix according to K, the time interval between weeks. Figure 1 diagrams this.

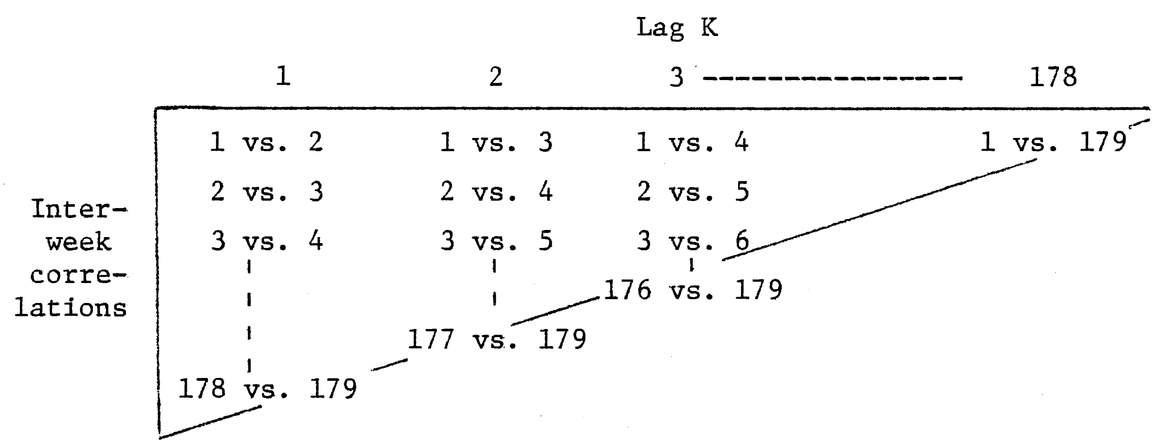

Figure 1. Diagram of the Organization of Inter-weekly Correlations

Each of these scores were normalized by converting them into Fischer Z scores. At this point the mean Z scores were found for each time lag (K) and finally a conversion was made back to correlations. The result was the mean correlation for each lag.

Empirical curve fitting procedures, which are outlined in the next chapter, were utilized to estimate the parameters of the regression equation. The regression of the mean correlations on the lags was plotted using the General Linear Models Procedure in SAS.

After inspecting the results it was decided that the parameter estimates could be improved upon. Thus an iteration program and a plotting program were used on an Apple II Plus computer to better the estimates.

CHAPTER III

RESULTS

Separate analyses were carried out for each group observed in the study. Recall that two groups of employees were included in the data collection. Group I consisted of 19 non-sewing machine operators and Group II was composed of 27 sewing machine operators. Discussion of the analyses will proceed in the order in which they were performed. The results for both groups will be presented simultaneously.

In order to grasp some understanding of the differences, if any, between the two groups, the weekly average output in terms of piecerate earnings were calculated for each group. These figures were based on the piecerate equivalent of the number of units produced by the employees while they were at their operation and on piecerate time. In addition, the range and the number of employees for whom data were available were found. Appendix D shows the means for Group I, Appendix E for Group II. Table III shows how the two groups compare by quarters. For reference, in June, 1980,the expected earnings based on engineering studies were $3.92 and $3.98, respectively. The most notable distinction between the two groups is that throughout the study the group one employees had higher mean piecerate earnings than group two. The average for group one employees fell below group two during only 4 of the weeks. The range for the remaining weeks was from $0.08 to a difference of $0.76. The mean difference over all the weeks was $0.325 per hour which amounts to a $12.80 per week average difference between the groups. There are a number of reasons that may lead to this discrepancy in pay. In spite of the fact that engineering studies have attempted to equate incentives surrounding each group of tasks, errors could have been made in these estimates.

TABLE III

QUARTERLY MEAN PIECERATE OUTPUT FOR GROUP I AND GROUP II

	Group I	Group II
Quarter	Mean	Mean
1	$ 4.06	$ 3.76
2	4.13	3.79
3	4.06	3.65
4	3.97	3.68
5	4.16	3.94
6	4.12	3.88
7	4.29	4.02
8	4.33	4.12
9	4.90	4.55
10	4.92	4.55
11	4.82	4.37
12	4.93	4.47
13	5.11	4.75
14	5.06	4.79

One of the main purposes of this study is to explore the stability or consistency of week to week performance in order to indicate how accurately one might predict future performance. Thus, several intermediate analyses had to be performed in order to arrive at a regression equation which might explain this phenomenon. Some of these analyses are interesting in and of themselves and each step will be explained.

The first step was to compute a matrix of inter-week correlations between every possible week for each group. The data used for the correlations was the average per-hour output rate based on piecerate which was explained previously. Each Pearson r indicated the relationship between the output rate, for one week and that of another week. As would be expected all correlations were positive. The majority of correlations for Group I were .70 and above. For Group II the intercorrelations were more varied with the majority of them at .60 and higher. Again, the difficulty of the task may contribute to these differences.

The next step was to organize the mass of correlations by lags. That is, the correlations were grouped by the number of weeks separating the weeks whose output rates were checked for interdependence. Thus, for a lag, K, = 1 all correlations for adjacent weeks were grouped together. For K = 2 all correlations performed on pairs of weeks with one week separating them were grouped together (i.e., $r_{\text{week 1 vs. 3, 2 vs. 4, . . . 177 vs. 179}}$). The largest lag was 178 and under this heading could be found the correlation between the output rate for all employees during week 1 and week 179. As the lag increased, the number of correlations arranged under the heading decreased. The resulting organization was a triangular matrix.

In order to make some comparisons with Rothe's work Tables IV and V show the frequency distribution of rs for a lag equal to one. That is, these are the correlations of each week's output with its adjacent weeks output as calculated by the Pearson Correlation methods. Since there were 179 weeks, there are 178 correlations. Table IV displays Group I's distribution and Table V shows Group II's. Inspection reveals that the distribution of r's for Group I was definitely more skewed than the distribution for Group II. Of the 178 r's, 84% of them were .91 or greater for Group I, while only 59% of the Group II r's were in the same range. The median correlations obtained were .98 and .94 for the respective groups. This is quite high relative to the correlations Rothe found for employees working under incentive systems. Briefly, he found correlations which ranged from .67 to .85 for various groups of workers. The thirteen zero's are the result of correlations involving weeks for which no data was available on the subjects (i.e., holidays, vacation periods). However, post hoc calculations which adjusted for these weeks resulted in only slightly higher correlations.

These mean correlations may indicate high consistency from week to week but they do not suggest any trend which may take place. Therefore, it was desirous to plot change in mean r as K increased in order to recognize any trend which might occur. However, in order to accomplish this the correlations had to be converted to Z scores using Fischer's transformation. The equation for the transformation is:

$$Z = \tfrac{1}{2} \log e\ (1 + r) - \tfrac{1}{2} \log e\ (1 - r).$$

TABLE IV

FREQUENCY DISTRIBUTION OF PEARSON
r'S FOR K = 1: GROUP I
EMPLOYEES

r	Frequency
.96 - 1.0	120
.91 - .95	30
.86 - .90	5
.81 - .85	6
.76 - .80	2
.71 - .75	1
.66 - .70	0
.61 - .65	1
0.00	13
	178

Median = .98

TABLE V

FREQUENCY DISTRIBUTION OF PEARSON r'S FOR K = 1: GROUP II EMPLOYEES

r	Frequency
.96 - 1.0	34
.91 - .95	71
.86 - .90	33
.81 - .85	13
.76 - .80	5
.71 - .75	3
.66 - .70	4
.61 - .65	1
.56 - .60	0
.51 - .55	1
0.00	13
	178

Median = .94

This transformation was necessary for several reasons. First, the shape of the sample distribution of r is dependent on the magnitude of r because r varies between finite limits 0 to 1. In using Z transformations this relationship is broken up. The resulting r's then vary between plus and minus infinity.

Tables VI and VII list the mean correlations for each lag value. It may be noted that Group I experienced a higher level of performance consistency over the length of the study. One may speculate that the job content may have an influence on the level of consistency from one week to the next but the incentive levels for the groups also may not be equivalent.

From this data the regression of the mean correlations on the lags, K, were plotted for each group. These are illustrated in Figures 2 and 3. These curvilinear plots were then inspected with the goal in mind of developing regression equations which could mathematically describe the trend. The curve fitting procedures as outlined by Lewis (1960) were followed to an extent. A description of the exact steps follows.

