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A Detailed Analysis of Task Performance With and Without Computer Monitoring

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Participants (*N* = 115) performed a computerized task under 3 conditions: no supervision, direct human supervision, and computer monitoring. Differences in performance across groups was evaluated using summary performance measures and detailed analyses of group performance over time. There was a statistically significant difference in performance quality but not performance quantity between the groups. The nonmonitored and computer-monitored groups had higher quality of performance compared with the direct human supervision group. Performance varied when examined in detail at different points in time during the experimental task. Together the results suggest that direct human supervision motivated participants but that participants in the other 2 groups were more sensitive to varying task demands.

1. INTRODUCTION

The use of electronic performance monitoring has continued to rise in recent years (DeTienne, 1993; Sipior & Ward, 1995). Orthmann (1998) reported that more than two thirds of companies surveyed by the American Management Association used some type of employee monitoring or surveillance system. Employees are monitored by means of a variety of devices such as video cameras and active badges, but the monitoring of e-mail, Web browsing, and other network activities appears to be one of the newest growth areas in employee monitoring (Sipior & Ward, 1995; Sipior, Ward, & Rainone, 1998). Using a modem or network connection, supervisors and others such as information technology personnel can remotely observe the activities on em-

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ployee computers, track how long employees were at their workstations, what software they used, and many other details of their computer use.

Field research has provided substantial evidence that electronic monitoring of job performance has adverse associations with job satisfaction, psychological distress, job performance, and a number of related variables (Chalykoff & Kochan, 1989; DiTecco, Cwitco, Arsenault, & Andre, 1992; Kidwell & Bennett, 1994; Kraut, Dumais, & Koch, 1989; Smith, Carayon, Sanders, Lim, & LeGrande, 1992; Westin, 1992). A variety of laboratory-based investigations have attempted to unpack these effects by contrasting various conditions of computer monitoring, direct supervision, and no supervision (e.g., Aiello & Kolb, 1995; Aiello & Svec, 1993; Galletta & Grant, 1995; Griffith, 1993; Stanton & Barnes-Farrell, 1996). A general finding from these laboratory results is that computer monitoring affects task performance in similar ways to direct, close supervision. Some of these investigations have utilized a social facilitation framework to predict the impact of computer monitoring on task performance. One distinctive characteristic of most of these laboratory studies resulted from their operationalization of performance: Performance was measured as a single quantity accruing from the completion of a whole task. Even in studies such as Schliefer, Galinsky, and Pan (1995) and Nebeker and Tatum (1993) that have examined performance over a period of days, variations in the time course of performance were not examined in detail. These aggregated views of performance have the potential to hide important clues about how monitoring affects performance throughout the process of learning a task and sustaining motivation to complete it. Stanton's (2000) recent review and analysis of the performance monitoring literature indicated that this was a deficit in the literature that needed to be addressed. In this article, we address this concern by presenting a detailed analysis of performance on a speeded clerical task as the task unfolds. Software used in this study provided a detailed, second-by-second record of performance and allowed us to examine the social facilitation effects of monitoring at different points in time during task performance.

2. BRIEF REVIEW OF SOCIAL FACILITATION

Changes in task performance in the presence of an observer have been attributed to a phenomenon called *social facilitation* (Zajonc, 1965). Because of a work supervisor's ability to use electronic means to be remotely "present" when workers perform a task, organizational researchers have found social facilitation to be as relevant for electronic performance monitoring as it is for direct human observation. Social facilitation theory generally predicts that the presence of others facilitates the emission of well-learned responses but impairs acquisition and performance of new responses (Zajonc, 1965). For example, if a worker has rehearsed the task of opening and saving a word-processing document several times, being observed while performing this activity may not impair performance but instead may increase it. However, if an employee who is unfamiliar with computers tries to learn or perform this activity in the presence of others, performance may be impaired.

Various explanations have been proposed to explain social facilitation effects. One explanation is based on drive theory. Zajonc (1965) proposed that "the presence of others increases activity of the adrenal cortex, thus causing a general increase in arousal or drive level" (p. 269). Drive energizes habitual activities and this increases the probability of the strongest (i.e., dominant) response and decreases the probability of the weaker response (Bond & Titus, 1983). For a simple task, the dominant response is often the correct response, and performance is facilitated by it. However, for a new or difficult task, the dominant response may not always be the correct response; hence it may impair performance. Other processes have been proposed to cause the social facilitation effect such as evaluation apprehension (Cottrell, 1972), distraction caused by the presence of others shifting attention away from the task (cf. Baron, 1986), and concern for positive self-representation (Bond, 1982). Psychophysiological research has also established that individuals perceive evaluative social situations as stressful and that, as a stressor, social evaluation causes physiological arousal and effects on task performance consistent with social facilitation (Avero & Calvo, 1999; Burns, 1995; Hartley, 1995; Hartley, Ginsburg, & Heffner, 1999; Revelle & Loftus, 1992). Prior research on computer monitoring has also confirmed that monitored research participants exhibit these physiological arousal effects (Henderson, Mahar, Saliba, Deane, & Napier, 1998).

Researchers have refined initial formulations of social facilitation theory with empirical findings. Contrary to Zajonc's (1965) proposition that mere presence of an audience causes social facilitation, some studies found that effects differ depending on whether the presence of others is direct or indirect (Cottrell, 1972). Criddle (1971) found that participants made more errors when watched by an audience behind a one-way mirror than when they worked alone. Cohen (1980) found similar results and also showed the importance of permanence of the performance record (Cohen, 1979). Evidence for a moderating effect of familiarity with the task has come from research on athletic performance. Bell and Yee's (1989) study of karate performance showed no differences in accuracy or errors among experienced students who performed in the presence of an audience. However, accuracy decreased for inexperienced students. Similar findings appeared in a study of children's performance on dynamic balance. MacCracken and Stadulis (1985) found that in the presence of spectators, children with higher levels of experience showed an increment in performance. Performance decreased for children with lower levels of experience on the task.

