

## Testing Human Relations Hypothesis of the Hawthorne Studies\*

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### Abstract

Employing the method of time series analysis, this paper analyzes data obtained from the Hawthorne experiment from the perspective of human relations. Although previous studies adopted statistical tools to analyze the “first relay” experiments, direct inclusion of “human relations” variables was absent. The study includes “human relations” variables that suggest social facilitation and social learning process in the statistical analysis. Unlike previous studies, the direct inclusion of such variables resulted in the support for the human relations hypothesis.

**Keywords:** Hawthorne studies, social facilitation, social learning process, human relations, time series analysis

### Testing Human Relations Hypothesis of the Hawthorne Studies

The Hawthorne Studies, 1924-32 (See Roethlisberger and Dickson, 1939), are one of the best-known and most influential research studies in the field of social science (Hassard, 2011). The studies are often associated with Elton Mayo, a Harvard Business School professor who joined the research team at the Western Electric Company in Illinois in 1924. The results from the study formed the basis of the human relations approach, which challenged the principles of scientific management by Frederick F. Taylor (1911). The major finding of the studies includes that (1)

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behavior and sentiments are closely related, (2) group influences significantly influence individual behavior, (3) group standards establish individual worker output, and (4) money is less of a factor in determining output than were group standards.

Despite the reputation of the Hawthorne studies, when scholars later analyzed the data with modern statistical tools, the results have not been as clear as originally claimed. Frank and Kaul (1978) were the first scholars who analyzed what we know as the “first relay” experiment. Their motive to analyze the data can be seen in the following excerpt:

The massive Hawthorne experiments of some 50 years ago serve as the paradigmatic foundation of the social science of work. The insights gleaned from these experiments provide a basis for most current studies in human relations as well as for subareas, such as participation, organizational development, leadership, motivation, and even organizational design. But aside from visual inspection and anecdotal comment, the complex of data obtained during the eight years of the Hawthorne experiments has never been subjected to thorough-going scientific analysis. (p 623)

The Hawthorne experiments, as they put it, became the foundation of the field of human relations by providing the following conclusion: Instead of measured experimental variables, such as physical conditions and economic incentives scheme, the unmeasured quality of human relations between workers and management and among peer groups was responsible for the overall output improvement of worker productivity. Interestingly and disputably, what Franke and Kaul (1978) found in their analysis was the opposite of what the original Hawthorne researchers described. Using stepwise regression, Franke and Kaul identified three factors that explained 94.48% of the variance when output is measured by hourly output: (1) managerial discipline, (2) economic depression, and (3) scheduled rest time. These external factors rather than internal factors such as human relations are key to the increase in productivity. These factors were left in the equation to explain worker productivity after stepwise regression.

Although Franke and Kaul made an adjustment for autocorrelation in their analysis, their use of stepwise regression casts doubts on whether they treated the human relations

hypothesis fairly. When Jones (1992) later re-analyzed the data with more sophisticated statistical tools, he found no evidence to support the traditional interpretation of the Hawthorne effects after controlling for various other factors. The major problem with the previous studies that employed statistical tools for the Hawthorne Studies is that they did not directly include variables that represent the human relations hypothesis. To be able to test whether the human relations hypothesis is adequate or not, a model that describes the human relations hypothesis (i.e., group interaction and interpersonal influences significantly affect individual behavior) should be set up and tested. Given this context, the objective of the study is to set up a human relations model and test it using time series analysis, which is far more adequate given the nature of the data in the “first relay” experiments.

## **THEORETICAL BACKGROUNDS AND MAJOR HYPOTHESES**

Human relations represented by leadership, motivation, and group interaction deal with an intrinsically internal process. Given the data by Franke and Kaul (1978), variables that might be related with human relations are not specifically modeled. However, given the notion of human relations that peers can affect each other, the productivity of other coworkers can affect a worker’s productivity. Thus, keeping track of the influence of other coworker’s productivity on a given worker is meaningful to see the effect of human relations.

Then, what are the kinds of influence that coworkers or a group of coworkers can exert on an individual’s productivity? I identified two kinds of influence: (1) social facilitation and (2) social learning. Social facilitation (Allport, 1924) is often defined as a tendency for individuals to perform better in the presence of others. Norman Triplett (1898) pioneered the research first observing that cyclists ride faster when in a competition compared to when rode alone. Two theories in particular identify uncertainty experienced in a social setting as the origin of social facilitation. They are the drive theory by Zajonc (1980) and the monitoring theory later further developed by Guerin (1983, 1993) and Guerin and Inns (1982). Both theories argue that organisms are predisposed to monitor and prepared to react to the ever-changing demands induced by social presence. In addition, Zajonc (1965)’s seminal review suggests that

social presence improves the performance of a simple and well-learned task and impairs the performance of complex and novel tasks. Uncertainty and alertness which act as a precursor of social facilitation will be more prevalent within highly productive groups and social facilitation will be more likely as most of the relay experiments in the Hawthorne studies involve simple and repetitive tasks.