Empirical curve fitting procedures were used to arrive at equations to describe the curves. To begin with, inspection curves were drawn through the data and then their shapes were examined. It appeared that they could be described by the general equation for a hyperbolic curve with an added constant. The general form of the equation is $Y = aX^b + c$. The constant, c, is the asympotote or the lower limit of the curve. The slope of the line is indicated by b and a. When b assumes a negative value the curve is said to be of a hyperbolic type.

TABLE VI

MEAN CORRELATIONS FOR EACH LAG FOR
GROUP I EMPLOYEES

Lag	Mean Correlation	Lag	Mean Correlation
1	.9598	27	.8939
2	.9486	28	.8823
3	.9404	29	.8900
4	.9386	30	.8868
5	.9312	31	.8842
6	.9294	32	.8796
7	.9254	33	.8778
8	.9213	34	.8751
9	.9202	35	.8704
10	.9113	36	.8717
11	.9077	37	.8706
12	.9103	38	.8726
13	.9096	39	.8692
14	.9033	40	.8673
15	.8977	41	.8615
16	.8967	42	.8660
17	.8945	43	.8662
18	.8987	44	.8618
19	.8893	45	.8591
20	.8871	46	.8580
21	.8868	47	.8613
22	.8855	48	.8616
23	.8916	49	.8639
24	.8904	50	.8613
25	.8889	51	.8648
26	.8908	52	.8653

VI (Continued)

Lag	Mean Correlation	Lag	Mean Correlation
53	.8585	85	.8127
54	.8572	86	.8219
55	.8507	87	.8191
56	.8529	88	.8210
57	.8488	89	.8173
58	.8448	90	.8220
59	.8503	91	.8205
60	.8516	92	.8171
61	.8495	93	.8242
62	.8462	94	.8302
63	.8381	95	.8268
64	.8367	96	.8267
65	.8290	97	.8321
66	.8390	98	.8365
67	.8392	99	.8486
68	.8345	100	.8444
69	.8332	101	.8393
70	.8315	102	.8450
71	.8208	103	.8442
72	.8163	104	.8487
73	.8160	105	.8419
74	.8076	106	.8334
75	.8112	107	.8255
76	.8155	108	.8222
77	.8077	109	.8263
78	.8075	110	.8310
79	.8061	111	.8184
80	.8119	112	.8233
81	.8173	113	.8134
82	.8147	114	.8109
83	.8126	115	.8138
84	.8131	116	.8144

VI (Continued)

Lag	Mean Correlation	Lag	Mean Correlation
117	.8209	148	.8419
118	.8236	149	.8394
119	.8186	150	.8483
120	.8184	151	.8635
121	.8129	152	.8650
122	.8269	153	.8640
123	.8231	154	.8723
124	.8229	155	.8722
125	.8258	156	.8663
126	.8264	157	.8608
127	.8277	158	.8516
128	.8357	159	.8715
129	.8318	160	.8743
130	.8426	161	.8690
131	.8470	162	.3579
132	.8448	163	.8484
133	.8494	164	.8434
134	.8514	165	.8414
135	.8375	166	.8291
136	.8541	167	.8111
137	.8442	168	.8163
138	.8460	169	.8217
139	.8491	170	.8153
140	.8427	171	.8055
141	.8420	172	.7986
142	.8385	173	.7903
143	.8435	174	.7989
144	.8421	175	.7810
145	.8449	176	.7981
146	.8466	177	.7932
147	.8369	178	.7983

TABLE VII

MEAN CORRELATIONS FOR EACH LAG
FOR GROUP II EMPLOYEES

Lag	Mean Correlation	Lag	Mean Correlation
1	.9018	30	.7329
2	.8773	31	.7341
3	.8631	32	.7231
4	.8549	33	.7187
5	.8466	34	.7144
6	.8405	35	.7159
7	.8300	36	.7156
8	.8301	37	.7137
9	.8091	38	.7078
10	.8110	39	.7075
11	.8027	40	.6975
12	.7985	41	.7003
13	.7903	42	.6968
14	.7956	43	.6958
15	.7932	44	.6949
16	.7863	45	.7021
17	.7766	46	.6957
18	.7800	47	.6975
19	.7696	48	.6983
20	.7628	49	.6997
21	.7591	50	.6995
22	.7476	51	.6936
23	.7436	52	.6983
24	.7440	53	.6899
25	.7485	54	.6797
26	.7429	55	.6837
27	.7413	56	.6717
28	.7344	57	.6718
29	.7321	58	.6755

VII (Continued)

Lag	Mean Correlation	Lag	Mean Correlation
59	.6653	90	.6251
60	.6673	91	.6310
61	.6619	92	.6358
62	.6667	93	.6310
63	.6663	94	.6307
64	.6668	95	.6293
65	.6676	96	.6273
66	.6617	97	.6274
67	.6608	98	.6313
68	.6529	99	.6359
69	.6628	100	.6327
70	.6614	101	.6438
71	.6492	102	.6560
72	.6487	103	.6432
73	.6453	104	.6506
74	.6324	105	.6330
75	.6314	106	.6245
76	.6291	107	.6237
77	.6369	108	.6301
78	.6315	109	.6205
79	.6292	110	.6326
80	.6279	111	.6204
81	.6334	112	.6338
82	.6317	113	.6173
83	.6371	114	.6113
84	.6341	115	.6201
85	.6328	116	.6288
86	.6390	117	.6319
87	.6377	118	.6342
88	.6341	119	.6357
89	.6305	120	.6386

VII (Continued)

Lag	Mean Correlation	Lag	Mean Correlation
121	.6388	150	.5975
122	.6569	151	.6235
123	.6296	152	.6180
124	.6333	153	.6384
125	.6224	154	.6385
126	.6112	155	.6334
127	.6183	156	.6178
128	.6232	157	.6352
129	.6287	158	.6387
130	.6394	159	.6705
131	.6310	160	.6693
132	.6313	161	.6508
133	.6378	162	.6620
134	.6359	163	.6580
135	.6465	164	.6583
136	.6323	165	.6596
137	.6267	166	.6406
138	.6285	167	.6520
139	.6204	168	.6342
140	.6139	169	.6274
141	.6088	170	.6343
142	.6085	171	.5960
143	.6146	172	.6066
144	.5942	173	.6152
145	.6013	174	.5963
146	.6064	175	.5770
147	.6199	176	.5643
148	.6111	177	.5588
149	.6093	178	.5931