In the area of electronic performance, monitoring studies have demonstrated the impact of social facilitation in which the presence of an "electronic" observer was introduced for a brief time (e.g. Aiello & Kolb, 1995; Aiello & Svec, 1993; Griffith, 1993; Stanton & Barnes-Farrell, 1996). The social facilitation perspective is also compatible with conceptual models of computer monitoring that have incorporated physiological arousal as a component process (e.g., Amick & Smith, 1992; Stanton, 2000). However, it is possible that people habituate to the presence of such supervisory monitoring. In early exposure to monitoring, there may be an increase in arousal due to the perceived uncertainty and evaluation apprehension. This arousal could cause an initial surge in performance. As time unfolds, however, there may be a decrease in arousal due to practice on the task and familiarity with the monitoring situation. This idea has served as a rejoinder to critics of electronic performance monitoring; adverse effects monitoring may have on workers would probably wear off over time. Although social facilitation theories do not explicitly describe the effect of time course on performance, researchers who have measured arousal and tested for habituation effects have some evidence for habituation. Beidel, Turner, and Dancu (1985) as well as Eckman and Shean (1997) have found that low-anxiety individuals (measured as a personality variable) exhibited habituation of physiological arousal in a stressful social situation. In contrast, high-anxiety individuals in these studies did not habituate to the social stressor as readily. Theory and research on stress processes also has suggested that arousal has a natural time course even in the continued presence of a stressful stimulus (e.g., Ganster & Schaubroeck, 1991; Lazarus & Launier, 1978). It would thus be reasonable to expect initial variation in task performance due to differences in supervision conditions followed by gradual habituation and less marked differences in performance later in a task.

In summary, social facilitation theories raise five issues to consider when probing the effect of supervisory monitoring on task performance. The difficulty of a task is important because this affects whether successful task performance is the dominant response (Bond & Titus, 1983). The amount of learning involved in mastering a task is important because audience presence appears to inhibit the acquisition of new skills (Bond, Atoum, & VanLeeuwen, 1996). Likewise, the performer's familiarity or experience with the task is another determinant of whether successful task performance is the dominant response (Bell & Yee, 1989). The psychological strength of the presence of the supervisor is important in establishing the intensity of facilitation that the performer feels (Cottrell, 1972; Criddle, 1971). Finally, the time course of performance is important because of the possibility that social facilitation effects would eventually wear off because of habituation to the presence of a supervisor.

In this study, task complexity was held constant, and our task was a relatively simple one that could be learned in a few minutes (see Stanton & Barnes-Farrell, 1996). We measured research participants' computer familiarity and used this as a control variable and a moderating influence on performance. In accord with the research paradigm of prior computer monitoring studies (e.g., Aiello & Svec, 1993; Griffith, 1993), we contrasted three conditions of supervision. A baseline condition had no supervision. A direct human observation condition placed the task performer in a physical presence of an erstwhile supervisor. In the third condition, computer monitoring provided extensive cues that the participants were being remotely supervised through a network connection to a supervisor's computer. In contrast to prior studies of computer monitoring, we collected detailed second-by-second records of performance progress to assess the impact of social facilitation on task performance in detail over a course of time to examine possible habituation effects.

3. HYPOTHESES

Hypothesis 1a: Because little is known about how social facilitation affects task performance over time, this first hypothesis is exploratory and was examined using time series analysis and review of graphical evidence rather than null hypothesis tests. Early in the task, we predicted that the human-supervision and computer-monitored groups would quickly outstrip the performance of the no-supervision group because of the social facilitation induced by supervision. The no-supervision group would show gradual gains in overall productivity, but this increase would not match that of the supervised groups.

Hypothesis 1b: During the later course of the experimental task, the early performance boosts in the supervised groups would level off due to habituation of the social facilitation effect. In other words, although early performance gains would still manifest in overall differences between groups, the supervised groups would cease to gain relative to the no-supervision group later in the task.

Hypothesis 2: During the initial learning period of the task, the positive benefits of high computer familiarity on task performance would be suppressed due to social facilitation effects in the human and computer monitoring conditions, whereas computer familiarity should enhance learning in the no-supervision condition.

Hypothesis 3: Across the whole task period, we predicted a main effect of supervision on performance after controlling for computer familiarity. As discussed, a primary feature of the social facilitation framework is a prediction of increased drive or arousal in the presence of an observer. Prior research suggests that a direct observer should cause higher drive than a remote observer (Cottrell, 1972). Therefore, a human supervisor present in the same room should facilitate performance more strongly than a supervisor who is only present through a computer link, but those under supervision would perform better than those in the no-monitoring condition. Among the monitored groups, human supervision would outperform the computer-monitored group.

4. METHOD

4.1. Sample and Design

Experimental participants (*N* = 115) were recruited from undergraduate psychology classes and given course credit in exchange for participation. The majority of the sample were women (82%). The mean age was 19 years and the mean number of semesters of college completed was three. All participants had prior computer experience. Approximately 80% of the participants reported that they had been required to use computers for course work, and over half of the sample reported prior job experience that required the use of a computer. Participants worked in noninteracting groups of sizes from 10 to 18 participants. Each group was randomly assigned to one of three experimental conditions. Unequal cell sizes resulted from different experimental group sizes (cell totals: *n* = 36 for no supervisor; *n* = 38 for computer monitored; *n* = 41 for direct supervision).