Secondly, being around the most productive workers will spur the social learning process. Albert Bandura (1971) emphasizes the learning process occurring in interpersonal contexts that are adequately dealt with in traditional learning theories, such as classical and operant conditioning. According to Bandura, learning is not purely behavioral as behaviorists argue. But, it often involves a cognitive process in a social context. Social learning theory also highlights what is called vicarious learning where learning occurs by observing behavior and the consequence of learning. This process of observational learning or modeling posits the possibility that workers in the Hawthorne Studies may have learned from the most productive individual in the group as the individual can become a positive role model where vicarious learning was possible. According to this line of thought, the following hypotheses are generated.

**H1:** The past and current average of group productivity will influence a person's current productivity.

**H2:** The past and current productivity of the most productive individual will influence a person's current productivity.

In addition to these hypotheses, I will also consider the possibility that a person's past productivity level will influence his/her current productivity. Most importantly, the effects of these human relations variables on a worker output will be directly pitted against those of external factors. This is possible by including these human relations variables into the time series equation while controlling for the external factors.

## METHOD

### Sample

In total, 270 weeks were available. The original work of Franke and Kaul (1978) includes only 23 periods in which the total weeks of the experiment are somehow collapsed into groups. But, Franke (1980) lists weekly data for hourly output productivity. Because of the equal duration (week) for each time point, weekly data is used in this analysis. However, the weekly data has missing data during the 1<sup>st</sup> to 3<sup>rd</sup> week and the 251<sup>st</sup> to 270<sup>th</sup> week. Thus, the data during these periods are deleted listwise. The 67<sup>th</sup>, 68<sup>th</sup>, 117<sup>th</sup>, 118<sup>th</sup>, 169<sup>th</sup>, 170<sup>th</sup>, 221<sup>st</sup>, and 222<sup>nd</sup> weeks were also deleted since these were vacation periods. Also, there were 11 missing cells (47<sup>th</sup> ~50<sup>th</sup> and 63<sup>rd</sup> ~ 71<sup>st</sup> weeks) in terms of voluntary rest time for Worker 1, so these values were replaced with the average (=6.2) of all the voluntary time of Worker 1. In total, 239 time points of data were entered into the final analysis.

### Measure

*The hourly output (HO3).* Originally, the Hawthorne studies track the hourly output of five workers over nearly five years. In my analysis, Worker 3 is the focus of the analysis for two reasons: (1) Worker 3 shows a middle level of productivity over the experimental period, and (2) Worker 3 has never been replaced by managers.

*The hourly output of the most productive individual (HO2).* The most productive individual is Worker 2, who showed consistently better output over the 243 weeks.

*The group's hourly productivity (HOAV).* The group productivity level that can function as group pressure to Worker 3's hourly output is measured by the average work output that excludes Worker 3's output.

*Managerial Discipline (MD).* As in Franke and Kaul (1978), managerial discipline is a dummy variable that indicates the replacement of two of the five workers (codes as 1; 0 otherwise).

*Economic depression (ED).* As in Franke and Kaul (1978), economic depression is measured by a categorical nature (1=economic depression; 0 otherwise)

*Scheduled rest time (SRT).* As in Franke and Kaul (1978), scheduled rest time is measured by rest time measured by minutes, time which is scheduled by managers.

### Analysis

The model is set up using the two input variables that represent human relations (HO2 and HOAV) and three control variables (MD, ED, SRT) that represent the external factors of Frank and Kaul (1978). Since it is time series data, the lagged input for HO2 and HOAV (that are,  $HO2_{t-1}$  and  $HOAV_{t-1}$ ) is also entered as well as the autoregressive term(s) of hourly output of Worker 3 ( $HO3_{t-1}$ ). Using a linear stochastic difference equation model, the parameters (represented by  $\alpha$  and  $\beta$ ) are associated with these terms.

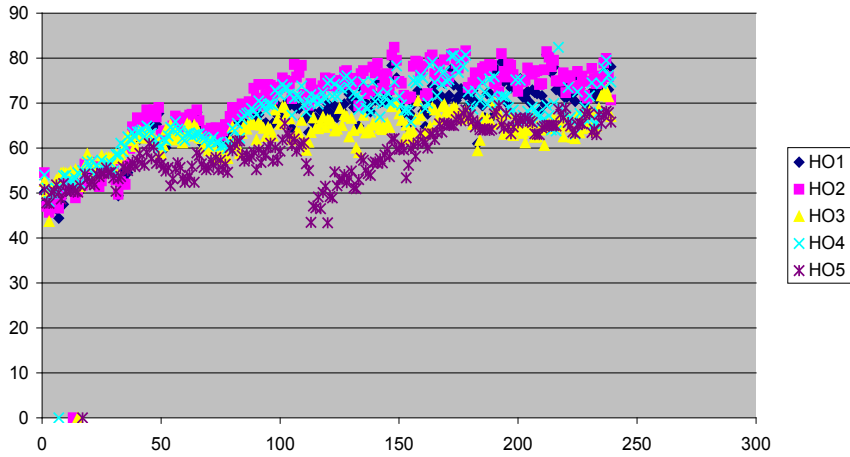
The model is represented in equation 1.

