Ergonomic Management Software and Work Performance:

An Evaluative Study.

Report by

Professor Alan Hedge, PhD, AFBPsS, MErgS
Department of Design and Environmental Analysis
Cornell University
Ithaca, NY 14853-4401

and

Scott J. Evans
Manager Facilities and ESH
Lockheed Martin Enterprise Information Systems
Orlando, FL

February, 2001

Cornell University Human Factors Laboratory Technical Report /RP2501

CONTENTS

ABSTRACT

This study tested the effects of using ergonomic work pacing software (EMS - Ergonomic Management System) on typing (accuracy and amount of keying), and mouse work (frequency and duration of mouse use). The performance of fifty-six highly skilled computer software programmers, technical development staff and executives at Lockheed Martin were passively monitored using the EMS system for four weeks, to establish a baseline. The EMS system then was fully activated for all personnel, and work performance monitored for an additional four-weeks period. Complete keying error data were recorded for one-week during the baseline and test periods respectively. Full activation allowed the EMS software to coach users to take periodic microbreaks throughout the day depending on their work rate (if workers are pacing themselves appropriately then the EMS will not need to provide rest-break alerts).

There was a statistically significant 59% improvement in work accuracy following implementation of the EMS system. There was no difference in total keystrokes or in mouse use between the baseline and test conditions. Results confirm previous research that showed that alerting users to take more short rest and break periods did not impair their overall keystroke and mouse use, but did improve their work accuracy. Economic analysis shows that in this situation the performance benefits alone that accrued from using ergonomic work pacing software show a return on investment of less than one-week. It is concluded that appropriate work pacing plays an important role in facilitating office work performance.

DISCLOSURE

The author is a Professor of Ergonomics at Cornell University. The author has made a best effort to analyze and present all results contained in this report in an impartial manner, as is customary academic practice. The author chairs an Ergonomics Advisory Board of leading experts that provides strategic advice to Magnitude Information Systems Corporation and, at the time of writing this report, also owns stock in the company responsible for the development and commercial production of the ErgoManager™ (EM) software.

The co-author is employed at Lockheed Martin and continues evaluating the use of the EM software as part of an overall ergonomics management program for a widely distributed IT workforce. He was responsible for undertaking the pilot program that tested the micro-breaking feature of the EM software to ensure that this was not disruptive and did not adversely affect employees' satisfaction, and that evaluated the operational requirements of networks and desktops within the Lockheed Martin internal IT organization.

1.0 INTRODUCTION

Physical work comprises sequences of muscle contractions interspersed with periods of rest. Our physiology dictates that this is so. The muscles responsible for physical work require a good circulatory supply to provide oxygen and nutrients for energy, and a means of removing waste metabolites, such as lactic acid. A muscle's ability to work is compromised if there are insufficient rest periods interspersed between muscle contractions, because the circulatory supply cannot keep pace with the metabolic demand. Examples of this process are widespread. A person running will eventually have to stop to 'take a breather', i.e. a period of recovery, or a person performing arm curls with a weighted dumbbell can only execute a given number of repetitions before the arm muscles fatigue sufficiently that the weight can no longer be lifted. After a period of rest, muscle function recovers and the repetitive task can be performed again. The ability of muscles to repeatedly contract is greater whenever dynamic movement occurs, because the change in length of the muscles helps to pump blood through the muscles. The ability is substantially less for static work, where the muscle has to sustain a state of contraction without the aid of this process.

Typing and mouse use is physical work requiring muscle contraction. Although the instantaneous force required to perform such work is small, the high repetition rates and poor work postures associated with this kind of work result in muscle fatigue and increase the risks of developing a cumulative trauma injury, such as carpal tunnel syndrome. Interspersing bouts of typing at a keyboard and mouse use with frequent, brief rest periods, termed microbreaks, can reduce muscle fatigue, decrease the risk of injury and improve work performance (Henning *et al*., 1996).

Microbreaks are muscle specific, i.e. they can be targeted at specific muscle groups rather than a whole limb or even the whole body. During a microbreak, all work activity does not have to stop, providing that work activities use muscles different to those being rested. For example, making a phone call is work but at the same time can provide a rest for the muscles involved in typing and mouse use since it requires different muscle groups. Alternatively, microbreaks can be filled with brief stretching exercises of educational information.