4.2. Materials and Measures

The stimulus for this study was a custom computer program running on a personal computer. Jeffrey Stanton developed this program for the research reported in

Stanton and Barnes-Farrell (1996). A variety of program upgrades were introduced for this research including the ability to measure performance in time increments of 1 sec. The graphical user interface to this program operated within a popular personal computer windowing system and employed both a conventional computer keyboard and a mouse-pointing device. This computer program displayed supplementary experimental instructions, administered all survey items, measured moment-by-moment task performance, and supplemented experimental manipulations. From the participant's point of view the primary function of the program was the presentation of the experimental task. The computer presented 91 records sequentially from a mail-order address database. The participant's task was to cross check the database record against a corresponding record on a paper form and correct any discrepancies in the online version of the record. Completed forms were handwritten and contained extensive distracter information. Only nine of the fields on the form appeared on the computer screen. Most records contained an error in one or two fields, although some records contained as many as five errors. Errors included mistyped, improperly punctuated, and erroneously blank fields. This correction task was chosen over a data entry or typing task to minimize the importance of typing skills. In responses to a manipulation check item, about 76% of the participants reported that the task required a high amount of concentration.

In advance of the correction task, participants completed a demographic survey (gender, age, number of completed semesters) and a timed work-sample test of computer familiarity. The work-sample test comprised a small set of interactions with the computer that exercised the participant's skills at reading instructions from the screen, using the mouse to point at screen elements, and using the keyboard to type words. Performance on this task was measured as the number of seconds between the appearance of the initial instructions and completion of the test. Time taken to complete this task varied from 20 sec to 3 min. In previous research, the timed work-sample test correlated with self-report measures of computer experience and actual performance on a computer task (Stanton & Barnes-Farrell, 1996); therefore, we felt that this was a suitable measure of familiarity or experience with the particular windowing interface we used.

Task performance was recorded in detail during the 35-min work period. The software recorded changes made to the database at every second during the task period. This included the total number of records examined, number of corrections made to each record, and the moment at which the participant progressed to the next record. The total number of records examined and the total number of corrections made provided a measure of productivity. A measure of quality of performance was computed by calculating the ratio of number of corrections made to the number of records examined. Accordingly, a participant attempting to complete many records but not responding to the complete set of errors in the record would get a low score in quality of performance. The records and the errors contained in them were identical across conditions. This provided a suitable method of comparing work efforts for people who worked at different paces and under different conditions. This task did not place extraordinary cognitive demands on the participants. Simple corrections had to be made, and the difficulty of these corrections did not increase as the task progressed. All participants had exactly the same period of time to work. Therefore, the task was considered a speeded clerical task. Note that 35 min is a relatively brief period when compared with a normal work day, but previous laboratory research on computer monitoring has provided worthwhile results and insights with task periods of approximately this length (Aiello & Kolb, 1995; Aiello & Svec, 1993; Griffith, 1993; Kustis & Ekeberg, 1993; Silverman & Smith, 1995; Stanton & Barnes-Farrell, 1996).

4.3. Procedure

The study was conducted with groups of 10 to 18 participants in a computer laboratory. Each workstation was separated from the others by at least 2 ft, and all participants worked independently. Participants began and ended work on the 35-min computer task at the same time. The trials took place during morning, afternoon, and evening hours.

A research assistant seated each participant at a personal computer in the experimental room. The participants were instructed to perform an initial practice task and fill out an on-screen presurvey. The research assistant left the room during this period to give the participants privacy. The computer removed the survey from the screen before the experimenter returned. After completion of the practice task and survey, participants were instructed concerning the main task and the details of manipulation they were about to receive. Standardized, scripted, verbal and written instructions were used.

In the computer-monitoring condition, the research assistant led the participant through an interactive connection sequence in which the network link to the supervisor was established. The participant typed a brief message and the supervisor (as simulated by the computer program) responded with a greeting. Next a one-page version of the experimental instructions appeared on the screen. These instructions reiterated both the task directions and the manipulation. This is the point when the experimental manipulation began. From here the participant worked for 35 min on the task and then approximately 8 min on the final survey (self-paced). The computer provided minimal feedback during the task: A display of number of orders completed and number of minutes remaining in the trial appeared on the upper left of the screen.

4.4. Manipulation of Independent Variables

In the human-supervision condition, two supervisors (graduate students) were present in the room with the participants during the entire 35-min work period. To make the supervision salient, the supervisors circled around the room observing each participant while he or she completed at least one record. During this time, the supervisors took notes on the participants' performance and occasionally counted the number of sheets (paper copy of records) they had completed. Each participant was observed at least five times during the 35-min computer task.

In the computer-monitoring condition, participants were told that their computer was linked to the supervisor's computer located in the same room (the experimenter pointed to the supervisor's computer) and that their supervisor could remotely monitor their performance on the computer task. The participants had no control over when their supervisor observed their performance. The system informed the participant graphically about monitoring using an illustrative icon (an eyeball) and verbally with a written message. The monitoring message appeared in a dialog box that had to be dismissed by the participant before continuing with the task. These reminders occurred at 2-min intervals during the experimental period. The eyeball and the message remained on the screen for 1 min after the participant dismissed the dialog box.

In the third condition, participants worked without any supervision. Participants were given instructions about the computer task by the experimenter and told that their performance was not going to be monitored or assessed in any way. The experimenter was not present in the experimental laboratory during this time.

Participants in all conditions were told that speed and accuracy were both important for successful completion of the task. To enhance motivation to work on the task, participants in the human-supervision and computer-monitoring conditions were told that high performers would be rewarded at the end of the study period and the experimenter pointed toward a reward box. Previous research has quite consistently demonstrated the motivational effects of token food or monetary rewards on the performance of research tasks (Earn, 1982; Groves, Cialdini, & Couper, 1992; Hom, 1987; Julian & Stanton, 1999; Levine, Gorman, & Sherry, 1978; Munro, 1970). Participants were unaware of the contents of the box during the experimental period. Although participants in the human and computer-monitoring conditions were told that their reward would depend on their task performance, all participants received a food reward at the end of the study period after all measures were completed.

