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# Toward decreasing the risk of carpal tunnel syndrome in video display terminal users through feedback.

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TOWARD DECREASING THE RISK OF  
CARPAL TUNNEL SYNDROME IN VIDEO DISPLAY TERMINAL USERS  
THROUGH FEEDBACK

A Thesis Presented

by

KATHLEEN E. BLAKE

Submitted to the Graduate School of the  
University of Massachusetts in Partial fulfillment  
of the requirements for the degree of

MASTER OF SCIENCE

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Psychology Department

Toward Decreasing the Risk of  
Carpal Tunnel Syndrome in Video Display Terminal Users  
Through Feedback

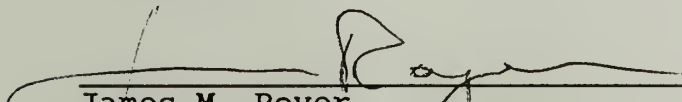
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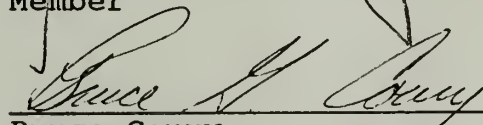
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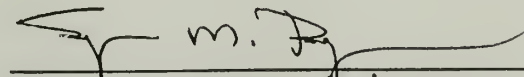
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ABSTRACT

TOWARD DECREASING THE RISK OF  
CARPAL TUNNEL SYNDROME IN VIDEO DISPLAY TERMINAL USERS  
THROUGH FEEDBACK

SEPTEMBER, 1991

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Directed by: Professor Beth Sulzer-Azaroff

The purpose of this study was to attempt to decrease the risk of developing Carpal Tunnel Syndrome (CTS) in Video Display Terminal (VDT) users. A multiple baseline across subjects was used to directly observe subjects' posture and hand-wrist positions as they entered text on a VDT. Following baselines of varying lengths, subjects received oral and graphic feedback on their behavior. The intervention produced a dramatic increase in both the percentage of posture items performed correctly and the percentage of time hand-wrist positions were at neutral for all subjects. This research may contribute significantly to the extensive ergonomic and medical literature currently addressing CTS. Implications of the results and suggestions for future research are discussed.

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## CHAPTER 1

### INTRODUCTION

Behavior analysis, a rapidly growing branch of psychology, has been applied to a wide range of socially important performances (Baer, Wolf, & Risley, 1968; Baer, Wolf, & Risley, 1987). Industry is but one of the settings in which behavior analysis has been found to be extremely useful. Behavioral techniques have long been known to aid in increased productivity and motivation of the workers. Accurate and efficient job productivity also has been enhanced through such methods (Kreitner, Reif, & Morris, 1977; Nadler, Mirvis, & Cammann, 1976). Similarly, Quilitch (1975) and others not in industry have demonstrated that behavioral interventions can improve the outcome of training programs. An especially critical aspect of industry that has been found to benefit from behavioral technology is the area of industrial safety (Alavosius & Sulzer-Azaroff, 1986; Komaki, Barwick, & Scott, 1978; Sulzer-Azaroff & de Santamaria, 1980).

Schaeffer (1976) has emphasized a comprehensive approach to accident prevention that combines epidemiology with increases in industrial safety. Epidemiology examines the relation between the host

(human victim), the causal agent (physical, biological, etc.), and the environment. The probability of injury is greatly increased when there is a disturbance in the equilibrium of the above three factors.

Behavior analytic approaches to accident prevention epitomize this emphasis. For instance, the analysis of the worker and the causal agent in the environment is exemplified in studies that increase safety through the reduction of environmental safety hazards (Sulzer-Azaroff, 1978; Sulzer-Azaroff & de Santamaria, 1980).

Behavioral techniques have been applied to many aspects of job safety including the increase of use of protective eye and earwear (Smith, Anger, & Uslan, 1978; Zohar, 1980; Zohar & Fussfeld, 1981), plus a large assortment of safe behaviors such as proper lifting technique (Alavosius & Sulzer-Azaroff, 1986; Alavosius & Sulzer-Azaroff, 1990), safe and complete job performance (Chhokar & Wallin, 1984; Fellner & Sulzer-Azaroff, 1984, Komaki, Barwick, & Scott, 1978; Komaki, Heinzman, & Lawson, 1980) and numerous others.

