MARVIN DAINOFF ASSOCIATES, INC.

FINAL REPORT

IRS CONTRACT TIR-92-0074

September 7, 1995

EXECUTIVE SUMMARY

This document is the final report of an ergonomic intervention study at the Cincinnati Service Center among Data Conversion personnel. This study is the U.S. national component of a international multidisciplinary project: "Musculoskeletal strain, eyestrain, and psychosocial stress in optimized environments" -- abbreviated "MEPS."

The basic goal of the international project was to measure how effective improving physical working conditions would be in reducing musculoskeletal, visual and psychosocial stress among visual display terminal (VDT) operators. To accomplish this goal, a standard battery of tests was developed which would assess aspects of musculoskeletal stress, eye strain, and psychological stress. The tests included questionnaires, physical monitoring of employees during a work sample, and professional examinations by physicians and eye care specialists.

Each participating country selected a group of VDT operators for study at a given work location. At the beginning of the study, the operators would be measured using the standard battery of tests at their original work site. After the measurements were concluded, improvements in the workplace would be made following principles of good ergonomic design. The entire battery of tests would be repeated one month after ergonomic improvements were in place, and again after a period of one year. The impact of the improvements should be reflected in changes measured by the test battery.

The U.S component of the MEPS project was carried out at the Cincinnati Service Center with IRS support and funding. The ergonomic improvements included advanced ergonomic chairs, motorized adjustable workstations, adjustable keyboards, adjustable copyholders, adjustable footrests, and monitor support surfaces. Intensive ergonomic training and followup coaching were provided along with appropriate eyeglasses where required.

Statistical analysis of items from these test showed that the intervention was highly successful. After one month of work in the improved workstations, the operators had lower levels of muscle pain and fewer visual complaints. These lower levels of muscular and visual pain were maintained even after one year. Operators had better working postures and felt much better about their working conditions. Productivity showed an initial decrease as operators accommodated to their new equipment, but then returned to normal.

The study showed that ergonomic improvements in working conditions are effective in reducing symptoms of musculoskeletal and visual disorders. In an era of rapidly rising worker compensations costs and rapidly decreasing personnel levels, it is an important business objective to keep existing employees healthy and productive. Thus, an ergonomic investment makes good business sense.

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ERGONOMIC STUDY -- CINCINNATI SERVICE CENTER

September 7, 1995

THIS RESEARCH WAS CONDUCTED UNDER THE TERMS OF IRS CONTRACT NO. TIR-92-0074. STATEMENTS OF FACT OR OPINION APPEARING IN THIS REPORT ARE SOLELY THOSE OF THE CONTRACTORS AND ARE NOT NECESSARILY ENDORSED BY THE INTERNAL REVENUE SERVICE.

TABLE OF CONTENTS

I. INTRODUCTION

This document is the final report of an ergonomic intervention study conducted at the Cincinnati Service Center among Data Conversion personnel. This study, an investigation of the effects of optimized workplace environments in reducing musculoskeletal, visual, and psychosocial stress among visual display terminal (VDT) operators, is the U.S. national component of a multinational multidisciplinary project: "Musculoskeletal strain, eyestrain, and psychosocial stress in optimized environments" -- abbreviated "MEPS."

A. History/Overview of the MEPS Project.

The MEPS project represents an unparalleled effort at multinational and multidisciplanary collaboration. A large body of evidence suggests the potential benefit from ergonomic interventions for reducing risk factors for work-related musculoskeletal disorders, as well as increasing operator productivity. Overviews of the evidence may be found in Kuorinka and Forcier (1995) and Sauter, Dainoff and Smith (1990). An excellent non-technical summary of the documented benefits of ergonomics can be found in MacLeod (1995). At the same time, it has also been realized that understanding what makes ergonomic solutions effective requires a variety of perspectives--both professional and cultural.

It was this attempt to operationalize the multiple perspective approach to ergonomic solutions in complex work environments which formed the core of the MEPS project. The project team consisted of an international group of researchers (Japan, Norway, Poland, Singapore, Sweden, United States) representing the professional disciplines of ergonomics, occupational medicine, optometry, social and industrial psychology, and work physiology. In developing the overall structure of the MEPS research project, the following operating principles were adopted:

a.) The overall goal of the project was to provide an assessment of the effectiveness of ergonomic interventions.

b.) While the primary focus of the project was on reduction of musculoskeletal strain, it was emphasized that visual and psychosocial factors interact with musculoskeletal strain, and must, therefore, be explicitly focused upon.

c.) Organizationally, each country participating in the study agreed to establish at least one study site at which an ergonomic intervention would be carried out. The minimum conditions for participation were that the work site would consist of at least 24 female data entry workers.

d.) Each study site was free to design its own ergonomic intervention. The only constraint was that eyeglasses appropriate for VDT work be a part of the intervention.

Based on these principles, a standardized assessment protocol was developed. The basic structure of the protocol consisted of procedures for the measurement of musculoskeletal, visual, and psychosocial variables, to be carried out in the existing workplace, and then one month and one year following the ergonomic intervention. This protocol would be employed by each participating country, with the resulting data to be incorporated into a common data base. MEDSTAT Research AS, Strommen, Norway, was designated as administrative secretariat for the MEPS project and was responsible for developing the data base structure and for conducting statistical analyses for data collected under the MEPS protocol.

B. IRS Participation

IRS national headquarters agreed to participate as the first United States component of the international MEPS project, and to support that participation financially through the issuing of IRS-92-0053. The benefits of participation in this study to IRS are that a careful assessment of the effects of ergonomic intervention will be available, through a multinational investigation. No ergonomic investigation of this complexity has previously been attempted; therefore this study must be considered a landmark. The results of this study will provide immediate practical information to IRS decision makers regarding the effectiveness of ergonomic interventions. At the same time, as a portion of the broader scientific study, it should provide valuable information regarding effective working conditions for the increasingly larger population of computer operators.

A major benefit to IRS from its participation in this study is that the MEPS protocol has been developed by an interdisciplinary team of internationally known and respected specialists. Carefully standardized measurement procedures and a centralized statistical data base have been devised, and analytic tools are available. This level of complexity is required by the nature of the problem, but unlikely to be attained from any single contractor working independently.

In addition to the research effort specified within the context of the MEPS protocol, additional analyses of operator productivity were planned and carried out as part of the U.S. component of the project. Productivity analysis will be discussed below as part of the project final report.

C. Scientific Rationale.

The overall scientific rationale for the MEPs project is based on the reduction of musculoskeletal load through ergonomic improvements in the workplace. Musculoskeletal load refers to the combination of muscle force and duration over time required by an individual to exert effort during work. Load can be either dynamic or static. In the case of a VDT operator performing data entry work, dynamic effort is exerted by finger and forearm muscles in order to operate keys. Static effort, however, is exerted by upper arm and forearm muscles in order to the maintain postural orientation of fingers in a working position.

If levels of musculoskeletal load are excessive, the outcome may be immediate discomfort, and possible long term disability (Aarås, et al., 1990; Kuorinka and Forcier, 1995). Thus, reduction of musculoskeletal load is a goal of ergonomic design. Three factors can be identified as potentially having major impacts on musculoskeletal load: posture, vision, and psychosocial influences. These three factors provide the focus for this study.

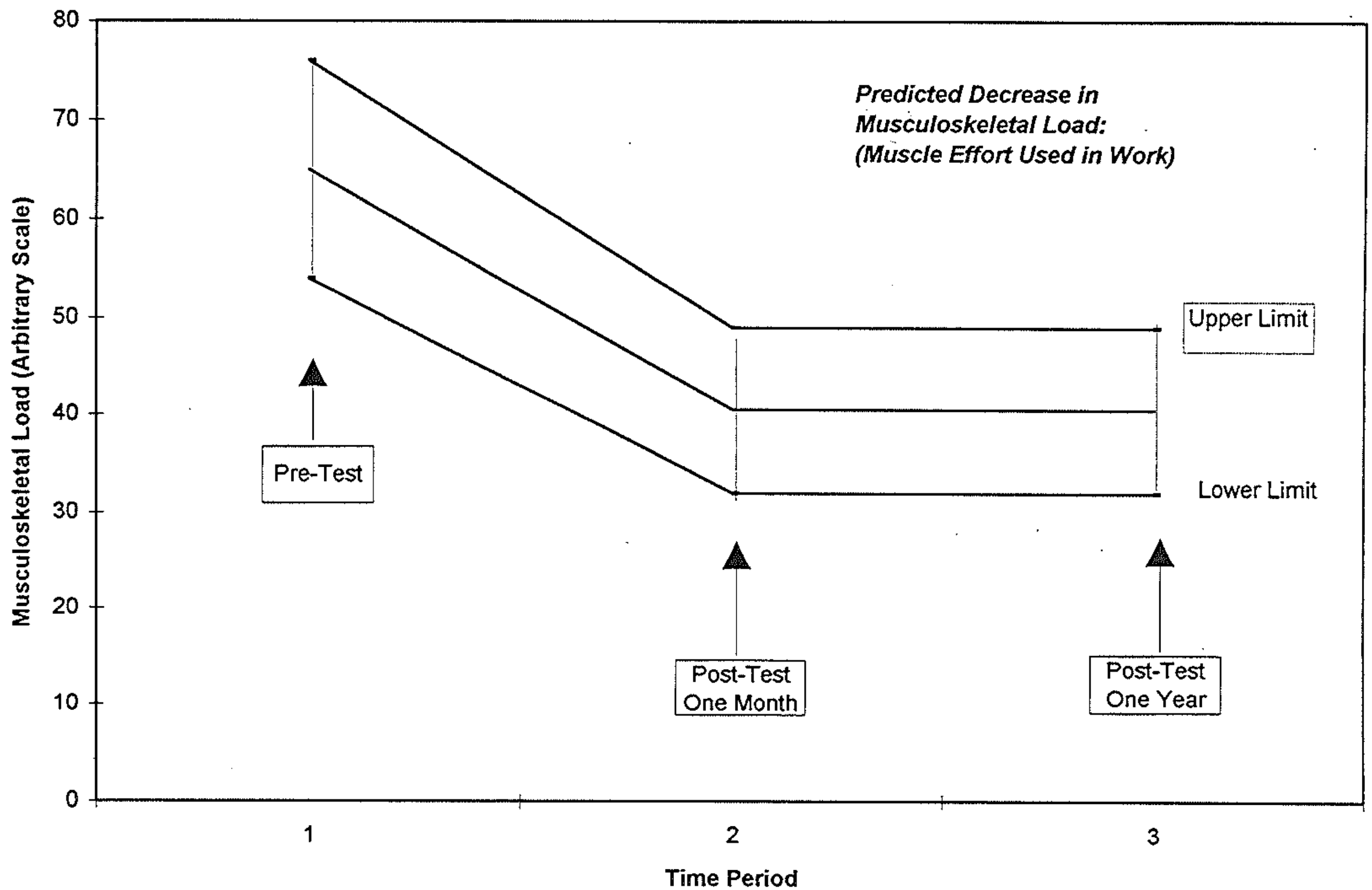
Postural factors produce the most obvious influence on musculoskeletal load. Muscle strain is most likely to occur from awkward postures -- that is, when parts of the body are displaced from their neutral or natural position (Putz-Anderson, 1988). The neutral position for the shoulder, for example, is with the person standing upright while the arm hangs straight down. When the shoulder is elevated, as in screwing in an overhead light bulb, the muscles are not functioning as efficiently as they do when the shoulder is in neutral posture; fatigue and strain occurs quickly.

On the other hand, for visually demanding tasks like data entry work, awkward head and neck postures might well be dictated by the state of the operator's eyesight. If eyeglasses are not properly corrected for VDT working distances, the operator may have to bend the head and neck forward to see adequately. The result is that a visual problem causes muscle strain in neck and shoulder, as well as the possibility of eye strain itself.

Finally, the importance of psychosocial influences on levels of musculoskeletal load is becoming increasingly recognized. Smith and Sainfort (1989) have proposed a model of job design, documenting mechanisms by which muscle load can be affected by factors such as job future uncertainty, role conflict, overtime, paced work, and lack of control. Hubbard (1994) presented experimental evidence indicating that the level of electrical activity in a single muscle fiber can be directly increased by the presence of a psychological stressor.

An overview of the scientific approach to the present study is presented in Figure 1. This figure depicts the hypothetical level of musculoskeletal load in a group of VDT data entry operators at four different time periods. During the Pre-Test, the level of load for these individuals will fall within a certain range of values, indicated by the error limit lines. Individual operators will fall at different points within this range depending on the combination of postural, visual, and psychosocial factors influencing each person at this point in time. Next, an intervention occurs in which the workplace is improved and appropriate eyeglasses provided. The expected effect of the intervention is to reduce the overall average level of musculoskeletal load as measured during a post-test

Figure 1
Predicted Pattern of Results



one month after working under the improved conditions. We would further expect that, after one year of working under improved conditions, the low level of musculoskeletal load would be maintained or even drop further. This is the picture depicted in Figure 1. However, an alternative possibility is that the effect of the intervention was successful (drop in load between time periods 1 and 3), but that organizational changes between time periods 3 and 4 would produce a general increase in psychological stress levels, and this, in turn, causes the average level of musculoskeletal load to increase.

The above approach has been evaluated through a set of standardized measurement procedures. These have been developed to assess musculoskeletal load as well as the postural, optometric and psychosocial factors which might relate to it. The standardized measures have been applied to groups of VDT workers in each of the participating countries, with the stipulation that a minimum sample of workers consists of 24 female data entry operators. Each participating country then carried out an ergonomic intervention. It was recognized that the intervention was necessarily different from country to country; however, each intervention included an optometric examination and the provided corrective lenses appropriate for working conditions at the job site.

The standardized measurement procedures were repeated one month after the intervention has been completed, and again one year later. The expectation is that the combination of ergonomic and optometric intervention will reduce the overall level of musculoskeletal load. This should be apparent in the one month post-test. If the load is, in fact, reduced, the next question is: is this a short or long term effect? This question will be assessed by the one year post-test. The role of the psychosocial measures will be to identify possible moderating or confounding variables which might have covaried across the time period of the measurement.

II. Contract Management

IRS Tir 92-0074 specified certain tasks to be completed and deliverables to be provided. The following section consists of a summary of these tasks and deliverables. Where appropriate, expanded discussion of tasks and deliverables will be provided in subsequent portions of this report.

Task 1. Obtain the MEPS Protocol. This was accomplished, and was provided to COTR as Deliverable #1.

Task 2. Furnish a Research Plan Which Adheres to the MEPS Protocol. The major components of the research plan, as specified by the MEPS protocol, are discussed in the following section on Methodology. For each such component, the elements of the research plan which provides a methodology to accomplish the protocol is outlined. The details of this research plan were provided as Deliverable #2.

Task 3. Furnish and Implement an Ergonomic Intervention Plan. The ergonomic intervention plan involved the planning and coordination of the following intervention components: corrective lenses; adjustable workstations, chairs, keyboards, and other ergonomic accessories; and individualized ergonomic training. This included specification of optometric criteria for corrective lenses in accordance with MEPS protocol (Tasks 10, 12, 13), providing furniture with specifications for optimum ergonomic environments (Tasks 4,6, 13), and designing an individualized ergonomic training program (Task 9). The intervention plan was provided as Deliverable #3.

Task 4. Specifications for Workstations, Chairs, and Accessories. Detailed specifications for procurement of workstations, chairs, and accessories which strictly adhere to state of the art principles of ergonomics, and which conformed to existing standards (i.e. ANSI/HFS 100 Human Factors Engineering of Visual Display Terminal Workstations). The specifications included requirements defined in IRS 92-0053, Phase 4, for keyboards which are separately adjustable for left and right hands, correct lighting, ergonomic chairs with forward tilt and separately adjustable back support, adjustable worksurfaces, and other accessories, such as foot rests, wrist rests, and copy holders necessary to complete an optimized ergonomic environment. These specifications constituted Deliverable #4.

Task 5. Provide Validated Questionnaires Depicting Interaction of Workplace, Work, and Worker. Standardized questionnaires were contained within the MEPS protocol. Specific items address social conditions, psychosocial aspects of working life, and ergonomic aspects of the workplace. These items were made available as Deliverable #5

Task 6. Provide Specification of Lighting and Other Environmental Aspects. Specifications for lighting and temperature, humidity, and airflow which complied with (i.e. ANSI/HFS 100 Human Factors Engineering of Visual Display Terminal Workstations) were required. However, an initial examination by the contractor indicated that: (a) lighting and environmental factors were adequate; and (b) it would not be feasible to carry out additional lighting and environmental changes within the scope of the current project This stipulation was included as part of the intervention plan constituting Deliverable #3.

Task 7. Conduct Measurements to Insure that Working Conditions are Optimal. Measurements indicative of optimality of working conditions were specified in the MEPS protocol and were conducted during the pre-intervention and post-intervention phases of data collection. These include photometric, keystroke pressure, and trigger point measurement using force gauge procedures. Results of such measurements were communicated orally to IRS management following installation, along with an assessment of the intervention itself; this constituted Deliverable #7.

Task 8. Conduct Musculoskeletal Measurements During Work Samples. Electromyographic and postural angle measurements required by Task 8 were specified in the MEPS protocol and were to be conducted during the pre-intervention and post-intervention phases of data collection. Musculoskeletal analyses are provided in the final report; this constituted Deliverable #8.

Task 9. Conduct Ergonomic Training. A customized ergonomic training program was designed to allow each participant to take full advantage of the flexibility provided by the ergonomic intervention. Accomplishment of this training program constituted Deliverable #9.

Task 10. Provide Specifications for Optometric Examinations. Specifications for Optometric Examinations were found in the MEPS protocol. Also included in the protocol were Standard Operating Procedures for the optometric examinations in written form and supplemented by video tape. These specifications were provided as Deliverable #10.

Task 11. Provide Specifications for Medical Examinations and Interviews. Specifications for Medical Examinations and Medical Interviews were found in the MEPS protocol. Also included in the protocol were Standard Operating Procedures for the medical examinations in written form and supplemented by video tape. These specifications were provided as Deliverable #11.

Task 12. Conduct Optometric and Physical Examinations. Qualified medical practitioners (ophthalmologist and physician) conducted the optometric and physical examination. Corrective lenses were provided, when required, in conjunction with the optometric examination.

Task 13. <u>Conduct Consultation as to Adherence to Protocol, Analyses, and Medical/Optometric Recommendations.</u> A schedule of consultations was set up between the contractor and applicable IRS personnel, and included communication of relevant medical and optometric information to IRS facilities managers as well as the furniture contractor. Consultation was included in Deliverables #7 and #12.

Task 14. <u>Conduct Statistical Analysis</u>. The statistical analysis described in Task 2 relating to the MEPS protocol has been carried out by MEDSTAT statistical staff and Marvin Dainoff Associates, Inc. Interpretation and discussion were provided by the contractor. Participant productivity data has been analyzed locally. Absenteeism data was originally also scheduled to be included in the analysis, but the required records were not available at the work site. Interim statistical results have been submitted as part of Deliverable #12. Final results included herein constitute Deliverable #13.

Task 15. <u>Report to IRS at Three Intervals</u>. Deliverables #6 and #12 have been submitted. The present report constitutes Deliverable #13. Other status reports were prepared as requested by IRS.

Task 16. <u>Final Report</u>. This final report includes introduction, methodology, statistical analysis, discussion of results, and recommendations. The report includes, in addition to the IRS component of the MEPS, those portions of the international data base for which analyses have been completed, and productivity data. This report constitutes Deliverable #13.

III. METHOD

A. Design and Approach.

The basic research plan, as laid out in the MEPS protocol, calls for standardized measurements of musculoskeletal, visual, and psychosocial stress. These standardized measurement procedures were carried out in the workplace before the intervention, and then one month following the ergonomic intervention. A third set of measurements, identical to the first two, was carried out eleven months following the ergonomic intervention. An additional productivity analysis was conducted which was based on existing operational records throughout the period of the study.