5. RESULTS

5.1. Manipulation Checks

To evaluate the efficacy of the experimental manipulation of monitoring conditions, two items were used in the posttask questionnaire. The first item was, "During the task, was your work being monitored by a supervisor?" In the human-supervision and computer-supervision conditions, 100% of the participants responded "Yes" to this item. In the no-supervision condition, 81% responded "No." This difference was statistically significant, $\chi^2(2, N = 115) = 85.1$, $p < .001$, although it indicated that seven people in the no-monitoring condition may have been suspicious that they were monitored. The second item was, "How was the supervisor monitoring your work?" In the human-supervision condition, 100% of the participants responded "visual observation," and in the computer-monitoring condition, 100% responded "computer link." These results suggested that the manipulations of both human supervision and computer supervision were successful.

In the no-monitoring condition, 44% of participants responded to that same question ("How was the supervisor monitoring your work?") with either "visual observation" or "computer link." The only other response option was "other method," however, so this was a leading question in that it provided no appropriate alternative for those who believed that they were not monitored. This phrasing was an oversight by us in the design of the manipulation check survey. To test whether our result really reflected a problem with the no-monitoring manipulation, we conducted further tests to ascertain perceived differences between the no-monitoring condition and the other two conditions. An additional manipulation check item read, "My work on the data correction task was monitored through a network link." In the computer monitoring condition, 89% of the participants responded "Yes." In contrast, for both the human-supervision and no-monitoring conditions, about two thirds of the participants responded that they were "not sure." These differences were statistically significant, $\chi^2(2, N = 115) = 65.4, p < .001$. Additionally, on the questions, "I had to click on 'OK' during the task to remove messages about monitoring," and, "There was a 'Monitoring Status Window' on the screen during the data correction task," about 90% of respondents in all conditions answered these questions correctly. We concluded from these results that almost all respondents in the human-supervision and no-monitoring conditions correctly perceived the cues that we provided as part of the manipulations. In these groups, however, there was some natural and perhaps justified suspicion that the computers (which all respondents knew were networked) were monitoring their performance even though the experimental manipulations (both verbal and written) said that they were not.

5.2. Randomization Results

Prior to assessing our hypotheses, we conducted a routine examination of our variables to ensure that the three experimental groups were equivalent at the beginning of the experiment. There was no significant difference in computer familiarity across the three supervision conditions, $F(2, 109) = 1.09$. There were no significant differences in productivity due to gender either in the total number of records examined, $F(1, 110) = 2.96$, or the total number of corrections, $F(1, 110) = 1.55$. However, a statistically significant difference was obtained for quality of performance (mean number of corrections made per record) due to gender, $F(1, 110) = 4.64, p < .05$. Recall that quality of performance was operationalized as the ratio of corrections completed to records examined. Men showed greater concern for the quality of their work ($M = 1.82$, $SD = 0.28$) compared to women ($M = 1.62$, $SD = 0.47$). Comparing five different types of self-reported prior work experience (factory, restaurant, office, other, none), there were no significant differences in any of the performance measures.

5.3. Descriptive Statistics

The means, standard deviations, and intercorrelations of the computer familiarity measure and the various performance measures appear in Table 1. On average,

Table 1: Mean, Standard Deviations, and Intercorrelation Among the Dependent Measures

	Human Supervision[a]		*Computer Monitoring*[b]		*No Monitoring*[c]		*Overall*[d]						
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*1*	*2*	*3*	*4*	*5*
1. Computer familiarity	48.49	26.55	53.95	29.60	46.39	11.67	49.63	24.16					
2. Records completed	68.93	12.28	66.32	9.59	66.36	12.74	66.89	12.03	–.22				
3. Total corrections	126.88	26.92	122.62	23.17	119.44	23.20	121.73	26.58	–.34**				
4. Quality	1.41	0.61	1.84	0.15	1.81	0.20	1.66	0.44	–.07	–.06*	.18		
5. *M* elapsed time	31.23	5.29	32.07	4.67	32.48	6.19	32.25	6.59	.20*	–.95**	–.81**	.02**	
6. SD of elapsed time	9.90	2.68	10.27	1.96	11.30	2.68	10.91	4.53	.25**	–.57**	–.66**	–.14	.70**

Note. Elapsed time refers to the amount of time (in seconds) taken to examine each record.
[a]$n = 40$. [b]$n = 37$. [c]$n = 36$. [d]$N = 1130$.
*$p < .05$, ** $p < .01$.

participants examined 67 records and corrected about 122 errors. The mean index of quality of performance was 1.66 corrections per record with a minimum value of .52 and a maximum value of 2.12. The mean time taken to complete a record was 32.25 sec. The average standard deviation of elapsed time was 10.9 sec (calculated by examining within-subjects variability). Computer familiarity was modestly correlated in the expected direction with all of the performance measures except quality. A strong positive correlation was detected between the total number of records examined and total number of corrections made (r = .82). A near perfect negative correlation was obtained between total number of records examined and the mean elapsed time per record (r = –.95). A strong negative correlation was obtained between mean elapsed time per record and total number of corrections made (r = –.81). These results simply underscore the commonsense idea that those who worked at a faster pace completed more records and corrections. A strong negative correlation was obtained between standard deviation of elapsed time and total number of records examined (r = –.57). Standard deviation of elapsed time was a measure of variability in the time taken to complete records. A negative correlation with total records indicates that those who examined more records spent a similar amount of time (had little variability) in investigating and completing corrections within each record. A negative correlation was also obtained between total number of corrections and standard deviation of elapsed time (r = –.66). These results indicate that those who made fewer corrections also varied more in the amount of time they spent investigating each record. No significant correlation was obtained between quality of performance and any of the other dependent measures.