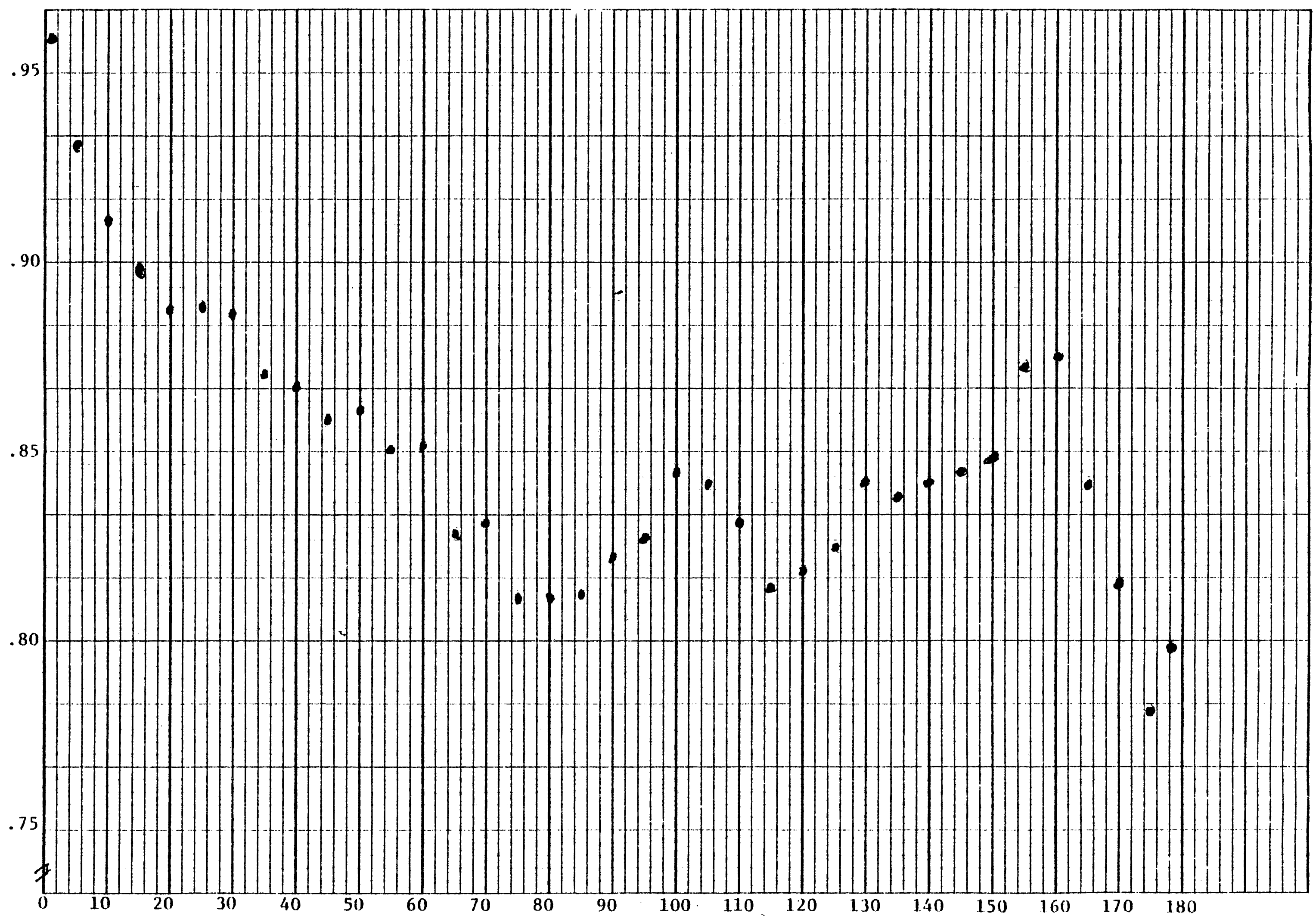

Figure 2. Regression of Mean Correlations on the Lags: Group I

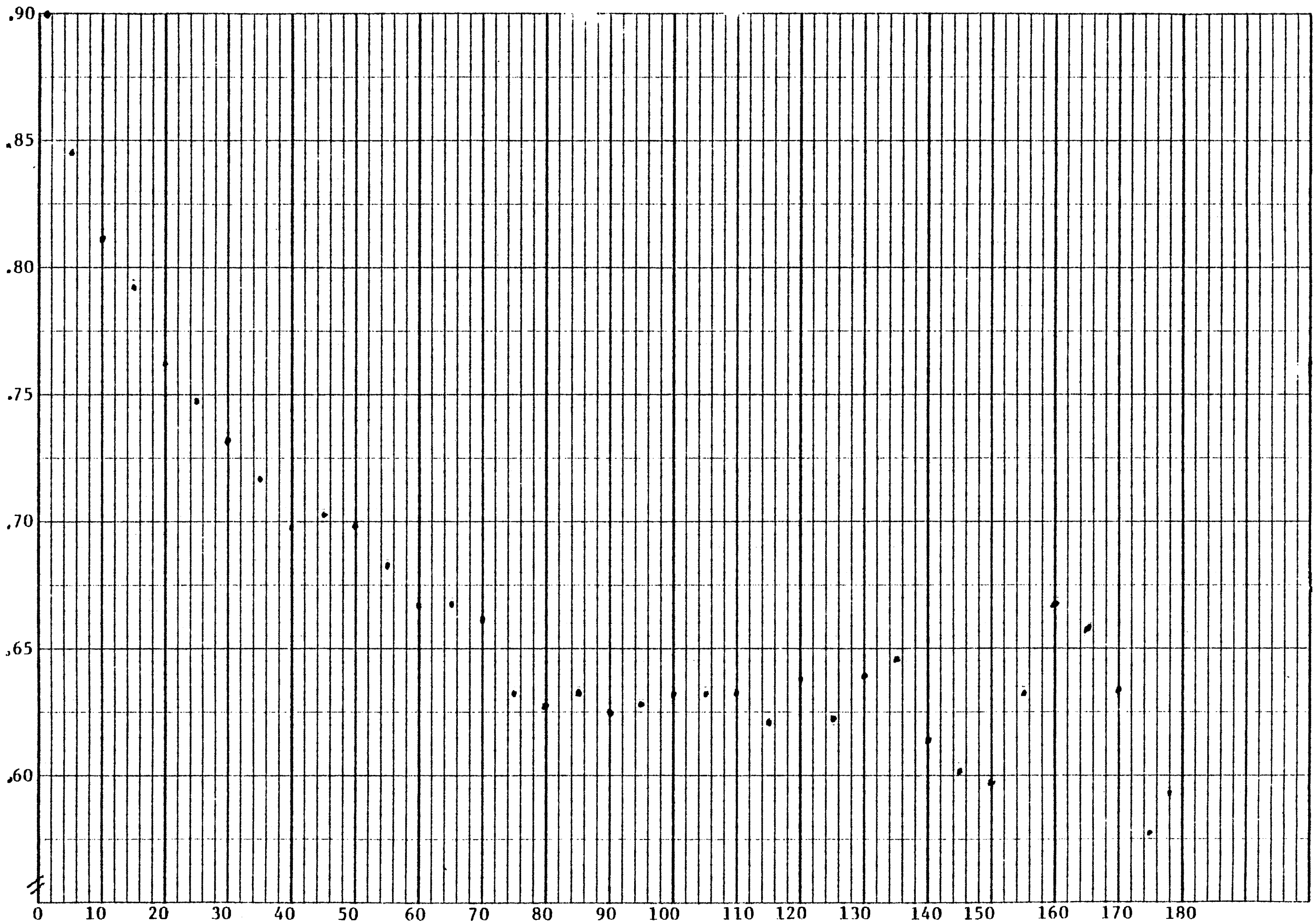

Figure 3. Regression of Mean Correlations on the Lags: Group II

The asymptote value must be estimated. An initial attempt was made to estimate c by inspection of the autocorrelations. This produced asymptotic values of .83 for Group I and .63 for Group II. This placed half of the values on either side of the line. Unfortunately these estimates were abandoned because when the constants were subtracted from every Y value the logarithms of (Y-c) were found to yield some negative values, and the log of a negative number is imaginary. Finally, it was decided that reasonable estimates would be values which were just below the curves. These values would be compatible with the definition of an asymptote in that the curves approached these values but did not go beyond them. These estimates were .78 and .55, respectively.

If the hyperbolic function was appropriate to describe the curves then the plot of [log X, log (Y-c)] should approximate a straight line. Therefore the constants had to be subtracted from every mean correlation and the logs had to be calculated for every lag and difference score. The general equation is log (Y - c) = log a + b log X.

Equipped with these transformations and the General Linear Model procedure, which is a SAS (Statistical Analysis System) program, estimates for the constants a and b were determined for each curve. The values for Group I were given as -0.5024 for the intercept and -0.3932 for the slope. The corresponding Group II estimates were -0.1199 and -0.4719. After finding the antilog of the a values, the resulting equations were given as:

$$Y = .3145\ X^{-0.3932} + .78$$

for Group I and for Group II:

$$Y = .7588\ X^{-0.418} + .55.$$

This procedure also produced ANOVA tables which may be seen in Tables VIII and IX. These tables contain estimates of the sum of squares which are attributed to the model and to error. The total degrees of freedom refer to the number of lags minus one. The mean square is the sum of squares divided by the appropriate degrees of freedom. The mean square for error estimates the variance of the residuals. The F value is the ratio of the mean square for error. R-square indicates how much variation in the dependent variables (mean r) could be accounted for by the hyperbolic equation that was fitted to the data, and is obtained by dividing the sum of squares for the model by the sum of squares for the corrected total.

TABLE VIII

ANALYSIS OF VARIANCE FOR GROUP I

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	PR>F	R^2
Model	1	4.6645	4.6645	114.96	0.0001	0.3951
Error	176	7.1411	0.0406			
Total	177	11.8056				

The plots of log ($\bar{r}$ - c) on log K where $\bar{r}$ is the mean correlation for Groups I and II are found in Figures 4 and 5. The right hand side of both curves shows considerable variability where one expects an approximation to a straight line. One explanation may be that as the lags got larger the number of observations used in determining the mean correlations decreased. Therefore, the reliability of these estimates would probably decrease.

TABLE IX

ANALYSIS OF VARIANCE FOR GROUP II

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	PR>F	R^2
Model	1	6.7180	6.7180	443.39	0.0001	0.7159
Error	176	2.6666	0.0152			
Total	177	9.3846				

After evaluating the ANOVA tables, it was felt that the R-squares of 0.3951 and 0.7159 for Group I and Group II did not adequately reflect the consistency seen in the data. In other words, the fit of the curves could be better. Reverting back to the non-transformed mean correlation data, and with the estimates given as starting points, an procedure involving successive approximations was used to better the fit of the equations.