B. Selection of participants:

The study was conducted at the Cincinnati Service Center. Participants in the study initially included 29 employees selected from volunteers working in Data Conversion. Twenty six employees remained in the study through its completion. This represents an extraordinarily high retention rate for a study of this duration and complexity, and is a tribute to the dedication and interest of our volunteers.

The MEPS protocol specifies the following inclusion and exclusion criteria for participants in the study:

1. Inclusion

a. Below 60 years of age at the end of the study and preferably evenly age distributed.

b. Have carried out the same work for at least the last six months before entering the study.

c. Employed or associated with the participating organization.

d. Employed in Data Entry work; defined as routine work with the display screen and keyboard which only consists of one-way communication with the computer by entering data for at least 60% of the workday.

e. Female.

2. Exclusion

a. Pregnancy or planned pregnancy

b. Rheumatological illness

c. Serious eye disease or excessive myopia (>6 D)

d. Physical handicap such that taking measurements becomes difficult.

e. Subjects not likely to complete the entire study.

C. Methodological Components

The major methodological components listed below are specified by the MEPS protocol. For each such component, the elements of the research plan which provide specific details for implementation of the MEPS protocol are outlined.

1. Organizational Description. Once the specific group of volunteers was identified, an overall description of the organizational unit was carried out, a task analysis was done, and demographic information from volunteers was obtained. This information was obtained by on-site interviews of administrative staff, and examination of applicable personnel records (with appropriate safeguards for privacy).

2. Study Participant Orientation. A full briefing and orientation session was carried out for study participants. This included filling out of voluntary consent forms, and collection of individual demographic data.

3. Data Collection.

The following measurements, conforming to the MEPS protocol, were collected at three periods of time within the study. The preintervention measurements were collected during the month of June 1993. The intervention itself took place during July 1993. The first post-intervention measures were collected during September, 1993, after participants had worked for one month with their new equipment. The second post-intervention measures were collected during July 1994, eleven months following the intervention.

a. Work Environment Questionnaires (Psychosocial and Ergonomic components) were administered to all participants. The psychosocial questionnaire included items on general working conditions, type and content of work, workload, control, satisfaction, and life situation. The ergonomic questionnaire included items on chair, keyboard surface, and monitor adjustability, lighting and glare, workspace arrangement, and noise and climate.

b. Medical Examinations were scheduled for each participant. The medical examination consisted of the following components: Musculoskeletal Symptom Checklist, General Examination, Identification of Tender/Trigger Points, Neck/Shoulder Mobility, Carpal Tunnel Syndrome Signs. The medical examinations were carried out by H. Blatman, MD, who is Board Certified in Occupational Medicine.

c. Optometric Examinations were scheduled for each participant. The optometric examination consisted of the following components: Visual Symptom Checklist, Optometric Analysis -- Adequacy of Current Correction, Ophthalmic Examination -- Visual Function, including acuity, visual field, phoria, and refraction. The examinations were carried out by J. Sands, MD, Professor of Ophthalmology at the University of Cincinnati Medical College.

d. On-site musculoskeletal/postural measurements were carried out during participant work samples of around 45 minutes duration. These included electromyographic recording of right and left trapezius along with simultaneous measurement of position angles of head (flexion/extension), arm (flexion/extension and abduction/adduction), and back (flexion/extension). A model PHY 400 Physiometer (Premed AS) was used for both measurements. Standard calibration procedures as specified in the MEPS protocol were carried out for each subject just prior to collecting work sample data. This included determination of resting EMG levels for right and left trapezius muscles, and determination of maximum EMG (MVC) for both right and left trapezius muscles relative to a previously calibrated force transducer. Next, a visual biofeedback procedure was used in which a linear relationship was established between resting level and 30% MVC. Finally, the position sensors were calibrated against fixed neutral body positions.

e. In conjunction with the musculoskeletal/postural measurement described above, ergonomic assessments of each participant's workstation were conducted. The assessment included luminance and illuminance measurement with a Hagner photometer (Model S1), dimensional and angular measurement of workstations, and a combination of expert and user assessment of workstation usability. Keyforce pressures were measured with a Chattillon Model DPP gauge.

4. Ergonomic Intervention.

a. Corrective Lenses: An ophthalmologic examination of each participant was conducted as part of the preintervention Data Collection Phase. This examination specifically considered the visual function of the participant with respect to the particular visual demands of the workplace. When needed, appropriate corrective lenses were prescribed according to specific optometric criteria as laid out in the MEPS protocol.

b. Workstation Redesign: A complete redesign of each workstation was carried out so as to provide an optimum ergonomic workplace. The redesign included the following components:

(1) Ergonomic chairs which were utilized all had independent height, seatpan angle, and backrest angle adjustments. In addition, seatpan and backrest could be put into dynamic movement. The seat height adjustment range was from 16 to 20.5 inches. The backrest was height adjustable over a range of 3 inches, and the height of the backrest was at least 14 inches. Seatpan angle inclinations included a range of from 5 degrees forward to five degrees backward. The backrest inclined 11 degrees from vertical. All chairs had adjustable arm rests, waterfall fronts, and five-prong bases. Chairs meeting these criteria were provided, on a no-cost loan arrangement, from three manufacturers: Fixtures Furniture, The Harter Group, and Neutral Posture Ergonomics.

(2) Motorized adjustable worksurfaces were provided which allowed operators push button control of the worksurface height from a sitting to a standing posture. Two sets of worksurfaces were provided: those which ranged from 25-41.9 inches, and those which ranged from 26-43.9 inches. The latter were assigned to the taller employees. Horizontal dimensions were 60 inches wide by 40 inches deep. The workstations were purchased on contract from Spec-Tech, Inc.

(3) The keyboards employed were fully adjustable. Each keyboard was divided into three movable sections: the section usually keyed by the left hand, the section usually keyed by the right hand, and the numeric keypad. Each section of the keyboard could lift, tilt, swivel, and be moved right or left along the base, and be locked in position after adjustment. It was possible to interchange sections so that the numeric keypad could be placed in the center.

The keyboard followed the IBM/AT QWERTY layout, and met or surpassed ANSI standards with respect to keytravel, force, tactile feel, and keyspacing. Because the IBM/AT layout differs from that of the Motorola Four-Phase systems current in Data Conversion, an exact match of key locations and positions was not possible. Therefore, mapping of the adjustable keyboard was carried out iteratively over a period of two months. Data Conversion employees participated in the mapping process. The keyboards were purchased under contract with Health Care Keyboard Company, Inc.

(4) Copyholders were provided which met the following requirements: accommodate a stack of documents 3 inches thick; provide a transparent spring-loaded clip to facilitate working through documents without cutting off the view of codes underneath; adjustable in viewing height and angle. This copyholder was provided under separate contract with Marvin Dainoff Associates, Inc.

(5) Custom-made monitor supports were provided for each person, according to measurement of the individual's most comfortable monitor viewing height. These supports were angled to increase the tilt range of the monitors, to help minimize glare. These supports were provided under separate contract with Marvin Dainoff Associates, Inc.

(6) Adjustable footstools were provided all participants. The footstools could be adjusted through an 8 in. range in 1 in. increments. Half were purchased from Biofit, Inc; the remainder were made available at no cost to the government from Biofit.

c. Training. A customized ergonomic training program was designed to empower each participant to take full advantage of the flexibility provided by the ergonomic intervention. This training incorporated a general knowledge of ergonomic principles along with specific instruction relating to the particular pieces of ergonomic equipment (e.g., chairs, workstations, keyboards). Thus, the participants were provided with knowledge of "why" a given working posture might be more comfortable and efficient, along with "how" ergonomic equipment might be adjusted to achieve such postures. The training plan was divided into the phases indicated below.

(1) Phase 1 -- Classroom training: A classroom workshop introduced participants to the principles of ergonomics, with emphasis on human physiology as the rationale for making ergonomic recommendations. This emphasis on principles was important in that it educated the participants in ergonomics they could use both on and off the job -- all of which impacts the worker's ability to function well at work.

(2) Phase 2 -- On-site coaching: Once workstation equipment was installed, individual instruction/coaching at the worksite was conducted until participants were familiar with all equipment and able to use it as required.

(3) Phase 3 -- Follow up visits #1: Throughout the intervention period, follow up coaching visits at the workstations were made from time to time, as convenient with the CSC staff.

(4) Phase 4 -- Follow up visits #2: Following the first postintervention data collection, additional follow up visits were scheduled in cooperation with the CSC staff. These visits were carried out throughout the remainder of the contract period until the tax season; they included a "Progress Report" questionnaire, some measurements of the adjustments being made by the participant, and coaching in achieving ergonomic health and comfort. Ergonomic thinking was further encouraged by the "MEPS Newsletter," which was distributed periodically to all participants at no additional cost to the government.

IV. RESULTS

A. Rationale and Strategy

The framework for the statistical analysis as initially set forth in the international MEPS trial plan, was that of an overall set of analyses conducted on the combined international data, with individual national analyses to be presented as a subset of the international results. A major strategic concern in approaching the analysis was that of the large number of measured variables (approximately 435). The initial method proposed in the MEPS protocol of reducing and compressing the original data set was through principal components analysis on the entire international data. However, a number of operational problems have prevented some of the national studies from being completed. As a result, the size of the international data base is now too small to allow the principal components approach to be feasible. Therefore, on the international level, alternative approaches are still being explored, but the data analysis is considerably behind schedule.

Accordingly, for the U.S. component of the study, a different strategy has been developed. We call this the critical question approach. Within each of the groups of measures described above, we have identified a small number of individual variables or combinations of variables which would seem to bear most directly on the question of whether or not the intervention was effective. We then present univariate tests on these critical variables across the time periods corresponding to the point at which measurements were taken. The null hypothesis is that there is no difference across the three time periods; the alternative hypothesis that there is an improvement immediately following the intervention and that this improvement is maintained for a period of one year. These hypotheses are evaluated using, as appropriate, one way repeated measures analysis of variance, Friedman two-way analysis of variance by ranks, and chi square for test the overall main effects; and Tukey HSD and its Friedman equivalent, for comparisons across means.

The results indicated below will fall in three sections. The first section will consist of a critical variables analysis performed on the U.S./IRS component of the MEPS protocol. The second section will consist of preliminary results in which international comparisons have been made for three of the participating countries in the MEPS project: Norway, Poland, and the U.S. The third section will consist of results from the productivity analysis of the U.S. data. This analysis was conducted independently of the MEPS protocol.

B. Critical Outcome Measures -- U.S. Component

1. <u>The Participants</u>. As indicated previously, 26 of the original 29 participants remained in the study through completion. All analyses which follow will be conducted only on these individuals. All participants were permanent employees of CSC working in

Data Conversion. Their average age was 41.02 with a standard deviation of 9.58. The mean number of years working at IRS was 15.71 with a standard deviation of 6.55. All of the participants were female. Seven of the participants were Black, the remainder were White. Nine described themselves as married/cohabiting with children at home, five were married/cohabiting with no children at home. Ten of the participants described themselves as not living with another adult; of these eight had children at home.

2. Results of the Physical Examination. Three critical items from the physical examination were selected for analysis. Each reflects an objective determination of specific signs or precursors of musculoskeletal disorder. Further, it should be emphasized that, on the two postintervention examinations, the examining physician was not aware of the previous findings on the physical examination for each participant.

The first of these measures was a determination of the number of painful pressure or trigger points. Results, utilizing the Friedman test, indicated that there was a statistically significant decrease in the number of trigger points from Commencement to the 30 Day Posttest. The difference between the 30 Day Posttest and 1 Year Posttest was not statistically significant. For the overall F test, Fr=198.69, $p<.001$ for 26 subjects and 3 conditions. Total number of observed trigger points for each observation period can be found on the first line of Table 1. Modal numbers of trigger points are in adjacent parentheses. It can be seen that the modal number of trigger points was six at Commencement, but dropped to zero after the intervention.

The second measure from the physical examination represents a combination of elements from the clinical examination of the shoulder joint: isometric and endurance test, palpation with and without resistance, and mobility in the joint. The overall variable consists of the number of positive signs across all of the tests, where a positive sign indicates the presence of a potential musculoskeletal problem. The results indicate a significant decrease in frequency of positive signs following the intervention; chi square (2 df) = 817.5, $p<.001$. Table 1, line 2, contains number of positive signs for each observation period. Percentages of positive signs seen among all participants within each observation period are in adjacent parentheses.

The third measure from the physical examination also represents a combination score resulting from the clinical examination of neck mobility. This score consists of the number of participants who experienced pain during manipulation of the neck in flexion, extension, sideways flexion, or rotation. The results indicate a significant decrease in pain following the intervention; chi square (2 df) = 429.4, $p<.001$. Table 1, line 3, contains number of pain reports for each observation period. Percentages of positive signs seen among all participants within each observation period are in adjacent parentheses.

Table 1			
Positive Signs in Physical Exam (Modes and Percentages)			
	Commence	30 Days	1 Yr
Trigger Points	128 (6)	34 (0)	17 (0)
Shoulder Tests	23 (22.12)	12 (11.54)	7 (6.73)
Neck Mobility	19 (24.36)	4 (5.13)	1 (1.28)

Thus, the results from the physical examination, with relatively objective measures, indicate a clear decrease in indicators of musculoskeletal disorder following the ergonomic intervention -- a decrease which persisted over the period of one year.

3. Musculoskeletal Pain -- Subjective Ratings. Combination measures were derived by averaging critical variables selected for analysis from the participants' subjective ratings of musculoskeletal pain or discomfort. The critical variables were intensity of pain, and frequency of pain. These ratings were obtained from questionnaires filled out by participants. For each of the critical variables analyzed, reports of pain or discomfort in the neck, shoulder, forearm/hand, back, and legs were combined in a single measure.

The first combination measure consisted of participants' reports of the average intensity of pain experienced during the past six months. Intensity was indicated on a Visual Analog Scale (VAS) ranging from 0 to 100. This scale consists of a horizontal line of standard length (100 mm). The attribute being measured, in this case, pain, is labeled at points along the scale, and the respondent places a mark indicating the extent of pain. The distance of the mark, in millimeters, from the left of the scale is a measure of the response. On this scale, the larger the number, the greater the degree of reported pain or discomfort. For all VAS measures in this study, the maximum score is 100; the minimum is zero.

Results, utilizing analysis of variance, indicated that there was a statistically significant decrease in the average pain/discomfort intensity from Commencement to the 30 Day Posttest. Use of the Tukey HSD test indicated that the difference between the 30 Day Posttest and 1 Year Posttest was not statistically significant, indicating long-term decrease in pain. For the overall test, $F(2,50)=12.96$, $p<.001$. Table 2 indicates mean combined VAS scores with 95% confidence intervals in parentheses. In Table 2, for example, the mean VAS rating for intensity of pain at Commencement was 36.15 out of a possible score of 100. The 95% confidence limit was +/- 5.27 around the mean, ranging from 41.42 to 30.88.

Table 2			
Musculoskeletal Pain -- Means and Confidence Intervals Combined Values -- 6 Months			
	Commence	30 Days	1 Yr
Intensity	36.15 (5.27)	25.36 (5.21)	27.46 (5.23)
Frequency	1.55 (0.32)	0.97 (0.21)	0.92 (0.21)

The second combination measure consisted of participants' report of the average frequency of pain experienced during the past six months. Frequency was indicated on a six point category scale ranging from "never" to "daily". On this scale, the larger the number, the greater the degree of reported pain or discomfort. Results, utilizing analysis of variance, indicated that there was a statistically significant decrease in the average frequency of pain/discomfort from Commencement to the 30 Day Posttest. Use of the Tukey HSD test indicated that the difference between the 30 Day Posttest and 1 Year Posttest was not statistically significant. For the overall test, $F(2,50)=22.43$, $p<.001$. Table 2 indicates mean combined scores with 95% confidence intervals in parentheses.

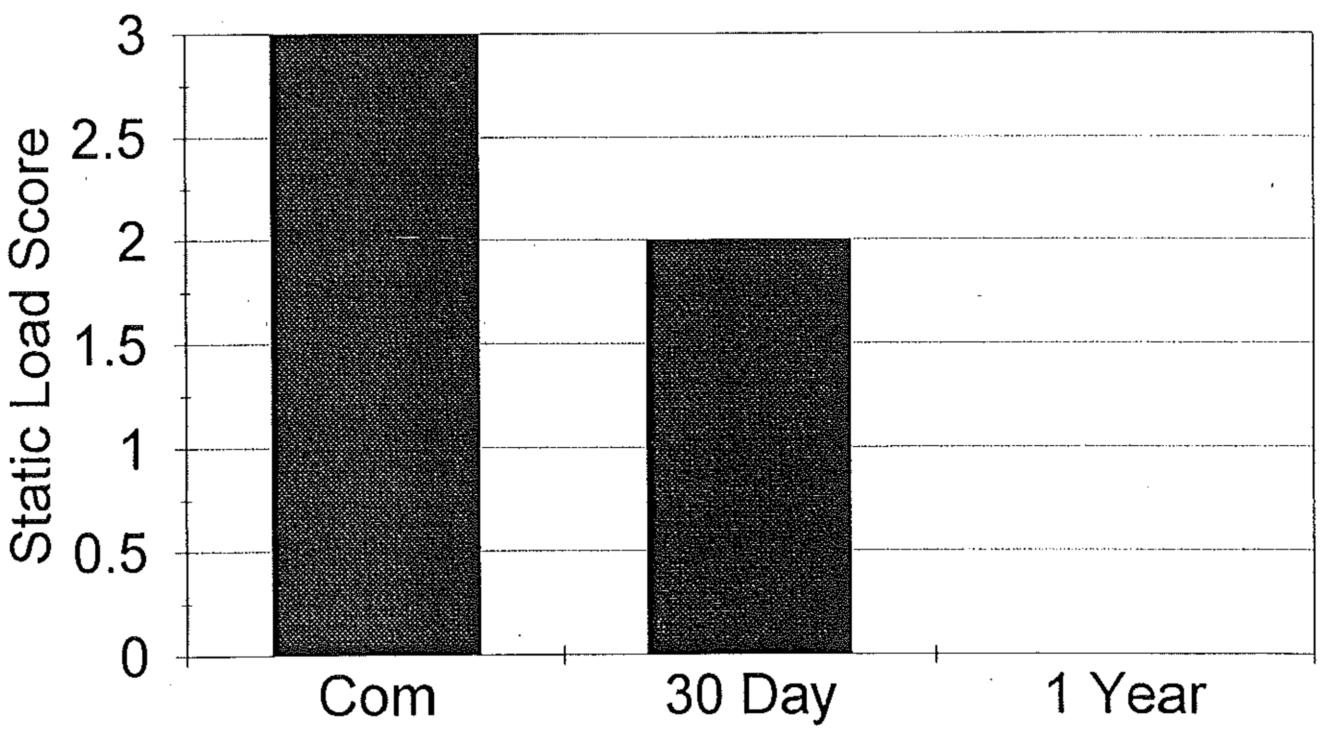
Thus, the results from the participants' subject reports indicate a clear decrease in musculoskeletal pain or discomfort following the ergonomic intervention -- a decrease which persisted over the period of one year.

4. <u>Static Load Assessment</u>. During the work samples, ergonomic evaluations were carried out in parallel with the electromyographic and postural angle measurement. One component of this evaluation was an expert assessment by the ergonomist of the extent to which each participant's working posture was likely to result in high static loads. This assessment was made after direct observation of the participant during the 45 min. period of the work sample, using a standardized checklist. Six separate postural components were evaluated: wrist angle, forearm angle, head/neck angle, trunk angle, support for lumbar spine, and stereotyped movement. The maximum possible score -- indicative of high static load -- for each participant was 6 points. A score of zero indicated absence of static load. Results, utilizing the Friedman test, indicated that there was a statistically significant decrease in the static load scores from Commencement to the 30 Day Posttest. The difference between the 30 Day Posttest and 1 Year Posttest was not statistically significant. For the overall F test, $Fr=25.01$, $p<.001$. The modal static load score, shown in Figure 2, was 3 for Commencement, 2 for 30 Day Posttest, and 0 for 1 Year Posttest.