5.4. Hypothesis 1

Hypotheses 1a and 1b predicted differences between the groups in the pattern of performance over time. To evaluate these hypotheses, we made a descriptive examination of performance by graphing individual performance at 5-sec intervals through the entire 35 min of the task. These graphs contrast the profiles of performance for all participants in the human-supervision (Figure 1) and computer-monitoring (Figure 2) groups. The no-monitoring group was similar to the computer-monitoring group in its visual configuration and therefore has been omitted. Several features of these graphs stand out. First, as expected, productivity increased over time as each individual made more and more corrections. This was reflected in the upward trend of each component line. Note that the small, discontinuous steps visible in each line indicate the time taken to complete corrections within each particular record. Thus, the density of these bumps can be read as the speed of examination of records per unit time, whereas the size of the rise for each bump indicates the number of corrections made.

Next, note that there are substantial individual differences in performance within each group. The fan shape of each graph highlights the fact that some people worked quickly, some worked moderately, some worked slowly, and so forth. We can attribute this variation to both skill and motivational differences (neither of which was controlled for in these graphs). Also of importance is the fact that

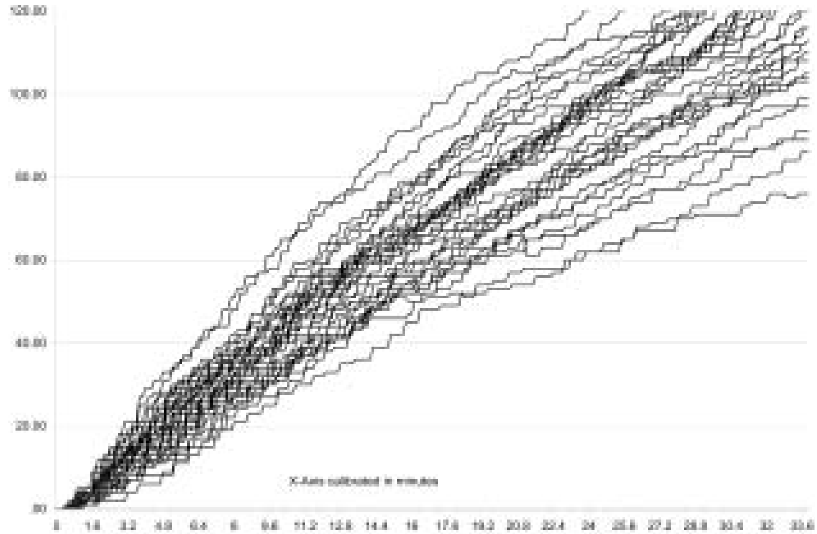

FIGURE 1 Time (x-axis) versus total corrections (y-axis) for the human-supervision group.

within-group performance became increasingly heterogeneous over time. This result suggests that regardless of the type of supervision, individual differences in motivation and/or computer familiarity substantially influenced performance over time.

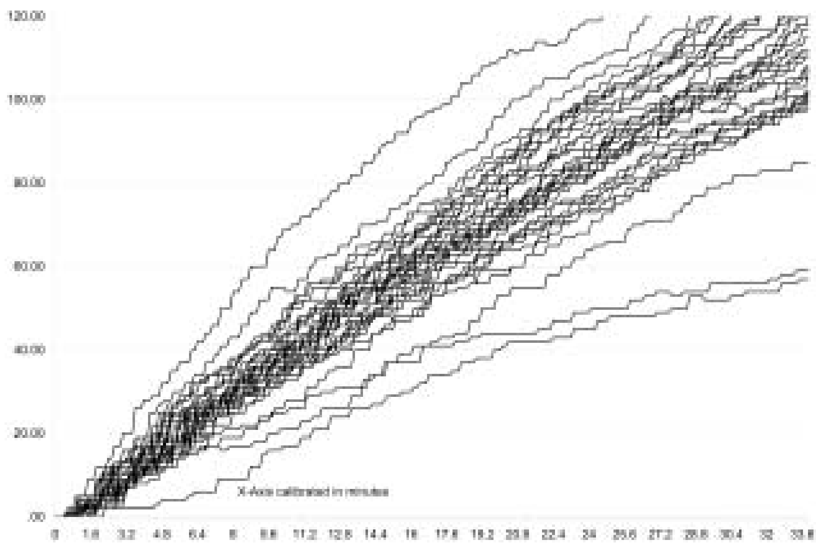

FIGURE 2 Time (x-axis) versus total corrections (y-axis) for the computer-supervision group.

Finally, the somewhat wider spread of the fan in Figure 2 suggests that individuals were less constrained to work at a particular pace in the computer-monitoring condition than in the human-supervision condition. This contradicted the prediction of the hypothesis: Computer monitoring seems to have been more similar to no monitoring than to human supervision in this respect. As evident from the width of the fan at later points in time, human supervision appears to have exerted the most controlling effect over individuals' rate of corrections.

Further distinctions between the conditions based on the graphs of the individual profiles were difficult to distinguish. Thus, we continued the analysis by generating group summary statistics for each 5-sec interval of task performance. Figure 3 depicts the profiles of group mean performance. To facilitate comparisons between the groups, each set of data points has been centered by subtracting out the grand mean for that time period. In Figure 3, performance in the human-supervision group immediately diverged from the other two groups close to the beginning of the task. Performance in this group continued to rise relative to the two other groups up until about the 16th min of the task. At about 19 or 20 min, performance differences ceased their divergence until the last few minutes of the task, at which point the human-supervision group showed one additional rise relative to the other two groups. Using 2 standard errors (*SE*s) as a rule of thumb for statistical significance, the human-supervision group mean became significantly higher than the other two groups between 6 and 8 min. We estimated a *SE* of approximately one correction based on pooled within-group variance estimates from within the three groups. At no time did the difference between the computer-supervision and the no-supervision group means become large enough to establish a nonrandom difference between these groups. The profile is consistent with Hypotheses 1a and 1b,

