

Familiarity and Group Productivity

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Abstract:

The effects of familiarity on group productivity were examined. Familiarity refers to the specific knowledge workers have of their jobs, co-workers, and work environment. In this study of coal-mining crews, absenteeism led to staffing changes that affected the level of familiarity in the work group. Data from 26 crews in two underground coal mines indicate that lower levels of familiarity are associated with lower productivity.

Article:

The effects of familiarity on group productivity were examined in this study of coal-mining crews. Absenteeism led to short-term changes in these crews, which affected the levels of crew familiarity. Familiarity refers to the knowledge group members have about specific job, crew, and work-environment configurations. Declines in levels of familiarity were hypothesized to be associated with declines in productivity.

This study extends prior research (Goodman & Garber, 1988) showing that familiarity affects the rate of accidents. Though based on a similar theoretical framework, the present study involves different analytical procedures *and* a different data set.

Empirical Literature

Several different literatures point to the relevance of familiarity as a determinant of productivity. The literature on the consequences of absenteeism (cf. Goodman, 1984) provides some clues. The basic argument is that absenteeism affects staffing replacement policies, which change levels of familiarity within the work group.

Katz, Kochan, and Weber (1982) and Katz, Kochan, and Gobeille (1982) used plant-wide data to provide some evidence that higher absenteeism is associated with lower labor efficiency. Mach and Fitzgibbons (1982) reported that absenteeism of more central employees (for example, maintenance personnel) had negative effects on production and that less automated production was more vulnerable to the negative effects of absenteeism. These analyses were conducted at the firm level; our analysis was conducted at the group level.

Studies in which seniority, job experience, and performance were examined also bear on our concept of familiarity as a determinant of productivity. The argument is that greater levels of seniority or experience are associated with greater familiarity and performance. Studies at the group level by Katz (1982) and by Banker, Datar, and Kemerer (1987), for example, have shown that lower seniority is associated with lower performance. Some studies at the individual level have shown that seniority, when coupled with the similarity of prior jobs (a possible indicator of familiarity), is also related to performance (cf. Gordon & Fitzgibbons, 1982). Schmidt, Hunter, and Outer-bridge (1986) reported that the length of job experience directly affects job knowledge (a possible indicator of familiarity), which in turn affects measures of job performance. We propose that the

relationship between seniority and performance may be due to familiarity (Although seniority was measured in years in these studies, our focus was on daily variation of familiarity on performance).

Finally, studies of managerial succession indirectly support the concept of familiarity as a determinant of productivity. For example, Allen, Panian, and Lotz (1979) reported that midseason succession of a manager in sports teams seemed more disruptive than end-of-season succession, and outside succession appeared to be more disruptive than inside succession. Succession between seasons allows more opportunities for managers to become familiar with the players and the environment and hence should be less disruptive. The inside successor is probably more familiar with the team personnel, strategies, and environment than an outside successor. These studies provide some indirect support for the concept of familiarity. We now turn to a more detailed examination.

Theoretical Relationships

Familiarity

Familiarity is the principal theoretical construct in our investigation. Every workplace is a unique configuration of machinery, physical environment, people, performance strategies, and jobs. Familiarity refers to the specific knowledge a person has about these aspects of work. We use the word *specific* to focus attention on the unique aspects of the work place.

In continuous coal-mining technology, a general configuration of machinery, environment, people, performance strategies, and jobs is common to all mining sections. However, within each section or work area, unique configurations can also be found. Although the sections often have the same general type of continuous mining machine or bolting machine, each machine is unique because of variations in manufacturing source, age, and maintenance activities. Similarly, although most mining crews experience a variety of physical conditions in any day or week, over long periods of time the average physical condition in one section is likely to be different from another section. So, in this context, we use the words *specific knowledge* or *familiarity* to refer to knowledge about the unique characteristics of machinery, physical environment, people, performance strategies, and jobs in a particular section at a particular time.

Our central premise is that, because of the hazardous and dynamic nature of mining, such specific knowledge is critical to effective production. When absenteeism occurs, the replacement worker is unfamiliar with the unique properties of the machinery, physical environment, job, and work habits unique to the crew. In addition, existing crew members are unfamiliar with the work habits of the replacement worker.

Familiarity in our conceptualization is a cognitive or knowledge-based variable. High familiarity should facilitate job performance and minimize coordination losses (cf. Steiner, 1972). Familiarity differs from other group concepts, such as cohesiveness, that focus on the affective orientation toward group members or the task (Goodman, Ravlin, & Schminke, 1987). High degrees of familiarity may enhance cohesiveness, but the two concepts are analytically different. Also, the concept of familiarity used in this article should not be equated with such concepts as friendship. Familiarity refers to the level of knowledge a person has about co-workers and work activities, not to a person's feelings toward his or her co-workers.