Developing an optimum schedule for work and rest periods for a person is fundamental to designing jobs for optimum productivity, in terms of work accuracy and performance. Studies that have investigated the effects of frequent microbreaks have found beneficial results. Laboratory studies have shown that subjects' work performance increases 12.8% when they were allowed frequent microbreaks (Janaro and Bechtold, 1985). Risks of musculoskeletal discomfort and injury and error rates during intensive computer work are significantly decreased when laboratory subjects are allowed discretionary microbreaks that totaled 30 seconds every 10 minutes (Henning *et al*., 1996).

Similar beneficial effects are reported in field studies of microbreaks. There was a 5% increase in typing performance when subjects experienced frequent microbreaks and almost a 15% increase in typing performance when these microbreaks were combined with stretching exercises (Henning *et al*., 1997). Hedge (1999) showed a reduction in keyboarding errors when computer workers were allowed discretionary microbreaks. Galinski *et al.* (2000) compared the effects of a conventional schedule (15-min break during the first half of the work shift and a 15-min break during the second half of the shift) with a supplementary schedule contained the same two 15-min breaks, and a 5-min break during each hour which otherwise did not contain a break, for a total of 20 extra minutes of break time. Results showed beneficial effects on musculoskeletal discomfort without reductions in data-entry performance for those experiencing supplementary rest breaks.

Results from these laboratory and field research studies show that the provision of microbreaks interspersed at appropriate intervals to minimize musculoskeletal fatigue, can enhance computer worker performance, and reduce discomfort. Also, performing brief, mild stretching exercises during microbreaks can minimize the risks of musculoskeletal.

Previous research on discretionary microbreaks (Hedge, 1999) has evaluated a commercially available software program, the ErgoManager™ (EM), that monitors the amount of keyboard and mouse activity and provides users with information on appropriate discretionary rest breaks based on these workload measures. The EM also provides users with information on appropriate stretching exercises and other ergonomic considerations, such as appropriate postures and appropriate workstation adjustments, during these microbreaks. The EM also gathers data on work performance that can be used to evaluate the impact of discretionary rest breaks, or other workplace interventions. The present study is a field experimental test of the effects of using the EM on computer work productivity for employees working in an IT group within a large aerospace and defense company.

2.0 METHODS

2.1 Test Site

The Orlando, Florida, Enterprise Information Systems (EIS) offices, a separate business unit of a major aerospace corporation and defense contractor (Lockheed Martin) was chosen as the test site for this study. Computer use is an integral part of work for employees at the test facility. This test site included groups of employees that perform software development, security administration, customer help desk operations, administration and executive functions that support other Lockheed Martin business units and other clients. The site did not have a history of ergonomic problems, and employees were not reporting widespread musculoskeletal problems prior to the study. However, the management at this facility is proactive in ergonomics and in promoting employee well being.

2.2 Participants

Fifty-six employees from some 200 people were chosen to participate in this study. These employees were chosen to represent a variety of jobs, including highly skilled computer software programmers, technical development staff and executives. Some 54% (30) of participants were women and 46% (26) were men.

2.3 Software

The test software (ErgoManager™ - EM) was installed on the corporate network. The software was used to monitor the computer work performance of all participants. The software independently tracks the patterns of keyboard and mouse activity. It coaches users into more healthful work patterns by providing a cumulative sequence of alerts indicating the need for a microbreak based upon the intensity and duration of keyboard and mouse activity. In addition, the software provides periodic 'stretch-break' alerts based on overall computer usage patterns."