Thus, the results from the ergonomist's professional evaluation indicate a clear decrease in indicators of musculoskeletal static load following the ergonomic intervention -- a decrease which persisted over the period of one year.

Figure 2

High Static Load



5. Postural Angles. During the work samples, angle sensors were used in conjunction with the Physiometer to determine head, arm, and trunk posture. One indication of the effectiveness of the ergonomic intervention (furniture plus training) might be an improvement in participants' working posture as reflected in a decrease in flexion angle (forward bending). Therefore, mean flexion angle (in degrees) for head, shoulder, and trunk, over the period of the work sample, comprised three critical variables.

Results, utilizing analysis of variance, indicated that there was a statistically significant decrease in the average flexion angle for head and trunk from Commencement to the 30 Day Posttest. Use of the Tukey HSD test indicated that the differences between the 30 Day Posttest and 1 Year Posttest were not statistically significant. For the overall test for head angle, $F(2,50)=12.85$, $p<.001$. For the overall test for trunk angle, $F(2,50)=12.22$, $p<.001$. On the other hand, the results are opposite to expectation for shoulder flexion. In this case, there was a statistically significance **increase** in average flexion angle from Commencement to the 30 Day Posttest, but no difference between the 30 Day Posttest and 1 Year Posttest. For the overall test for shoulder angle, $F(2,50)=10.68$, $p<.001$. Table 3 indicates mean postural angles with 95% confidence intervals in parentheses.

Table 3

Postural Angles- Means and Confidence Intervals
(Degrees of Flexion Angle)

	Commence	30 Days	1 Yr
Head	19.65 (1.49)	13.52 (3.10)	12.23 (3.58)
Shoulder	5.58 (4.06)	13.5 (3.29)	10.11 (3.56)
Trunk	8.00 (1.72)	3.62 (2.13)	2.15 (1.90)

The results from the postural angle measures indicate a clear decrease in head and trunk flexion, indicating an improvement in working posture following the ergonomic intervention, an improvement which persist over the period of one year. In the case of increased shoulder flexion, the results of the previous analysis of static load, coupled with more informal observations, lead us to the conclusion that the increase in shoulder flexion was a positive adaptation to the new configuration of the adjustable keyboard.

6. Visual Problems. As part of the optometric examination, participants were asked to indicate whether they had, within the past six months, experienced any of five types of visual problems: fatigue, burning/itching, red eyes, or double/hazy vision. Results indicated that the number of people reporting each of the above visual problems decreased following the intervention. Chi square values (2 degrees of freedom) and

associated probabilities for each problem are as follows: fatigue=14.0 ($p<.001$); burning=22.0 ($p<.001$); redness=17.0 ($p<.001$); hazy=7.35; ($p<.05$). Table 4 indicates numbers of people reporting each visual problem. Percentages are in parentheses.

Table 4

Frequency of Visual Problems
(Number and Percent of People Reporting)

	Commence	30 Days	1 Yr
Fatigue	11 (42.3)	3 (11.5)	1 (3.8)
Burning/itching	16 (61.5)	5 (19.2)	0 (0)
Redness	11 (42.3)	3 (11.5)	0 (0)
Hazy/double vision	13 (50.0)	7 (26.9)	3 (11.5)

Thus, the results from the visual examination indicate a clear decrease in reports of visual problems following the ergonomic intervention -- a decrease which persisted over the period of one year.

7. Ergonomic Evaluation -- Subjective Assessment. Participants were asked for their subjective evaluations of various ergonomic attributes of their workplace. Two of these attributes, chair comfort and height adjustability of the keyboard support surface, were selected as critical variables. Each attribute was evaluated using a Visual Analog Scale ranging from 0 to 100, where a larger number indicates a more positive evaluation. Results, utilizing analysis of variance, indicated that there was a statistically significant increase in the positive evaluations of both chair comfort and keyboard height adjustability from Commencement to the 30 Day Posttest. Use of the Tukey HSD test indicated that the differences between the 30 Day Posttest and 1 Year Posttest were not statistically significant. For the overall test for chair comfort, $F(2,50)=50.76$, $p<.001$. It was not necessary to carry out a similar test for keyboard adjustability, since the distributions did not overlap. Table 5 indicates mean combined VAS scores with 95% confidence intervals in parentheses.

Table 5			
Participants' Ergonomic Evaluations VAS Values-Means and Confidence Intervals			
	Commence	30 Days	1 Yr
Seated Comfort	42.50 (7.34)	75.65 (5.20)	75.77 (6.28)
Keyboard Height Adjustability	5.50 (5.45)	83.80 (4.00)	85.27 (3.51)

Thus, the results from the participants' ergonomic evaluations indicate a clear increase in their impressions of chair comfort and keyboard surface height adjustability following the ergonomic intervention -- an increase which persisted over the period of one year.

8. Electromyography. During the work samples, electromyographic (EMG) recordings of right and left trapezius muscle were obtained, but only the records for the preferred arm were selected for analysis. Since muscle activity should be indicative of static postural load during data entry work, the critical variable to be examined relates to the extent to which muscle activity falls below a specified minimum level: 1% Maximum Voluntary Contraction (MVC). Two alternative measures of this variable were selected: the number of times EMG load dropped below 1% MVC (number of shifts), and the proportion of the cumulative distribution of EMG activity falling below 1% MVC (Aarås et al, 1990).

Examination of the EMG records indicated that a number of subjects seemed to have difficulty with the biofeedback/tracking portion of the calibration. Accordingly, only 9 of the 26 participants had recordings which were acceptable across all three measurement sessions. Analysis of variance results from these nine subjects indicates that, for both variables, the null hypotheses of no differences across measurement sessions cannot be rejected. For the overall test for shifts, $F(2,16)=3.37$; $p=.06$. For the overall test for proportion, $F(2,16)=2.60$; $p=.10$. The mean number of shifts and proportions below 1% MVC are indicated in Table 6; 95% confidence intervals are in parentheses.

Table 6			
Electromyographic Measures -- Trapezius Muscle (Means and Confidence Intervals)			
	Commence	30 Days	1 Yr
No. Shifts < 1%MVC	19.67 (12.5)	29.71 (19.4)	4.11 (5.4)
Proportion < 1%MVC	3.02 (2.07)	6.83 (6.04)	1.28 (1.38)

Examination of these results indicates two points of interest. First, the F test for number of shifts was quite close to statistical significance at the .05 level. It is reasonable that, had we not had to discard so many subjects, the corresponding increase in power would have allowed us to achieve statistical significance. Thus, if we now examine only the comparison between Commencement and the 1 Month Posttest, and correct for loss of power, there is at least a suggestion that muscle load decreased as expected following the intervention.

However, the 1 Year Posttest results are quite problematic. For both variables, these values are lower than at Commencement, presumably indicating a higher level of muscle load. Since these findings are in conflict with the consistent pattern of results observed thus far, a closer look at the 1 Year records was carried out.

It was determined that baseline resting levels during the 1 Year Posttest were excessively high compared with previous levels. Since this resting level enters into the calibration equations, the effect would have been to artifactually lower both of our critical variables. Recall that resting levels were taken immediately after the participant was connected to the electrode leads. These high levels -- specific to the 1 Year Posttest -- were obtained despite the use of relaxation techniques.

We have identified two possible causes for these excessive high levels. The first may have reflected differences in the circumstances under which measurements were taken rather than actual differences in EMG levels among participants during the two post-intervention periods. There were two differences in procedure between the 30 Day and 1 Year Post-tests. The first was that a different laptop computer was used because of malfunction of the original laptop; the second was that a different room was utilized for the calibration. We cannot rule out equipment differences as an explanation since we have been informed by the manufacturer of the Physiometer that if an electromagnetic field from some nearby equipment were present during calibration, this might have affected the results.

A second possibility is that, despite the situational differences above, the elevated resting levels were, in fact, accurate. If so, the consistency of these high levels across participants might be explained by some organization-wide increase in stress levels.

Addressing this possibility formed part of the rationale in selection of critical psychosocial variables to be examined in the following section.

The procedure for electrode placement, and, in particular, assessing the effectiveness of skin preparation through measurement of electrical resistance prior to calibration, was carefully followed and documented in all three measurement sessions. Records indicate no differences among sessions in placement and resistance.

9. Psychosocial Measures. The MEPS protocol contained a large number of psychosocial questions to which participants were asked to respond. We have selected seven independent items, the pattern of responses which might bear on two different issues. The first issue, which is broadly conceptual, relates to any potential effect of the ergonomic intervention on the broader psychosocial context of the participants' workplace and home environments. The second issue, which is more narrowly focussed, is concerned with identifying possible factors which might have resulted in the elevation of baseline EMG measures discussed in the previous section.

Each of the psychosocial variables was evaluated using a VAS score ranging from 0 to 100. "Job Satisfaction" represents the response to the question: "For how much of your working day can you say that you feel genuinely satisfied with your job?" A VAS score of 100 represent "always"; zero represents "never." The next two questions asks the participant to compare other work tasks relative to VDT work. "Physical-other" reflects a comparison with respect to physical demand; "Stress-other" reflects a comparison with respect to stress. Both items are reverse coded so that VAS scores of 100 indicate that the non-VDT work is less physically demanding and less stressful. VAS scores of 50 indicate that both kinds of tasks are about the same.

"Unscheduled Breaks" represents the response to the question: "Can you decided when you want to take short unscheduled breaks for a few minutes?" A VAS score of 100 represents "always." "Opportunity to Learn" represents the response to the question: "To what extent do your work tasks involve the opportunity to learn something new." A VAS score of 100 represents "very much." "Job Security" represents the response to the question: "How is the security in your present employment?" This scale is reverse coded in that a VAS score of 100 reflects "Low -- reason to fear release." "Income" represents the response to the question: "How do your regard your income?" A VAS score of 100 represents "very good."

Analysis of variance results indicated that none of the seven psychosocial variables approached statistical significance at the 0.05 level. Means VAS scores are indicated in Table 7; 95% confidence intervals are in parentheses. F values (2 and 50 degrees of freedom) and associated probability values are as follows: Satisfaction=0.26, p=0.77, Physical=1.41, p=0.25; Stress=0.95, p=0.39; Breaks=2.11, p=0.13; Learn=0.78, p=.46; Security=1.76, p=0.18, Income=2.27, p=0.11.

Table 7			
Participants' Self-Assessments VAS Values-Means and Confidence Intervals			
	Commence	30 Days	1 Yr
Job Satisfaction	53.96 (7.59)	51.19 (6.27)	52.58 (6.98)
Physical -Other	64.46 (11.63)	61.81 (12.78)	53.04 (11.02)
Stress-Other	56.19 (11.39)	64.84 (11.13)	57.92 (10.50)
Unscheduled Breaks	45.77 (12.64)	54.85 (11.82)	59.08 (12.00)
Opportunity to Learn	40.58 (10.61)	34.54 (8.08)	38.85 (9.54)
Job Security	36.77 (9.63)	45.31 (8.85)	35.73 (7.60)
Income	35.73 (7.59)	41.73 (5.83)	44.31 (6.38)

It does not appear that these psychosocial items are very helpful in addressing either of the two questions posed above. The most global measure, Job Satisfaction, is virtually constant across all three measurement periods. There are only two items which even approach statistical significance. Both seem to indicate a positive environment (increases in income and ability to take unscheduled breaks). Neither is obviously related to the ergonomic intervention. Thus, there is no pattern of psychosocial results which reflects either an apparent effect of ergonomic intervention or a specific organizational stressor which might explain the inflated EMG resting levels.

C. International Comparisons -- Preliminary Data.

This section describes some preliminary results from the international MEPS database accomplished by the MEDSTAT organization. There will be two components of these results. The first will present some univariate comparisons among three participating countries -- Norway, Poland, and U.S. -- across two of the three measurement periods. The second will describe a series of multivariate models attempting to demonstrate some relationships among variables within the combined data base.

1. <u>Univariate Comparisons</u>. The statistical tests on the following materials were accomplished using Kruskal-Wallis tests followed by pairwise comparisons by Wilcoxon rank sum tests with Bonferroni correction. In the following description, only significant paired comparisons will be discussed; the presence of a significant comparison implies a significant overall effect. It may be assumed that all comparisons and tests are conducted at the 0.05 level. Means and 95% confidence intervals will be found in Table 8.

In considering these data, one must keep in mind that the observed results are not necessarily attributable only to national/cultural factors. There may well be social and economic factors among the particular groups sampled. Moreover, the structure of the ergonomic interventions were quite different across the three countries, with the U.S. having the most extensive. At the same time, it should be recalled that all of the participants -- across the three countries -- are performing similar kinds of work.

a. Economic Conditions. Differences in ratings of participants' economic condition are seen between the Norway and Poland, and between the U.S. and Poland in that the economic condition is seen as poorer in Poland. (See Figure 3.) There were no significant differences regarding relative changes from Commencement to 30 Days. That is, the interaction between economic condition and time was not statistically significant. As can be seen in Figure 3, the overall differences among country in level of response are not affected by the time of measurement.

b. Sleeping Problems. There was a significantly higher level of sleeping problems reported by U.S. participants as compared with Norwegians. (See Figure 4.) There were no significant differences regarding relative changes from Commencement to 30 Days.

c. Feelings of Tenseness. There was a significantly higher level of feelings of tenseness reported by Norwegian participants as compared with those from the U.S. (See Figure 5.) There were no significant differences regarding relative changes from Commencement to 30 Days.

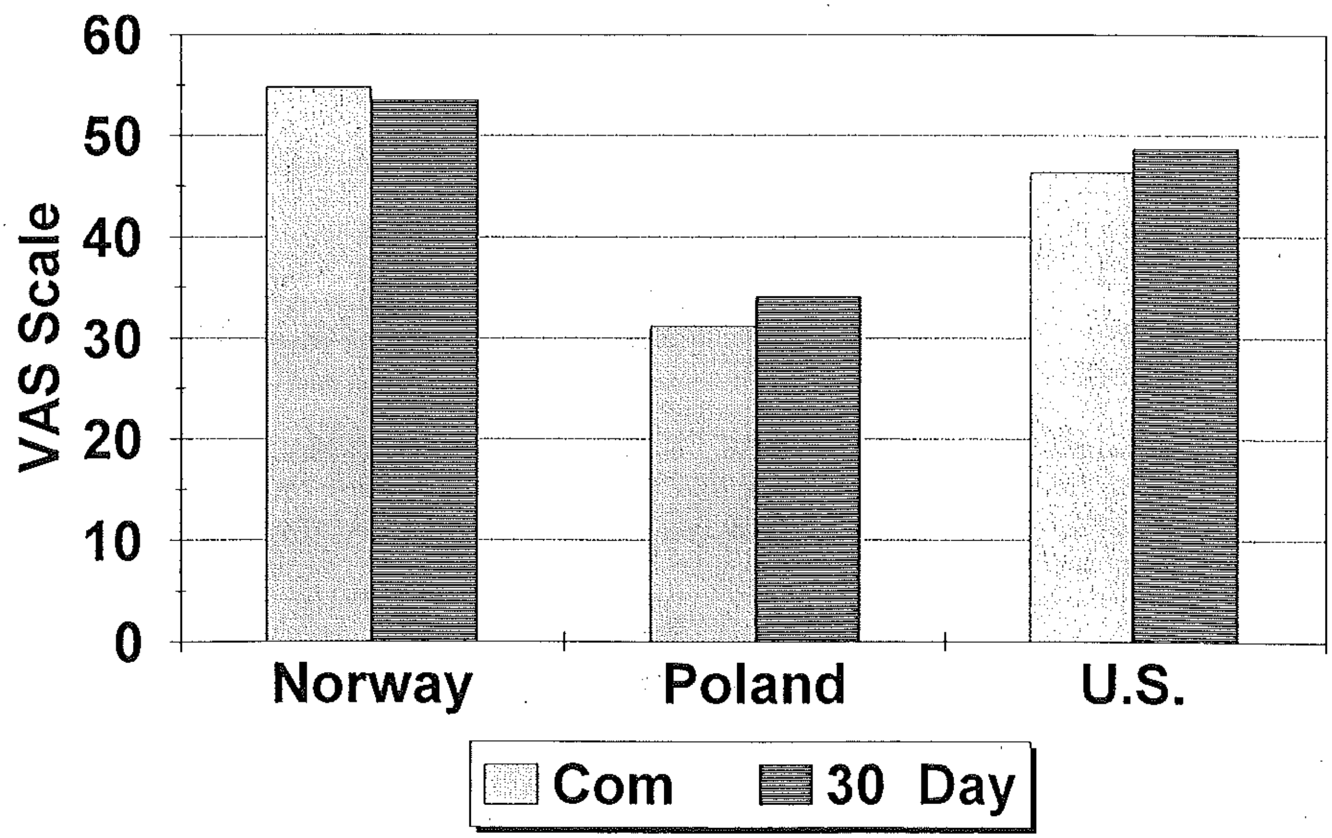
d. Shoulder Pain -- 6 Months. U.S. participants were significantly more likely to report pain in the shoulder during the past six months than were those from Poland. (See Figure 6.) There were no significant differences regarding relative changes from Commencement to 30 Days.

e. Back Pain -- 6 Months. U.S. participants were significantly more likely to report back pain during the past six months than were those from Norway. (See Figure 7.) The relative changes from Commencement to 30 Days approached statistical significance ($p=0.06$) with the U.S. participants showing a larger decrease in pain following the intervention compared with the other two countries.

f. Head Flexion. Significantly greater amounts of head flexion (forward bending) were observed among the Polish participants than for their U.S. counterparts. (See Figure 8.) Moreover, there was a significant difference in the relative change from Commencement to 30 Days between Poland and the U.S., in that flexion increased in the former and decreased in latter.