Many of the successful behavioral studies in industrial safety have shared a common theme -

feedback. Feedback is an extremely effective method for achieving behavioral change (Balcazar, Hopkins, & Suarez, 1986; Emmert, 1978; Ford, 1984; Frederiksen, Johnson, & Solomon, 1982; Karan & Kopelman, 1986; McCuddy & Griggs, 1984; Prue & Fairbank, 1981). Prue and Fairbank (1981) have highlighted the advantages of feedback. Feedback is a relatively low cost route to behavioral change when compared with other methods such as extensive incentive systems. Implementation of feedback techniques is fairly simple and is relatively easy to teach to managers. It is flexible and thus available to virtually all settings regardless of their size. Finally, the emphasis which feedback, as conventionally practiced by applied behavior analysis, places on positive aspects of behavior is thought to decrease unsystematic aversive control.

Several parameters of feedback must be considered when implementing it as part of a behavioral program according to Prue and Fairbank (1981). These include the following: 1) recipient - the recipient of feedback can be either an individual or a group, and it can be received either publicly or privately; 2) mechanism - feedback can be verbal, written, mechanical (graphed), pictorial and/or self-

recorded; 3) content - several types of comparisons can be made dependent upon the targeted behavior, and the content of these comparisons should be clear, specific, positive, and objective; 4) temporal characteristics - these include the duration of the feedback program and the contiguity between performance and feedback; 5) source - the person administering the feedback, whether a peer, supervisor, or other, should be competent and convey a sincere message. Numerous other factors, such as the specific nature of the response and the contextual factors of the organization remain to be fully explained.

Balcazar, Hopkins, and Suarez (1985) further analyzed the effectiveness of the specific parameters of feedback through an extensive review of behavioral literature employing the mechanism. The most salient result was that feedback is most effective when combined with either goal setting, tangible positive behavioral consequences, or both. Not surprisingly, the most noticeable increases in industrial safety in the studies cited above were achieved using precisely these methods. Training packages incorporating this methodology are probably the most straightforward and promising approaches to future safety studies.

Although the financial ramifications are relatively unexplored, it seems that behavioral approaches are cost effective, both in time and expense.

Besides the costs directly involved in production and service delivery, industry spends an enormous amount of money on training in accident prevention and other management issues, and the reduction of these costs is crucial to the profitability of many companies. Work related injuries are among the major costs to industry. Recently, as indicated by marked increases in worker compensation claims, Australia suffered an "epidemic" of a type of industrial injury loosely classified as Repetition Strain Injury (RSI) (Browne, Nolan, & Faithfull, 1984; Ferguson, 1984; Hall & Morrow, 1988; Stone, 1983). New legislation concerning workers compensation probably explains the apparent epidemic because previously RSI was not considered legitimate compensable complaint (Kiesler & Finholt, 1988). The increase in RSI claims is not a medical epidemic but instead reflects the fact that the channels of complaint are now open. Although RSI is hardly indigenous to a single continent, the media attention in Australia resulted in a similar focus in many other industrialized countries (Hall & Morrow, 1988;

Kiesler & Finholt, 1988). Statistics provide a limited indication of the true incidence of RSI because many different disorders fall into the category and the inclusion of these in compensation claims varies widely (Ferguson, 1984). It is clear, however, that the incidence is on the rise (Stone, 1983; USDL-89-548).

### Definition

Repetition strain injuries (RSIs) are those suffered from the continuous repetitive motions of any part of the body; particularly in the hand, wrist, and arm. Tendons, muscles, nerves, and other soft tissues are targeted as especially susceptible to such injury (Blair & Bear-Lehman, 1987). Synonyms for RSI include repetitive stress injury, repetitive motion injury, cumulative trauma disorder, overuse injury, and overuse syndrome. Other disorders which are not normally categorized as RSI are included when their origin is mechanical in nature. Tenosynovitis, tendonitis, nerve compression syndromes, and other neuropathies are often counted among RSI (Blair & Bear-Lehman, 1987), but an RSI of growing concern in medicine and ergonomics is the Carpal Tunnel Syndrome (CTS). Phalen (1972) reported that CTS is the most frequently reported type of nerve entrapment. Carpal



tunnel syndrome differs from the diffuse category of RSI because it is a specific, chronic disease often associated with occupation and from which there is no complete recovery (Ferguson, 1984; Louis, 1987; Mallory, Bradford, & Freundlich, 1989).