As a visual aid a plotting program was used on an Apple II Plus computer. This program (see Appendix B) plotted the original data followed by a superimposed curve which was established by the estimates in the regression equation. Of the three variables which could vary

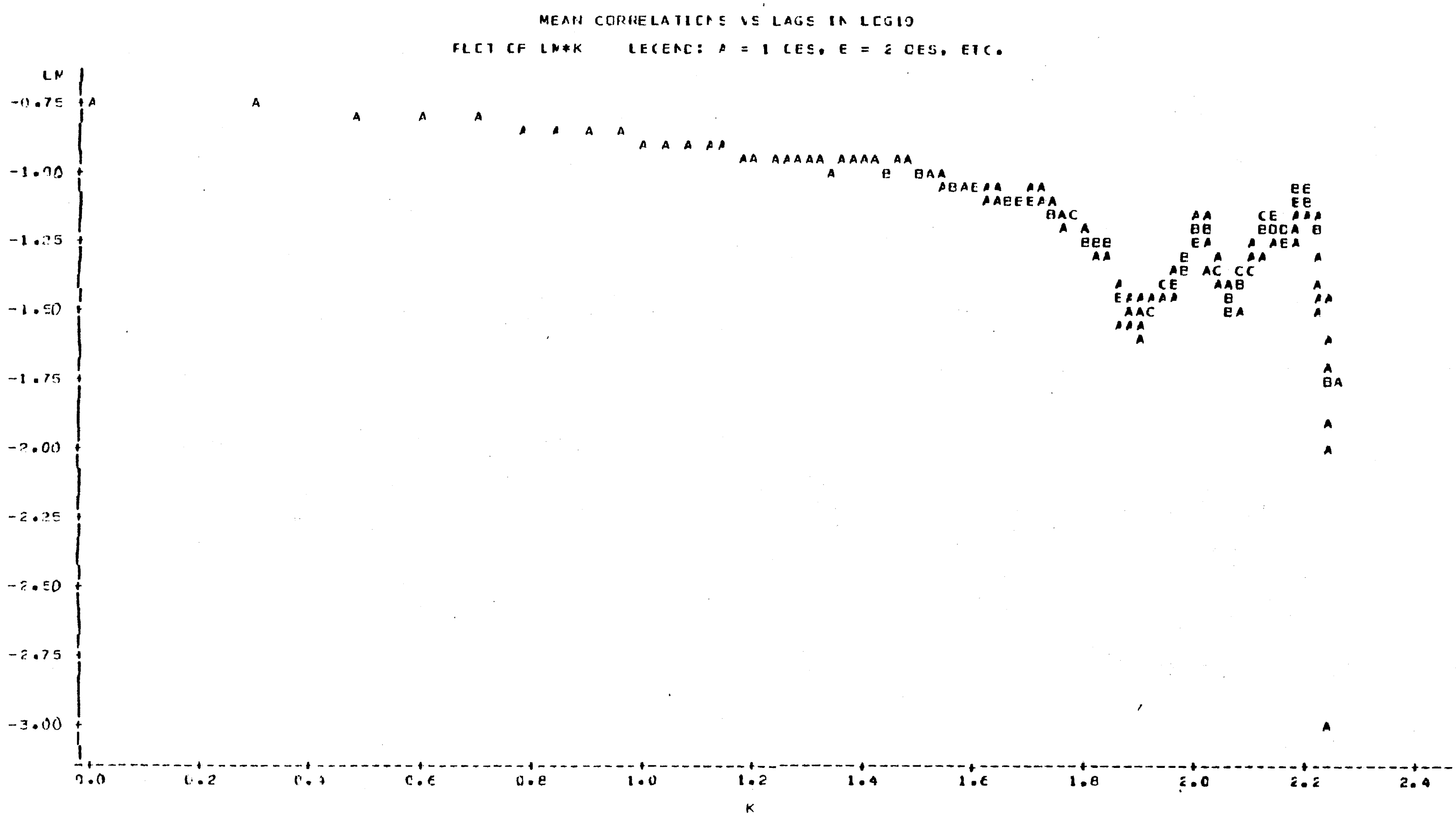

Figure 4. Plot of Mean Correlations vs Lags in Log 10 for Group I

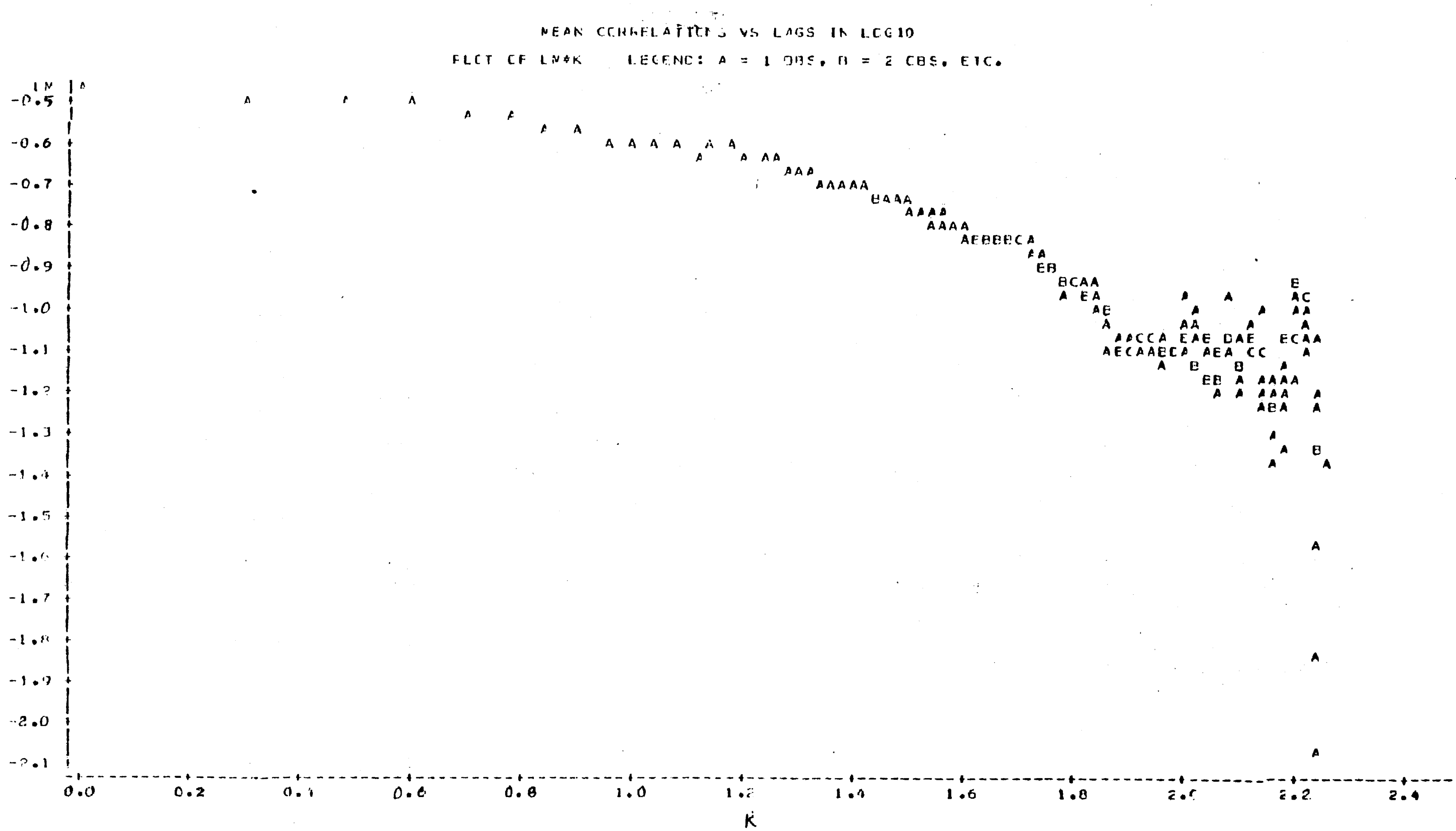

Figure 5. Plot of Mean Correlations vs Lags in Log 10 for Group II

(slope, intercept or asymptote) it made sense to attempt to keep the asymptotes as close as possible to the visual inspection estimates of the non-transformed regression curves of $\bar{r}$ on K. These estimates were .78 and .55 for Group I and II, respectively.