Figure 3

Economical Conditions



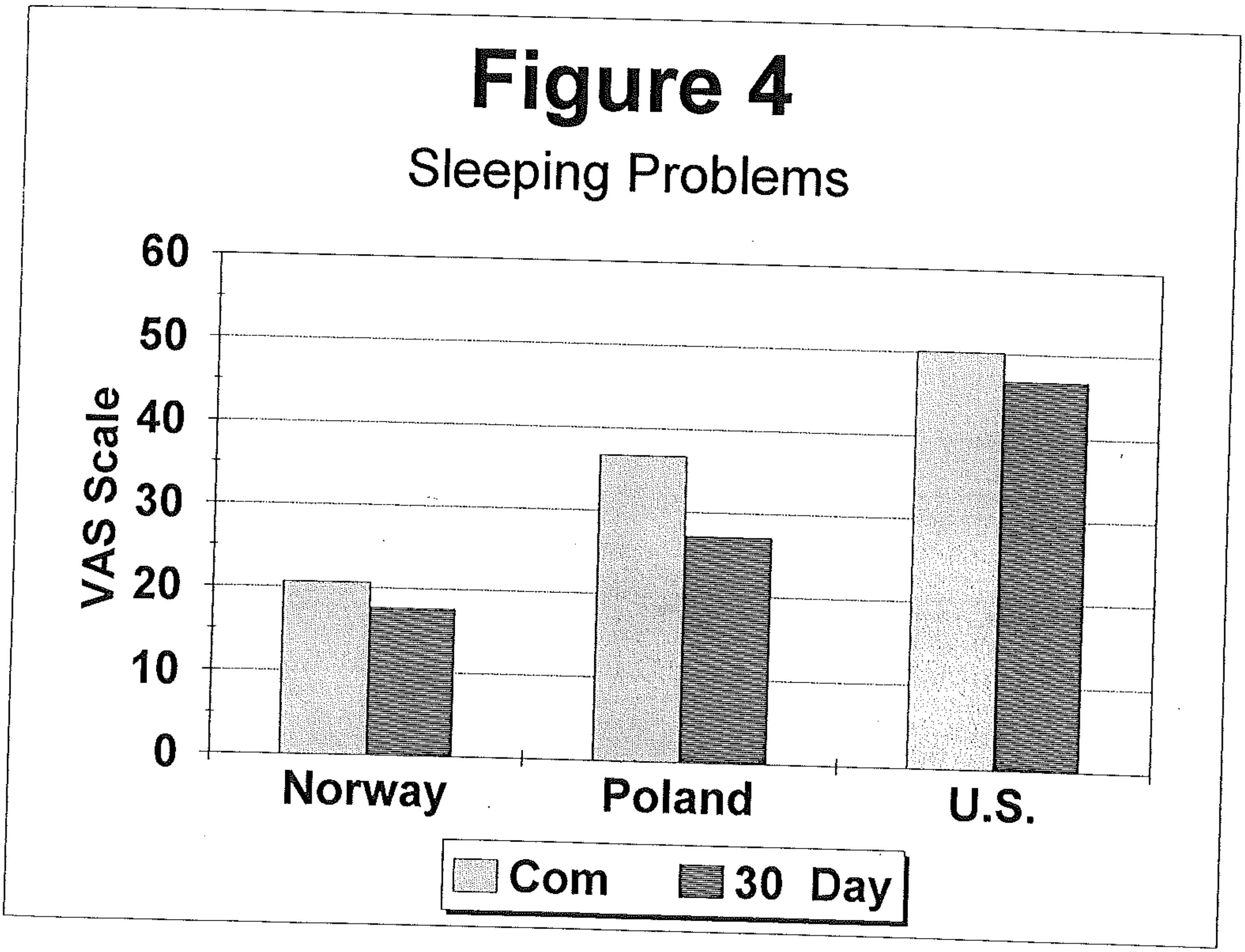
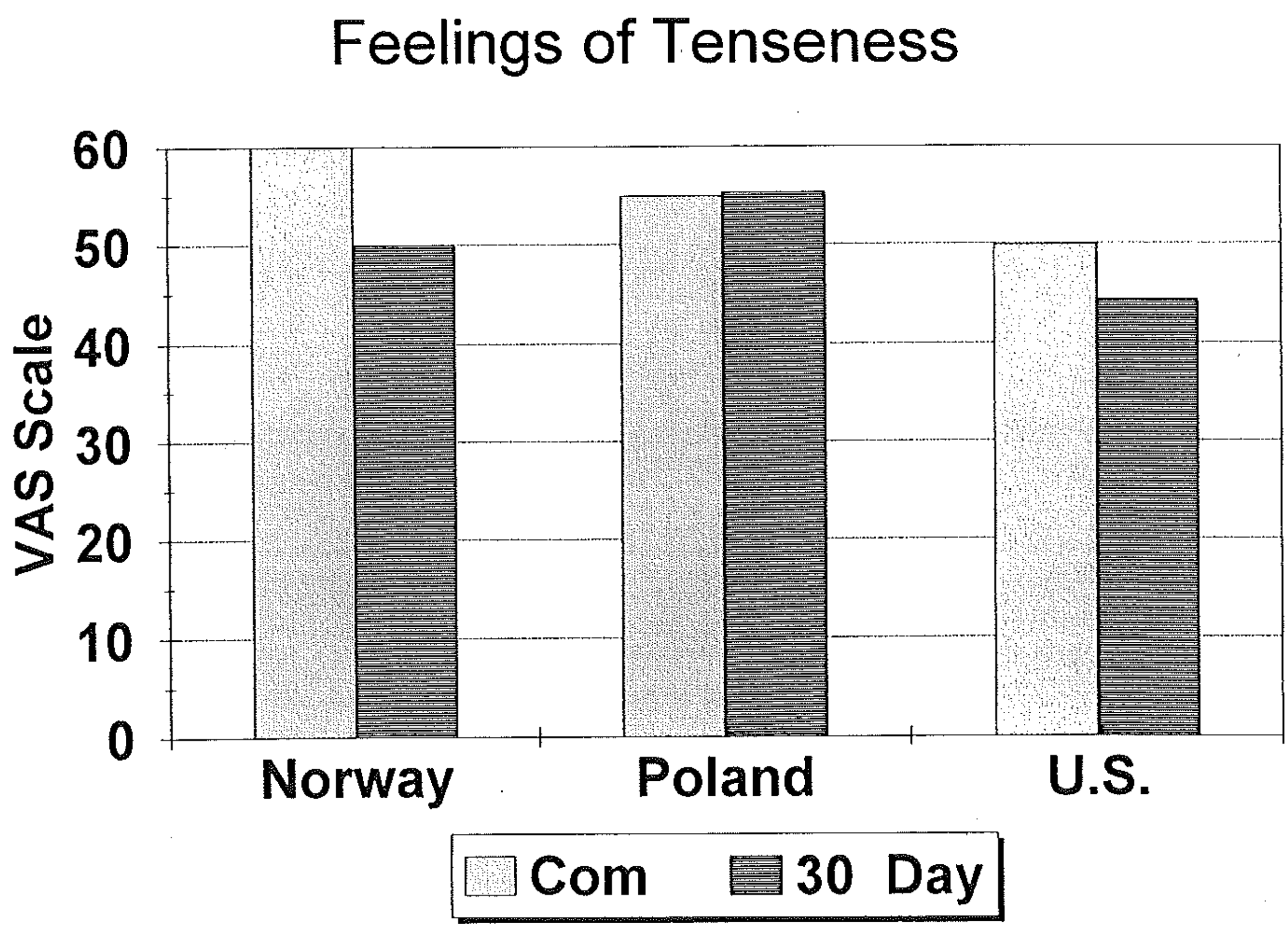


Figure 4
Sleeping Problems
60
50
40
30
20
10
0
VAS Scale
Norway
Poland
U.S.
Com
30 Day

Figure 5


Feelings of Tenseness
VAS Scale
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Norway
Poland
U.S.
Com
30 Day

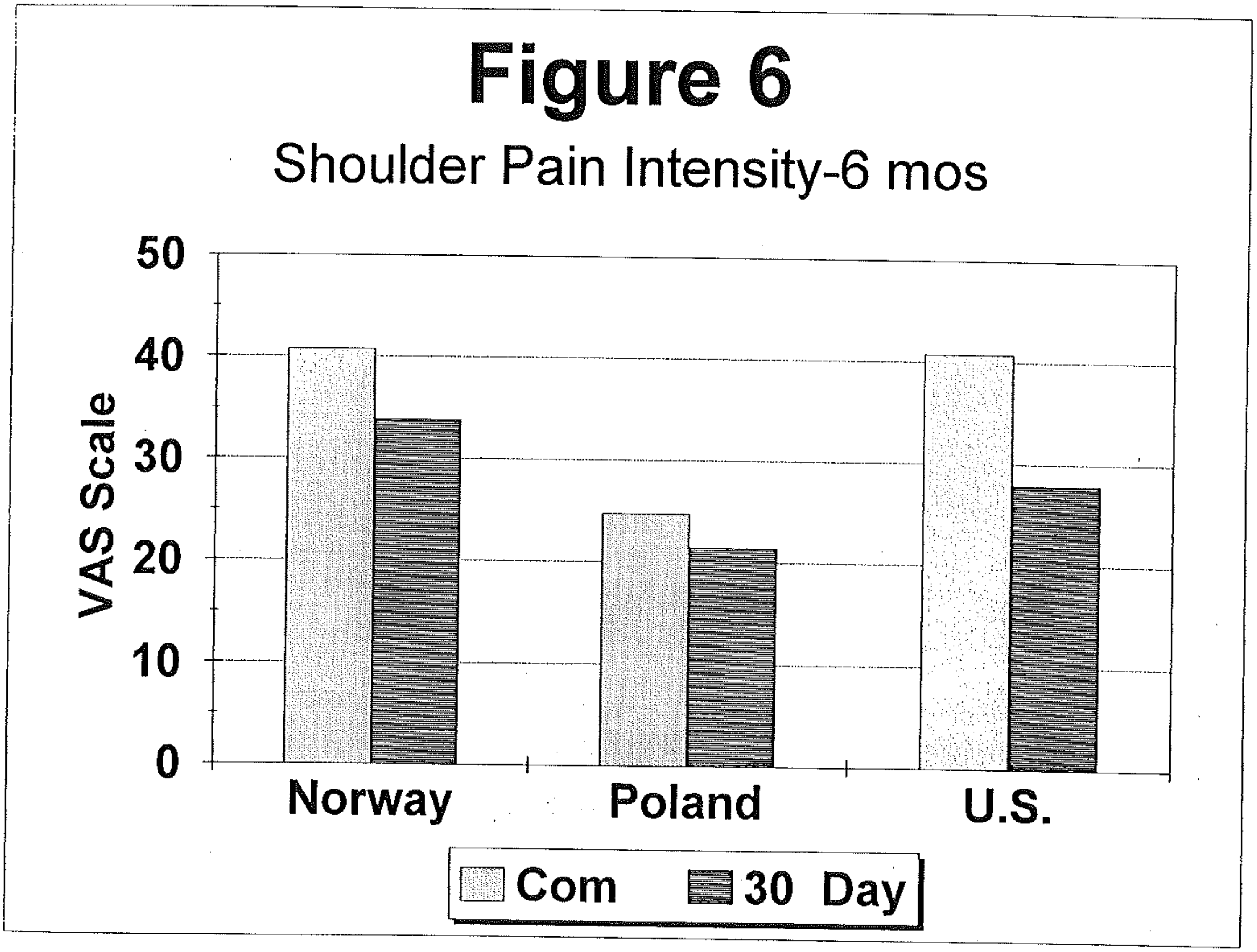
Figure 6
Shoulder Pain Intensity-6 mos
VAS Scale
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40
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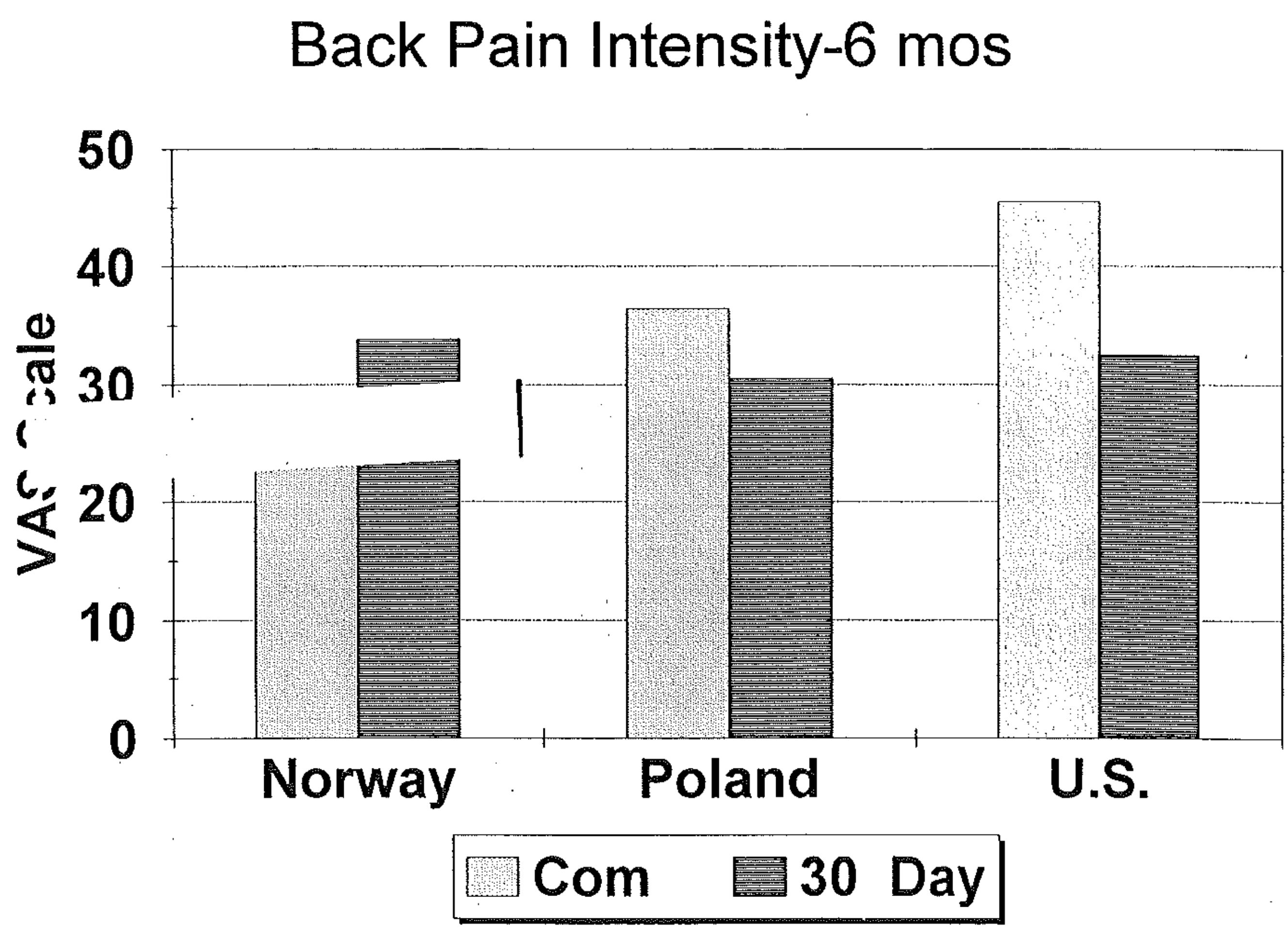
Norway
Poland
U.S.
Com
30 Day

Figure 7


Back Pain Intensity-6 mos
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VAS Scale
Norway
Poland
U.S.
Com
30 Day

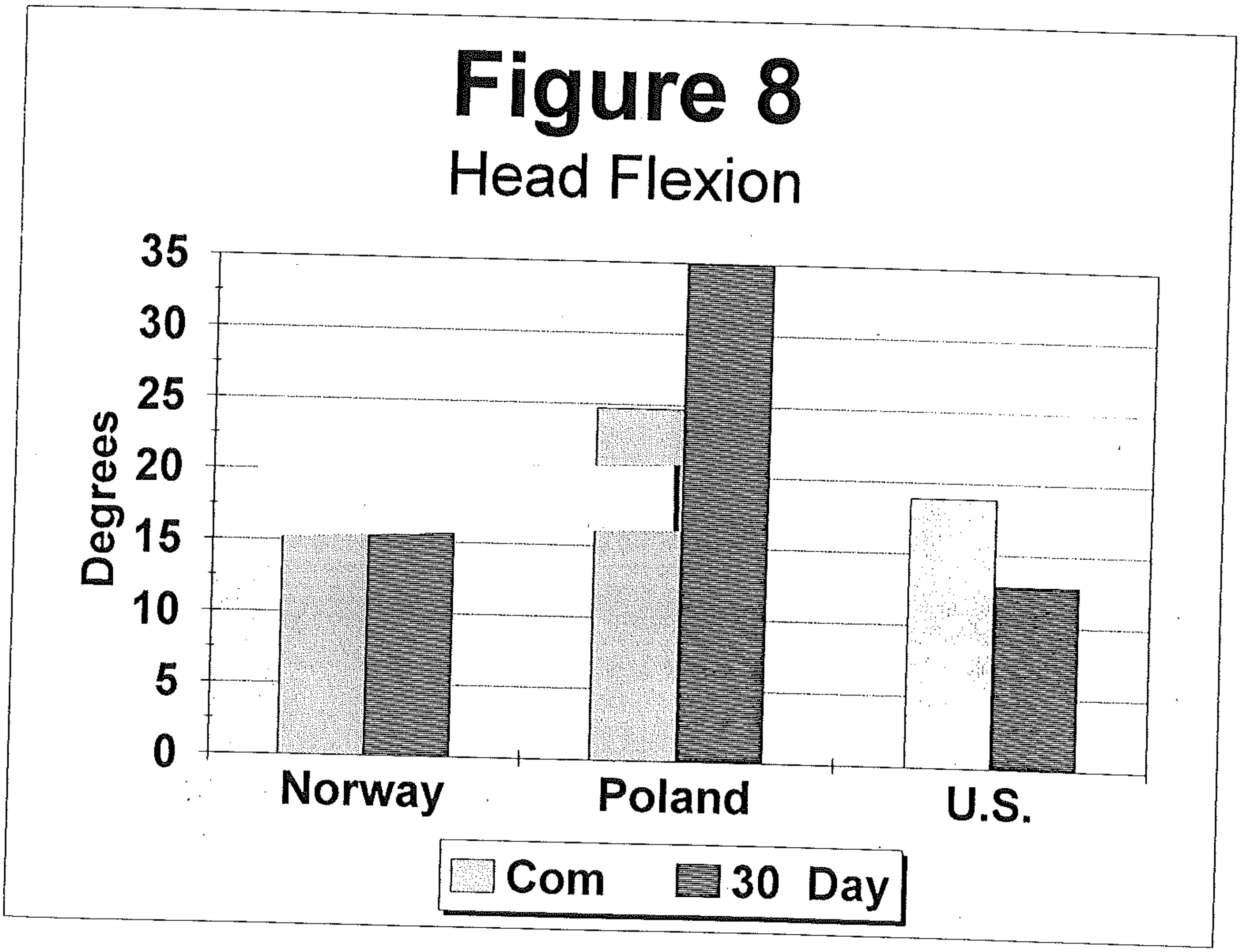


Figure 8
Head Flexion
Degrees
35
30
25
20
15
10
5
0
Norway
Poland
U.S.
Com
30 Day

g. Visual Problems. There were no significant differences among countries in the extent to which problems were present during the past six months. (See Figure 9.)