2.4 Procedure

The computer use performance of all participants was monitored for a four-week (20 days) baseline period without activating the EM icons and rest break capabilities. Following this, the full capabilities of the EM were activated for all participants and their work performance was monitored for a further 4 weeks (20 days) period. Participants received brief individual instruction at their workstations about the nature and function of the EM, including a brief review of the software-based ergonomic tutorial information that includes animated stretching and relaxation exercises. Initial default values were set for the computer-use time period required to activate rest breaks and they remained unchanged for the duration of the study. The basic microbreak alert settings are shown in Table 1:

TABLE 1

Default settings for the keyboard and mouse alerts at each of the 5 alert levels monitored by the EM software

Alert Level	Keyboard Work Minutes to alert:	Mouse Work Minutes to:
1	25	25
2	10	10
3	8	8
4	6	6
5	5	5

The software ‘StretchTimer’ prompted users to take a microbreak with a Stretch Alert after 60 work minutes (i.e. 60 minutes of consecutive work without a microbreak).

2.5 Research Design

The research was designed as a pre-treatment/post-treatment repeated measures study, where all participants served as their own controls.

2.6 Data Analysis

Keystroke rates, mouse seconds of activity and errors, counted as the use of 'backspace' and 'delete' keys, were recorded for all participants. To preserve complete confidentiality, employee raw data files were processed by the co-author within the company and anonymous daily aggregate performance data were summarized and provided to the author for subsequent statistical analysis.

All performance data were analyzed using appropriate repeated-measures analysis-of-variance models and paired-t-tests to compare the effects of the EM software on performance (pre- and post-installation Section 2.4). Correlation analyses were conducted to test for possible speed-accuracy trade-off effects in employee performance.

3.0 RESULTS

3.1 Survey Profile

The data gathered in the study covers 8,960 person/hours of computer usage, equivalent to 2,240 person/days of computer use and almost 13.5 million keystrokes. Participants used a computer full-time for 8 hours per day throughout the study.

3.2 Alerts

The average daily keystroke alerts per person for the 20 test days are shown in Figure 1, and the mean daily mouse and keyboard alerts at each of the 5 alert levels is shown in Table 2.

FIGURE 1

Mean daily alerts per person for the 20 days test period.

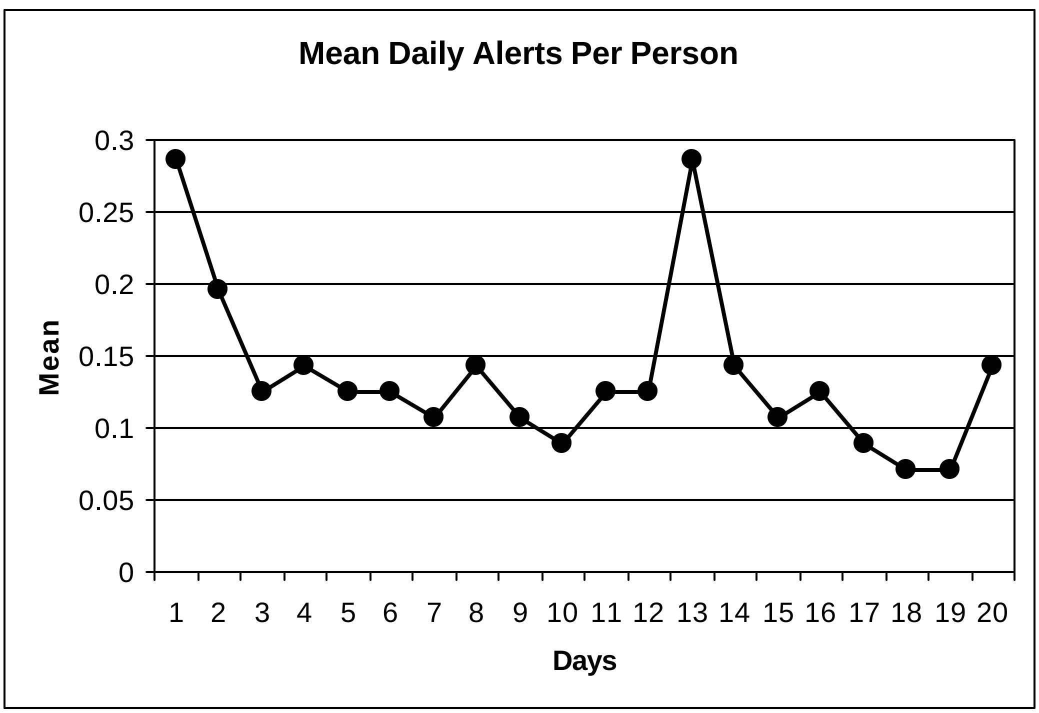


TABLE 2

Mean daily mouse and keyboard alerts at each of the 5 alert levels monitored by the EM software