Bleecker and Agnew (1987) offer a clear and concise definition of CTS:

A simple definition of carpal tunnel syndrome is a disorder resulting from compression or irritation of the median nerve as it passes into the hand between the carpal bones and the transverse carpal ligament with subsequent discomfort and impaired use of the hand. The carpal canal is formed by the concave arch of the carpal bones and is roofed by the transverse carpal ligament. These structures form a rigid compartment through which nine tendons and the median nerve must pass. (p. 385).

### Epidemiology

A syndrome is a disorder in which the symptoms characterize the disease and serve as subjective evidence of its existence (Jackson & Clifford, 1989). Accordingly, CTS has a definitive set of symptoms associated with it. The symptoms are localized in those portions of the hand innervated by the median

nerve; the palmar sides of the thumb, index, third, and half of the fourth finger and the majority of the palm. The symptoms include one or more of the following and are presented in their general order of occurrence: pain (onset often nocturnal and episodic), numbness (paresthesia), tingling, hypo- or hyper- sweating, burning, aching, clumsiness, decreased sensitivity (especially to vibration), edema, and extension of pain and/or numbness through the arm and shoulder (Armstrong & Chaffin, 1979; Bleecker and Agnew, 1987; Feldman, Travers, Chirico-Post, & Keyserling, 1987; Herrick & Herrick, 1987; Jackson & Clifford, 1989).

### Diagnosis

Payan (1988) as well as others in the medical community hasten to point out the relative lack of diagnostic tools in the assessment of CTS. Currently six methods are widely utilized in the diagnosis of CTS, although much debate surrounds their efficacy. The most conservative view is that diagnosticians use all tools and, in conjunction, perform rigorous physical examinations. They seriously consider the presence of any indicative symptoms before taking any invasive action (Bleecker & Agnew, 1987; Bleecker, Bohlman, Moreland, & Tipton, 1985; Golding, Rose, &

Selvarajah, 1986; Heller, Ring, Costeff, & Solzi, 1986; Payan, 1988). The diagnostic methods are Tinel's sign, Phalen's sign, vibration threshold testing, computerized tomography (CT), electrodiagnostic testing, and thermography. Ultrasound also has been suggested (Molitor, 1988). The specifics concerning these various tests will not be presented here; however, it should again be stressed that none of the above are conclusive and the medical field is fraught with controversy concerning many of them (Heller et al., 1988; Redmond & Rivner, 1988; Seror, 1988; So, Olney, & Aminoff, 1989).

As a final note on the diagnosis of CTS, Payan (1988) offers the following advice: "It is indeed not unknown for the patient to make the diagnosis, the doctor to disagree and the patient to be right. There is no substitute for having it oneself when it comes to making the diagnosis." (p. 365) Ultimately, there is no surefire method available and the personal experience of the sufferer is tantamount to the diagnosis.

### Treatment

Once CTS is clinically identified, a course of treatment is taken. Unfortunately, there are many

more diagnostic than treatment methods. The most conservative therapy is the initial step in the treatment of the symptoms. Rest, avoidance of repetitive tasks, and diuretics to reduce swelling are recommended; and, if the problem persists, simple splints that prevent excessive flexion and extension of the wrist are used (Payan, 1988; Schenck, 1988; Schenck, 1989; Sebright, 1986). The injection of steroids into the wrist tissues, and sometimes directly into the median nerve, often reduces swelling and irritation of the nerve (Gelberman, Aronson, & Weisman, 1980; Schenck, 1989). However, steroid injections have complications of their own and may weaken the carpal tendons, result in aesthetic abnormalities, and can chronically inflame the surrounding tissues (Kessler, 1986; Payan, 1988; Schenck, 1989).

Surgery is the final resort if the more conservative therapies are ineffective. The standard surgical treatment severs the transverse carpal ligament which relieves pressure in the carpal canal and reduces the irritation of the median nerve. Although surgery combined with less invasive procedures is the most extensive treatment available, it has a high failure rate and may in fact mask the

symptoms for a period of time postsurgically until they return in full force (Payan, 1988; Schenck, 1988; Schenck, 1989). At this point there is no reliable method for successfully treating CTS, and some of the apparently simple preventive methods proposed (i.e. splints) need to be evaluated with great caution (Habes, 1987). Ultimately, many sufferers are resigned to live with discomfort and drastically alter their daily activities.