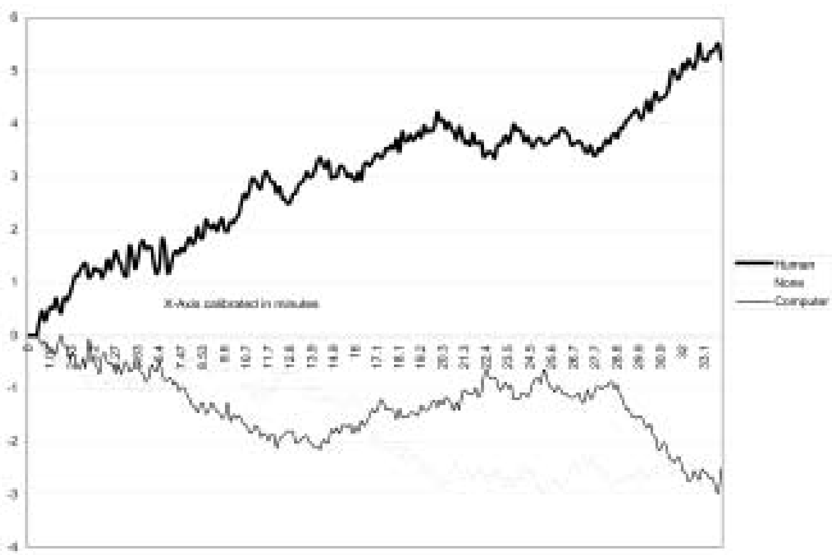

FIGURE 3 Centered group performance means: Differences in number of corrections per person.

except insofar as the computer-monitoring group clustered with the no-supervision group rather than the human-supervision group as predicted.

As a more formal method of modeling the group summary data, we analyzed each group as an autoregressive, integrated, moving average (ARIMA) process (Box & Jenkins, 1976). ARIMA provides a strategy for analyzing and describing the systematic and random processes underlying a sequence of time series data. In particular, ARIMA provides information about the sources and amounts of serial dependencies in a set of time series data. ARIMA processes are modeled by fitting three parameters known as p, d, and q, and the result is described as an ARIMA (p,d,q) model. If a time series contains an autoregressive component, p is an integer larger than zero. If a time series is nonstationary, for example, it contains a growth trend, d is an integer larger than zero. Finally, if a time series process contains a moving average, q is an integer larger than zero. Ascertaining the values of p, d, and q is an iterative process of examining diagnostics and model fit for alternative models. We followed the outline of analytical steps described by McCleary and Hay (1980).

As a first step, we examined autocorrelation diagnostics to ascertain the trend in each time series. As expected, each of the three conditions exhibited gradual growth over time as the participants in each group completed more and more corrections. Thus, for each of the time series, we removed this growth trend by differencing ($d = 1$). After examining the autocorrelation diagnostics for the $d = 1$ series, we ascertained that there was another underlying growth trend possibly due to participants' increasing facility with the task as the task period proceeded. We removed this trend by second order differencing ($d = 2$). This double-differenced time series was the basis of the subsequent model fitting. Although the growth trends were important indications that each group increased its overall productivity over time, ARIMA modeling requires removal of these trends prior to analysis of autoregressive and moving average components.

In the next step, we compared models with differing values of p and q. Model fit is reflected in several diagnostics including chi-square tests of the size of residuals and t tests of model coefficients. Time-lagged residuals with nonsignificant chi-square tests are desirable because they suggest that the systematic processes in the time series have been appropriately modeled. In addition, significant coefficients for autoregressive and moving average components indicate that the configuration of parameters accurately modeled the underlying time series. Results for the human-supervision condition indicated that a $p = 0$ (no autoregression) and $q = 2$ (second order moving average) model fit the data best. Results for both the computer-supervision and no-supervision conditions indicated that a $p = 0$ (no autoregression) and $q = 4$ (fourth order moving average) model fit those conditions best.

Moving average models indicate that, for a given point in time, the data for the q prior points in time influenced the value of current observation. Recalling that the time interval in this analysis was 5 sec, variations in productivity at the present moment were a function of the previous 10 sec of activity in the human-supervision condition and the previous 20 sec of activity in the computer and no-supervision conditions. These brief time periods are strikingly similar in scale to the average time participants spent examining each individual record (overall $M = 32.25$ sec). Together, the models from the three conditions indicated that performance on the current record was not a function of performance on previous records but instead a function of task demands of the current record. It is important that performance in the human-monitoring condition seems to have been influenced to a lesser degree than the other conditions by the varying contents of individual records.

5.5. Hypothesis 2

To test Hypothesis 2, we conducted a mixed between-subject and within-subjects analysis of variance with four time periods as a within-subjects factor, monitoring condition as a between-subject factor, and computer familiarity as a covariate. The dependent variable was an aggregate measure of corrections per minute captured at the beginning of the trial and at 4-min intervals thereafter (thus ending at 12 min). In support of the hypothesis, a significant interaction appeared between supervision condition and computer familiarity, $F(2, 106) = 3.45$, $p < .05$. A main effect appeared for supervision condition, $F(2, 106) = 3.78$, $p < .05$, and for computer familiarity, $F(1, 106) = 11.46$, $p = .001$. There was also a within-subjects effect for time, $F(3, 318) = 2.77$, $p < .05$. To simplify interpretation of the results, we trichotomized the computer familiarity variable and obtained plots of the means by monitoring condition and computer familiarity. Plots for low and moderate computer familiarity were similar; therefore, we contrasted only the high and low familiarity plots in Figure 4. One noticeable characteristic of the high familiarity plot is the reversal in the ordering of the means between Time 2 (4 min) and Time 3 (8 min). This pattern