Days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Kbd + Mouse	0.79	0.46	0.30	0.64	0.36	0.38	0.21	0.68	0.30	0.27	0.34	0.66	0.50	0.23	0.34	0.20	0.18	0.18	0.14	0.27
Kbd level 1	0.07	0.07	0.05	0.29	0.05	0.13	0.09	0.07	0.05	0.05	0.07	0.09	0.09	0.07	0.04	0.02	0.05	0.05	0.02	0.05
Kbd level 2	0.02	0.02	0.00	0.07	0.00	0.04	0.02	0.04	0.02	0.02	0.02	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Kbd level 3	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.02	0.04	0.04	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kbd level 4	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.02	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kbd level 5	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.21	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kbd Total	0.09	0.09	0.05	0.45	0.05	0.21	0.11	0.36	0.16	0.11	0.11	0.27	0.09	0.07	0.04	0.02	0.05	0.05	0.02	0.07
Mouse	0.29	0.20	0.13	0.14	0.13	0.13	0.11	0.14	0.11	0.09	0.13	0.13	0.29	0.14	0.11	0.13	0.09	0.07	0.07	0.14

These data show a decrease in alert levels towards the end of the 20 days time period, which suggest that a learning effect concerning appropriate work pacing may be occurring. The activation of an alert means that the person has attained a certain level of keying or mousing activity without taking a microbreak, so an ideal work pattern would have no alerts. In addition to this feedback, for every accumulated 60 minutes of activity (keyboard or mouse or both) users are prompted to take a 'Stretch-Timer' break, unless there has been 10 minutes of complete inactivity, which resets this alert message. Although not counted separately, examination of the performance logs shows that users received between 3 to 4 Stretch-Timer break messages per day.

When workers are perfectly pacing themselves, by taking appropriate breaks, the EM does not need to provide them with alert messages.

3.3 Error rates

Error data were compared for one-week of work prior to activation of the full EM and one-week after this had been activated. The percentage calculated error rates were computed as follows:

$$\% \text{ errors} = \# \text{ errors}/((\# \text{ keystrokes} + \# \text{errors})*100)$$

The overall mean error rates were as follows:

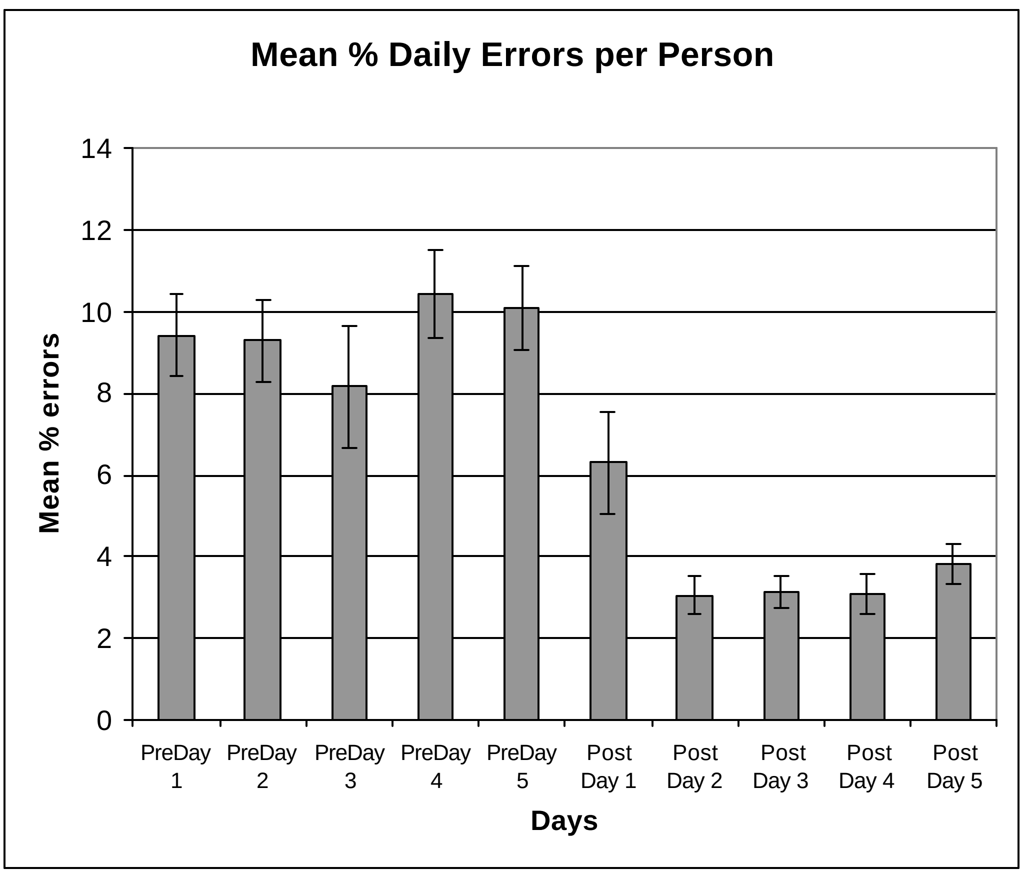
Pre-EM mean error rate = 9.48%

Post-EM mean error rate = 3.88%

The daily error percentages for each worker data were analyzed using a repeated measures analysis of variance that was performed to test two factors: pre-post EM and Days (1-5). There was a highly statistically significant effect for EM ($F_{1,220}$ = 59.887, p=0.0001), and after activation of the microbreaking feature of the EM the keyboard errors were reduced by 59.07%. There was no significant effect of days, nor was the interaction between EMS and days significant. This effect of the EM on mean percentage daily errors is shown in Figure 2.

FIGURE 2

Main effect of EM activation on mean Daily Percentage Errors per Person.



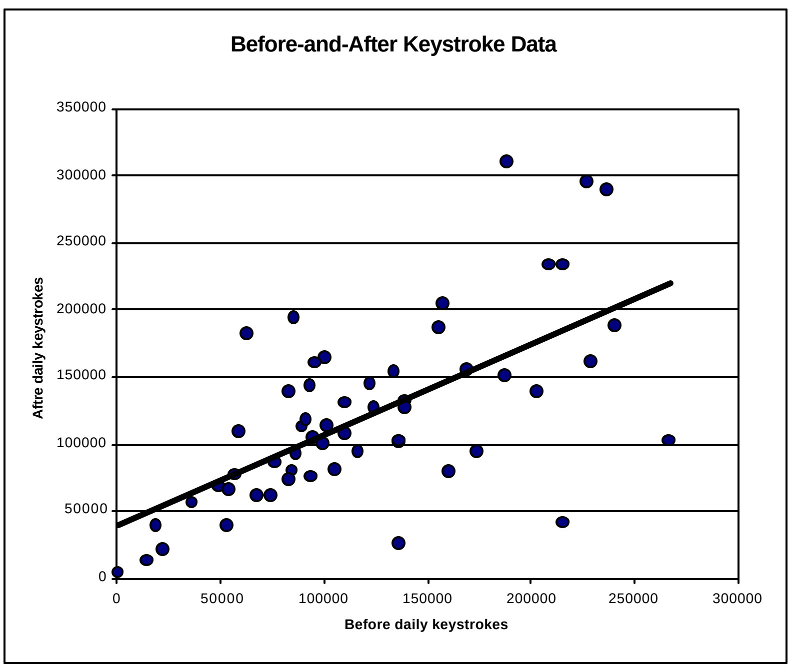
3.4 Keystroke Activity

There was no statistically significant main or interaction effect of EM activation on daily keystroke rates (means: pre-EM = 5,547.9; post-EM = 6,177.3, an 11.3% increase in keystrokes). High variability between days and among workers in the keystrokes data precluded statistical significance. Close inspection of the post EM data showed that the apparent increase in mean daily keystrokes actually was inflated by one day's data.