### Risk Factors

Biological. There are many factors which may result in a predisposition to CTS. None of these factors have an established causal relationship with the disease, but all have been highly correlated with its occurrence. The first is gender; females have a higher incidence of CTS than males (Armstrong & Chaffin, 1979; Armstrong, Fine, Goldstein, Lifshitz, & Silverstein, 1987; Clark, 1988; Dieck & Kelsey, 1985). One explanation is that females have a congenitally smaller carpal canal and even minimal swelling and friction can irritate the median nerve (Herrick & Herrick, 1987). Pregnancy has also been associated with an increased risk of CTS (Dieck & Kelsey, 1985; Gateless, 1983; McLennan, Oats, & Walstab, 1987; Nygaard, Saltsman, Whitehouse, &

Hankin, 1989). It is believed that pregnancy induced edema plus increased levels of estrogen contribute to the occurrence of CTS. CTS experienced during pregnancy, if not complicated by additional factors, is often mild and the symptoms tend to decrease with the termination of the pregnancy. Much controversy surrounds the relationship between estrogen and CTS and current research is being conducted to identify a more specific correlation.

Additional factors may predispose individuals to CTS and similar nerve entrapment syndromes. Arthritis, rheumatoid arthritis, tenosynovitis, and other muscular and joint diseases located in the hand and wrist have been associated with CTS. Diabetes, as well as any history of fractures, tumors, bone disease, or congenital hand defects apparently increase the risk of CTS (Armstrong & Chaffin, 1979; Armstrong et al., 1987; Bleecker, 1987; Browne, Nolan, & Faithfull, 1984; Dieck & Kelsey, 1985). Interestingly, hand and wrist size are not predictors of CTS nor have they been found in any way correlated with it (Armstrong & Chaffin, 1979). External measurements of the wrist are not indicative of the width of the carpal canal due to a high variability

in the mass of bone, fat, and muscle tissues across individuals.

Biomechanical. The presence of any of the above predisposing factors increases the risk of an individual contracting CTS, but the absence of these factors does not indicate invulnerability. Indeed, biomechanical causes of CTS are the critical factors in the majority of cases (Armstrong et al., 1987; Arndt, 1987; Cannon, Bernacki, & Walter, 1981; Herrick & Herrick, 1987; Nathan, Meadows, & Doyle, 1988; Silverstein, Fine, & Armstrong, 1987; Wieslander, Norbäck, Göthe, & Juhlin, 1989). The most prevalent biomechanical cause of CTS is repetition. Repetitive movements of the hand and wrist directly irritate the median nerve. Forceful exertion (degree of flexion, extension, or weight supported) of the wrist also is a contributor.

Silverstein, Fine, and Armstrong (1987) identified a series of jobs in an electronic plant as either low force (less than 1 kg) or high force (greater than 4 kg) and as low repetitive or high repetitive. Jobs were classified as high repetitive if they involved either a cycle time of less than 30 seconds or if greater than 50% of the cycle involved a set series of fundamental motions. Remaining tasks

were low repetitive. Predictably, high repetitive-high force jobs carried the greatest risk of CTS. It was also determined that the repetitive quality of a task was a far greater risk factor than the force requirements of the job.

In addition to repetition and force per se, other occupational practices have been reliably correlated with the incidence of CTS, especially when combined with repetition. The following have been specified: pinching motions, deviations of normal wrist alignment, work pace, increased muscular tension, exposure to vibration, and constrained or inefficient posture. Other occupationally related correlates with CTS are lack of training, excessive psychological stress, and extreme bonus or incentive systems targeted at high rates of production. The latter are believed to cause employees to dismiss or ignore symptoms of CTS in an effort to meet the incentive requirements (Arndt, 1987; Browne, Nolan, & Faithfull, 1984).

### Prevention

Prevention of cumulative trauma disorders can be divided into two main categories: ergonomics and training for behavioral change. Blair and Bear-Lehman (1987) stress the need for an integration of



these two methods to achieve maximal preventive strategies. Carpal tunnel sufferers can often find relief with relatively simple ergonomic changes in the work environment such as changing the height of a work bench, rotating the angle of a tool, and others (Armstrong et al., 1987; Lutz & Hansford, 1987; Pinkham, 1988), but once these alterations have been made the worker's behavior remains to be modified.