Once rough estimates were found through the plotting program, then the estimates were used in the program (see Appendix B). This program kept track of the estimates used and the corresponding sum of squares for the error term, the goal was to minimize this sum. Thus the eta-square would be greater. Eta-square is the nonlinear equivalent of R-square. The main concern during the iteration programming phase was that what might appear to be the lowest sum of squares for error might actually just be a local minimum. However, once again, an imposed criterion was that the asymptotes approximate those of the original visual estimates. Tables X and XI show the results of the iterative procedures. The resulting equation for Group I was:

$$\bar{r} = .26\ X^{-.24} + 75$$

and for Group II:

$$\bar{r} = .53\ X^{-.28} +.50.$$

If the estimates from the transformed data were used in the original data the eta-squares would have been .8239 and .8757. With the iterative estimates the eta-squares increased to .9663 and .9824 for Groups I and II respectively.

TABLE X

SUM OF SQUARES RESULTING FROM FINAL EQUATION ESTIMATES FOR THE GROUP I TREND LINE

Source	Sum of Squares	Eta-square
Model	1.888	.9663
Error	.065	
Total	1.953	

TABLE XI

SUM OF SQUARES RESULTING FROM FINAL EQUATION ESTIMATES FOR THE GROUP II TREND LINE

Source	Sum of Squares	Eta-square
Model	5.7788	.9824
Error	.1034	
Total	5.8822	

CHAPTER IV

DISCUSSION

A few problems arose during this study, the most important of which dealt with the curve fitting procedures. Although the curves appeared to be hyperbolic in shape the log-log plot yielded an approximation to a straight line which was not acceptable. However, most of the difficulty appeared in the area of the line which corresponded to the larger values of K. To elaborate, as the K or lag increased the number of correlations possible to use in determining the mean decrease. For example, when K = 177, the correlations are $r_{1 \text{ v } 178}$ and $r_{2 \text{ v } 179}$. Therefore, the mean is based on only 2 observations in this case. It is contended that the small number of observations are responsible for the variability in the figures when the lags were very large. One method to use to check this variability would be to collect another years worth of data and add it to the present data. This would increase the N considerably and the mean correlation values for the large lags would then be determined on the basis of a larger set of coefficients. It is hypothesized that this in turn would yield more stable values of $\bar{r}$ and that the curve would smooth out with an asymptote around .75 for Group I and .50 for Group II. If support for this prediction is not forthcoming then it might be that in order to fit the data more carefully, two equations might need to be developed, one for the first part of the plot including the curve and another for the asymptote. Upon visual inspection the latter half of the group two curve appeared cyclical.

In addition, if a more stringent curve fitting procedure exists, it is recommended that it be followed. When using the iteration procedure to arrive at equations to fit the curves, it became quite evident that numerous equations could accomplish the task adequately. However, the first criteria for the equations was that they had to make some sense. Of the three variables (intercept - a, slopes - b, and asymptote - c) it seemed reasonable to put some constraint on the asymptote, c, since this value could rather easily be estimated visually. An illustration may be helpful. At one point in the iteration program, values of 0.96, -0.03 and 0.00 were substituted for a, b and c respectively for the group one data. These values produced an error sum of squares term of .0660 which is quite good here. But the asymptote made no sense. To test the asymptote a lag of 2000 months or 40 years (the average working lifespan) was inserted into the equation using these variables. The results indicated that even with this equation, which had a small sum of squares value, after 40 years the ability to predict performance for group one employees was still around .7640. This is very close to the .78 used originally for the asymptote. Correspondingly the values for the group two employees which yielded the lowest error sum of squares of .0684 were 0.94, -0.09, and 0.02 for a, b and c. Using 2000 months again the mean correlation obtained was 0.492, again, a value not too different from the one originally used, 0.58. Thus, an external constraint was placed on the asymptotes which was that they need to be values close to those just mentioned. It is believed that the resulting equations were satisfactory given the constraints.

What these equations are indicating is that no matter how far into the future one tries to predict performance one can do no worse than 0.75 and 0.50. Although the mean correlations do not indicate the direction performance took - up or down, it is helpful to know that the predictive accuracy stablizes. It may have been intuitive that the shape of the curve should be such that the asymptote would equal 0.00. In other words, one might have thought that the K's increased the accuracy of prediction continued to worsen to the extent that eventually there was no predictive power at all.

Rothe (1978, 1970, 1951, 1947) and Rothe and Nye (1961, 1959, 1958) placed considerable emphasis on hypothesis that the correlation of week to week output may indicate an effective incentive system (financial, usually). The newest revision (Rothe, 1978) states that a "week to week correlation .65 indicates the presence of some effective incentives." In the present study the corresponding correlations for K = 1 were found to be .9598 for Group I and .9018 for Group II. These results even supported his initial hypothesis (Rothe, 1947) using .90 for the criterion which indicates effective incentives. When looking at the final regression of the mean correlation on K, the Group I workers never fall below that point when K = 71 weeks. At K = 122, 159 - 165 on K 167 the mean correlations were slightly above .65.

Although it would have been desirous to conclude that there is one overall general regression line of the mean correlations on lags for all jobs, this seems to not be the case. Along with the aforementioned information, there are several indications that there are differences even between the two groups examined in the present study which came from the same plant and were under the same piecerate incentive plan. When comparing the two regression lines, it appears that the slope for Group I is less severe and that the correlations level off at a higer level than for Group II. This leads one to compare the job specifications of the two groups. The group two workers have a more complicated job, therefore more variables are involved in the successful completion of their jobs. In addition, these jobs may be more pressure producing because it may be harder to meet quota. The differences between the group mean point to that. If these particular jobs are more pressure, the attitude of the worker may play a bigger role in performance consistency than for Group I employees.

For these reasons, it is important for each plant to establish the consistency levels of their jobs in order to better evaluate the effects of any procedural, etc. changes that may be implemented.

This study lends itself to new experiments. First, to evaluate the effect of the decreasing number of observations used in the establishment of $\bar{r}$ for large K's, additional data could be collected and a reexamination of the data could be done. Also, the trend line for one year could be compared to the next to see if the patterns are similar. A follow-up interview could be conducted to get the employees opinion of their jobs and their performance. In addition, it would be important to analyze the autocorrelations of individual workers.

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APPENDIXES

APPENDIX A

DESCRIPTION OF THE JOB OPERATIONS

DESCRIPTION OF THE JOB OPERATIONS

Group One - Non-Sewing Machine Operators
N = 19

Operation	Description	Lines Where Utilized
AJS		T-shirts
UL	Bar-tack label to garment	T-shirts
WIBB	inspect, fold and bag	T-shirts, Athletic shirts Briefs - Midways - Longies, Pajamas, Robes - Shave coats
UUU	3 bar tacks	Athletic shirts

Group Two - Sewing Machine Operators
N = 27

Operation	Description	Lines Where Utilized
DSH	Seam sleeve at top of shoulder	T-shirts, Pajamas - Shave coats
DN	Seam neckband	T-shirts
H_2	Sew tape	T-shirts
DSLV	Seam sleeve together	T-shirts
DSLG	Seam sleeve into garment	T-shirts
JJB	Hem bottom	T-shirts, Pajamas - Robes - Shave coats, Athletic shirts
DR	V-neck seam	T-shirts
ZA	2 needle armbinding to shirt	Athletic Shirts
ZNL	2 needle neck binding	Athletic Shirts
CTF	Tape fly to garment	Briefs - Midways - Longies
CZE	Apply leg band	Briefs - Midways - Longies

Operation	Description	Lines Where Utilized
CCC	Apply waist elastic	Briefs - Midways - Longies
DP	Sew in fly	Pajamas - Robes - Shave coats