Familiarity in this study is divided into three categories: job, section, and crew. In any mining crew there are three unique jobs—the miner operator, the bolter, and the car operator. (Most crews have two people for each of these jobs) Each job requires a specific set of skills. Unfamiliarity occurs when a person who regularly performs one job fills in on another job. For example, given the hazardous and dynamic nature of the mining environment, a person who is less familiar with the bolting job will probably be less productive than a person who is more familiar with the bolting job.

The section is the specific work area in a mine. It represents both the dynamic characteristics of the environment and the idiosyncratic nature of the machinery. Knowledge of the environment and the unique

properties of the machinery is critical for effective mining. Unfamiliarity with roof conditions or machinery should lead to lower productivity.

The third dimension is the crew. Mining is a highly interdependent activity. Because each crew is composed of unique individuals and performance strategies, crew members need to know these individuals and strategies to facilitate the interdependent task activities. Unfamiliarity with a particular crew should make the coordination of activities more difficult, which in turn should reduce productivity.

How Familiarity Relates to Mining Productivity

Our first study (Goodman & Garber, 1988) on familiarity was focused on accidents. The research question was "Do variations in familiarity in the three dyads in mining (continuous miners, bolters, and car operators) relate to accidents?" The results indicated that accidents are associated with lower levels of familiarity. In that study, the individual and the dyad were the critical units of analysis because of our focus on individual accidents. In this study, because of our interest in group productivity, we focused on group-level variables and measures of familiarity.

The basic hypothesis was that crews whose members are familiar with their jobs, section, and other crew members would be more productive than crews with lower levels of familiarity. In stating this hypothesis, we acknowledge several complicating factors. First, the functional relationship between familiarity and productivity is hard to specify a priori. Second, lack of familiarity may evoke compensatory behaviors. For example, a miner unfamiliar with a crew, section, or job may try to compensate by working harder. Third, it is difficult to determine how quickly one learns or forgets specific information about the work setting. For example, can one learn more quickly about the nature of physical conditions or how to coordinate activities with the work group? There are no easy answers to these three issues. We acknowledge their presence and reflect on these issues in our interpretation and discussion of the results.

Method

Data Requirements

Studying the relationship between crew familiarity and productivity poses some difficult data requirements. First, we needed to know who worked on what job, in what section, and in what crew. Second, we needed to create daily productivity measures for each crew. Third, we needed to have data on other factors that affect productivity (e.g., daily machine downtime per crew, daily physical conditions per crew) so that we could separate familiarity effects from other factors affecting productivity. All of these data had to be obtained for multiple crews over an extended time period. The Carnegie Mellon Coal Research Project has collected data from 26 mines run by 16 major firms in the coal industry. However, less than 5 of the mines generated the staffing-roster data required for this type of analysis.

Another restrictive data requirement was that, even if the data were available, the process of coding would be very time consuming and expensive. Daily codes had to be created for each individual in each crew, in terms of whether they worked in their regular job, section, and crew. Because of the expensive nature of the manual coding, we limited our analysis to 26 crews in two mines, but this is still a relatively large sample of organizational work groups.

Table 1
Sample Description

Basic elements	Mine 1	Mine 2
Number of observations	2,208	1,931
Time period	1/2/80–12/31/80	1/2/80–3/26/81
Number of crews	12	14
Number of sections	11	7
Number of shifts	3	3

Sample

The sample was taken from two mines (Mines 1 and 2) over a 15-month period beginning in January 1980 and ending in March 1981 (see Table 1). Observations totaled over 4,000 and were divided roughly equally between the two mines. Mine 1 was the larger mine with 11 sections; Mine 2 had only 7 sections. Both mines worked a three-shift, 24-hour clock; Mine 1 employed 12 crews, and Mine 2 employed 14 crews.

Measures

Familiarity: A crew's familiarity was defined in terms of its section (e.g., machinery, physical environment), job assignments, and crew membership. Moreover, it was possible that familiarity along two or more of these dimensions would produce effects greater or less than the sum of their individual effects because of various interactive (synergistic) effects. Thus, a number of measures combining the three types of familiarity were constructed: (a) section-job-crew match; (b) section-job match; (c) section-crew match; (d) job-crew match; (e) section match; (f) job match; (g) crew match; (h) no match (but working in the mine); and (i) other match (no match and no record of working).