$$HO3_t = \alpha + \beta_1 \cdot HO3_{t-1} + \beta_2 \cdot HO2_t + \beta_3 \cdot HO2_{t-1} + \beta_4 \cdot HOAV_t + \beta_5 \cdot HOAV_{t-1} + \beta_6 \cdot MD + \beta_7 \cdot ED + \beta_8 \cdot STR$$

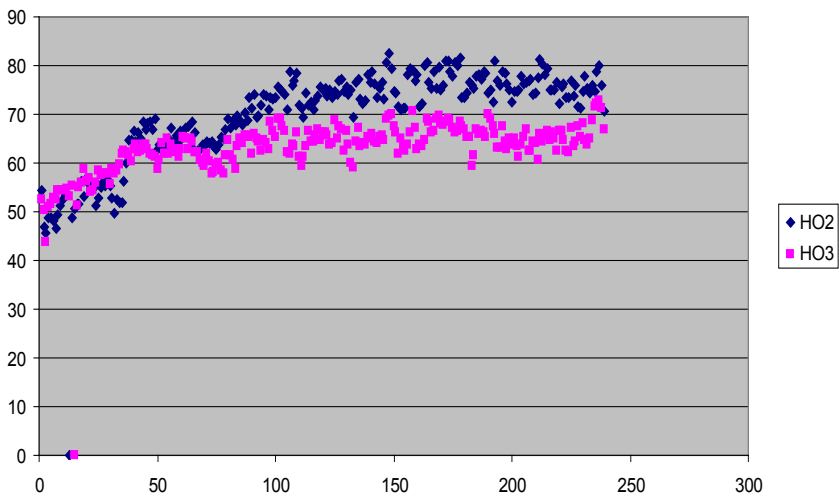
(Equation 1: First order assumed, more Orders are possible)

## RESULTS

Figure 1 shows the weekly time series of hourly output of five workers and the two workers, the most productive worker (Worker 2) and Worker 3. It shows an upward trend overall for all the workers, which allowed the Hawthorne researchers to conclude the mysterious productivity increase despite various external experimental factors. However, Franke and Kaul (1978) raised an issue regarding the lack of statistical analysis of the time series, which made the conclusion questionable. First, a descriptive analysis was done to see the nature of the given time series. Figure 1 shows the pattern of the hourly outputs of five workers (figure 1a) and Worker 2 and 3 (figure 1b).



a. Five worker outputs



b. Worker 2 and 3 outputs

Note:

HO1: Hourly output of worker 1

HO2: Hourly output of worker 2

HO3: Hourly output of worker 3

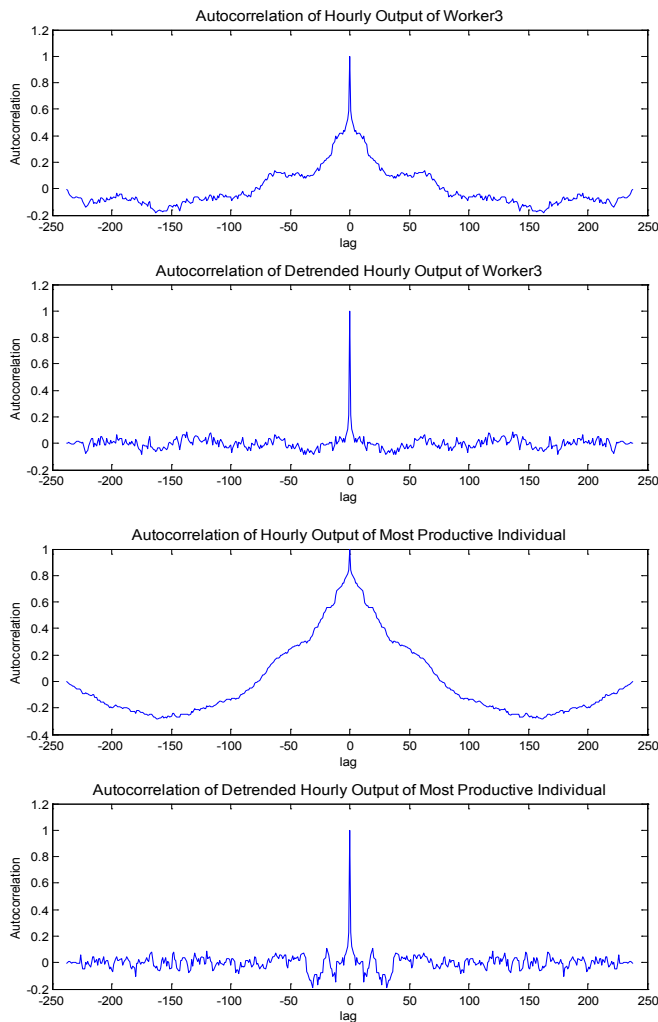
HO4: Hourly output of worker 4

HO5: Hourly output of worker 5

**Figure 1. Hourly Output of Five Workers over 243 Weeks**

### Autocorrelation

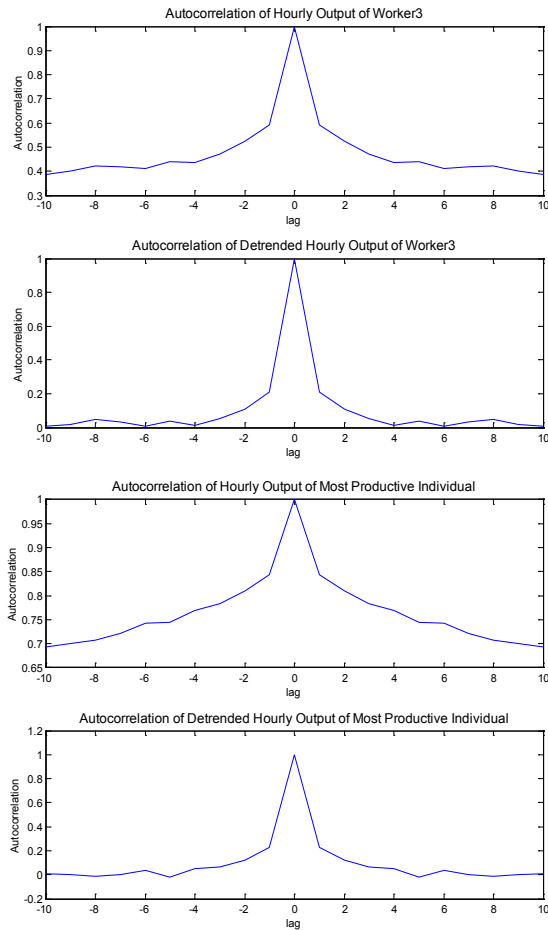
Figure 2 shows the autocorrelation plot of the hourly output of Worker 3 and the most productive individual before detrending and after detrending (detrended up to cubic terms). The Durbin-Watson statistics suggests that both data, when it is not detrended, show a high level of autocorrelation, specifically correlation among errors at lag 1. ( $DW_{HO3}=.81$  and  $DW_{HO2}=.30$ ).



**Figure 2. Auto-correlation (maximum lag = 238)**



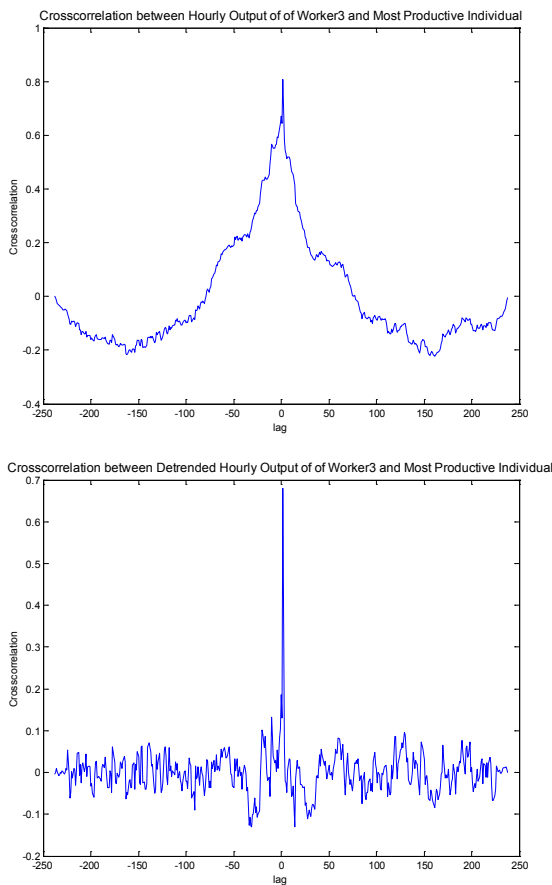
When the hourly output of two workers are detrended, the Durbin-Watson statistics got close to value 2, but the errors did not seem to be completely due to white noise ( $DW_{dHO3}=1.57$  and  $DW_{dHO2}=1.52$ ). When the maximum lag was reduced to 10 to see what happens in the earlier lags (figure 3), for the hourly output of Worker 3, there was a pattern of significant drop in terms of autocorrelation at lag 1 and a gradual decrease at further lags. This possibly indicates that the AR(1)MA(1) model is valid since a typically significant drop at lag  $k$  means the moving average model will have lag  $k$ . The autocorrelation pattern of the most productive worker (second half of figure 3) shows a similar pattern.



**Figure 3. Autocorrelation plot (maximum lag = 10)**

### Cross-correlation

The cross-correlation output (maximum lag = 238) is presented in figure 4. The figure is based on  $r_{HO3-HO2}(k)$ , which indicates an error correlation of HO3 and HO2 assuming HO3 leads HO2 with lag  $k$ . The right half of the diagram indicates  $r_{HO2-HO3}(k)$ , since lag  $-k$  means HO2 leads HO3 instead of the other way around. As seen in the figure, approximately up to lag 70,  $r_{HO3-HO2}(k)$  is less than  $r_{HO2-HO3}(k)$ , which indicates HO2 leads HO3. This is consistent with our hypothesis that the most productive worker (Worker 2) leads Worker 3 who is the worker of about the average of productivity in the group.