APPENDIX B

LISTING OF COMPUTER PROGRAMS

COMPUTER PROGRAM FOR DATA ANALYSES USING SAS

```
DATA WEEKLY;
INPUT SUBJECTS 1-2 OPERATE 6-7 CATEGORY 8 SENIORMO 9-10 SENIORDA
11-12 SENIORYR 13-14 (W1-W22) (22*3.2) #2 (W23 - W47) (@6 25*3.2)
#3 (W48-W72) (@6 25R3.2) #4 (W73-W97) (@6 25*3.2) #5 (W98 - W122)
(@ 6 8* 3.2) (W132 - W148) (@ 30 17 * 3.2) #7 (W149 - W173)
(@ 6 25 * 3.2) #8 (W174 - W179) (@ 6 6* 3.2);
W131 = .;
DROP SUBJECT OPERATE CATEGORY SENIORMO SENIORDA SENIORYR;
CARDS;

DATA NEWB;
ARRAY B(I) B1-B178;
J=0;
AGAIN: J = J + 1;
DO I = 1 40 178,
B = 1;
I F J = 1 THEN B = 0;
I F I = 1 THEN B = 0;
END;
OUTPUT;
I F J = 178 THEN RETURN;
GO TO AGAIN;
KEEP B1-B178;
PROC CORR DATA = WEEKLY OUTP =
ANA,SAVCORR, VAR W1 - W179;

DATA NEWCORR; SET ANNA.SAVCORR (TYPE=CORR);
IF _N_<4 THEN DELETE;
DROP _TYPE_ _NAME_;

PROC MATRIX:
FETCH A DATA = NEWCORR;
FETCH B DATA = NEWB;
DO I = 1 TO 178;
K = 0; L = I + 1;
DO J = L TO 179;
K = K + 1;
B (K;I) = A(K,J);
END;
END;
OUTPUT B OUT = ANNA. K MATRIX;
```

```
PROC PRINT DATA = ANNA.K MATRIX;

DATA 2, SET ANNA.K MATRIX;
ARRAY R(I) COL1-COL178;
DO I=1 TO 178;
R = (LOG(1 + R) - LOG (1 - R))/2;
END;

PROC PRINT;

PROC MEANS DATA=Z N MEAN STD MIN MAX RANGE MAXDEC = 5;
DATA R; SET M2;
ARRAY M(I) M1=M178,
DROR M1 - M178;
DO I=1 TO 178;
K=LOG10(I); R=(EXP(2 * M)-1)/(EXP(2 * M) + 1);
LM + LOG10 (R = .55); OUTPUT;
END;

PROC PRINT;

PROC GLM; MODEL LM = K;
PROC PLOT;
PROC PLOT;
PLOT LM * K;
TITLE MEAN CORRELATIONS VS LAGS IN LOG10.
```

ITERATION PROGRAM FOR APPLE II PLUS

```
10    DIM YEST(178),X(179),Y(178)
20    SM = 100000
21    INPUT "FILE NAME = ";F$
22    D$ = CHR$ (4)
23    PRINT D$;"OPEN ";F$
24    PRINT D$;"READ ";F$
30    FOR I = 1 TO 178:X(I) = I: INPUT Y(K): NEXT
35    PRINT D$;"CLOSE ";F$
40    REM 178 RAW R-VALUES GO HERE.
49    REM SST
50    YY = 0
60    Y2 = 0
70    FOR I = 1 TO 178
80    YY = YY + Y(I)
90    Y2 = Y2 + Y(I) * Y(I)
100   NEXT
300   REM ESTIMATES OF A,B,&C
310   P1 =
320   P2 =
330   P3 =
400   REM ITERATION LOOPS
410   FOR A = (P1 * 100 - 0) TO (P1 * 100 + 5) STEP 1
420   FOR B = (P2 * 100 - 0) TO (P2 * 100 + 1) STEP 1
430   FOR C = (P3 * 100 - 0) TO (P3 * 100 + 1) STEP 1
500   REM  COMPUTE ERROR SS
510   FOR J = 1 TO 178
511   A1 = A / 100:B1 = B / 100:C1 = C / 100
520   YEST(J) = A1 * (X(J) ^ B1) = C1
530   SS = SS + (YEST(J) - Y(J)) ^ 2
540   NEXT J
600   PRINT "A=";A;  SPC ( 3);"B";B; SPC( 3);"C=";C; SPC( 5);"SS=";SS
601   TS - Y2 + 178 * C1 * C1 - 2 * C1 * YY
602   REM TS=TOTAL SS FOR THIS C1
605   PRINT SPC( 3);"SS TOTAL = ';TS
610   IF SS > SM THEN 690
620   IF SS < SM THEN AM = A
630   IF SS < SM THEN BM = B
640   IF SS < SM THEN CM = C
650   IF SS < SM THEN SM = SS
690   SS = 0
700   NEXT C,B,A
810   HOME : VTAB 3
```

```
820    FOR I = 1 TO 15: PRINT " ": NEXT I
830    PRINT "A"=";AM; SPC( 5);"B=";BM: SPC( 5);"C=";CM
900    PRINT "MINIMUM SS = ";SM
```

PLOTTING PROGRAM FOR APPLE II PLUS

```
1     P1 = .54
2     P2 = -.56
3     P3 = .4
10    D$ = " "
12    DIM Y(178),X(178)
15    INPUT "FILE NAME = " ;F$
20    PRINT D$;"OPEN ";F$
30    PRINT D$;"READ ";F$
40    FOR I = 1 TO 178: INPUT Y(I):X(K) = I: NEXT
50    PRINT D$;"CLOSE ";F$
100   HGR : HCOLOR= 3
102   HPLOT 0,190 - 31
110   FOR I = 1 TO 178
120   X = X(I)
130   Y = 190 - 31 -  INT (Y(I) * 100)
140   HPLOT X,Y
150   NEXT
190   GET A$
200   FOR T = 1 TO 178
210   Y = P1 * X(T) ^ P2 + P3
220   HPLOT T,190 - 31 - Y * 100: NEXT
250   HOME : VTAB 23: PRINT "A=";P1;"  B=";P2;"  C=";P3
300   STOP
310   GOTO 100
```

APPENDIX C

SAMPLE OF WEEKLY PRODUCTION EARNINGS REPORT

SAMPLE OF WEEKLY PRODUCTION EARNINGS REPORT

JOB 867 — WEEKLY PRODUCTION EARNINGS REPORT — 6-02-18 — 02/18/78

EMPL	EMPLOYEE NAME	SENIORITY	OPN	QTR AV	7	6	5	4	3	2	1	52	51	50	49	48	47
	***************						T-SHIRTS							***************			
		11-17-75	DN	3.03	2.84	3.23	2.60	2.75	2.55	2.63	2.47	2.44	2.67	2.46	2.50	2.51	2.79
		01-26-76	DN	4.83										4.76		4.41	4.82
		03-10-76	DN	3.60	3.29	3.71	3.21	3.44	3.54	3.14	2.97	3.01	3.69	3.67	3.69	3.67	3.48
		05-11-76	DN	2.89	2.10				2.04	.98	1.53	1.17	1.57	1.97	1.18	1.70	
	OPERATION AVG		DN	3.56	2.97	3.55	3.19	3.21	2.88	2.53	2.66	2.43	2.80	3.24	2.67	3.10	3.58
		03-08-76	H2	2.89	2.00	1.55	2.12	1.45						2.00		2.54	2.34
		12-14-76	H2	2.89						.92		.74	.72	.78			
	OPERATION AVG		H2	2.89	2.00	1.55	2.12	1.45		.92		.74	.72	1.39		2.54	2.34
		07-29-77	OP	3.91	4.28	4.08	4.04	3.63	3.70	3.55	3.99	3.66	3.44	3.58	3.45	3.96	3.99
		03-22-71	DSLV	4.41	4.48	4.30	4.24		3.91	4.01	4.08	3.84	3.86	3.60	4.06	4.42	4.26
		08-26-74	DSLV	4.15	3.89	3.67	3.72		4.00	3.73	3.30	3.11	3.76	3.36	3.44	3.76	4.00
	OPERATION AVG		DSLV	4.28	4.19	3.99	3.98		3.96	3.87	3.69	3.48	3.81	3.48	3.75	4.09	4.13
		09-30-75	DSLG	4.93	5.05	5.16	5.19	4.81	4.65	4.59	4.74	4.45	4.57	4.66	4.72	4.59	4.65
		10-27-75	DSLG	5.02	4.86	5.77	5.22	5.16	5.65	4.61	4.54	4.16	4.98	4.90	4.57	5.06	4.56
		05-10-76	DSLG	2.89	2.75	2.68	2.98	1.70	2.44	2.41	2.35		2.75	2.64	2.42	2.07	2.18
		05-25-76	DSLG	4.10	4.14	4.12	4.43	4.87	4.04	3.70	3.77	2.88	3.43	3.67	3.99	3.78	[illegible]
		07-26-76	DSLG	3.26	3.20	3.28	3.11	3.10	2.81	2.91	2.99	2.78	2.99	2.98	3.10	3.05	3.01
	OPERATION AVG		DSLG	4.04	4.00	4.20	4.19	3.93	3.92	3.64	3.68	3.57	3.74	3.77	3.76	3.71	3.68
		01-14-66	JJB	2.97	2.82	3.11	3.17	3.22	3.26	3.27		2.38	2.87	2.91	2.86	3.00	2.74
		03-08-76	JJB	2.89	2.54	2.51	2.50	2.36	2.33	2.38	2.43	2.15	2.57	2.73	2.61	2.30	2.39
		08-11-76	JJB	3.63	3.59	3.80	3.59	2.76	3.54	3.23	3.20	2.75	3.17	3.30	3.12	3.17	3.33
		02-21-77	JJB	3.20	2.88	3.08	3.15	3.27	2.81	2.79	3.01	2.53	3.05	2.96	2.86	2.65	3.03
		03-11-77	JJB	3.22	3.04	3.19	3.35	3.08	2.97	2.95	3.44	2.62	2.95	3.33	3.19	3.07	1.94
	OPERATION AVG		JJB	3.18	2.97	3.14	3.15	2.94	2.98	2.92	3.02	2.49	2.92	3.05	2.93	2.84	2.69
		05-22-61	DR	4.29	4.35	4.36	4.82	4.49	3.89	3.78		3.40	3.71	3.92	4.44	3.89	4.10
	***************						ATHLETIC SHIRTS							***************			
		07-15-64	ZA	4.07	4.18	4.06	4.28	4.26	3.80	3.68		3.74	3.72	3.91	3.79	3.62	3.76
		01-13-72	ZA	4.75	4.43	4.32	4.53	4.24	4.18	4.27	4.21	4.16	4.46	4.53	4.06	4.24	4.45
		08-02-73	ZA	4.42	4.43	4.52	5.08		4.31	4.18	4.12	4.35	4.24	3.43	3.73	4.34	4.35
		10-04-73	ZA	4.82	4.77	4.70	4.74	4.74	4.48	4.48	4.18	4.32	4.47	4.60	4.39	4.48	4.47
	OPERATION AVG		ZA	4.52	4.45	4.40	4.66	4.41	4.19	4.15	4.17	4.14	4.22	4.12	3.99	4.17	4.26
		08-05-75	ZNL	2.89	2.90	3.05	2.98	2.87	2.82	2.66	2.83	2.85	2.78	2.67	2.84	2.34	2.35
		07-20-76	ZNL	3.06	3.42	3.34	3.11	3.01	3.01	2.67	3.02	2.94	2.96	3.04	2.96	2.78	2.93