Table 2
Work Record for Worker Smith

Day	Crew	Job	Section
1	C-1	J-1	S-1
2	C-1	J-1	S-2
3	C-2	J-1	S-2
4	C-1	J-2	S-1
5	C-2	J-1	S-1
6	C-2	J-1	S-1

Table 3
Examples of Familiarity Quantification for Worker Smith

Familiarity variable	Day 3	Day 4	Day 5	Day 6
Section-job-crew match	0%	0%	0%	50%
Section-crew match	0%	0%	0%	0%
Section-job match	50%	0%	0%	0%
Job-crew match	0%	0%	50%	0%
Section match	0%	0%	50%	50%
Job match	50%	0%	0%	0%
Crew match	0%	50%	0%	0%
No match (but working in the mine)	0%	50%	0%	0%
Other match (no match and no record of working)	0%	0%	0%	0%

The construction of these measures began with the individual worker. For each worker, we counted the number of times over a given period in the past that the worker had been in a similar situation as "today" (taking the current observation as today). If we were using a 3-week time period, we compared today's job or section with jobs or sections over the past 3 weeks. The more times a person had worked on the same job or section, the higher the level of familiarity (Consider the example in Table 2). With a 2-day time horizon, the first observation for which a familiarity measure can be constructed is Day 3. On that day, Smith worked in Section S-2, Crew C-2, and Job J-1. On the previous day, Smith worked in Section S-2, Crew C-1, and Job J-1. Thus, Smith's situation on Day 3 is the same as on Day 2 to the extent that Smith worked in the same section and at the same job. This degree of familiarity can be represented by a tally for a section-job match. Like-wise, on Day 1 Smith worked in Crew C-1, Section S-1, and Job J-1. Hence, Smith's experience on Day 1 is similar to that of Day 3 in that Smith worked the same job. Thus, a job match tally is recorded. Because two observations are compared to Day 3, the tallies can be translated into proportional terms: 50% of the time in the past (over the 2-day time horizon) Smith matched with respect to section and job, and 50% of the time Smith matched with respect to job alone. Smith's familiarity with the current (that is, Day 3) situation can be quantified by nine variables measuring the various ways in which the present situation matches up with past experience (see Table 3). For any given observation, the familiarity measures for an individual worker must add to 100%. In essence, these measures describe along nine dimensions the relationships between past work experiences and the present situation. Calculations for Days 4, 5, and 6 are also presented in Table 3.

The unit of measurement in this study was the crew. For each crew on a shift, we calculated the crew-wide averages of the proportion of shifts out of the previous 21 days that each worker matched in terms of these nine measures. We selected the 3-week period because it matches the shift-rotation cycle in the mines. The daily percentages resulting from the nine familiarity measures for each crew were then related to that crew's productivity.

The familiarity variables for each observation are averages across individual workers who were present, and thus they do not measure the effects of absenteeism per se. A short-handed crew does not necessarily mean a

change in the degree of familiarity If a worker is absent and is replaced, the effect of the replacement is to keep the total size of the crew fixed. However, the replacement changes the values of the crew's familiarity measures. The company policy is to replace absent workers.

Productivity. The productivity measure for this study, tons of coal mined per crew per shift, was derived from company records. Our experience in other projects that involved analyzing coal-mining productivity data is that mine records do not reflect recording biases at the section or crew level. There may be recording differences between mines, but that is not pertinent to our analysis.

Analytic Strategy

Our strategy (see Goodman, 1986) took the following form. We began with a fairly simple assumption: Variation in crew productivity can be explained by how the crew is staffed (i.e., whether there are workers on each task) and whether the machinery is working. We made no assertions about the quality of labor, the nature of the group process, leadership styles, and so on. This baseline model, or production function, asserts that labor and technology are the first step in understanding group productivity.

The labor variable consisted of the number of workers in a particular category per crew per shift. There are two categories: *Prime crew* refers to miners operating the continuous miner machine, the bolting machines, or the cars transporting the coal, and *general inside laborers* refers to workers assigned to crews on a day-to-day basis to do indirect work (e.g., controlling the air flow). Technology or machinery was operationalized in terms of the number of minutes a machine was down or delayed per crew per shift. The one exception for this set of measures was the number-of-cars variable, which was simply the number of cars available. An environmental dummy variable was used to denote bad physical conditions. Finally, three control variables were used to denote a second shift observation, a third shift observation, and the occurrence of an accident.

Our second step was to examine the incremental impact of additional variables in explaining crew productivity in each mine. In this step, we introduced the familiarity variable as a way of refining the labor variable, which initially was the number of people in the crew per day This allowed us to see what effect familiarity had on the baseline model.