**Figure 4. Crosscorrelation Plot (maximum lag = 238)**

When the cross-correlations are further investigated in shorter lags (maximum lag =10), the plot (figure 5) shows an interesting pattern. For some reason, at lag 2,  $r_{HO3:HO2}$  showed a significantly high jump pattern although the left side of the plot (which indicates  $r_{HO2:HO3}(k)$ ) overall is bigger than right side of the plot ( $r_{HO3:HO2}(k)$ ). This might indicate that at lag 2, the hourly productivity of Worker 3 (HO3) might lead the worker with the highest productivity (HO2); but overall, at other lags the other way holds true. This possibly indicates worker interdependence.

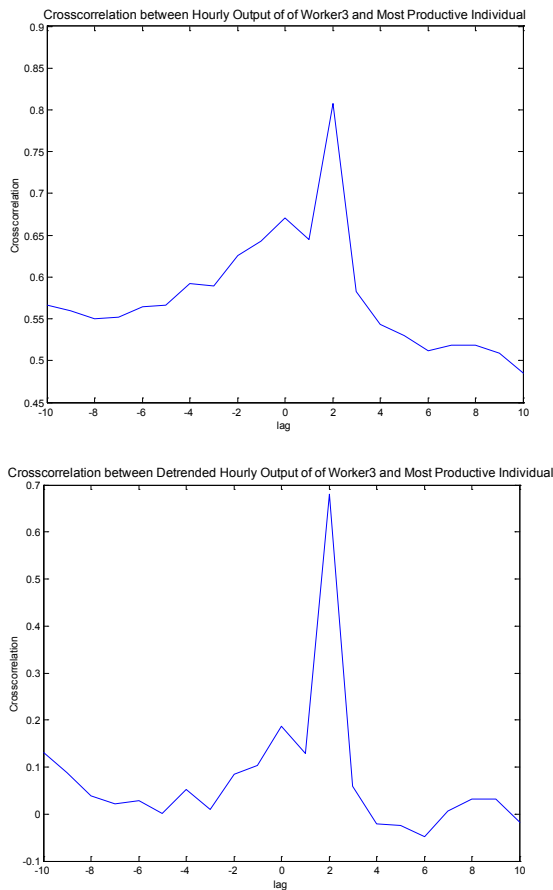
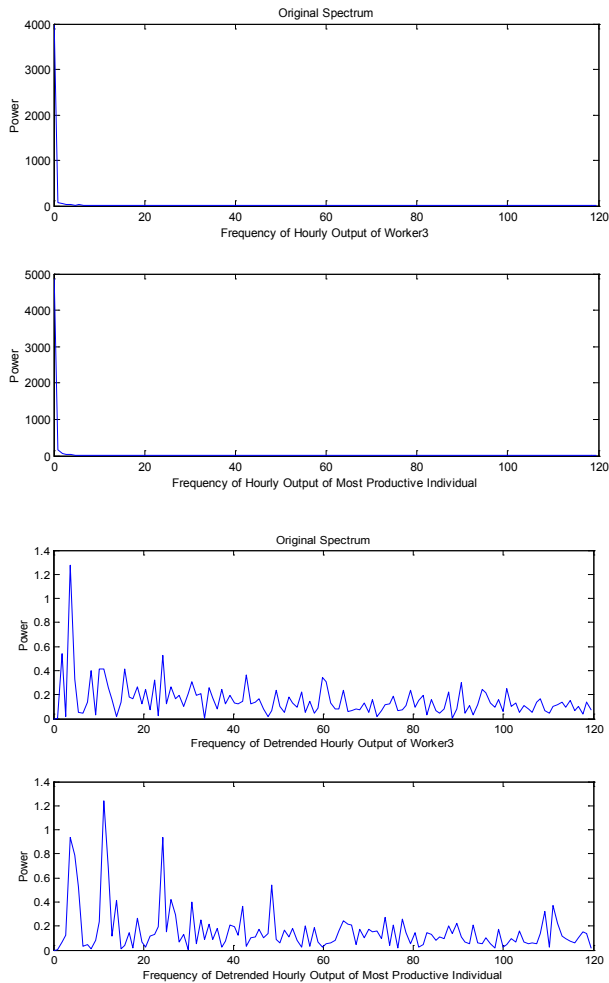


Figure 5. Crosscorrelation plot (maximum lag = 10)