To test the consistency of employee keyboard work performance for the two time periods of the study, average daily keystroke activity data for the before-and-after periods were correlated. There was a statistically significant correlation between keystroke activity during the before-and-after periods, when the microbreaking feature of the EM was activated (Pearson's correlation = 0.538, $p<0.001$ - 2-tailed). This positive correlation shows that similar keystroke activity occurred in the before-and-after 20 days periods (see Figure 3).

FIGURE 3

Scatterplot of Before-and-After Daily Keystrokes per Person.



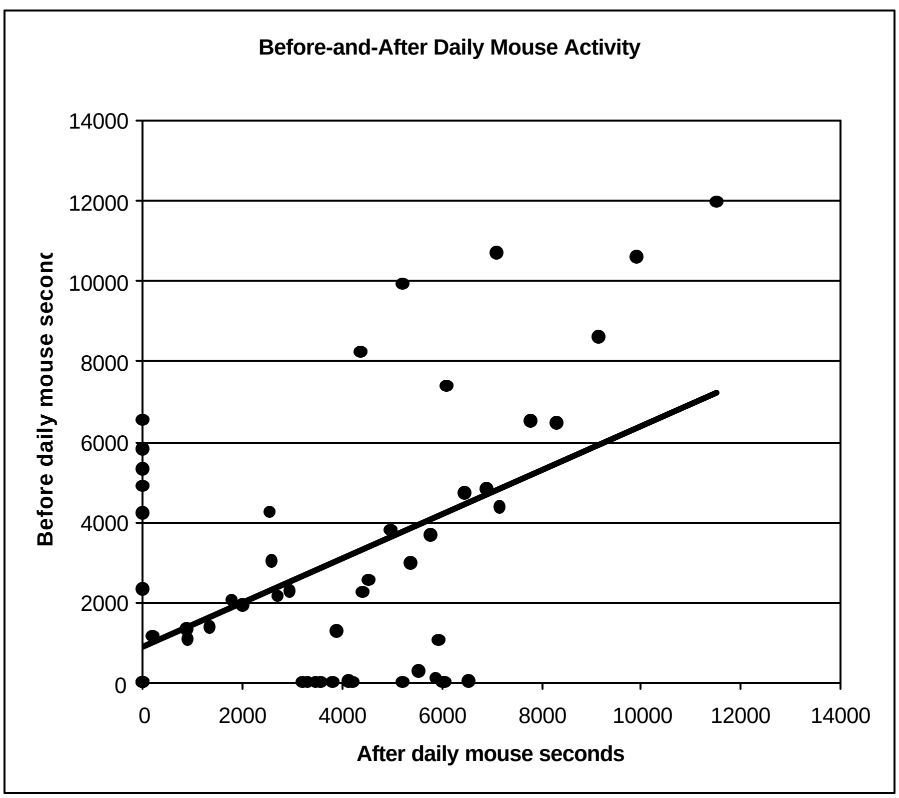
3.5 Mouse Activity

There was no statistically significant main or interaction effect of EM activation on daily mouse seconds (means: pre-EM = 4106.7, post-EM = 4201.4, a 2.3% increase in mouse activity seconds).

To test the consistency of employee mouse use for the two time periods of the study, average daily mouse seconds of activity data for the before-and-after periods were correlated. As with keyboard use, there was a significant correlation between mouse seconds activity before and after activation of the microbreaking feature of the EM (Pearson's correlation = 0.646, $p<0.001$, 2-tailed. The correlation is positive which shows that similar mouse activity occurred in the before-and-after 20 days periods (see Figure 4).

FIGURE 4

Scatterplot of Before-and-After Daily Mouse Activity Seconds per Person.



3.6 Keystroke and Mouse Use

Daily keystrokes and mouse seconds were correlated to test whether users were trading off keyboard activity and mouse work. There was a statistically significant correlation between keying and mousing both for before the microbreaking feature of the EM was activated (Pearson correlation = 0.504, p<0.001) and for after EM activation (Pearson correlation = 0.335, p<0.012). For all workers keyboard and mouse activity levels were positively correlated at each time.

3.7 Return on Investment Analysis

Table 3 presents a return-on-investment analysis[1] to quantify the potential economic impact of the significant improvement in accuracy (1% of overall keying activity) that occurred for the EM test group.