Our analysis focused on three questions:

1. What is the baseline production function for coal-mining crews?
2. Does the addition of the familiarity variable to the baseline model increase our ability to explain variation in crew productivity? Our specific hypothesis was that familiarity is positively related to productivity and should significantly contribute to our ability to explain variation in productivity over the baseline model. Given the relative newness of this research effort, we did not have hypotheses about the differences between the nine measures of familiarity. Although we did expect the highest familiarity measure (job—section—crew match) to be different from the others, it was difficult to know whether the job—crew match or the job—section match measures represented higher familiarity and, hence, higher productivity.
3. If each of the crews had perfect familiarity, would they produce significantly more than their actual observed productivity? This question introduced a new and different analytic approach for examining the effects of familiarity The basic hypothesis was the same.

Results

Mine 1

Baseline run. The baseline results for Mine I are presented in Table 4. The table is divided into four sections corresponding to the four types of baseline variables.

The model was estimated from daily production data. The labor terms are the number of workers in two different job categories. In general, the coefficients should be positive, with the prime crews being more essential to production. The technology variables were measured in terms of machine availability. The first variable is the number of shuttle cars per crew or section. The other measures are minutes of downtime. Not all of the machinery is equally important. Miner delay should have a greater effect on productivity than car delay. All delay variables should have a negative coefficient. The environmental variable is represented by a dummy variable for bad conditions. There were no hypotheses about control variables, but they should be included in the model.

Table 4
Simple Production Function: Mine 1

Variable	Developmental data	
	Coefficient	<i>t</i>
Labor		
Prime crew	3.04	2.4
General inside laborers	0.73	0.8
Technology		
Number of cars	29.12	16.7
Miner delay	-0.24	21.3
Car delay	-0.05	5.2
Direct bolter delay	-0.05	3.0
Indirect bolter delay	—	—
Other activity delay	-0.21	20.2
Managerial delay	-0.23	8.4
Inside equipment delay	-0.22	13.7
Outside equipment delay	-0.25	12.1
Minermove delay*	0.32	13.3
Environmental		
Physical condition dummy	-15.56	20.1
Control		
Shift 2 dummy	-0.56	0.4
Shift 3 dummy	0.97	0.7
Accident dummy	-7.44	1.0
Constant	113.40	14.2

Note. $N = 2,208$ observations. $R^2 = .63631$. Dashes indicate that data were not available.

* Delay caused by moving the continuous mining machine.

Labor variables. Each coefficient represents the marginal productivity of that labor type. Hence, the marginal prime-crew worker contributed over 3 tons of coal per shift. As expected, the marginal productivity of both the prime-crew worker and the general inside laborer was positive. Notice also how the marginal productivity of a prime-crew worker was over 4 times as great as that of a general inside laborer and that these values were only significantly different from zero for the prime-crew worker. Together, these results support our expectation that prime-crew workers, being more highly trained and using more sophisticated machinery, would be more productive than their general-inside-labor co-workers. As a result, the impact of absenteeism in this mine was higher for a prime-crew worker (3 tons per crew per shift) than for a general-inside-labor worker (less than 1 ton per crew per shift).

Technology variables. All delay variables (except minermove—the delay caused by moving the continuous mining machine) have the expected negative sign and all are significant. Notice also how the coefficients confirm the existence of two types of delays: those that shut down the production process and those that may or may not shut it down. Among the first group of delays are minor delay, managerial delay, and outside equipment delay. In all these cases, the delay stopped production and resulted in a loss of a quarter of a ton of coal per minute of delay time. On the other hand, the bolter and car delays may shut down the production process or simply slow it down. Hence, on average, 1 min of delay time in these categories reduced output only by one twentieth of a ton.

The final two variables in this category, number of cars and minermove, deserve a few separate comments. The number-of-cars variable (usually taking on the value of 1 or 2) was the number of shuttle cars used during the shift. Interestingly, the coefficient indicates that although the addition of a second car did, as expected, increase

output (almost 30 tons or around a third of the average output), it did not double it. This suggests that crews given only one shuttle car compensated in some manner to keep production up. Whether this increase in production was due to extra effort on the part of the crew or to the existence of slack capacity when two cars were used cannot be determined here. The other variable, *minermove*, had a small but significantly positive coefficient. This result is most probably due to the interaction of two factors. On the one hand, taking time to move the continuous miner means that coal cannot be dug; hence, there is a negative effect on production. On the other hand, the miner is moved to place it in a more productive area, the larger the number of minutes devoted to moving the continuous miner, the greater the productivity of the crew. Therefore, larger *minermove* values ought to be correlated with higher production. For Mine 1, the latter effect apparently dominated, and so the net effect was slightly positive.

Environmental variables. For both mines, we had only one measure of physical conditions: a dummy variable derived from foreman reports, which took a value of 1 when bad conditions were present. Hence, we expected a negative coefficient. In fact, the coefficient was significantly negative. Thus, when bad conditions were present, the average output was over 15 tons, about 10% lower than output under good conditions.