Ergonomics. The primary focus of any program of prevention of CTS, ergonomic or otherwise, is to reduce the incidence of the physical motions which have been associated with its occurrence. The majority of the recommended ergonomic guidelines have the following objectives: The reduction of any excessive force levels; of any extreme joint motions; and of high repetition and/or stereotyped movements (Meagher, 1987; Putz-Anderson, 1988). These objectives are accomplished through the design of work stations, work methods, and work tools. Work stations should be adjustable to accommodate many different body types and incorporate worker position, tool location, chair design, etc. The design of work methods includes: automation of repetitive tasks when possible; job-task rotation or combination; the use of fixtures rather than the alternative hand to hold

materials; and self-pacing and frequent breaks in routine when feasible. Lastly, tool design should maximize the avoidance of extreme and/or awkward joint positions, repetitive finger actions, vibration, and high force. In many cases ergonomic changes are the most direct and cost effective. However, an alteration in the work environment either may not be feasible for a company, or when implemented require behavioral changes along with it.

Training. Training workers to modify their behavior in the workplace may be a cost effective alternative to ergonomic changes and for many businesses may be the only option. Although training programs are recognized as a necessary measure to reduce the incidence of CTS (Smith, 1987), training needs to go beyond the simple distribution of information. Behavioral literature abounds with studies that clearly illustrate that the modification of behavior is most effectively achieved with systematically programmed contingencies in the environment; training alone is not enough (e.g. Alavosius & Sulzer-Azaroff, 1986; Chhokar & Wallin, 1984; Komaki, Heinzman, & Lawson, 1980). Training is most critical when subjects are involved in an occupation with inherently high risk of injury. The

literature is notably void of research which explores the impact of training plus behavioral interventions with CTS.

#### Occupations at Risk

No specific jobs or tasks have been causally related to CTS but it appears that some occupational factors may be partly responsible for the high incidence rates of CTS (Masear, Hayes, & Hyde, 1986). A wide variety of occupations have been identified as employing methods of work which carry a high risk of CTS. The increase in Australia's compensation claims were mainly filed by workers on video display terminals (VDTs), the use of which has increased dramatically over the past several years. Long hours spent at a keyboard and the highly repetitive specific hand movements appear to be the main culprits (Chapnik & Gross, 1987; Ferguson, 1984; Hall & Morrow, 1988; Kiesler & Finholt, 1988; Stone, 1983). Other areas where CTS has been problematic are in meat processing plants (Armstrong, Foulke, Joseph, & Goldstein, 1982), electronics assembly (Feldman et al., 1987), checkouts at supermarkets (Margolis & Kraus, 1987), professional dental hygiene (MacDonald, Robertson, & Erikson, 1988), and many others.

Recently, CTS has been the focus of much concern here in the United States. Although the Occupational Safety and Health Administration (OSHA) has yet to issue specific guidelines subject to enforcement, the fact that VDT users frequently suffer from the syndrome has gained national attention (Kilborn, 1989; Kilborn, 1990). Additionally, according to a report issued by the Bureau of Labor Statistics, injuries due to repetitive motions constituted nearly one-half of all occupational illnesses in 1988 and accounted for approximately four-fifths of the total increase in illnesses from the previous year (USDL-89-548).

Technological advancement has now made the manual typewriter virtually obsolete. No longer is an eight hour day of typing interrupted by carriage returns, the changing of sheets of paper, or laborious corrections of typographical errors. Rather, eight hours at a keyboard now often means precisely that. Individuals are making hundreds of thousands of keystrokes each day without the interruptions in motion that standard typewriters once provided. Probably as a result, the incidence of CTS and other related RSIs is markedly increasing in such occupations. It is the belief of the author

that the small repetitive motions of the hand and wrist combined with constrained body postures is the primary contributor to the rise of CTS in VDT workers. The deviation of the hand from the wrist is particularly important and can be measured as an angle of hand-wrist deviation. The most desirable position is that of neutral: the hand is aligned with the wrist and forearm and is neither excessively flexed nor extended.

#### Present Study

The goal of the proposed study is first, to develop a reliable observational system targeted at subject posture and hand-wrist positions, and then to implement an intervention consisting of intensive feedback on the above measures. It is anticipated that posture will improve and that the percentage of time hand-wrist positions are at neutral will increase. The chronicity of the syndrome discourages accurate outcome measures on risk reduction over short periods of time. However, based on the ergonomic, medical, and psychological literature, it is assured that any current risk of contracting CTS will subsequently decrease. Only broadscale measures at a later date can directly assess that bottom line result.