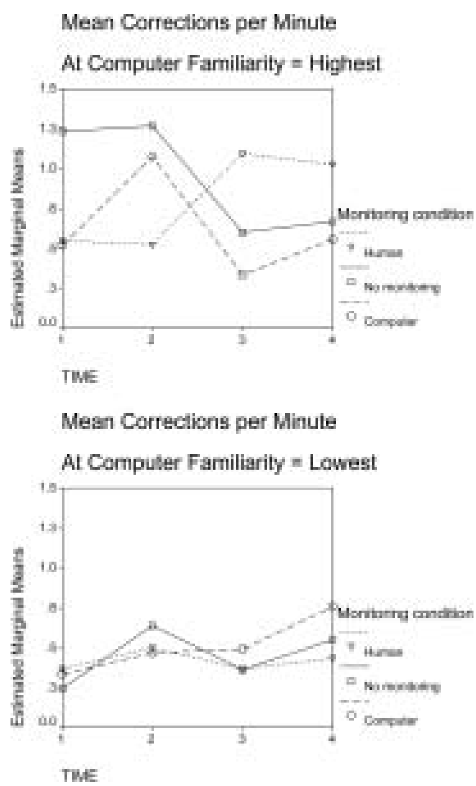

FIGURE 4 Means for corrections per minute by supervision group and computer familiarity at four different time points 4 min apart.

suggested that monitoring may be debilitating when first learning the task, but after a few minutes this effect wears off. After 8 to 12 min of working on this task, high-familiarity workers in the human-monitoring group worked fastest. These findings only partially support Hypothesis 2 because computer monitoring seemed more similar to the no-supervision condition than to the human-supervision condition. Note also that among the low computer familiarity workers, there seemed to be only minimal differences between monitoring conditions.

5.6. Hypothesis 3

Hypothesis 3 predicted a main effect for monitoring condition and was evaluated using a multivariate analysis of covariance with computer familiarity and gender as covariates. The Wilks's Lambda for gender (.92) was non-significant, but the Wilk's lambda for computer familiarity (.85) was significant, $F(5, 106) = 3.73$, $p < .01$, with modest univariate effects on all of the performance variables except quality. Supervision condition was a significant determinant of performance with a Wilks's lambda of .66, $F(10, 212) = 4.95$, $p < .001$. Univariate analysis of variance testing each of the performance variables revealed no significant differences in total number of records examined, elapsed time per record, or total number of corrections among the supervision groups. However, significant differences were found in quality of performance, $F(2, 109) = 16.0$, $p < .001$, and standard deviation of elapsed time, $F(2, 109) = 3.15$, $p < .05$. These results suggest that the groups differed in the quality of performance and the consistency of time taken to investigate and correct each record.

Pairwise comparison of the adjusted means with Bonferonni correction for multiple comparisons suggested that the human-supervision group significantly differed from the computer-monitoring and no-supervision groups with respect to quality of performance. The mean of the human supervision group ($M = 1.41$, $SE = .06$) was lower compared to the mean of the computer-monitoring group ($M = 1.84$, $SE = .06$) and the no-supervision group ($M = 1.81$, $SE = .06$). There was no significant difference between the computer-monitoring group and the no-supervision group. Similar results were obtained on the measure of the standard deviation of elapsed time per record. The mean of the human-supervision group ($M = 9.90$, $SE = .38$) was lower than the no-monitoring group ($M = 11.3$, $SE = .41$). Note that the standard deviation values were calibrated in seconds. These findings contradict Hypothesis 3. As in the results for Hypotheses 1 and 2, the computer-monitoring group was more similar to the no-supervision group than to the human-supervised group. Furthermore, based on an expectation of higher social facilitation in the human-supervision condition, we expected overall performance to be higher in this condition. In contrast, the results indicate that the computer-monitoring and no-monitoring groups obtained higher performance quality than the human supervision group.

6. DISCUSSION

The purpose of this study was to investigate the differential impact of supervision type on task performance and conduct a detailed analysis of task performance as it unfolded over time. For Hypothesis 1, we conducted a time series analysis of performance of each of the supervision groups and a qualitative review of the performance graphs. These detailed performance graphs showed clear differences between the groups, with the human-supervision group on a consistently higher "trajectory" than either the computer-monitored or no-supervision groups. The fan-shaped plots in Figures 1 and 2 also suggested that the human supervision group was "tighter" in the sense that there appeared to be less intragroup variation in performance. These data results suggest that participants in the human supervision group were motivated to work faster, but the ARIMA results suggest that they paid less attention to the variations in the number of errors per record. Detrended productivity for the current moment was influenced by the last 10 sec of activity in the human-supervision group but by the last 20 sec in the computer and no-supervision groups. The participants in the computer and no-supervision groups seemed to have spent roughly twice as much of their per record time scanning each record and deciding what fields needed repair within each record.

In Hypothesis 2, we proposed an interaction effect between monitoring condition and skill during the early minutes of the task. Statistical evidence and a plot of means indicated that participants in the computer and no-supervision groups had modest or low levels of social facilitation in comparison to the human-supervision group during the short period required to learn the task. Thus, in these supervision conditions, the computer skill of each participant influenced early task performance. In contrast, participants in the human-supervision group had higher social facilitation effects such that computer skill was not as beneficial in early performance. Of importance, the interaction effect manifested in the first few minutes of performance after which the human-supervision group began to outperform the other groups. Habituation may have occurred such that skill reasserted itself as a uniform determinant of performance regardless of the supervision condition. This finding also underscores the relative simplicity of our experimental task. After a few minutes of learning time, adequate performance on the task was probably the dominant response regardless of computer familiarity.

Results for Hypothesis 3 contradicted our predictions. There were no significant differences in performance among the three groups when measured in terms of overall productivity (total number of records examined or total number of corrections made). This absence of difference does not accord with results obtained in previous studies contrasting performance of monitored groups with nonmonitored groups on a complex task (e.g., Aiello & Kolb, 1995). The results do agree, however, with those of Griffith (1993) who also used a relatively simple clerical task similar to ours.