Control variables. We did not have hypotheses about the signs of the coefficients associated with the second and third shifts, and in fact the results were not significantly different from zero. Hence, although there may be differences in shift productivity, they are apparently small. For the accident dummy variable, we found an expected negative coefficient, but it was not significant. In general, an accident resulted in a loss of output on that shift of 7 tons of coal. Overall, the results of the baseline model are consistent with familiarity theory and other reported findings (Goodman, 1986).

Familiarity run. Having analyzed the baseline model, we then ran the same model with the addition of eight familiarity measures. The perfect familiarity variable, *section-job-crew match*, was left out to avoid the dummy variable trap. Hence, the constant term embodies the effect of perfect familiarity. In turn, the coefficients of the other familiarity measures must be interpreted in comparison with perfect familiarity. Thus, for example, the coefficient on the *section-job match* variable indicates the degree to which crew unfamiliarity (all other familiarity being perfect) changed productivity. We expected these coefficients to be generally negative.

The results confirmed our assumption that familiarity has an effect on production and that this effect is felt both through the baseline variables and independently (Table 5).¹ That familiarity had an effect on productivity is evident from a highly significant *F* statistic, which demonstrates the additional significance of the familiarity variables as a group in explaining output variability. In addition, *t* statistics for several of the individual familiarity coefficients were highly significant.

To distinguish the direct effects of familiarity from indirect effects that trace through the existing baseline model variables, we examined (a) the change in the squared multiple correlation (an informal measure of direct effects) and (b) how the baseline model coefficients changed with the introduction of the familiarity variables (an informal measure of indirect effects). The squared multiple correlation rose by .004 (an 0.7% rise), indicating the degree of influence by the familiarity variables exclusive of their influence on the baseline variables. Changes in the baseline model coefficients were primarily associated with the labor variables, with the coefficients for prime crew and general inside laborers falling by 17% and 84%, respectively. These results suggest that familiarity may affect the production process through its effect on labor. This is consistent with the fact that the familiarity measures represent a different dimension of the labor variable. Note the almost complete absence of changes in the coefficients associated with machine availability. It may be that delays are, for the most part, a function of technological variables, such as age and past maintenance, and thus are unaffected by familiarity.

Mine 2

Baseline run. The estimated baseline model for Mine 2 is presented in Table 6. The results paralleled those for Mine 1.

The labor variable coefficients were both positive and were much larger and more significant than those for Mine 1. The technology coefficients were closer to their Mine 1 counterparts. All delay variables had the expected negative sign and were significantly different from zero. In addition, they also displayed the dichotomy between direct and indirect delays. The physical condition variable had the expected negative coefficient indicating that, under bad conditions, output on average was more than 21 tons (around 20%) lower than under good conditions. The control variables again confirmed our suspicion that accidents are associated with lower output (on average, 7 fewer tons of coal were produced). The constant term, however, was much larger than for Mine 1 (175 tons), suggesting that Mine 2 was generally more productive than Mine 1 for reasons not explained by the variables used in this study Overall, the results of this baseline model are consistent with familiarity theory and other reported findings.

Table 5

Production Function With Familiarity Variables: Mine 1

Variable	Developmental data	
	Coefficient	<i>t</i>
Labor		
Prime crew	2.53	2.0
General inside laborers	0.12	0.1
Technology		
Number of cars	28.77	16.5
Miner delay	-0.24	21.5
Car delay	-0.05	5.1
Direct bolter delay	-0.05	2.9
Indirect bolter delay	—	—
Other activity delay	-0.20	19.9
Managerial delay	-0.23	8.2
Inside equipment delay	-0.22	13.7
Outside equipment delay	-0.25	12.1
Minermove delay ^a	0.31	13.2
Environmental		
Physical condition dummy	-15.58	20.0
Control		
Shift 2 dummy	-0.62	0.4
Shift 3 dummy	0.82	0.6
Accident dummy	-6.22	0.8
Constant	119.95	13.9
Familiarity^b		
Section match	-203.65	2.6
Job match	6.69	0.4
Crew match	-4.03	0.3
Section-job match	-104.90	0.9
Section-crew match	-15.85	2.2
Job-crew match	5.23	1.7
No match	20.24	1.3
Other match	-10.50	1.4

Note. $N = 2,208$ observations. $R^2 = .64075$. For the familiarity variable, $F(8, 2184) = 3.37, p < .0007$. Dashes indicate that data were not available.

^a Delay caused by moving the continuous mining machine. ^b Perfect familiarity, represented by section-job-crew match, was not included in the analysis to avoid the dummy variable trap.