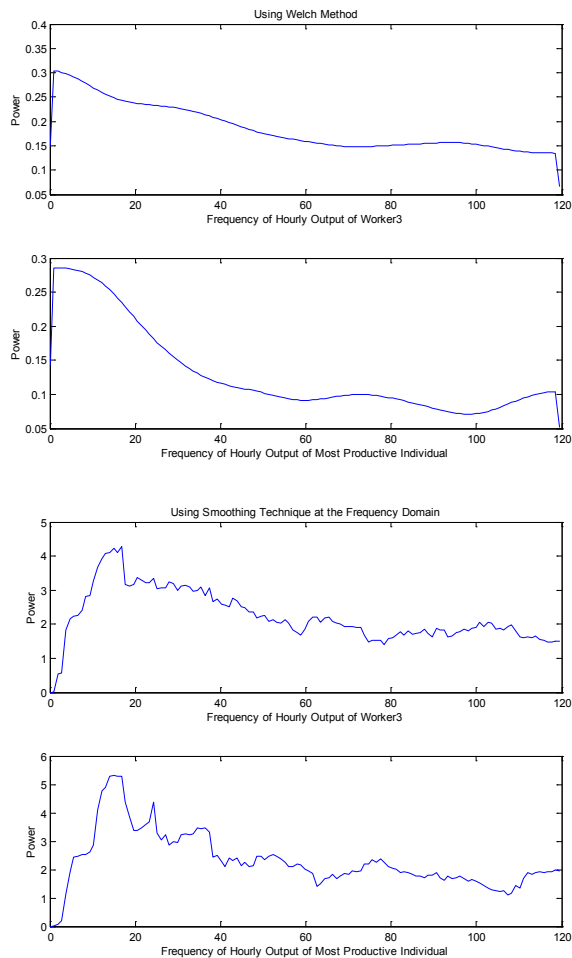
### Spectral analysis

Since the total number of observations during 239 weeks were 239, the frequency in the analysis will be 1 cycle/week. The Niquist frequency will be 120 cycles/240 weeks, which is .5. Deviations from a flat spectrum indicate some type of autocorrelation. Figure 6 shows periodograms for original and detrended data for the hourly output of Worker 3 and the most productive individual.

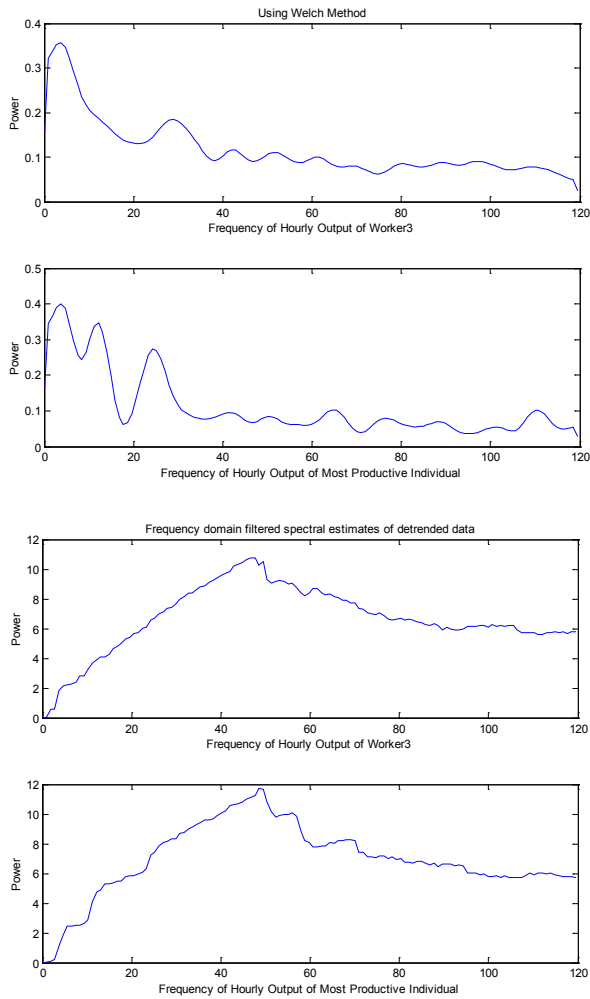


**Figure 6. Spectral Analysis for Original and Detrended Data**

The periodogram for the detrended data suggests that there may be some systematic signals at a lower frequency rather than a high frequency. To obtain consistent estimates, we must use smoothing or averaging techniques to reduce the variance of the estimates as the sample size increases. Two different window sizes are used: one with 10 and the other with 50. Figure 7 shows the spectral analysis for the detrended data with window size 10 using (1) the Welch method and (2) the frequency domain filtering method. Figure 8, on the other hand, shows a spectral analysis using window size 50.



**Figure 7. Spectral Analysis for Smoothed, Detrended Data (window size 10)**



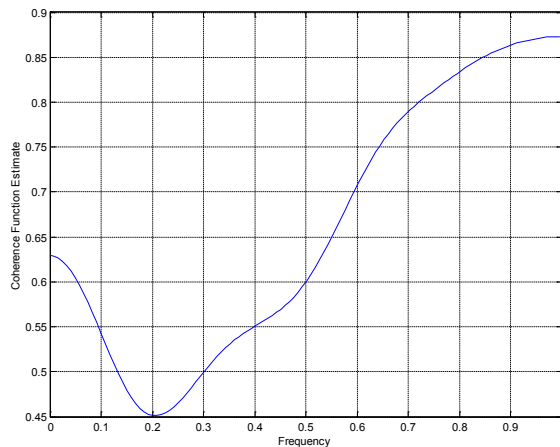
**Figure 8. Spectral Analysis for Smoothed and Detrended Data (window size 50)**