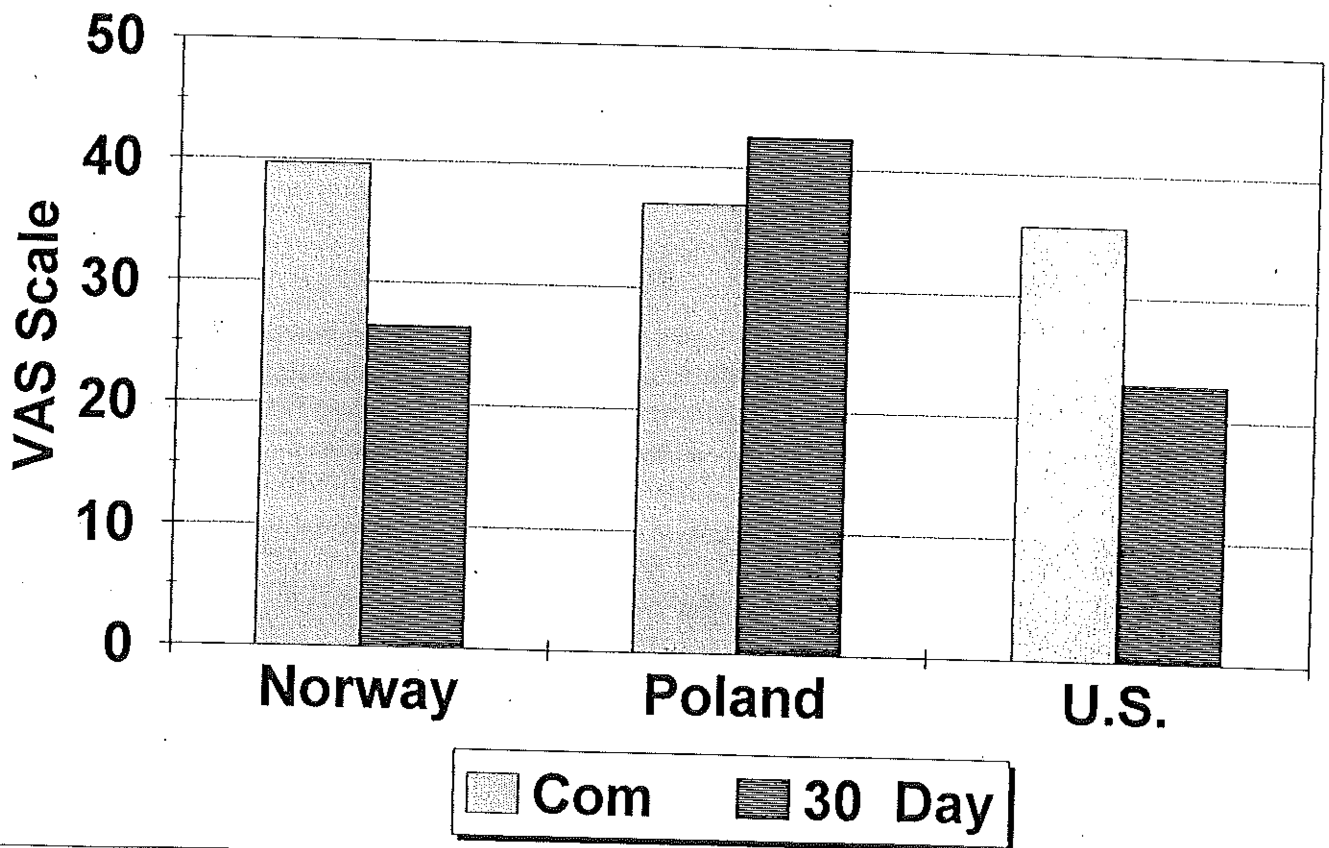
Table 8						
International Comparison Means and Confidence Intervals						
	Norway		Poland		U.S	
	Com	30 Day	Com	30 Day	Com	30 Day
Economics	54.8	53.5	31.2	34.1	46.3	48.7
	8.5	7.7	7.1	5.5	5.7	6.7
Sleep Problems	20.6	17.6	36.7	27.1	50.1	46.7
	8.9	8.7	11.3	12.0	8.5	7.9
Tenseness	60.0	50.0	54.9	55.3	49.0	44.3
	9.4	11.1	12.0	9.7	7.1	6.3
Shoulder Pain	40.8	33.8	24.7	21.4	40.8	27.9
	11.8	11.0	9.8	8.7	8.0	7.1
Back Pain	29.0	33.8	36.4	30.5	45.5	32.5
	9.9	9.6	14.3	11.9	8.6	8.7
Head Flexion	19.1	18.0	24.7	34.9	18.9	12.8
	3.2	4.0	4.1	8.8	1.7	3.2
Visual Problem	39.7	26.4	37.0	42.6	35.8	22.9
	9.9	9.6	9.9	11.7	10.9	9.9

It is of interest that the majority of the significant comparisons among the three countries relate to differences in overall level of response rather than differences in relative changes in response to the ergonomic interventions. Where there are such differences (head flexion, and perhaps back pain), the U.S. data tends to show a more extensive decrease. This can perhaps be interpreted as reflecting the effect of a more extensive ergonomic intervention.

2. Multivariate Analyses. Analysis of covariance was employed to construct a series of models attempting to explain outcome variables, such as pain in different body

Figure 9

Intensity of Visual Problems



areas in terms of work load and individuals. A series of preliminary findings is shown below. All relationships are significant at least at the 0.05 level.

a. A weak negative relationship is seen between average intensity of neck/shoulder pain during the past six months, and average time when trapezius muscle load is below 1 % MVC.

b. There is a significant relationship between visual problems and average intensity of neck/shoulder pain during the past six months.

c. There is a significant relationship between neck/shoulder pain during the past six months and family problems, sleeping problems, and feelings of tenseness.

d. Average intensity of neck/shoulder pain during the past six months relates significantly to the clinical isometric test.

These results, while preliminary, indicate that both visual and psychosocial concerns are associated with musculoskeletal symptoms. Such findings emphasize the importance of the multidisciplanary approach adopted in the present study.

D. Productivity

Productivity analyses, carried out independently of the MEPS protocol, are described below. This analysis utilized a data set consisting of individual productivity records of study participants made available by Data Conversion staff, and covers the period of the intervention as well as the previous one and one half years.

1. <u>Preparation of the Material</u>. Quarterly productivity records were made available for each of the participants. We also obtained a parallel set of productivity records for a group of comparable Document Conversion personnel who did not participate in the study.

Productivity data included both quality and quantity. An example of the Quarterly Individual Performance Summary Report is shown in Appendix A. The analyses carried out on these data were based on standard procedures used by Data Conversion Branch to rate employees who were not otherwise measurable during a given reporting period. An outline of these procedures follows; a sample work sheet is also included in Appendix A.

a. Analysis Procedure -- Quality

A total of all documents reviewed under document processing functions was obtained. (See Docs Rev'D column in Appendix A.) Note that work performed under function 990 was not included. Next, those programs were identified in which at least 30 documents had been selected for quality review. For each such identified program, percent accuracy was used to identify the appropriate quality rating from the fixed performance standards for that program. For example, an accuracy of 96.7% in program 11200 yields a rating of 3. These ratings were summed across all programs. Next, a quality index for each program was computed by dividing the number of documents reviewed per program by the total number of documents reviewed, and expressing the result as a percentage. This index was then multiplied by both the percent accuracy and the obtained rating. The result was a weighted score for percent accuracy and quality rating for each program. Finally, overall adjusted accuracy and ratings -- across all reviewed programs -- were computed by dividing the summed weighted accuracy or rating scores by the summed quality indices. These last two values -- obtained for each participant at each quarter -- were what formed the basis for the subsequent analysis.

b. Analysis Procedure -- Quantity

The quantity analysis was similar in structure to the quality analysis just described. First, a total was obtained of all hours worked on document processing . Next, those programs were identified for which the participant had worked at least 40 hours. For each identified program, the number of documents per hour processed was used to identify the appropriate quantity rating from the fixed performance standards for that program. For example, a rate of 54 documents per hour yields a rating of 3. Next, a time weight for each program was computed by dividing the number of hours worked per program by the total number of hours and expressing the result as a percentage. The time weight was then multiplied by the quantity rating to obtain a weighted rating score. Finally, overall adjusted quantity was computed by dividing the summed weighted rating scores by the summed time weights. This value formed the third element of the data obtained from a given participant in a given quarter.

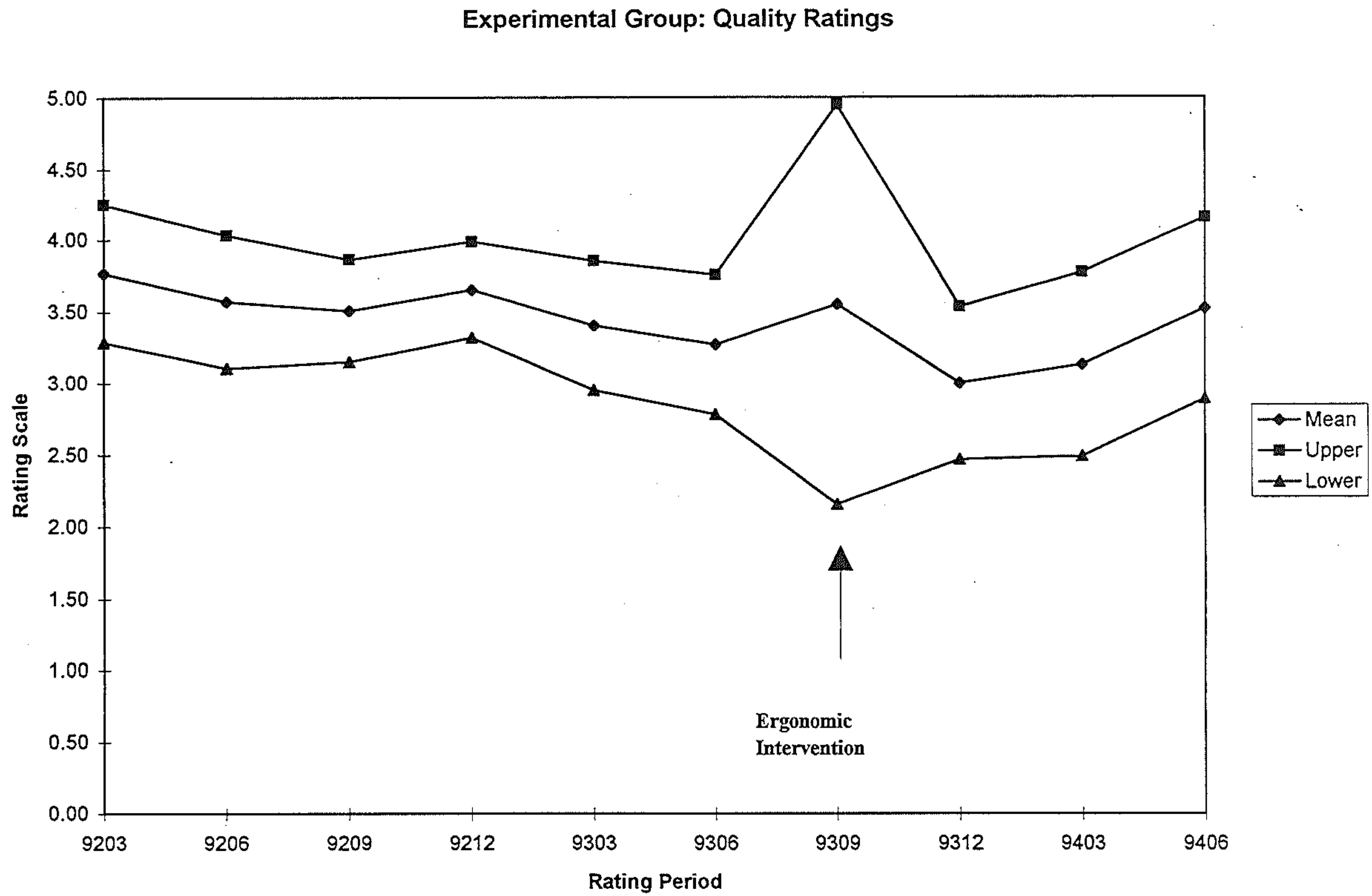
2. Primary Analysis -- Results . Appendix B contains accuracy ratings, percent accuracy, and quantity ratings for each of the original 27 participants in study. Data are tabulated by quarter and year; hence 9203 reflects data collected through January -March 1992. Also listed are means and standard deviations.

As is indicated, many of the data elements are missing. This was typically because participants were assigned to other duties (such as serving as lead clerks) during the reporting period. With this many missing cells, it would be inappropriate to carry out inferential statistics. Thus, the results and discussion will be based on descriptive statistics only.

Appendix C contains the data from the six control group participants for whom there was complete data across each of the quarters analyzed.

Figure 10 depicts the mean and upper and lower bounds of the 95% confidence interval for quality ratings. (Confidence interval = Mean +/- 1.96 [Standard Error of the

Figure 10
Means and Upper and Lower 95% Confidence Interval



Mean]). It can clearly be seen that, while the mean rating actually increased during quarter 9309--the first quarter measured after the intervention -- the variability was considerably larger than for other periods. During the next intervention quarter, the mean rating is slightly lower, but the variability has returned to where it was in the quarter just preceding the intervention. Finally, the two quarters of 94 show an apparent upward trend back to the level of 92 and 93. The comparable data from the control group, seen in Figure 4, do not show fluctuations in variability although, interestingly, there does seem to be a hint of an upward trend during the last three quarters paralleling the experimental group.

Figure 11 depicts mean and upper and lower bounds of the 95% confidence interval for percentage accuracy. These data are puzzling. They reflect a rather sharp drop in accuracy below earlier time periods, but this occurs in the quarter before the intervention--9306. Accuracy measured during the quarter after the intervention was also lower, but the data show a clear tendency towards movement back to the pre-intervention levels. The control data in Figure 13 do not help in explaining this result. There is a very slight drop in accuracy during quarter 9306, but nowhere near the magnitude of that in the experimental group.

Figure 12 depicts mean and upper and lower bounds of the 95% confidence limits for quantity ratings. Here the picture is clear. There is a substantial decrease in quantity (approximately one scale value) during the immediate post-intervention quarter. However, here again, in the subsequent quarters, the data return to previous levels. Inspection of the comparable control data from Figure 13 indicates a very stable pattern of quantity ratings.

Figures 14 and 15 allow a direct comparison between experimental and control subjects. Figure 14 compares means of the post-intervention reporting periods against the averages of all of the pre-intervention values for all 27 of the experimental participants and the six control participants.. Error bars indicate 95% confidence bands as described earlier. Finally the same plot is shown in Figure 15, but now in which the comparisons are made only between experimental and control participants for whom records were available in all reporting periods. (Inspection of Appendix B indicates that quality data was available in all reporting periods for 11 participants, and quantity data was available for 9 participants in the experimental group. Again, 6 control subjects had data in all periods.)

A comparison between Figures 14 and 15 yields virtually identical patterns of means. The only difference is that the variability of the experimental data is greater in Figure 14. (The variability is so low for the experimental participants in Figure 15 that the error bars disappear into the plotting symbols.)

3. <u>Additional Analysis -- Results and Discussion</u>. Let us first consider the results of study participants alone as seen in Figures 1-3. The rating data show a clear picture.