Table 6

Simple Production Function: Mine 2

Variable	Developmental data	
	Coefficient	<i>t</i>
Labor		
Prime crew	5.32	3.1
General inside laborers	6.60	6.1
Technology		
Number of cars	18.17	10.1
Miner delay	-0.43	41.4
Car delay	-0.09	11.5
Direct bolter delay	-0.48	17.4
Indirect bolter delay	-0.02	2.0
Other activity delay	-0.41	19.8
Managerial delay	-0.54	13.2
Inside equipment delay	-0.38	23.3
Outside equipment delay	-0.35	13.2
Minermove delay ^a	-0.35	10.2
Environmental		
Physical condition dummy	-21.86	3.6
Control		
Shift 2 dummy	3.54	2.0
Shift 3 dummy	4.83	2.7
Accident dummy	-7.27	1.7
Constant	174.80	17.0

Note. $N = 1,931$ observations. $R^2 = .55973$.

^a Delay caused by moving the continuous mining machine.

Familiarity run. The familiarity run for Mine 2 indicated that familiarity had an effect on production and that this effect was both through the baseline variables and independent (see Table 7).

Overall, several *t* tests of the familiarity variables were significant, and the *F* value of 15.2, which reflects the additional explanatory power provided by inserting the familiarity variables, was more significant than for Mine 1.

The analysis conducted to distinguish the direct effects of familiarity from the indirect effects manifested through the baseline model variables revealed larger direct effects than found for Mine 1. The squared multiple correlation rose by almost .026 (or 4.7%), thus indicating the degree of influence by the familiarity variables exclusive of their influence on the base-line variables.

There were, however, changes in the existing baseline-model variable coefficients. Again the labor variables bore the brunt of the influence; coefficients for prime crew decreased 40%, and coefficients for general inside laborers decreased 22%. This reflects the fact that the familiarity measures tap a different component of the labor variable. These figures also support the view that Mine 2 had a different labor relationship than Mine 1. The coefficients associated with machine availability changed little, as we found for Mine 1.

Size of Familiarity Influence

In this section, we propose an alternative procedure for assessing the impact of familiarity on productivity. The potential importance of familiarity can be measured by comparing the level of output that would be generated by some minimal level of familiarity with the level of output that would be generated by perfect familiarity. Moreover, comparing these predicted output levels to actual output levels (which embody various degrees of familiarity) should provide insight into the success that staffing policies may have in exploiting the possible gains associated with increased familiarity.

The construction of output under perfect familiarity was straightforward. We predicted output from the results from the analyses of baseline plus familiarity variables (Tables 5 and 7). For the baseline variables, we used the original data used in the regressions. For the familiarity variables, we set all values equal to zero.

Table 7
Production Function With Familiarity Variables: Mine 2

Variable	Developmental data	
	Coefficient	<i>t</i>
Labor		
Prime crew	3.17	1.9
General inside laborers	5.16	4.8
Technology		
Number of cars	17.13	9.8
Miner delay	-0.42	41.2
Car delay	-0.09	11.9
Direct bolter delay	-0.46	17.1
Indirect bolter delay	-0.02	2.0
Other activity delay	-0.41	20.2
Managerial delay	-0.51	12.8
Inside equipment delay	-0.38	23.7
Outside equipment delay	-0.36	13.9
Minermove delay ^a	-0.36	10.7
Environmental		
Physical condition dummy	-18.65	3.1
Control		
Shift 2 dummy	3.10	1.8
Shift 3 dummy	4.29	2.5
Accident dummy	-7.91	1.9
Constant	201.90	18.8
Familiarity^b		
Section match	-34.99	0.4
Job match	-35.51	2.8
Crew match	-54.75	2.9
Section-job match	-40.98	1.1
Section-crew match	-16.72	1.4
Job-crew match	-31.93	7.1
No match	-17.45	1.0
Other match	-25.10	5.5

Note. $N = 1,931$ observations. $R^2 = .58615$. For the familiarity variables, $F(8, 1906) = 15.21$, $p < .0001$.

^a Delay caused by moving the continuous mining machine. ^b Perfect familiarity, represented by section-job-crew match, was not included in the analysis to avoid the dummy variable trap.