APPENDIX D

SUMMARY OF MEAN PIECERATE

OUTPUT FOR GROUP I AND

GROUP II EMPLOYEES

SUMMARY OF MEAN PIECERATE OUTPUT
FOR GROUP I EMPLOYEES

Week	N	Mean	Standard Deivation	Minimum	Maximum
1	19	3.73	0.90	2	6
2	15	4.06	1.01	3	7
3	14	4.10	1.00	3	7
4	15	4.12	0.97	3	7
5	17	4.08	0.85	3	6
6	18	3.98	0.94	3	6
7	19	4.04	0.92	3	7
8	19	4.07	0.93	3	7
9	18	4.06	0.91	3	6
10	19	4.10	0.91	3	7
11	19	4.19	0.96	3	7
12	19	4.11	0.91	3	7
13	19	4.13	1.00	2	7
14	18	4.14	0.92	3	7
15	19	4.00	1.03	2	6
16	19	4.10	1.02	2	6
17	18	4.09	1.04	2	6
18	19	4.16	1.08	2	7
19	19	4.18	1.12	2	7
20	19	4.15	1.07	2	6
22	19	4.17	1.08	2	7

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
23	19	4.20	0.77	3	6
24	18	4.12	0.94	3	7
25	18	4.17	0.95	3	7
26	17	4.10	1.04	3	7
27	18	4.13	0.99	3	7
28	13	3.97	1.11	2	7
30	19	4.04	0.95	3	7
31	18	4.02	0.99	3	7
32	18	3.88	0.71	3	5
33	19	4.07	0.96	3	7
34	18	4.14	0.88	3	6
35	18	4.10	1.06	3	7
36	19	4.13	0.96	3	7
37	18	3.98	0.75	3	5
38	19	4.14	0.92	3	7
39	19	4.09	1.06	2	7
40	19	4.19	1.11	3	8
41	19	4.02	0.87	3	6
42	19	4.09	0.90	3	7
43	19	4.09	0.93	3	7
44	19	4.00	1.00	2	7
45	19	4.11	1.07	2	7
46	18	4.01	0.76	3	5
47	19	4.09	1.15	3	8
48	18	3.86	0.78	3	6
49	19	3.97	0.89	3	6
50	19	4.00	0.91	3	6
51	19	3.97	1.00	3	7
52	19	3.65	0.84	2	5
53	16	3.91	0.71	3	5

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
54	19	3.88	0.91	3	6
55	19	3.92	1.11	1	7
56	18	4.27	1.01	3	7
57	19	4.36	0.97	3	7
58	19	4.17	0.98	2	7
59	19	4.22	1.05	2	7
60	19	4.13	1.03	2	7
61	19	4.20	1.11	2	7
62	19	4.26	1.16	2	7
63	18	4.22	1.08	3	7
64	18	4.19	1.09	2	7
65	18	4.00	0.88	2	5
66	18	4.10	0.92	2	5
67	17	4.09	0.81	2	5
68	19	4.30	1.01	2	7
69	19	4.26	1.00	2	7
70	19	4.21	1.18	3	8
71	18	4.03	0.79	3	5
72	19	4.33	1.05	3	7
73	19	4.20	1.00	3	7
74	19	4.28	1.03	3	7
75	18	4.35	1.16	3	8
76	19	4.15	1.22	1	7
77	19	4.15	1.18	1	7
78	18	3.96	0.98	1	5
79	18	3.97	0.98	2	5
80	12	3.35	1.70	1	6
83	18	4.19	1.22	2	7
84	19	4.14	1.12	1	6
85	19	4.21	1.19	2	7
86	16	4.45	1.03	3	7

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
87	17	4.39	1.19	2	7
88	19	4.19	1.16	2	7
89	19	4.38	1.20	2	7
90	19	4.34	1.15	2	7
91	18	4.40	1.61	2	10
92	17	4.45	1.04	3	7
93	17	4.16	1.36	1	7
94	15	4.04	1.26	1	5
95	16	4.42	1.42	1	7
96	18	4.24	1.33	1	7
97	18	4.19	1.30	1	7
98	19	4.30	1.42	1	8
99	19	4.52	1.40	3	8
100	18	4.28	1.14	3	7
101	19	4.38	1.14	3	8
102	19	4.33	1.11	3	8
103	18	4.34	1.20	3	8
104	19	4.29	1.14	3	8
105	19	4.04	1.14	2	7
106	19	4.31	1.14	3	7
107	17	4.43	1.40	2	7
108	16	4.58	1.25	3	8
109	16	4.68	1.36	3	8
110	18	4.81	1.19	3	8
111	16	5.07	1.12	3	8
112	18	4.89	1.34	3	8
113	18	4.77	1.49	3	9
114	16	5.07	1.30	3	8
115	18	4.97	1.35	3	8
116	18	4.77	1.22	3	8
117	18	4.92	1.31	3	9

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
118	18	4.95	1.40	3	9
119	17	4.91	1.37	3	8
120	18	4.97	1.42	3	9
121	19	4.93	1.26	3	8
122	19	4.94	1.23	3	8
123	19	4.92	1.34	3	8
124	17	4.93	1.42	3	9
125	18	4.92	1.31	3	9
126	18	4.95	1.30	3	8
127	18	5.00	1.37	3	8
128	16	5.06	1.40	3	8
129	19	4.88	1.22	3	8
130	18	4.91	1.30	3	8
132	9	4.64	0.93	3	6
134	18	4.91	1.14	3	8
135	19	4.92	1.19	3	8
136	17	4.94	1.15	3	8
137	19	4.93	1.12	3	7
138	19	5.00	1.26	3	8
139	19	4.94	1.16	3	8
140	19	4.82	1.26	3	8
141	19	4.95	1.24	3	8
142	19	4.83	1.31	3	8
143	18	4.82	1.17	3	8
144	19	4.72	1.22	3	8
145	19	4.78	1.14	3	8
146	18	4.60	0.89	3	6
147	17	4.68	0.87	3	6
148	18	4.88	1.21	3	8
149	17	4.71	0.98	3	6
150	18	4.97	1.22	3	8