Figure 11
Means and Upper and Lower 95% Confidence Interval

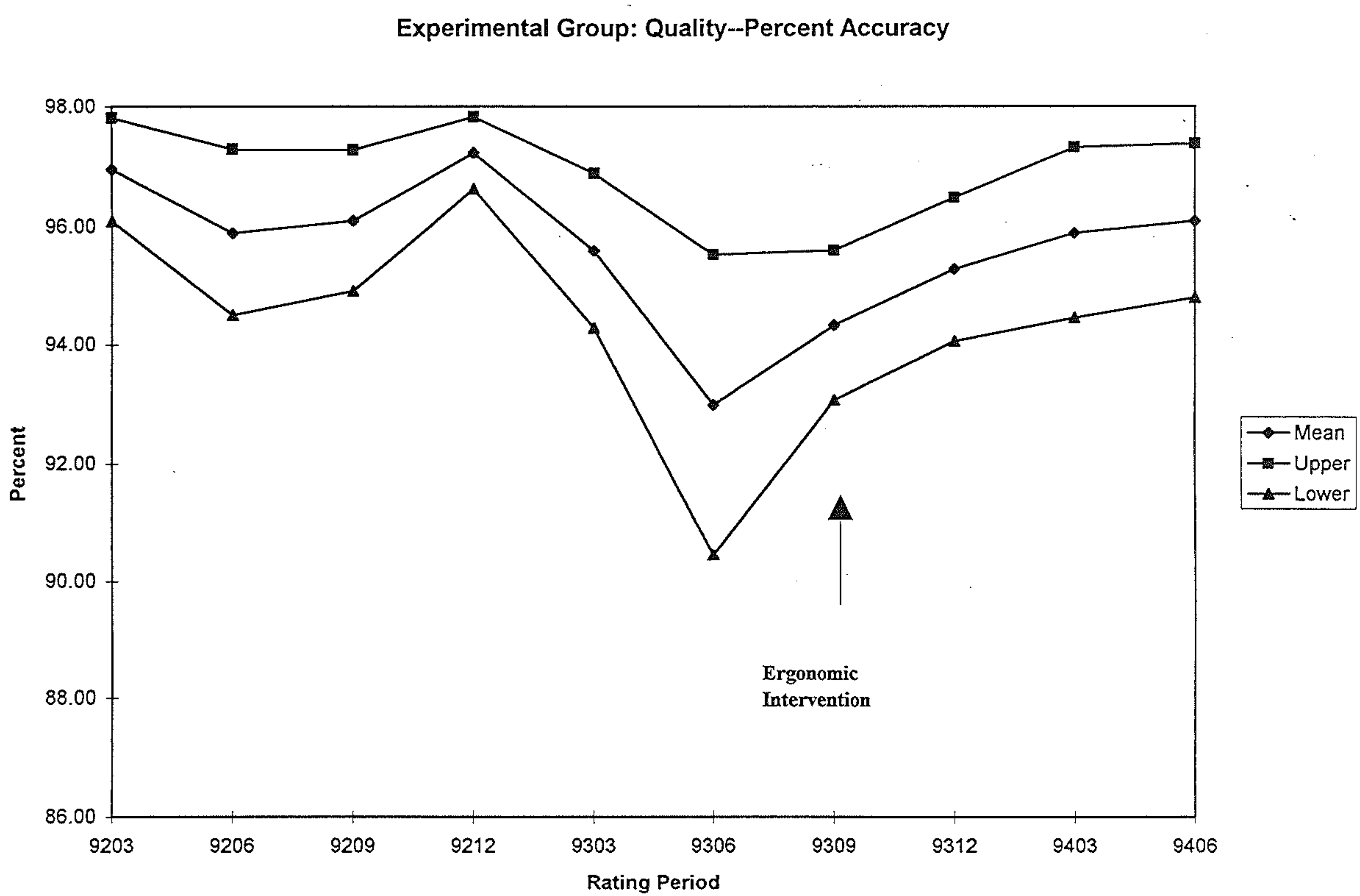


Figure 12
Means and Upper and Lower 95% Confidence Interval

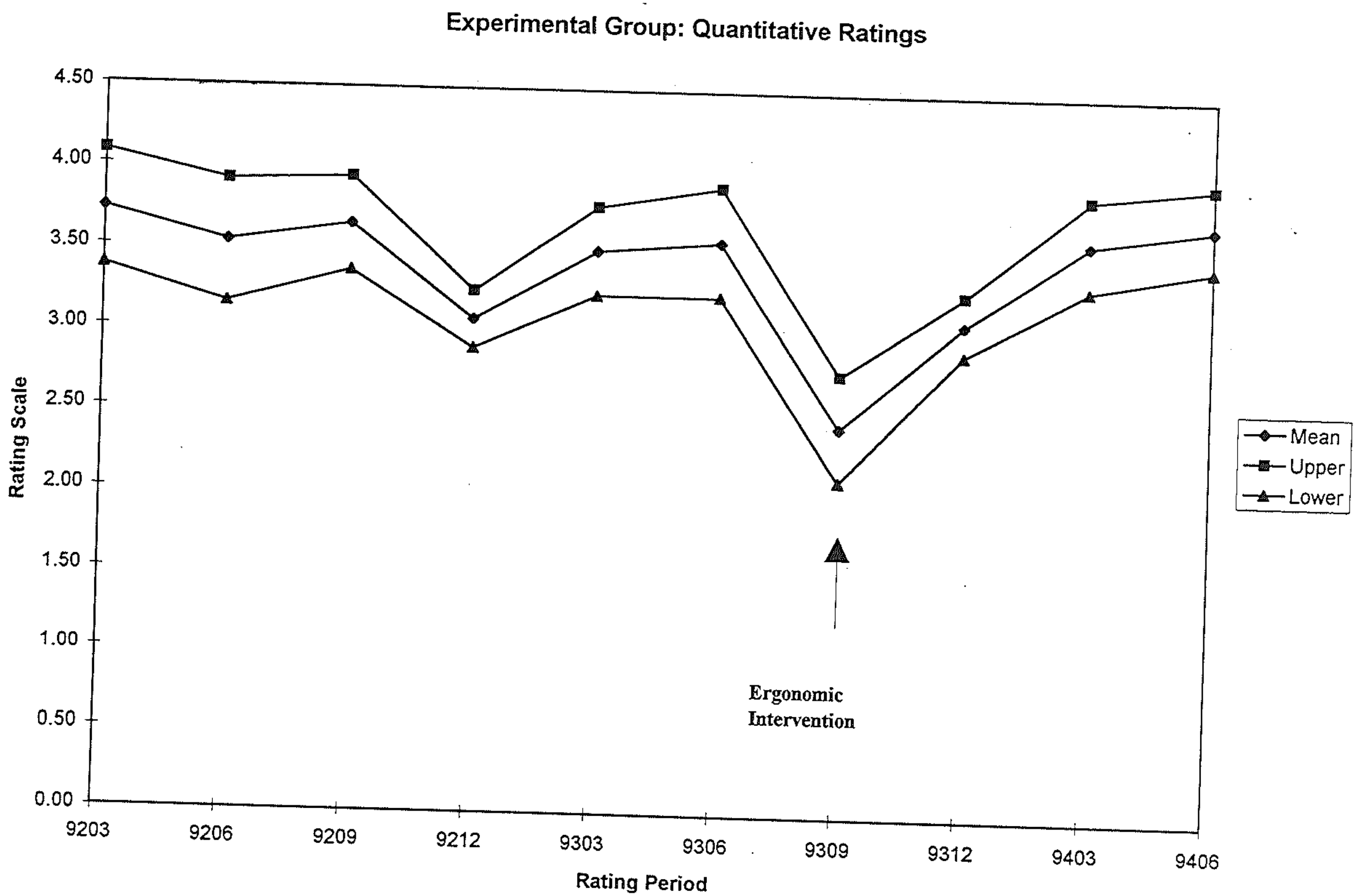
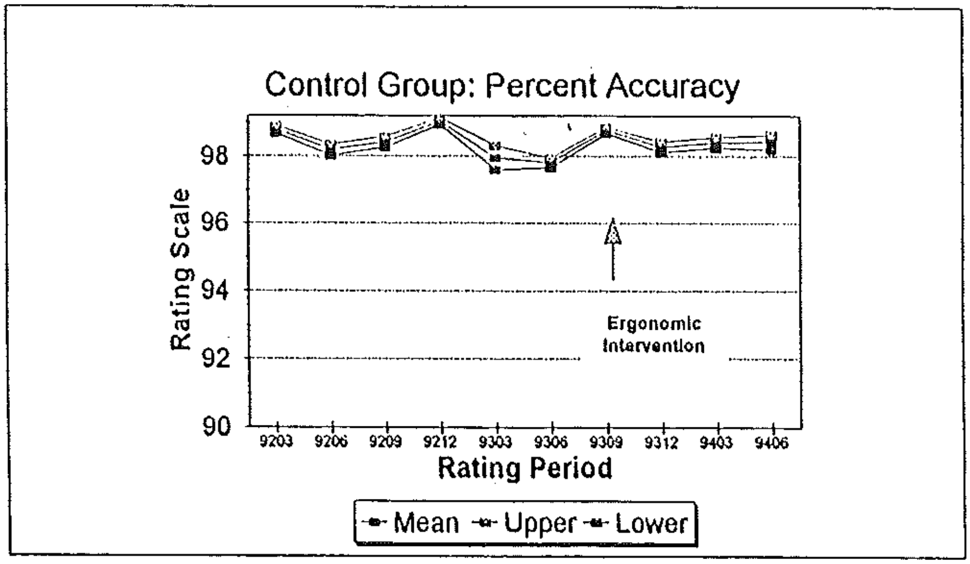
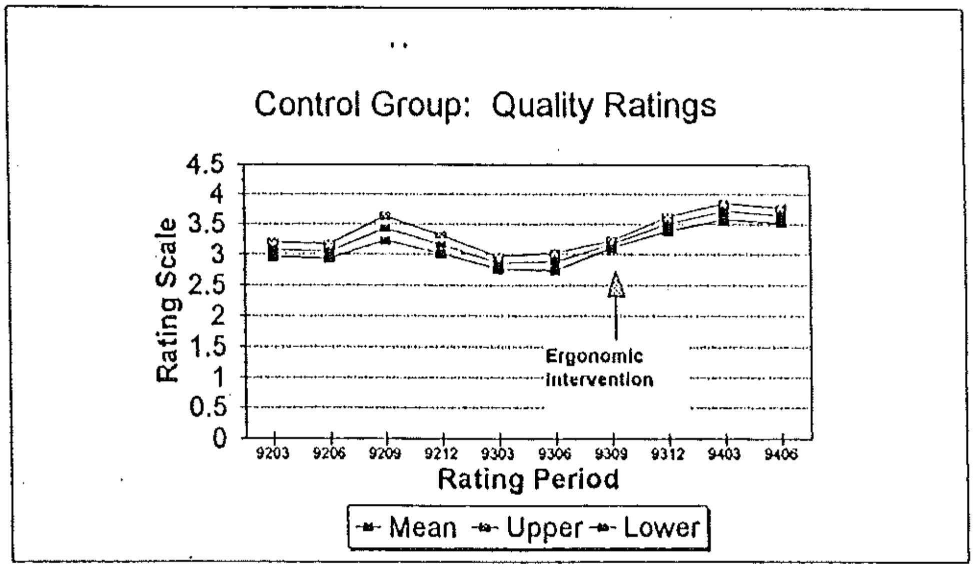


Figure 13


Control Group: Percent Accuracy
Rating Scale
98
96
94
92
90
9203 9206 9209 9212 9303 9306 9309 9312 9403 9406
Rating Period
Ergonomic Intervention
Mean Upper Lower


Control Group: Quality Ratings
Rating Scale
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
9203 9206 9209 9212 9303 9306 9309 9312 9403 9406
Rating Period
Ergonomic Intervention
Mean Upper Lower

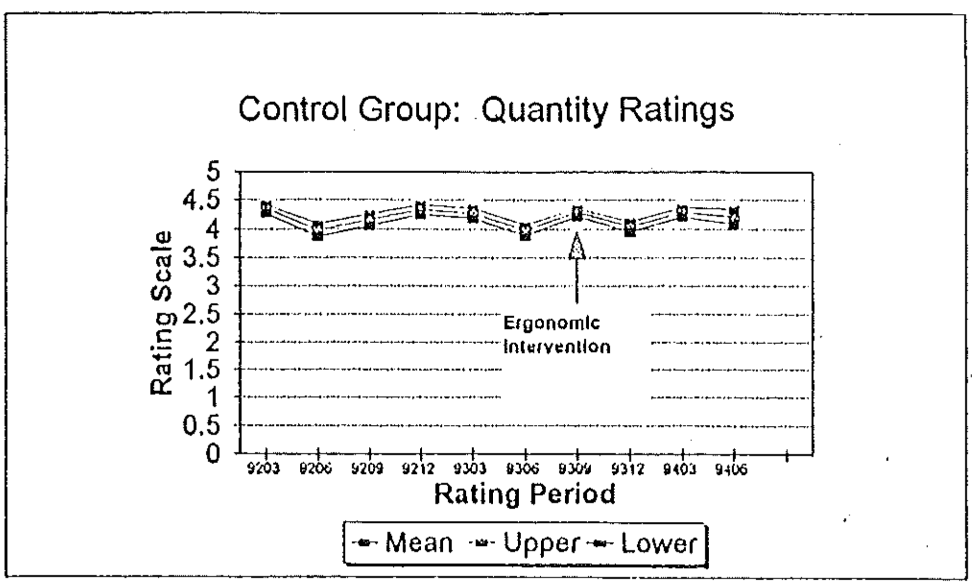
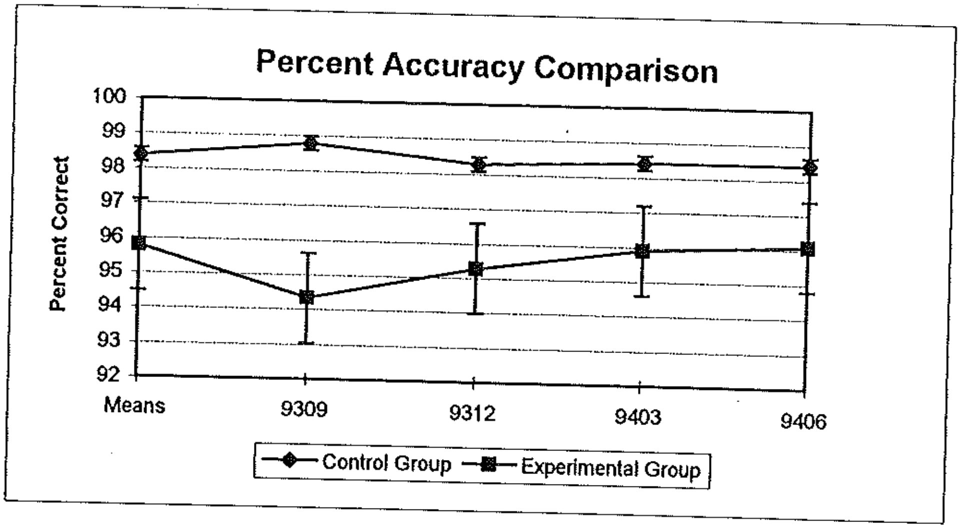
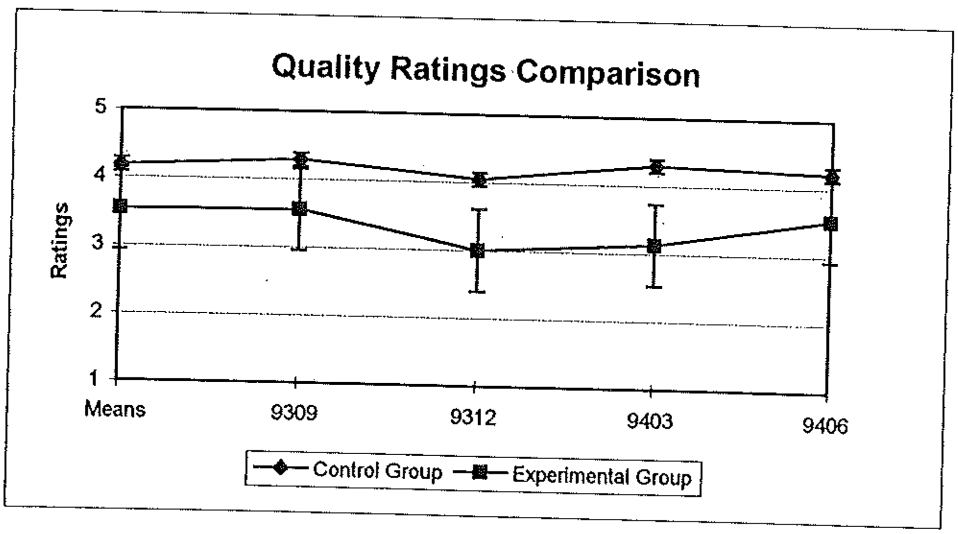

Control Group: Quantity Ratings
Rating Scale
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
9203 9206 9209 9212 9303 9306 9309 9312 9403 9406
Rating Period
Ergonomic Intervention
Mean Upper Lower

Figure 14

Comparison of Post-Intervention Data with Pre-Intervention Means:





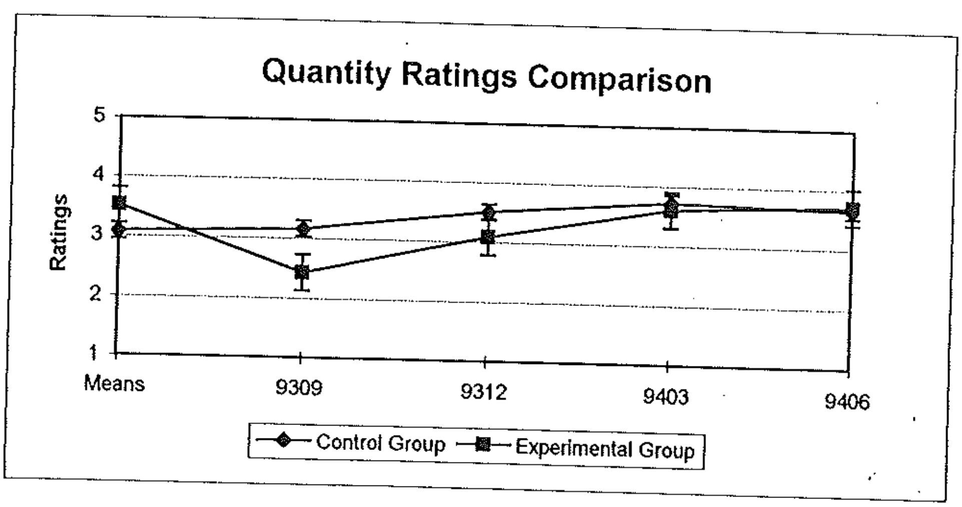
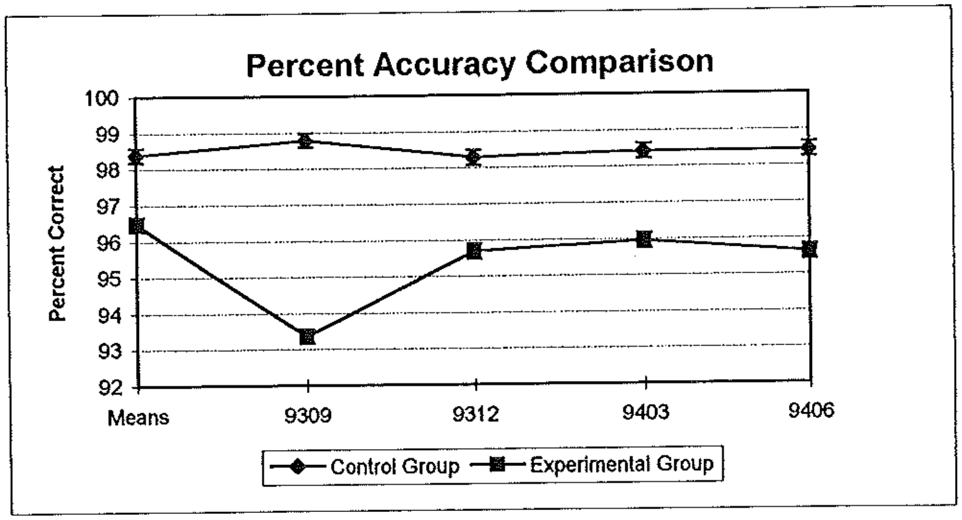
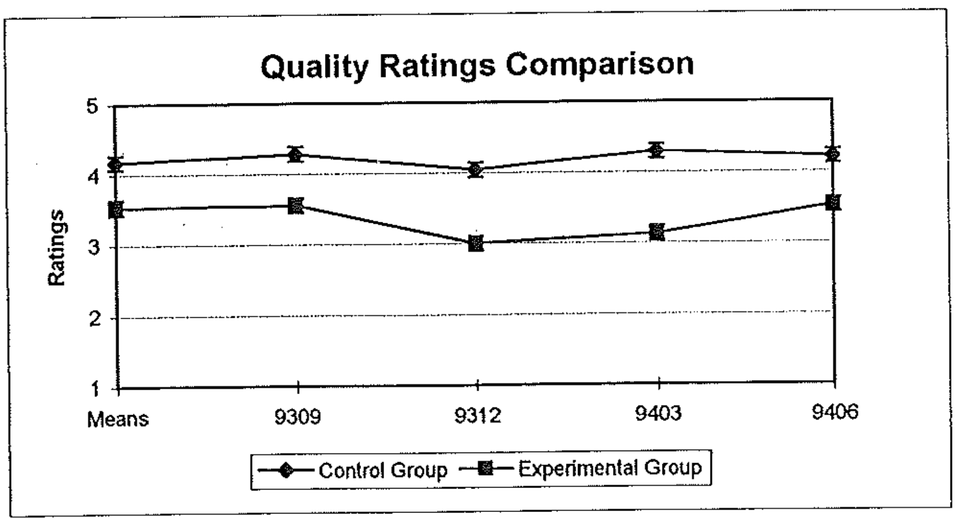
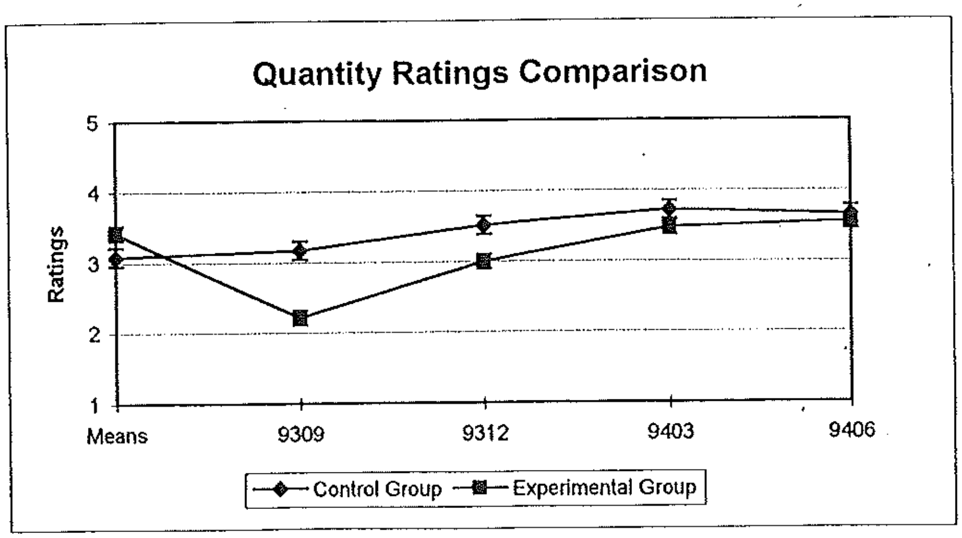


Figure 15

Comparison of Post-Intervention Data with Pre-Intervention Means:
[Participants with Complete Data Only]







During the months of July, August, and September of 1993 -- those periods where the participants were receiving their new equipment and getting used to their new glasses and keyboards -- performance was clearly disrupted. This is shown by the increase in variability in ratings of quality, and the decreased ratings of quantity. However, in the following quarter, there is just as clear an indication that the participants were getting used to their new equipment and that both quality and quantity had improved. Certainly, by first and second quarters of 1994, productivity was just as good as it was during comparable periods of 1992 and 1993.

In the case of percentage accuracy, the pattern of results is consistent, but the reason for the drop in accuracy prior to the intervention is not clear. In looking at these data, however, it must be realized that accuracy demands across programs are not identical. For example, the minimum accuracy required to attain a rating of 2 ranges from 85% (program 13131) to 97% (program 11110) Possibly, the drop reflects an unusual frequency of more difficult programs during that period. In any case, there is no reason to draw conclusions from accuracy data that are any different than those described above.

These interpretations can be supported by the data seen in Figures 14 and 15 in which the four post-intervention periods are compared with the means of the six pre-intervention periods (located on the y axis). While the average control group accuracy and quality ratings are consistently higher than the experimental group, they are also relatively stable. Thus, there is no compelling reason not to attribute the fluctuations in the experimental data to anything other than the effects of the intervention.

For purposes of this analysis, therefore, we can assume that these pre-intervention data consist of a baseline or standard against which the effect of the intervention can be compared. If one examines both means and confidence limits, it can be seen that percent accuracy has returned to baseline by 9403, and quantity ratings, by 9312. The quality ratings are a bit puzzling since it appears as if the negative effects of the intervention have been delayed by a quarter. However, if we refer back to Figure 10, we can reasonably argue that a large portion of the recovery has occurred by 9403, since the level of performance during this period is virtually identical to the period just prior to the intervention. Hence, we can argue, that, for all practical purposes, operator performance was back to normal by 9403. The recovery during the first two quarters of 1994 is particularly encouraging since this reflects the operators' first use of their ergonomic equipment during the height of the tax season.

V. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

A. The Effects of the Intervention -- MEPS Protocol

1. Positive Outcomes: Results from the selected critical variables indicate a remarkably clear and consistent pattern of evidence indicating the effectiveness of the ergonomic intervention. This pattern is based on several independent sources of measurement.