The construction of output under some minimal level of familiarity required more thought. Though the minimal level of familiarity could be defined by setting the no match variable equal to 1, this seemed extreme and unlikely to be a useful standard. Instead, we defined the minimal level of familiarity as that level which would occur if workers were to be assigned to sections, jobs, and crews in a random manner. This procedure allowed us to determine whether actual staffing policies produced more output than could have been generated by random personnel assignment. Our construction of a minimal level of familiarity provides a standard against

which to compare actual performance. In actual practice, assignments are not made randomly, but random assignment served as a needed reference point against which actual performance could be evaluated. To construct familiarity variables consistent with this random assignment process, we used the following procedure. Consider a mine with S sections, J jobs, and C crews. The chance of matching on section is $1/S$, the chance of matching on job is $1/J$, and the chance of matching on crew is $1/C$. If section, job, and crew assignments are made independently, then the matching variables will be the products of probabilities. For example, the value of the section match variable will be the product of the chance of matching on section ($1/S$), the chance of not matching on job ($[J - 1] / J$) and the chance of not matching on crew ($[C - 1] / C$). The complete set of definitions is provided in Table 8.

Mine 1. The results of the analysis for Mine 1 are presented in Table 9. On average, Mine 1 produced 111 tons of coal per crew-shift. The regression analysis reported earlier, however, predicted that, if crews in Mine 1 had perfect familiarity, they could produce 113 tons of coal per crew-shift, or 1.8% more than was actually produced. Though potential gains from perfect familiarity varied, two thirds of the observations recorded a potential gain between 5.3 and -1.3 tons.

Table 8
Construction of Familiarity Variables Under a Random Assignment Process

Variable	Value under random assignment
Section match	$\left(\frac{1}{S}\right)\left(\frac{J-1}{J}\right)\left(\frac{C-1}{C}\right)$
Job match	$\left(\frac{S-1}{S}\right)\left(\frac{1}{J}\right)\left(\frac{C-1}{C}\right)$
Crew match	$\left(\frac{S-1}{S}\right)\left(\frac{J-1}{J}\right)\left(\frac{1}{C}\right)$
Section-job match	$\left(\frac{1}{S}\right)\left(\frac{1}{J}\right)\left(\frac{C-1}{C}\right)$
Section-crew match	$\left(\frac{1}{S}\right)\left(\frac{J-1}{J}\right)\left(\frac{1}{C}\right)$
Section-job-crew match	$\left(\frac{1}{S}\right)\left(\frac{1}{J}\right)\left(\frac{1}{C}\right)$
No match	$\left(\frac{S-1}{S}\right)\left(\frac{J-1}{J}\right)\left(\frac{C-1}{C}\right)$
Other match	0

Note. Setting other match to zero implicitly assumes zero absenteeism. S = number of sections; J = number of jobs; C = number of crews.

Table 9
Impact of Unfamiliarity on Production

Measure	Tons
Mine 1	
Mean actual output	111.0
Mean output under perfect familiarity	113.0
Mean output under random familiarity	111.7
Maximum gain possible with perfect familiarity	1.3
Gain due to familiarity actually exploited	-0.7
Gain due to familiarity not exploited	2.0
Mine 2	
Mean actual output	122.0
Mean output under perfect familiarity	135.8
Mean output under random familiarity	109.2
Maximum gain possible with perfect familiarity	26.6
Gain due to familiarity actually exploited	12.8
Gain due to familiarity not exploited	13.8

Interestingly, it appears that workers in Mine 1 performed worse than they could have if assignment had been simply random. Under random assignment, mean output per crew-shift would be 111.7 tons or 0.6% greater than actual output. Whether or not this is statistically significant is unclear.

Mine 2. The results for Mine 2 are also summarized in Table 9. Unlike Mine 1, these results are more supportive of the view that familiarity has an effect on output. Mine 2 had an average output of 122 tons of coal per crew-shift. This output, which embodied varying degrees of familiarity, was much lower than the output that would have been produced had there been perfect familiarity. In that case, output would have averaged 136 tons per crew-shift, or an increase of 11% over actual production levels. In addition, though the variance of this increase was larger than for Mine 1, for all observations output would have increased, with values ranging from 1.6 tons to 44.1 tons per crew-shift.

Examination of the output levels that would have been generated had assignment been random indicate that Mine 2 man-agers were somewhat successful in exploiting the gains possible through increased familiarity. If assignment had been random, output on average would have been only 109 tons per crew-shift. Actual output

was thus almost 13 tons per crew-shift higher than this minimal level. In essence, then, Mine 2 management was able to exploit roughly half of the total gain possible through increases in familiarity.

Discussion

The goal of this study was to examine whether crew familiarity affects group productivity. From the various analyses, familiarity seems to affect productivity. Moreover, a comparison of

output under conditions of perfect familiarity, actual familiarity, and random familiarity revealed the size of the familiarity influence as well as the degree to which the mines were able to exploit its influence. In the analysis of direct and indirect effects, much of the impact of familiarity was on the labor variables. This makes sense. In the baseline model, we used only the number of workers as a measure of labor. In the extended model, we used number of workers plus familiarity, a more refined way to reflect labor input.