Apparently, window size 10 smoothed the data too much to see the amplitude of systematic frequency. For the frequency output of Worker 3, Figure 8 shows that there are two systematic frequencies that explain the variance: 5 cycles per 240 weeks and 28 cycles per 240 weeks, which are 5 cycles and 28 cycles for a 5-year period. That is approximately equivalent to 1 cycle per a year and 0.5 cycles

per year. In other words, the effect of a year or a half-year seems to be the reason for this systematic frequency although the power of the year is stronger than the half-year effect. A similar kind of pattern was shown for the most productive worker's hourly output, but there was one more bump at 12 cycles/240 weeks. That is about 2.4 cycles per year. However, it is hard to identify what causes such systematic cycles for that frequency. The spectral plot filtered through the frequency domain shows a different pattern. Both for Worker 3 and Worker 2, the frequency level of approximately 48 cycles/240 weeks, which is equivalent to 9.6 cycles per a year, showed a possible significant contribution to the variance.

### Coherence Analysis

Coherence is the covariance between the amplitudes of the two series at a frequency. Figure 9 shows that there is strong coherence in a high frequency. That means there is high covariance between the amplitudes of the two series, hourly output of Worker 3 and the most productive worker, at a high frequency.



**Figure 9. Coherence Plot**

### **Model estimation**

I started the model testing based on Hypothesis 1 and 2 by putting contradicting theoretical variables (external factors vs. human relation factors) separately into the regression equation. This is to get an idea of how much variance each theoretical set of variables can solely explain the variance of Worker 3's hourly output. Table 1 shows the result of the analysis.

The R-square that is explained by the external factor model and the human relations model are .51 and .53, respectively. Without having control variables, this shows that the variance explained by each set of theoretical terms seems to be about equal when the effects of the human relations variable are lagged by one week. The result shows that conflicting conclusions are possible in interpreting Worker 3's output. However, the Durbin-Watson statistics of the external factor model suggests that there is indeed error correlation (DW=1.66), indicating that further time series analysis is needed.

To test the hypotheses and model testing, first order, second order and third order models that include both human relations factors and external factors that can be considered control variables were tested. The result is summarized in table 2.

Overall, the R-square explained by the three models improves significantly when the order of the model increases ( $R^2 = .55$ ,  $R^2 = .77$ ,  $R^2 = .83$ ). The F-differential test cannot be performed since the three models are not exactly nested due to the loss of one sample size by the lag effect. The first data point of a variable when lagging the variable will be missing, and the listwise deletion reduces one sample size that includes the missing variable as the lag increases by one. However, a dramatic increase in the R-square and F-statistics suggests that the best model to explain the given hourly output of Worker 3 is third order model.

In addition to the R-square and F-statistics, the estimated parameters included in model 3 overall were statistically significant compared to the other two models. Out of the three autoregressive terms, Worker 3's hourly output at lag 1, lag 2, and lag 3, hourly output at lag 1 and lag 2 were significant ( $p < .001$  and  $p < .01$ , respectively). What is interesting is that the output of Worker 3 at lag 2 has negative coefficients meaning that it is negatively related with the current output of Worker 3. In other words, the output of the last week is positively related with that of the current week, but



**Table 1: Model testing Using Contrasting Theoretical Variables**

Variable	Label	Zero Order, <u>External Factors Only</u>			First Order, Human Relations Variables Only		
		Parameter Estimate	Standard Error	t Value	Parameter Estimate	Standard Error	t Value
Term	Intercept	50.93	0.92	55.39***	19.93	3.27	6.09
AR(1)	HO3_1				0.18	0.06	2.81**
MA(0)	HO2				-0.02	0.08	-0.21
MA(1)	HO2_1				0.06	0.08	0.76
MA (0)	HOAV				0.47	0.14	3.35***
MA(1)	HOAV_1				-0.04	0.14	-0.26
MA (0)	MD	7.76	0.89	8.68***			
MA (0)	ED	2.21	0.66	3.34**			
MA (0)	SRT	0.20	0.04	4.94***			
F		80.49***			51.85***		
R-square		0.51			0.53		
Adjusted R-square		0.50			0.52		
Durbin Watson		1.66			2.07		
First Order Correlation		0.17			-0.04		

\* p &lt; .05; \*\* p &lt; .01; \*\*\* p &lt; .001.