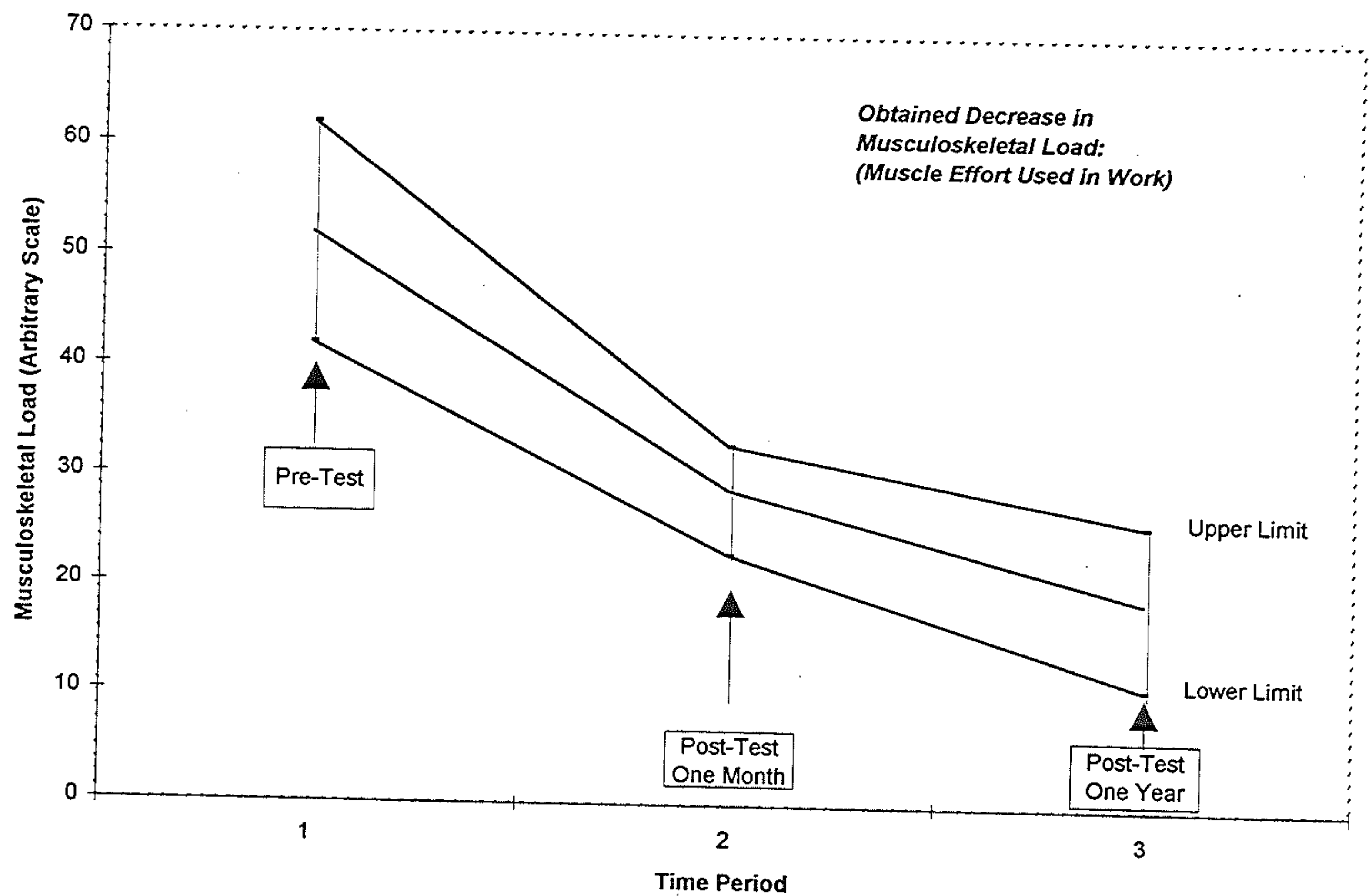
The physical examination, which involved relatively objective assessments of physiological signs of musculoskeletal disorders, revealed a dramatic drop in the number of such signs following the intervention -- a drop which was maintained for a period of one year. These physiological results were identical to those observed in the participants' combined ratings of intensity and frequency of musculoskeletal pain, and for each of the symptoms of visual problems. Further indications that intervention led to healthier and more efficient working postures were as follows. First, direct measurement of head and trunk angles showed a decrease in the amount of flexion (awkward forward bending). This was confirmed by a parallel decrease in the ergonomist's standardized assessment of indicators of static load. Second, two indicators of the participant's own assessment of the ergonomic adequacy of the workplace -- seat comfort and adjustability of keyboard support surface -- showed dramatic increases following the intervention.

This pattern of results supports the conclusion that the ergonomic intervention was highly effective. The combination of training plus highly adjustable equipment produced a measured improvement in working posture along with a perception, by the participants, that their work environment had, in fact, been improved. The hypothesis was that this improvement in working posture would have, in turn, reduce musculoskeletal load and produce a consequent drop in signs and symptoms of musculoskeletal disorder. These drops were observed. Finally, the decrease in visual problems seems to indicate that the optometric intervention was likewise effective.

Figure 11 represents a composite measure of biomechanical load in which results from the physical examination, pain reports, static load judgements, postural angles, and judged seated comfort are normalized against a scale of 0 to 100 and averaged. Error lines are obtained from 95% confidence limits. Comparing Figure 11 with Figure 1 indicates that we have, indeed, supported our predictions that musculoskeletal load would decrease as a result of the intervention.

2. Unexpected Results. Examination of the two unexpected results suggests that neither seriously contradicts the above conclusion. The observed increase in arm flexion can be attributed to a required readjustment in working posture due to the new configuration of the keyboard. If this increase in flexion had actually increased

Figure 16
Combined Results



musculoskeletal load, we would have expected an increase in signs and symptoms of shoulder discomfort. In fact, exactly the opposite occurred. Evidence from the physical examination, subjective reports, and partial results from the EMG data suggest that the higher flexion levels represented a beneficial adaptation to a new work place configuration.

With regard to the problem of the EMG results, we have no definitive answers. We observed a distinct increase in the amount of time the EMG signal was below 1% MVC immediately following the intervention. This effect is considered a critical indicator of reduced load (Aarås et al., 1990). We believe that the results from the one year post test represent either an equipment malfunction or a widespread local stressor which raised participants' resting levels. However, if this occurred, it was not detected in the psychosocial questionnaire responses. In either case, the most reasonable strategy is to discard the one year posttest, and accept the marginal results from the first two recording periods, which are completely consistent with the remaining pattern of results.

3. International Database. Results from the international database, while preliminary, are suggestive. With respect to the series of direct comparisons among the three participating countries, the majority of the differences were differences in baseline levels of variables. These are to be expected; it would be more surprising not to find such differences. Of the seven variables analyzed, only one -- head flexion -- showed a significant difference between countries in terms of patterns of responses to the ergonomic intervention. A second variable, back pain, approached statistical significance on this dimension. In both cases, however, the U.S. results showed a greater positive effect of the ergonomic intervention than the other countries. This is suggestive in the sense that the U.S. intervention was much more extensive than that of the other two countries.

The multivariate results, while very preliminary, begin to give important information regarding linkages among variables. Perhaps most important is the finding of a relationship between visual problems and intensity of neck and shoulder pain. A major factor in the history of the development of the MEPS project was the realization that visual and musculoskeletal concerns, while typically addressed in an independent, piecemeal fashion, are, in fact, interdependent. Similar support for the importance of psychosocial factors is seen in the positive relationship between neck/shoulder pain, and feelings of tenseness, sleep problems, and family problems.

B. The Effects of the Intervention -- Productivity.

Quality and quantity productivity records from MEPS study participants and a control group of non-participants were examined from six quarters prior to the ergonomic intervention and four quarters following the intervention. Since not all participants had records available from each quarter, the analysis was based on descriptive rather than inferential statistics. Results indicated that both quality and quantity measures were disrupted during the initial quarter following the intervention, but that there was clear evidence that this disruption was short lived, and that by the first quarter of 1994, productivity had essentially returned to baseline.

However, the goal of the ergonomic intervention was to improve working conditions. Can we be satisfied with just demonstrating a return to baseline?

There are several issues involved in this discussion. First, a key element of the intervention was the introduction of a fully adjustable keyboard. The primary advantage of the keyboard was that it allowed the operator's wrists and hands to attain a more natural posture, thereby reducing the load on the musculoskeletal system. The outcome from such a load reduction should be reflected in reduced muscle complaints and symptoms. Results appearing in this report indicate that we have clearly attained that goal.

At the same time, it is reasonable to assume that the primary cause of the initial drop in quality and quantity can be attributed to the different and changing mapping of keys and the different (improved) touch of the new keyboard. Because of the discrepancy between the modern IBM/AT layout of the adjustable keyboard and the older specialized layout of the Motorola, it was not possible to achieve an exact match in key layout. In fact, it took several iterations before an layout which was even acceptable could be achieved. Furthermore, the physically demanding (and potentially injurious) pounding required by the Motorola was replaced by state-of-the-art, light-touch keys.

Given the extensive experience of our group participants with the older keyboard (the average duration of employment at IRS was 15.7 years), it is not surprising that some time would be required to readapt to a new keyboard layout. Therefore, the introduction of the new, more efficient keyboard to operators who have used the same keyboard for many years, represents a major technological change requiring a major change in keying technique. In fact, the transient disruption and return to baseline is precisely what would be predicted for any technological innovation, and represents a typical tradeoff of short term loss for long term gain. (See, for example, Cyert and Mowrey, 1989.)

Two additional points may be relevant. First, we were not able to obtain sufficient productivity data to determine whether the productivity levels would actually increase over baseline. Even if these levels did not increase, however, a case can be made that the long term benefits resulting from this new technology are manifest in more indirect ways. Specifically, the work output itself may not improve drastically -- particularly among experienced employees who may be close to their own personal limits of keying rates -- but the likelihood of lost work hours due to cumulative trauma disorders should be much lower. This also would result in an improvement of organizational productivity. This argument will be further developed below.

Secondly, since the MEPS protocol had been developed prior to the commercial availability of adjustable keyboards, it did not contain items relevant to such adjustability. Thus, we had to rely on other, more informal, methods to determine participants' reactions.

Some participants expressed concern over their ability to adjust to the new keyboard. Three of them switched back to the old keyboard during the course of the study (all after the 30-day posttest). The majority of participants adapted to the keyboard, and many were extremely enthusiastic about it, despite the initial loss in incentive pay due to the drop in productivity as they acclimated to the key layout. One participant actually offered to purchase her keyboard herself, rather than give it up at the end of the study.

Two or three participants also preferred their old chairs, which, during training, they had learned for the first time how to adjust.

At one point in the study, computer maintenance made it necessary for the participants to go to another node with the old workstations for a week. Many commented about increased musculoskeletal problems during that week; they expressed great relief when they returned to their ergonomic workstations.

C. Cost Benefit Issues:

The ergonomic intervention carried out in the context of this project has been extensive. There may have been more extensive ergonomic interventions carried out in office environments but, to our knowledge, this is the most extensive which has been documented for scientific assessment. The question to be posed is: can such an investment be considered cost-effective? The response to this question will have three components.

First, there is now an extensive literature documenting the beneficial effects of ergonomic interventions. Some of these studies have focused primarily on physical ergonomics -- seating, workstations and lighting. Dainoff (1990), Francis & Dressel (1990), Sullivan (1990) have each documented specific tangible benefits in term of increased productivity resulting from the employment of well designed ergonomic equipment. (See also Dainoff and Dainoff, 1986.) The most carefully documented analysis of the cost-effectiveness of an ergonomic intervention is that of Aarås and his colleagues (Spilling, et al., 1986). They determined that, over an eleven year period, the savings to the company resulting from the ergonomic intervention was over 850% of the initial investment.

In the detailed cost-benefit analysis reported in the work of Spilling and his colleagues, just cited, it is of considerable interest that a large fraction of the savings resulting from the ergonomic investment can be attributable to reduction of what are normally considered overhead items: training costs for replacement workers, medical expenses, sick leave, etc. In a compelling discussion regarding organizational barriers to technological innovation, Cyert and Mowrey (1989) point out the paradox that, while initial benefits to an organization from a technological innovation are typically found in reduced overhead, most organizational accounting systems are not set up to track these effects. The data of Spilling et al. (1986) would appear to provide additional support for this argument in the sense that an ergonomic intervention is one example of technological innovation. Thus, in assessing the costs of a technological system against the presumed benefits, it is essential not to overlook a large class of such benefits -- namely, reduced overhead costs.

Finally, it is important that ergonomic interventions not be examined in isolation, but considered part of the broader organizational context. Barge and Carlson (1993) have documented that costs of managing employee disabilities may vary by as much as a factor of 10 among companies within the same industry group. Those companies who were consistently low in disability costs were characterized as having a positive proactive approach toward safety and accident prevention, wellness, and open employee communication. Westin (1990) describes how a corporate ergonomic program embedded within such a proactive "people first" program was able to virtually eliminate cumulative trauma disorders at Federal Express during the period 1986-1990.

Relating all of the above to the current study, we note that, early in the study, two of the participants reported musculoskeletal problems which, while not disqualifying for the inclusion, were serious enough to represent potential disability. After the intervention, both individuals report that their problems had been greatly alleviated. We estimated that the basic cost of the intervention -- equipment plus training -- was approximately $2200 per participant. However, if the only effect of this project was to halt the progress toward two workers' compensation cases, and we calculated the full cost of a single such case (see above) which some have estimated as high as $75,000, we might argue that even this demonstration project has paid for itself.

D. Recommendations

The observed positive results from this study, together with the cost-benefit arguments just discussed, allow us to comfortably recommend that an ergonomic program should play an important role in the modern organizational environment. Such a program, if thoughtfully implemented, has the potential to significantly impact organizational productivity. This will typically occur first through reduction in overhead, but can later have more direct effects. (See MacLeod (1995) for examples.)

However, the organizational context within which an ergonomic program is embedded is crucial. It is critical that such programs not end up as a lock step system of automatic checklists, or the results may well be counterproductive. For example, the specific ergonomic components of the present study were based on the particular needs of a group of employees doing data entry from paper copy on rather old computer equipment. Other work environments, particularly those which are mouse-based, might involve different solutions. We regard ergonomics as primarily a process of problem solving rather than the application of a fixed set of rules.

Particular attention must be paid to the psychosocial context of the program. We have referred to the intimate relationship between musculoskeletal load and psychosocial stressors. As Smith and Sainfort (1989) have pointed out, the physical discomfort from a poorly designed work environment may become a source of psychological stress which, in turn, can directly act back upon the musculoskeletal system, further increasing the level of strain. Thus, the way in which physical ergonomic solutions are introduced become crucial. We believe that our approach to training/coaching played a major role in the success of our intervention. Not only were the participants given an understanding of the basic principles underlying their new equipment, but we made a sincere effort, through frequent coaching visits, newsletters, etc., to insure that each was empowered to use the equipment adjustability available to essentially control and solve her own individual postural problems. By giving the employees some degree of positive control over their own work environment, we have provided a powerful psychosocial benefit as well.

Ergonomic programs are an important tool in the improvement of overall organizational productivity. They become particularly valuable with the current emphasis on downsizing. In the modern organization, both public and private, personnel are stretched extremely thin; workloads, and associated stress loads, are extremely high. Under these conditions, the absence of a single well-trained employee due to sick leave can become critical. Hence, providing appropriate tools and working conditions becomes an essential part of doing business.

VI. REFERENCES

Aarås, A., Westgaard, R.H., Stranden, E., and Larsen, S. (1990) Postural load and the incidence of musculoskeletal illness. In: Sauter, S.L., Dainoff, M.J., and Smith, M.J.,(Editors). Promoting Health and Productivity in the Computerized Office. London: Taylor and Francis.

Cyert, R. M. and Mowrey, D. (1989). Technology, employment and U.S. competitiveness. Scientific American, 260, 54-62.

Dainoff, M.J. (1990) Ergonomic improvements in VDT workstations: health and performance effects. In: Sauter, S.L., Dainoff, M.J., and Smith, M.J.,(Editors). Promoting Health and Productivity in the Computerized Office. London: Taylor and Francis.

Dainoff, M. J., & Dainoff, M. H. (1986). People and Productivity: A Manager's Guide to Ergonomics in the Electronic Office. Toronto: Holt Rinehart and Winston.

Francis, J., and Dressel, D.L. (1990). Workspace influence on worker performance and satisfaction: an experimental field study. In: Sauter, S.L., Dainoff, M.J., and Smith, M.J.,(Editors). Promoting Health and Productivity in the Computerized Office. London: Taylor and Francis.

Hubbard, D. (1994). Needle EMG evaluation of trigger point response to a psychological stressor. Psychophysiology, 31.

Kuorinka, I. and Forcier L. (Eds.) (1995) Work Related Musculoskeletal Disorders (WMSDs). London: Taylor and Francis

MacLeod, D. (1995) The Ergonomics Edge. New York: Van Nostrand Reinhold.

Sauter, S.L., Dainoff, M.J., and Smith, M.J.,(1990). Promoting Health and Productivity in the Computerized Office. London: Taylor and Francis.

Putz-Anderson, V. (1988). Cumulative Trauma Disorders: A Manual for Musculo-skeletal Diseases of the Upper Limb. London: Taylor and Francis.

Smith, M.J., and Sainfort, P.C. (1989). A balance theory of job design for stress reduction. International Journal of Industrial Ergonomics, 4, 67-79.

Spilling, S., Eitrheim, J., & Aaras, A. (1986). Cost benefit analysis of work environment investment at STK's telephone plant at Kongsvinger. In N. Corlett, J. Wilson, & I. Manenica (Eds.), The Ergonomics of Working Postures. London: Taylor and Francis.

Sullivan, C. (1990) Employee comfort, satisfaction, and productivity: recent efforts at Aetna. In: Sauter, S.L., Dainoff, M.J., and Smith, M.J.,(Editors). Promoting Health and Productivity in the Computerized Office. London: Taylor and Francis.

Westin, A., (1990) Organizational culture and VDT policies: a case study of the Federal Express Corporation. In: Sauter, S.L., Dainoff, M.J., and Smith, M.J.,(Editors). Promoting Health and Productivity in the Computerized Office. London: Taylor and Francis.

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We wish, as well, to offer our sincere and heartfelt thanks to many staff members at CSC who supported this study. We wish to single out, in particular, Marlene Storey, Phyllis Erkins, and Glenda Leonard for efforts which went far beyond the call of duty.

Finally, it is impossible to adequately express our appreciation for the participants who stayed with this study for over a year. Their dedication and cooperation has made this a memorable experience for all of us.