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
152	18	4.88	1.32	3	9
153	17	4.81	1.33	3	8
154	17	4.75	1.24	3	8
155	17	4.82	1.20	3	8
156	16	4.61	1.60	1	9
157	14	3.83	1.59	1	6
158	16	4.75	1.23	3	8
159	17	5.39	1.35	3	9
160	16	5.26	1.40	3	9
161	17	5.32	1.40	3	9
162	18	5.36	1.42	3	9
163	17	5.33	1.36	3	9
164	17	5.26	1.36	3	9
165	19	5.21	1.39	3	9
166	18	5.21	1.37	3	9
167	19	5.17	1.35	3	9
168	18	5.02	1.02	3	7
169	17	4.91	1.03	3	6
170	18	4.82	0.93	3	6
171	17	5.07	0.93	3	6
172	17	5.21	1.33	3	9
173	19	5.17	1.39	3	9
174	19	5.27	1.44	3	10
175	17	5.03	1.02	3	6
176	17	5.05	0.95	3	6
177	18	4.98	0.95	3	6
178	18	5.00	0.95	3	6
179	18	5.21	1.19	3	8

SUMMARY OF MEAN PIECERATE OUTPUT
FOR GROUP II EMPLOYEES

Week	N	Mean	Standard Deviation	Minimum	Maximum
1	24	3.58	0.49	3	5
2	25	3.81	0.54	3	5
3	26	3.75	0.62	2	5
4	26	3.79	0.60	2	5
5	26	3.80	0.64	2	5
6	27	3.71	0.74	1	5
7	26	3.71	0.64	2	5
8	25	3.75	0.65	2	5
9	25	3.79	0.64	2	5
10	26	3.79	0.64	2	5
11	25	3.72	0.66	2	5
12	27	3.79	0.60	2	5
13	27	3.93	0.66	2	5
14	26	3.87	0.55	2	5
15	26	3.86	0.56	2	5
16	27	3.83	0.61	2	5
17	27	3.83	0.60	2	5
18	27	3.85	0.61	2	5
19	26	3.88	0.60	2	5
20	27	3.77	0.61	2	5
22	26	3.88	0.55	3	5
23	26	3.78	0.64	2	5
24	27	3.76	0.75	2	5
25	27	3.67	0.76	2	5
26	26	3.70	0.85	2	6

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
27	26	3.65	0.77	2	5
28	22	3.58	0.79	2	5
30	24	3.85	0.76	2	5
31	27	3.69	0.77	2	5
32	27	3.66	0.70	2	5
33	27	3.61	0.68	2	5
34	27	3.60	0.65	2	5
35	27	3.51	0.68	2	5
36	27	3.60	0.64	2	5
37	26	3.66	0.79	2	6
38	25	3.65	0.68	2	5
39	27	3.73	0.67	2	5
40	27	3.75	0.74	2	5
41	27	3.60	0.68	2	5
42	27	3.62	0.73	2	5
43	25	3.65	0.70	2	5
44	26	3.71	0.69	2	5
45	26	3.75	0.64	2	5
46	26	3.78	0.63	2	5
47	27	3.70	0.65	2	5
48	27	3.69	0.65	2	5
49	26	3.76	0.62	3	5
50	26	3.79	0.56	3	5
51	25	3.71	0.63	3	5
52	26	3.52	0.58	3	5
53	22	3.60	0.49	3	5
54	26	3.60	0.61	2	5
55	24	3.67	0.64	3	5
56	25	3.87	0.63	3	5
57	25	3.99	0.62	3	5
58	27	3.93	0.61	3	5

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
59	27	3.94	0.62	3	5
60	27	3.93	0.71	3	5
61	26	3.91	0.63	3	5
62	27	3.94	0.74	2	5
63	27	4.00	0.67	3	5
64	27	4.00	0.57	3	5
65	25	4.08	0.60	3	5
66	25	4.00	0.57	3	5
67	27	3.98	0.61	3	5
68	26	3.99	0.64	3	5
69	27	4.00	0.71	3	5
70	27	3.94	0.65	3	5
71	27	4.05	0.67	3	5
72	27	4.00	0.65	3	5
73	27	3.93	0.60	3	5
74	27	3.89	0.64	3	5
75	25	4.05	0.71	3	5
76	27	3.79	0.94	1	5
77	27	3.68	0.89	1	5
78	27	3.83	0.88	1	5
79	27	3.87	1.00	1	7
80	16	3.46	1.01	1	5
83	27	3.91	0.83	1	5
84	26	4.05	0.85	1	5
85	27	3.99	0.88	1	5
86	27	3.97	0.81	1	5
87	26	3.99	0.89	1	5
88	26	4.11	0.66	2	5
89	27	4.12	0.90	1	5
90	27	4.03	0.83	1	5
91	27	3.93	0.89	1	5

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
92	26	4.01	0.81	1	5
93	27	4.01	0.98	1	6
94	27	4.05	0.93	1	5
95	27	4.06	0.91	1	6
96	27	4.00	0.87	2	6
97	22	4.01	0.84	1	6
98	26	3.99	0.78	2	6
99	26	4.24	0.52	3	6
100	25	4.13	0.67	3	6
101	26	4.07	0.85	1	6
102	27	4.08	0.82	2	6
103	27	4.15	0.73	2	6
104	26	4.11	0.69	2	6
105	25	3.97	0.80	2	6
106	25	4.21	0.76	3	6
107	23	4.15	0.70	2	6
108	25	4.49	0.66	3	6
109	27	4.50	0.74	3	6
110	24	4.51	0.70	3	7
111	26	4.46	0.74	2	6
112	26	4.49	0.71	3	6
113	26	4.50	0.79	3	6
114	26	4.57	0.78	3	6
115	25	4.58	0.77	3	6
116	26	4.54	0.78	3	6
117	26	4.64	0.63	3	6
118	26	4.62	0.62	3	6
119	26	4.63	0.64	4	6
120	25	4.64	0.60	4	6
121	27	4.46	0.87	2	6
122	27	4.50	0.85	2	6

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
123	26	4.59	0.69	3	6
124	25	4.49	0.71	3	6
125	25	4.52	0.74	2	6
126	25	4.59	0.71	3	6
127	25	4.56	0.72	3	6
128	20	4.63	0.60	4	6
129	24	4.55	0.88	2	6
130	27	4.58	0.69	3	6
132	22	4.45	0.85	2	6
134	27	4.53	0.67	3	6
135	27	4.65	0.63	3	6
136	26	4.54	0.74	3	6
137	25	4.52	0.69	3	6
138	26	4.45	0.64	3	6
139	26	4.42	0.64	3	6
140	26	4.44	0.63	3	6
141	26	4.31	0.80	2	6
142	26	4.34	0.71	3	6
143	26	4.31	0.72	3	6
144	26	4.28	0.73	3	6
145	26	4.28	0.75	3	6
146	26	4.36	0.67	3	6
147	27	4.42	0.69	3	6
148	27	4.31	0.79	3	6
149	27	4.37	0.76	3	6
150	26	4.45	0.70	3	6
152	26	4.47	0.71	3	6
153	27	4.34	0.76	3	6
154	26	4.46	0.71	3	6
155	27	4.41	0.70	3	6
156	27	4.26	0.70	3	6

(Continued)

Week	N	Mean	Standard Deviation	Minimum	Maximum
157	26	3.69	1.11	1	5
158	26	4.43	0.77	3	6
159	27	4.63	0.84	3	7
160	27	4.69	0.81	3	6
161	26	4.78	0.76	3	7
162	25	4.71	0.79	3	6
163	26	4.81	0.79	3	7
164	27	4.77	0.80	3	7
165	26	4.77	0.78	3	7
166	27	4.86	0.76	3	7
167	26	4.76	0.73	3	6
168	27	4.82	0.73	3	6
169	27	4.73	0.77	3	7
170	26	4.69	0.81	3	7
171	27	4.70	0.80	3	7
172	27	4.75	0.78	3	7
173	25	4.80	0.69	3	7
174	27	4.72	0.76	3	7
175	27	4.68	0.74	3	6
176	27	4.75	0.69	4	6
177	27	4.78	0.72	3	7
178	27	4.80	0.74	4	7
179	27	4.80	0.73	3	7

VITA

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Candidate for the Degree of

Master of Science

Thesis: A STUDY OF AUTOCORRELATIONS FOR PERFORMANCE CONSISTENCY

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