TABLE 3

Return-on-Investment Analysis of the Increase in Keying Accuracy

A. Estimates hourly IT wages (not LMC data)	$75.00
B. Pre-EM Hourly Error costs (@9.48%)	$7.11
C. % Increase in Keying Accuracy	59%
D. Hourly error savings per person (B x C)	$4.20
E. Hourly EM Cost	$0.05
F. Net hourly Savings per person (D-E)	$4.15
G. Net hourly Return on Investment ((E/F)x100)	8,300%
H. Annual per seat EMS cost	$104
H. Breakeven/Payback Period (H/F)	25.1 hours

[1] The software's annual seat cost does not include internal technical and administrative implementation costs, which may vary among organizations. The assumptions for cost and error measurement that were used in this study were not provided by Lockheed Martin. Although productivity, in terms of errors, was increased, it is understood that it will vary by computer usage and how measurement of errors are defined and recorded. The results of the pilot demonstrated to the Lockheed Martin IT organization specifically that the use of this third generation microbreaking software did show a positive ROI and the Post Survey indicated employees where satisfied.

4.0 DISCUSSION

This field study evaluated the effects of using the EM software system on the performance of 56 professional workers. Baseline data were collected for four weeks before and after full activation of the software, and detailed error analysis was performed for a one-week period before and after the EM microbreaking activation. Prior to the study, participants at the test site were not reporting widespread problems with musculoskeletal discomfort. Management at the site is proactive about office ergonomics.

Results from the study show that the use of the EM software produced a statistically significant increase in keying accuracy, with a 59% decrease in the error rate between the pre-test and post-test conditions. This result agrees with previous research (Hedge, 1999; Henning *et al*., 1996) that has shown that the provision of microbreaks based upon work intensity and the provision of feedback about rest break utilization reduces typing errors. Although on occasions the 'backspace' key was used during normal formatting work operations, this use of the key remained the same during both the pre- and post-intervention sessions. Consequently, the 59% reduction in errors may be an underestimate of the real reduction in errors, because the denominator may be smaller than the value that was used, which may also contain some correct keystrokes.

When this effect on errors is combined with the potential reduction in injury risks associated with discretionary rest breaks (Galinski *et al*., 2000, Henning *et al*., 1996), a compelling economic case can be made for the corporate use of this ergonomic software.

The present study also showed that the use of the EMS software does not interfere with normal computer work activity. Use of the EMS software which alerts users to the need for periodic microbreaks, where the interbreak interval is based upon the intensity of their computer use, did not adversely effect either the quantity of keyboard or mouse work, and there was no evidence of a speed-error tradeoff that could confound the observed improvement in accuracy (i.e. user's were not improving their keying accuracy by slowing down).

Further studies of the application of this type of ergonomic workflow software could prove useful and beneficial in evaluating the effects of microbreaks on participants who are experiencing musculoskeletal problems and in quantifying the performance benefits of this software for a larger number of workers over a longer period.

5.0 REFERENCES

Galinsky, T.L., Swanson, N.G., Sauter, S.L., Hurrell, J.J. and Schleifer, L.M. (2000) A field study of supplementary rest breaks for data-entry operators, Ergonomics, **43** (5), 622-638.

Hedge, A. (1999) Effects of Ergonomic Management Software on Employee Performance, Cornell University Human Factors Laboratory Technical Report /RP9991, September.

Henning, R.A., Callaghan, E.A., Ortega, A.M., Kissel, G.V., Guttman, J.I. and H.A. Braun. (1996) Continuous feedback to promote self-management of rest breaks during computer use. International Journal of Industrial Ergonomics, **18**, 71-82.

Henning, R.A., Jacques, P., Kissel, G.V., Sullivan, A.B. and S. Alteras-Webb. (1997) Frequent short rest breaks from computer work: effects on productivity and well-being at two field sites, Ergonomics, **40** (1), 78-91.

Janaro, R.E. and S.E. Bechtold. (1985) A study of the reduction of fatigue impact on productivity through optimal rest break scheduling, Human Factors, **27** (4), 459-466.

ACKNOWLDEGEMENTS

We thank EIS at Lockheed Martin for agreeing to participate in this study.