Table 2: Parameter Estimation of First Order, Second Order, and Third Order Model

Variable	Label	First Order Model			Second Order Model			Third Order Model		
		Parameter Estimate	Standard Error	t Value	Parameter Estimate	Standard Error	t Value	Parameter Estimate	Standard Error	t Value
Term	Intercept	26.44	5.76	4.59	25.86	4.40	5.87***	18.56	4.23	4.39***
AR(1)	HO3_1	0.14	0.07	2.08*	0.13	0.05	2.69**	0.44	0.06	7.74***
AR(2)	HO3_2				-0.10	0.05	-1.92	-0.13	0.05	-2.93**
AR(3)	HO3_3							0.08	0.05	1.77
MA(0)	HO2	-0.05	0.08	-0.59	-0.16	0.06	-2.52*	-0.12	0.05	-2.17*
MA(1)	HO2_1	0.03	0.08	0.38	-0.11	0.06	-1.87	-0.04	0.06	-0.65
MA(2)	HO2_2				0.85	0.06	14.19***	0.93	0.05	17.81***
MA(3)	HO2_3							-0.50	0.07	-7.03***
MA (0)	HOAV	0.42	0.14	2.92**	0.56	0.12	4.82***	0.54	0.10	5.25***
MA(1)	HOAV_1	-0.05	0.14	-0.33	-0.01	0.11	-0.05	-0.20	0.11	-1.87
MA(2)	HOAV_2				-0.63	0.10	-6.03***	-0.55	0.09	-5.83***
MA(3)	HOAV_3							0.21	0.10	2.09*
MA (0)	MD	2.81	1.59	1.76	-0.57	1.21	-0.47	-0.01	1.08	-0.01
MA (0)	ED	-0.27	0.93	-0.29	-1.81	0.70	-2.60**	-0.64	0.62	-1.03
MA (0)	SRT	0.11	0.04	2.35*	0.07	0.03	2.21*	0.04	0.03	1.57
F		34.35***			68.07***			74.69***		
R-square		0.55			0.77			0.83		
Adjusted R-square		0.53			0.76			0.81		
Durbin Watson		2.02			1.33			2.31		
First Order Correlation		-0.01			0.31			-0.03		

\* p &lt; .05; \*\* p &lt; .01; \*\*\* p &lt; .001.

the output of the two weeks before is negatively related with that of the current week. It seems to suggest that there is an adjusting nature of feedback terms. In fact, workers keep adjusting their output level depending on various situations. Thus, Hypothesis 3 that expects a relationship between a person's past and current productivity is supported when external factors are controlled.

In terms of hypothesis 1 that expects a relationship between past and current group productivity and Worker 3's productivity, the coefficients that are associated with the four moving average terms are the focus of the analyses. The group's current hourly output is positively related with Worker 3's output ( $p < .001$ ) as well as their past output level at lag 2 and lag 3 which are negatively ( $p < .001$ ) and positively ( $p < .05$ ) related with Worker 3's current output level. What is interesting is that the group productivity at lag 1 does not effect the current output of Worker 3. Based on the results, it is concluded here that Hypothesis 1 is supported.

Hypothesis 2 predicts that the past and current productivity of the most productive worker will influence Worker 3's productivity. The three coefficients that are part of the most productive worker's hourly output were significant. Those are: most productive worker's current hourly output ( $p < .05$ ), most productive worker's hourly output at lag 2 ( $p < .001$ ), and that of lag 3 ( $p < .001$ ). The current and lag 3 output of the most productive worker had a negative relationship, but the lag 2 output of the most productive worker had a positive influence on Worker 3's output. This suggests that the influence of the leading individual has different influences at different lags. Thus, hypothesis 2 is supported.

While the parameters associated with human relations factors are significant, the external factors that are employed by Franke and Kaul (1978) and the alternative explanations of the overall output increase over time were insignificant. Opposed to what Franke and Kaul argued, external factors did not play a significant role in explaining the output increase in the Hawthorne studies.

## DISCUSSION

Previous statistical analyses by Franke and Kaul (1978) and Jones (1992) provide no support for the human relations hypothesis using "first-relay" experiments data from the Hawthorne Studies. Our

study suggests the possibility that without the inclusion of human relations variables in the statistical model, the conclusion of such statistical analyses can be misleading. Based on this possibility, social facilitation and the social learning process were identified as the primary underlying process of the human rela

tions hypothesis in the Hawthorne Studies. By employing a more sophisticated time series analysis, it is concluded here that the group and the most productive individuals motivate and exert pressure on an individual's output over time. When these variables were considered in the model, surprisingly, external factors, such as economic depression, managerial discipline, and scheduled rest time had little effect on the output level of a worker when these human relations variables were taken into account into the time series model. Thus, the model testing included in the paper supports the notion of human relations from the Hawthorne Studies (Roethlisberger and Dickson, 1939).

The current study contributes to the literature in two distinct ways. First, it theorizes social facilitation (Guerin, 1993) and social learning (Bandura, 1971) as the underlying process of the human relations hypothesis. Secondly, methodologically, it employs time series analyses that capture the wave effects of these variables. The approach is much more adequate than the previous studies.

The study, however, is not without limitations. Due to missing data, conclusions on all other workers were not possible. If more advances in statistical analyses are available, perhaps further investigation that analyzes other worker's output level other than that of Worker 3 may be possible in the future. This can be helpful to validate the conclusion provided here.

Despite the potential limitations, this study suggests that the previous statistical analyses on "first-relay" experiment of the Hawthorne study did not properly test "Human Relations" hypothesis. When variables representing group influences and interpersonal interaction (i.e., social facilitation and social learning) were included in the model, these variables explained the significant portion of the individual worker productivity (Worker 3's productivity), supporting the notion of human relations.

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