In any empirical investigation there are numerous puzzles. In this analysis, there were clear differences between the two mines. In Mine 2, the effects of familiarity were much more pronounced. It is very difficult to explain the differences between the two mines because they vary in so many ways. They represent different companies, managerial practices, training practices, and so on. The mines use different types of equipment (although the basic technology is the same) with different maintenance policies and different mining practices, and the list goes on. Given the long list of possible variables it is difficult to explain differences between mines. Our purpose in using more than one site was to look for some stability in the findings. We wanted to see if the effect of familiarity would appear in different organizations. It did, but in different magnitudes. We had no hypotheses, theory or methods to determine whether the effect would be greater in one mine than another.

Another puzzle is that the different measures of familiarity had different effects in the two mines. For example, the absence of section matches seemed more important in Mine 2 than in Mine 1. Again, because of the many differences between the mines, it is difficult to speculate on why section unfamiliarity made a difference in one mine but not in the other. However, the signs and magnitudes of the coefficients generally seemed consistent with our theory. Compared with the highest level of familiarity (section-job-crew match), the other familiarity measures should have exhibited negative signs. Also, the significant coefficients for the single matches (lowest familiarity) were lower than those for dual matches (e.g., job-crew). The critical question, however, was whether familiarity made a difference, not whether a particular type of familiarity was important.

There are two important questions for future research: why different measures of familiarity had different effects in different settings, and whether different combinations of familiarity have additive or nonadditive effects. For example, there could be some synergistic effects (Tziner & Eden, 1985) when crew members have high levels of familiarity compared with when crews experience lower levels of familiarity.

In any empirical investigation there are always other things that might have been done. Though we chose a 3-week time period to construct the familiarity measures, other periods could have been used. We chose 3 weeks because this period matched the shift cycle in the mines. In preliminary explorations, we had looked at alternative time periods; the findings were not different from what we reported here.

It could be argued that we should have introduced more traditional variables, such as group cohesiveness, group attitudes, or different leadership styles. Although these variables may be important, they do not appear to be alternative explanations for our findings or to interact with our familiarity variables. Consider the concept of cohesiveness. This concept refers to the level of attachment members hold toward their group or the level of commitment to the group task. Familiarity refers to the knowledge miners had of their job, section, and crew. These are analytically distinct concepts. From other work (Goodman, 1979), we know that cohesiveness in mining crews comes about through major structural changes and not simply because of the level of familiarity that exists in a group. It is unlikely that cohesiveness accounts for the familiarity findings reported here.

This study demonstrates that group familiarity can affect group productivity. We have presented a new conceptualization of the effect of familiarity, and we used a fine-grained data set to capture the effects on a daily basis. We have also demonstrated a new way to conceptualize and estimate familiarity's effects on group productivity. The use of the baseline model and the incremental analysis of the familiarity variables, along with the strategy of estimating perfect familiarity, are alternative approaches to analyzing productivity in work groups.

The findings from this research should stimulate other investigations. The issue underlying this work is how people learn specific information about their job, machinery, environment, and co-workers. Both the learning and decay functions for this type of learning should be examined, as well as factors (e.g., technological requirements, type of socialization mechanisms) that affect these functions. In addition, how group contextual factors bear on familiarity and productivity needs to be understood. For example, familiarity ought to have a greater influence on productivity in groups operating in a dynamic and complex environment than in groups operating in a stable and less complex environment.

The study also has some implications for practice. Familiarity seems to make a difference. It is also likely, simply because of absenteeism, that there will always be different levels of group familiarity. The implication of this analysis is that an organization's replacement policy should try to enhance familiarity. In the mining context, this would mean training replacement workers and assigning replacement workers to increase the likelihood of section-job-crew matches.

Notes:

¹ As for the baseline model, estimation was performed with ordinary least squares (OLS) regression. An anonymous referee argued that the presence of the familiarity measures (because they are constructed from lagged variables) creates a serial correlation problem that destroys the consistency of the OLS estimator and inflates the squared multiple correlation. Hence, estimation should be based on time-series techniques that correct for such correlation. After further research and careful consideration, we concluded that, because each familiarity variable is constructed from lagged *independent* variables over a finite 3- week horizon, the presence of the familiarity variables does not destroy the consistency of the OLS estimator or the reliability of the squared multiple correlation (see Johnston, 1972, p. 293, or Harvey, 1981, p. 222). However, this issue is tied closely to one's view of whether familiarity measures are better based on prior work experiences over a finite or an infinite period. (For a discussion of the econometric issues involved, see Harvey, 1981; Chap. 7).

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