Unlike previous studies, we also had measures of performance quality, and our results for both corrections per record and variability in record examination time did reflect significant differences due to supervision condition. Specifically, the computer and no-supervision groups made more corrections per record and had higher variability in the time taken to complete each record. This evidence suggests an important distinction between the groups: Participants in the human-supervision group attained their productivity by working quickly on a larger number of records, whereas participants in the computer and no-supervision groups visited fewer records but corrected more errors in each. We conclude that participants in the human-supervision group were less sensitive to varying task demands (i.e., differences in the number of errors per record) than participants in the other two groups. This evidence meshed perfectly with the time series modeling conducted for Hypothesis 1. Both analyses suggest that higher social facilitation may increase the speed of performance at the cost of diminished sensitivity to varying task demands.

The question arises of why the summary results documented for Hypothesis 3 contradicted the group performance profile in Figure 3. First, the summary performance measures collapsed across periods when there were minimal differences between the groups as well as other times when the groups were more substantially different. Although differences between the groups observed in Figure 3 may have occurred by chance, the consistent superiority of the human-supervision group discounted this possibility. Second, the fan-shaped plots in Figures 1 and 2 both indicated considerable within-group performance variability. Significance tests conducted for Hypothesis 3 were weakened by this within-group variability. Moreover, note that within-group variability grew substantially over time. This finding is of both statistical and practical importance: first because many conventional statistics assume homoscedasticity, which was clearly violated here, and second because the influence of individual differences on group performance obviously increases in importance over time. For a simple, repetitive task such as ours, experience/ability on the computer interface and motivation apparently count at least as much as if not more than the type of supervision employed.

Together the analyses for Hypotheses 1 through 3 shed light on anecdotal reports of workers' experiences with close monitoring. Findings by Brewer (1995) and Brewer and Ridgway (1998) have suggested that close monitoring of task performance focuses effort on the quantity of performance to the detriment of the quality of performance. Evidence from this study indicates that this effect may manifest because workers become less sensitive to varying task demands as the social facilitation effect of close supervision increases.

In prior research on electronic monitoring (e.g., Aiello & Kolb, 1995; Aiello & Svec, 1993) the electronic presence of a supervisor has sufficed to create close supervision conditions. In contrast, analyses of our study suggest that computer monitoring grouped more closely with no monitoring. Three issues may have combined to create this unexpected result. First of all, our manipulation checks showed that individuals in the no-monitoring group were suspicious that they were being monitored through the network to which their computers were attached. Although this may have reflected a failure on our part to properly control impressions in the experimental setting, we believe that participants' beliefs about computer monitoring and surveillance have been affected by publicity about computer privacy and related issues (e.g., Greene, 1998; Hatch & Hall, 1997). Anecdotally, volunteer research participants also seemed to expect deception from experimenters. Heightened suspicion of surreptitious monitoring would have tended to increase participants' level of social facilitation and made them more like a monitored group. Secondly, the computer monitoring manipulation used in this study may not have been sufficiently strong enough to evoke as much social facilitation as in previous studies. Although similar manipulations were used effectively in Stanton and Barnes-Farrell (1996) and Griffith (1993), the salience of pop-up dialog boxes and graphical status icons may have worn off among participants who are comfortable with the extensive graphics, animations, and sounds common to current computer software (e.g., Web browsers). Third, participants in this study worked in groups similar to Aiello & Kolb's (1995) group monitoring condition such that they may have felt that the computer monitoring was "diffused" over a large number of people. In any event, we do not interpret these effects as a failure of the experiment but instead as a demonstration that any adverse or beneficial effects of computer monitoring are highly dependent on the configuration of the monitoring system as well as the social environment of the monitored employees' jobs. Evidence from our study emphatically does not indicate that computer monitoring is the same as no monitoring at all.

As Attewell (1987) suggested, however, conditions created by computer monitoring do differ somewhat from conditions of extremely close traditional supervision (i.e., with the physical presence of a supervisor). The results from our study suggest that the physical presence of a human supervisor throughout the course of a task can cause higher social facilitation effects than the intermittent presence of an electronic supervisor. Notably, however, the results of this study also provide some evidence that individuals can habituate even to the arousal caused by the physical presence of a human supervisor.

7. LIMITATIONS OF THE STUDY AND FUTURE RESEARCH DIRECTIONS

The most substantial limitation of this study was restricted generalizability to organizational settings. Results obtained from inexperienced college workers in a contrived setting may not transfer easily to an office setting. However, studies such as these help understand complex phenomena that may be investigated further in a more realistic setting. We provided a more detailed instrumentation of task performance than has been accomplished in any other study of the effects of monitoring. Our results showed evidence for habituation of the social facilitation effect, even over the brief course of our experimental task. Our laboratory conditions also offered control over extraneous influences (e.g., differences in computer equipment, work assignments, rewards and incentives) that can undermine the internal validity of field research. Moreover, there may be ethical concerns in administering differential interventions to different groups within the same organization, especially when the consequences of intervention are unknown. There are certainly ethical concerns with the continuous performance monitoring of regular employees to the extensive degree that we did with these voluntary study participants.

Results of our study can generalize to situations in which relatively unskilled workers perform fairly repetitive clerical tasks. Note that the use of electronic performance monitoring is common in just such situations often because managers see it as a necessity for maintaining productivity. Our results suggest that monitoring systems or techniques that increase social facilitation or motivation to work quickly may do so at the expense of sensitivity to varying task demands. We also found, however, that workers seemed to fairly quickly habituate to some of the effects of close monitoring. Future research should attempt to ascertain whether habituation occurs in situations in which workers have a greater stake in the outcome of their performance. Because workers in this study were not earning a living from their work, they could "afford" to ignore the motivational effects of supervision after the novelty had worn off.

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