VII. APPENDICES

A. Sample Quarterly Individual Performance Summary Report
B1. Quality - Ratings: Experimental Group
B2. Quality - Percent Accuracy: Experimental Group
B3. Quantity - Ratings: Experimental Group
C. Quantity and Quality: Control Group

APPENDIX A

QUARTERLY INDIVIDUAL PERFORMANCE SUMMARY REPORT
PERIOD COVERED: 01/01/92 - 03/30/92

QUARTER 9203 RECAP

ORG	FUN	PROG	GR	QUALITY BASE POINT	DOCS REVD	ERRS	% ACCUR	QUALITY FIXED STANDARDS [2]	[3]	[4]	[5]	QUANTITY BASE POINT	VOLUME	HOURS	DOCS/ HOUR	QUANTITY FIXED STANDARDS [2]	[3]	[4]	
35	231	11100	94	97.6	30	0	100.0	95.4	96.9	98.1	99.3	93.9	1233	20.2	61.0	51.6	65.7	133.0	13
		11110		93.0	30	0	100.0	97.0	97.4	93.4	99.4	135.5	1039	11.0	93.0	74.4	94.7	155.6	13
		11200		96.6	135	1	99.5	94.9	95.6	97.3	99.0	83.5	5925	53.7	73.1	44.3	56.4	92.6	11
		11400		93.0	210	1	99.5	97.0	97.4	93.4	99.4	144.4	2265	19.3	114.4	79.4	101.1	165.1	23
		11600		93.0	75	3	96.0	97.0	97.4	93.4	99.4	109.9	1426	15.1	94.4	60.4	76.9	126.4	15
		11700		93.0	150	2	93.7	97.0	97.4	93.4	99.4	196.9	1266	8.9	142.2	103.3	137.3	225.4	27
		11710		98.0	0	0	0.0	97.0	97.4	93.4	99.4	68.6	226	1.9	113.9	37.7	48.0	73.9	7
		11800		96.7	0	0	0.0	95.1	95.7	97.4	99.0	61.4	323	5.7	57.5	33.8	43.0	70.6	8
		12100		97.5	120	6	95.0	96.5	96.8	93.0	99.3	57.1	2796	59.6	46.9	31.4	40.0	65.7	7
		12200		93.8	30	0	100.0	90.7	91.9	95.0	93.1	45.5	1013	24.5	41.3	25.1	31.9	52.4	6
		12201		94.0	0	0	0.0	91.0	92.2	95.2	93.2	33.5	2	0.1	20.0	21.1	26.8	44.0	5
		12300		93.0	30	2	95.3	97.0	97.4	93.4	99.4	70.4	590	7.4	79.7	33.7	49.3	31.0	9
		12400		95.6	0	0	0.0	93.4	94.3	96.5	98.7	21.5	127	6.3	20.2	11.3	15.1	24.7	3
		12401		94.8	0	0	0.0	92.2	93.2	95.3	93.4	29.5	106	4.4	24.1	16.1	20.5	33.7	4
		13110		94.6	45	5	83.9	91.9	93.0	95.7	93.4	30.4	339	12.6	33.9	16.7	21.5	35.0	4
		13120		97.0	15	0	100.0	95.5	95.1	97.6	99.1	42.4	77	2.0	33.5	23.3	29.7	48.8	5
		13130		98.0	0	0	0.0	97.0	97.4	93.4	99.4	36.0	35	1.4	25.0	19.3	25.2	41.4	5
		13131		90.0	0	0	0.0	85.0	87.0	92.0	97.0	17.3	15	0.9	14.4	9.8	12.5	20.5	2
		13140		97.1	0	0	0.0	95.7	96.2	97.7	99.1	17.5	6	0.3	20.0	9.6	12.3	20.1	2
		13141		97.1	0	0	0.0	95.7	95.2	97.7	99.1	39.5	113	3.1	33.1	21.7	27.7	45.4	5
		13162		93.0	0	0	0.0	97.0	97.4	93.4	99.4	33.0	57	0.5	95.0	20.9	26.5	43.7	5
		15303		93.0	45	0	100.0	97.0	97.4	98.4	99.4	383.8	10581	34.5	305.7	213.8	272.2	447.1	54
		15304		93.0	0	0	0.0	97.0	97.4	93.4	99.4	203.0	437	2.1	203.1	114.4	145.5	239.2	231
		15900		93.0	0	0	0.0	97.0	97.4	93.4	99.4	304.9	2952	5.6	527.1	157.7	213.4	350.5	42
		15901		93.0	0	0	0.0	97.0	97.4	93.4	99.4	63.9	3193	3.6	370.9	37.9	43.2	79.2	9
		15910		98.0	15	0	100.0	97.0	97.4	98.4	99.4	253.7	1391	6.3	204.5	139.5	177.6	231.8	35
		33801		93.0	0	0	0.0	97.0	97.4	93.4	99.4	80.2	57	1.1	51.3	44.1	56.1	92.2	11
		44200		93.0	30	0	100.0	97.0	97.4	93.4	99.4	102.1	905	9.8	92.4	55.2	71.5	117.4	14
		44400		93.0	0	0	0.0	97.0	97.4	93.4	99.4	36.5	94	1.4	67.1	47.6	60.6	99.6	121
		44500		96.9	30	4	86.7	95.4	96.0	97.5	99.1	52.0	322	5.7	48.1	23.6	36.4	59.3	72
		44910		99.0	0	0	0.0	85.0	87.0	92.0	97.0	25.8	4	0.1	40.0	13.1	16.7	27.4	33
		45500		93.0	60	1	98.3	97.0	97.4	93.4	99.4	98.4	771	8.5	90.7	54.1	63.9	113.2	137
		45507		94.0	0	0	0.0	97.0	97.4	98.4	99.4	286.7	124	0.7	177.1	157.7	200.7	329.7	401
		45700		93.0	0	0	0.0	97.0	97.4	93.4	99.4	63.8	2	0.1	20.0	37.3	43.2	79.1	96
		45701		93.0	0	0	0.0	97.0	97.4	93.4	99.4	55.4	2	0.1	20.0	31.0	39.5	54.9	77
		45710		93.0	0	0	0.0	97.0	97.4	93.4	99.4	237.9	2259	10.9	203.2	153.3	201.5	331.1	403
		59501		93.0	0	0	0.0	97.0	97.4	93.4	99.4	320.2	2	0.1	20.0	176.1	224.1	358.2	443
		59602		98.0	30	2	93.3	97.0	97.4	93.4	99.4	132.6	1299	9.7	133.9	72.9	92.8	152.5	135
		59702		98.0	0	0	0.0	97.0	97.4	93.4	99.4	192.2	72	0.8	90.0	105.7	134.5	221.0	259
	232	44910		93.0	0	0	0.0	97.0	97.4	93.4	99.4	10.0	2	0.2	10.0	5.5	7.0	11.5	14
		45710		98.0	0	0	0.0	97.0	97.4	93.4	99.4	23.9	59	2.9	20.3	13.1	15.7	27.5	33
		59501		98.0	0	0	0.0	97.0	97.4	93.4	99.4	432.0	500	1.7	294.1	265.1	337.4	554.3	674
		59602		93.9	30	0	100.0	97.0	97.4	93.4	99.4	183.9	669	4.3	139.4	101.1	123.7	211.5	257
		59702		98.0	0	0	0.0	97.0	97.4	93.4	99.4	185.7	106	0.9	117.3	102.1	130.0	213.6	250

Appendix A

Quality Ratings
Docs Reviewed >30
Total= 1160

Adj Accuracy= 97.55
Period Covered 9302

Adj Rating= 3.5545

Function	Program	Docs Revd	% Accuracy	Rating	Qual. Index	Wt. Accuracy	Wt Rat
231	11100	30	100	5	2.59	258.62	12.93
	11110	30	100	5	2.59	258.62	12.93
	11200	185	99.5	5	15.95	1586.85	79.74
	11400	210	99.5	5	18.10	1801.29	90.52
	11600	75	96	1	6.47	620.69	6.47
	11700	150	98.7	4	12.93	1276.29	51.72
	12100	120	95	1	10.34	982.76	10.34
	12200	30	100	5	2.59	258.62	12.93
	12300	30	93.3	1	2.59	241.29	2.59
	13110	45	88.9	1	3.88	344.87	3.88
	15803	45	100	5	3.88	387.93	19.40
	44200	30	100	5	2.59	258.62	12.93
	44500	30	86.7	1	2.59	224.22	2.59
	45500	60	98.3	3	5.17	508.45	15.52
	59602	30	93.3	1	2.59	241.29	2.59
232	59602	30	100	5	2.59	258.62	12.93
					0.00	0.00	0.00
					0.00	0.00	0.00
					0.00	0.00	0.00
					0.00	0.00	0.00
					0.00	0.00	0.00
					0.00	0.00	0.00
					0.00	0.00	0.00
	SUM	1100	1449.2	48	94.83	9250.43	337.07

Quantity Ratings
Hours=>40
Total= 401.6

Adj Rating 3

Function	Program	Hours	Docs/Hr	Ratings	Time Weigh	Wt. Ratings
231	11200	68.7	73.1	3	17.11	51.32
	12100	59.6	46.9	3	14.84	44.52
					0.00	0.00
					0.00	0.00
					0.00	0.00
					0.00	0.00
	SUM	128.3	120	6	31.95	95.84

Appendix B1

Quality Ratings:Experimental Group

Participant	9203	9206	9209	9212	9303	9306	9309	9312	9403	9406
1	4.93	5.00	5.00	4.92	4.52	5.00	4.79	4.85	4.93	4.05
2			4.63	4.43	4.03	4.18	3.57	3.91	4.24	3.63
3	2.92	2.36	2.29	2.68	1.51		2.07	1.78		
4			3.89	4.31		5.00	3.50	3.88		
5		1.00	2.60	3.42	1.00	1.63	2.11			
6	3.55	2.90	2.81		3.24	3.62	3.71	2.90		
7	3.65	3.47	4.11	3.49	3.03	2.87	1.89	2.92	3.54	2.32
8	3.55	4.57	4.04	3.67	4.13	3.77	3.92	3.62	3.86	4.34
9	4.22	4.33	4.57	3.87	4.01	3.90	3.11	4.20		
10	2.54	2.91	3.93	3.56	2.98	2.40	1.84	3.19	2.36	2.26
11	2.76	1.78	2.40	2.44	2.08	1.67	2.37	1.16	1.08	
12	4.29	3.97	3.11	4.32	3.78	3.08	2.00	4.46	4.00	3.95
13	4.56	3.65	4.00	3.46	5.00	3.74	3.00	3.59	3.63	4.56
14			4.34	4.66	4.05		3.05	3.88	4.53	
15			2.00	2.47			21.46	2.66		
16	4.63	4.50	4.71	4.26	4.07	4.77	4.55	4.14	4.44	4.75
17	1.00	4.00	2.86	3.52	4.23	4.00	3.29	0.00	0.00	0.00
18	3.06	2.35	3.04	1.92	1.70	1.19	1.86	1.00	2.12	3.43
19	4.56	5.00	3.33	3.00	4.00	2.41	1.00	2.31	2.39	3.77
20	5.00	5.00	2.00	3.13			1.35	1.00		
21	5.00	3.00	4.21	4.49			4.14	4.81	4.16	4.08
22					2.97	2.07	2.00	1.69	2.09	4.34
23		2.47	3.00	4.55			3.50	1.95		
24		4.57	3.88	2.51	3.75	3.13	3.25	4.53		
25	4.07	4.21	4.14	4.13	3.98	3.58	2.94	2.35	2.32	4.48
26	3.50	3.43	4.24	5.00			3.30			
27		4.00	2.00	3.06	3.40	3.39	2.32	4.20	3.57	2.86
Mean	3.77	3.57	3.50	3.65	3.40	3.27	3.55	3.00	3.13	3.52
Upper	4.25	4.03	3.86	3.99	3.85	3.76	4.95	3.53	3.77	4.15
Lower	3.28	3.10	3.15	3.32	2.95	2.78	2.15	2.47	2.49	2.89
N	18.00	22.00	26.00	25.00	21.00	20.00	27.00	25.00	17.00	15.00
SD	1.04	1.11	0.93	0.85	1.05	1.11	3.70	1.36	1.35	1.24
SE	0.48	0.46	0.36	0.33	0.45	0.49	1.40	0.53	0.64	0.63

Appendix B2

Quality- Percent Accuracy: Experimental Group

Participant	9203	9206	9209	9212	9303	9306	9309	9312	9403	9406
1	99.63	99.92	100.00	99.64	99.86	99.91	99.30	99.67	99.84	98.72
2			99.13	98.02	98.33	98.53	97.51	97.71	98.79	97.42
3	93.44	91.74	94.71	93.99	89.68		90.43	91.82		
4			97.19	98.01		98.87	95.31	96.85		
5		86.70	91.41	94.94	88.90	84.04	92.97			
6	97.55	97.00	96.94		96.37	97.01	97.79	96.53		
7	97.39	96.53	97.88	96.13	95.84	94.96	94.16	95.84	96.91	93.78
8	98.23	99.53	97.05	97.81	98.88	96.10	97.38	96.32	97.14	98.76
9	98.45	98.22	99.01	97.78	98.52	97.70	96.97	97.84		
10	94.08	95.20	96.98	96.59	96.05	94.20	94.11	95.41	96.92	96.10
11	95.66	93.77	95.75	95.89	92.57	90.91	93.82	89.56	90.25	
12	97.06	96.16	95.45	97.16	95.29	92.51	89.19	98.45	96.58	93.64
13	96.12	93.59	96.91	97.90	95.82	96.06	84.34	95.71	96.15	93.81
14			98.66	98.98	98.47	93.30	96.29	97.99	98.88	
15	96.70		89.19	96.32	89.84	82.22	95.29	91.16		
16	97.70	98.38	99.01	97.95	97.57	97.97	98.15	97.58	98.15	98.52
17	96.70	95.63	88.57	96.64	97.68	96.45	94.57			
18	95.27	93.35	96.66	94.84	92.22	89.80	91.95	91.55	94.63	94.26
19	96.67	100.00	94.45	96.15	95.17	89.91	90.79	90.21	89.86	93.77
20	100.00	100.00	96.70	98.32			92.95	93.34		
21	100.00	92.50	99.14	99.22			98.57	99.37	97.86	98.08
22					96.08	88.39	91.00	91.52	93.02	97.94
23	92.23	94.09	94.90	98.57			95.55	92.64		
24		96.68	95.33	97.07	96.10	75.77	94.61	97.79		
25	98.07	98.76	98.45	98.63	98.25	97.65	96.03	95.15	95.05	98.57
26	97.53	98.59	98.22	99.07			96.43			
27	97.53	93.30	90.80	95.09	95.48	93.51	91.57	96.64	94.18	91.82
Mean	96.95	95.89	96.10	97.23	95.59	92.99	94.33	95.28	95.89	96.09
Upper	97.81	97.28	97.28	97.83	96.89	95.52	95.60	96.49	97.32	97.38
Lower	96.09	94.50	94.91	96.63	94.29	90.45	93.07	94.07	94.46	94.80
N	21.00	22.00	26.00	25.00	22.00	22.00	27.00	24.00	16.00	14.00
SD	2.01	3.33	3.08	1.52	3.11	6.06	3.36	3.03	2.92	2.46
SE	0.86	1.39	1.18	0.60	1.30	2.53	1.27	1.21	1.43	1.29

Appendix B3

Quantity Rating: Experimental Group

Participant	9203	9206	9209	9212	9303	9306	9309	9312	9403	9406
1	4.04	4.00	4.43	3.00	4.00	3.00	2.72	3.00	3.26	3.77
2			5.00	3.00	4.00	4.00	3.00	3.00	3.52	4.00
3	4.00	4.29	3.00	3.00	3.00		1.00	2.00		
4			3.58			3.00	3.00	3.00		
5			3.40	2.00	3.00	3.00	2.00			
6	3.00	3.00	3.00			2.72		3.00		
7	4.39	3.79	4.46	3.00	3.57	2.81	1.72	3.00	4.27	3.31
8	3.62		3.00	4.00	3.76	4.01	3.00	4.00	4.49	4.47
9	4.57	4.81	4.75	4.00	4.78	4.44	3.00	4.00		
10	2.69	2.52	2.77	2.67	2.78	3.00	1.00	2.40	2.59	3.00
11	3.00	3.00	3.00	3.00	3.00	3.00		3.00	3.00	
12	4.19	3.82	4.00	3.00	3.25	3.35	3.00	3.00	3.00	3.47
13	3.97	2.96	4.07	3.93	3.98	3.91	1.00	3.56	4.06	4.00
14			4.56	3.00	3.60		2.77	3.00	4.30	
15			3.00	3.00				3.00		
16	4.73	3.65	4.63	3.00	3.70	3.76	3.26	3.00	4.00	4.52
17		5.00	4.00	3.00	4.00	5.00	3.40			
18	3.00	3.00	3.00	3.00	2.00	2.69	2.00	3.00	3.00	3.00
19	4.00		4.00	3.00	4.00	4.19	3.00	3.00	3.79	4.00
20							1.00			
21								4.00	4.00	4.00
22					3.00	3.00	3.00	3.00	3.67	3.37
23		2.00	3.00	3.00			2.00	3.00		
24		4.00	3.00	3.00	4.00	4.54	3.00	3.00		
25	3.00	3.26	3.00	3.00	3.00	3.00	3.00	3.00	3.60	3.33
26		3.00	4.00	3.00			2.00			
27		4.00	3.00	3.00	3.71	5.00	3.00	3.00	3.00	3.68
Mean	3.73	3.54	3.65	3.07	3.51	3.57	2.43	3.09	3.60	3.71
Upper	4.08	3.91	3.94	3.25	3.78	3.91	2.76	3.27	3.88	3.96
Lower	3.38	3.16	3.37	2.89	3.23	3.24	2.10	2.90	3.32	3.45
N	14.00	17.00	24.00	22.00	20.00	20.00	23.00	23.00	16.00	14.00
SD	0.67	0.79	0.72	0.43	0.62	0.76	0.81	0.45	0.57	0.48
SE	0.35	0.38	0.29	0.18	0.27	0.33	0.33	0.19	0.28	0.25

Appendix C

Control Group

Quality (Percent Correct)

	9203	9206	9209	9212	9303	9306	9309	9312	9403	9406
1	99.3	99.1	99.1	99.2	99.2	98.2	98.7	99	97.4	99.6
2	99.8	99.3	97.3	99.7	99.2	99.2	99.1	98.6	99.8	99.9
3	97.6	97.1	96.9	98.7	93.4	97	98.1	96.6	97	96.6
4	98.3	98.8	99.3	98.8	98.7	96.8	99	99.2	99.2	99.3
5	98.9	96.7	99	98.2	98.2	98.3	99.7	97.7	98.7	96.7
6	98.9	98.2	98.95	99.7	99.1	97.4	98.1	98.6	98.4	98.5
Mean	98.8	98.2	98.43	99.05	97.97	97.82	98.78	98.28	98.42	98.43
Upper	98.92	98.36	98.58	99.14	98.31	97.96	98.88	98.43	98.58	98.66
Lower	98.68	98.04	98.27	98.96	97.62	97.68	98.69	98.14	98.25	98.21
STD	0.702	0.987	0.95	0.544	2.073	0.833	0.567	0.888	0.97	1.331
N	6	6	6	6	6	6	6	6	6	6
SE	0.117	0.164	0.158	0.091	0.345	0.139	0.094	0.148	0.162	0.222

Quantity Ratings

	9203	9206	9209	9212	9303	9306	9309	9312	9403	9406
1	4.5	4.3	4.5	4.5	4.7	4.4	4.2	4.3	3.7	5
2	4.96	5	4.24	4.9	4.7	4.8	4.5	4.1	4.8	5
3	3.6	2.9	2.8	4.2	3.2	3.1	3.8	2.9	3.9	2.97
4	4.2	4.2	4.7	4.2	4.4	3.5	4.4	4.6	5	4.7
5	4.4	3.4	4.2	3.4	4.1	4.3	4.9	3.9	4.3	3.4
6	4.379	4.034	4.472	4.803	4.519	3.78	3.902	4.448	4.059	4.208
Mean	4.34	3.972	4.152	4.334	4.27	3.98	4.284	4.041	4.293	4.213
Upper	4.407	4.084	4.257	4.417	4.357	4.076	4.345	4.134	4.371	4.343
Lower	4.272	3.861	4.048	4.251	4.183	3.884	4.222	3.948	4.215	4.082
STD	0.405	0.67	0.627	0.496	0.52	0.577	0.371	0.558	0.469	0.783
N	6	6	6	6	6	6	6	6	6	6
SE	0.067	0.112	0.105	0.083	0.087	0.096	0.062	0.093	0.078	0.131

Quality Ratings

	9203	9206	9209	9212	9303	9306	9309	9312	9403	9406
1	3	3	5	3	2.7	3	3	4	3	3
2	3	3.3	3	3	3	3.4	3	3	4.3	3.9
3	3	3	3	3	2.5	2.7	3	3	3	3
4	4.5	4	5	5	4	4	4	4.7	5	5
5	2	1.7	1.6	2	2	1.2	3	2.6	3	3
6	3	3.314	3	3	3	3	3	3.745	4	4
Mean	3.083	3.052	3.433	3.167	2.867	2.883	3.167	3.508	3.717	3.65
Upper	3.205	3.167	3.636	3.316	2.968	3.026	3.229	3.627	3.846	3.773
Lower	2.961	2.937	3.231	3.017	2.765	2.74	3.105	3.389	3.587	3.527
STD	0.731	0.691	1.213	0.898	0.61	0.857	0.373	0.714	0.775	0.739
N	6	6	6	6	6	6	6	6	6	6
SE	0.122	0.115	0.202	0.15	0.102	0.143	0.062	0.119	0.129	0.123