## CHAPTER 2

### METHOD

#### Subjects

Subjects were 3 female students enrolled fulltime at the University and whose ages ranged from 20 to 34 years. All volunteered to participate and gave written informed consent (see Appendix A). Subjects were acquaintances of the experimenter and were told that numerous short sessions of their time would be required and would be scheduled at their convenience. Confidentiality was assured and no incentive was provided. All were screened prior to participation to determine that they did not display any predisposing factors which might increase the inherent risk of CTS (see Appendix B). Any indication that a subject was at such a risk would eliminate her from the study to prevent the exacerbation of the condition.

#### Setting

The experimental setting was an office in the Psychology Department on campus. The layout allowed the experimenter to observe and provide feedback privately to each subject. The office was approximately 12' x 10' and two large windows occupied the outside wall. Three desks and various

office furnishings (bookcases, filing cabinet, etc) were in the room. The only individuals present during observations were the subject, the experimenter and occasionally a Research Assistant (RA).

### Apparatus

The VDT was an International Business Machines Corporation (IBM) compatible personal computer with monochrome screen using the WordPerfect word processing program. The program allowed the user to input text and displayed the text onscreen as it was entered. The keyboard was at a height of 22 inches from the floor and the monitor was at each operator's eye level. A chair was provided in front of the screen and subjects were allowed to adjust it to the position most comfortable for them. A small adjustable platform was available to subjects if they chose for resting their feet. Text was provided on a standard typist's stand and subjects could move the stand to a location most comfortable for them. Text was selected from various sources (books, magazines, etc.) and consisted of enough information so that subjects would not be required to turn a page during an observation session. Text difficulty was

approximately that of an introductory college level textbook.

A Sony Walkman Cassette player was used to provide private auditory cues to the observers without the subjects' awareness. The cues defined each observational interval.

### Observation Procedures

Dependent Variables. The dependent variables measured were 1) correct posture items and 2) correct hand-wrist position. Both measures were obtained through direct observation. See Appendix C for behavior checklists.

Correct posture had 5 critical features. 1) Back straight: spine at an 85-95 degree angle with the floor. 2) Shoulders relaxed: line of shoulders not hunched upwards toward the neck or over the chest; shoulders form an even letter "T" with the spine, each shoulder at the same height; a line connecting both shoulders parallel with the floor, perpendicular to the spine. 3) Neck aligned with back: head held up, chin not in contact with either shoulders or chest, neck a continuation of the spine, head oriented toward either the VDT screen or to the typist's stand. 4) Feet flat on floor: both feet touch the floor or platform with both the heels and



toes, legs not crossed; Thighs parallel with the floor. 5) Forearms parallel to floor: both arms from elbow to wrist parallel with the floor.

Correct hand-wrist position measured the following deviations from neutral (angle of the joint between the hand and wrist at its midpoint) as described by Putz-Anderson (1988, p. 54):

Extension - bending the wrist up and back.

Flexion - bending the wrist down towards the palm.

Ulnar - bending the wrist toward the little finger.

Radial - bending the wrist toward the thumb.

Videotape samples of hand-wrist positions revealed that deviations were detectable at approximately 5 degrees from neutral. Data collected during training indicated that further elaboration seemed unnecessary.

Personnel. The author acted as the primary observer and provided all feedback. The author was trained in applied behavior analysis techniques and had numerous experiences with different observational and research methodologies. A research assistant (RA) conducted reliability observations. The RA was

an undergraduate who had completed a course in methods of scientific research and she earned psychology course credits for her work. The RA was trained by the author and was informed of the general purpose of the study but was kept naive as to the intervention. The RA was not present during the delivery of feedback.

Data Collection. Observers learned to score the dependent variables reliably by scoring videotaped samples and then conducting live observations. The taped samples depicted individuals typing at a computer and were divided into two categories: wide angle shots to evaluate posture and focused shots for the evaluation of hand-wrist positions. Training took approximately five hours and was completed in 3 sessions. The two observers discussed the observational definitions and observed several samples of about 10 minutes in length concurrently. The RA continued to record segments of the tape in this way and periodically was joined by the experimenter to assess interobserver agreement. Percentages of overall agreement were computed by dividing the number of observer agreements by the number of agreements plus disagreements and multiplying by 100. The RA was considered trained

when 10 consecutive five minute samples yielded interobserver agreements of no less than 80%. This criterion was used for observations of both posture and hand-wrist positions.

Each experimental session consisted of observations of posture for 20 10-second intervals followed by observations of hand-wrist position for another 20 10-second intervals. Subjects were unaware as to which behavior was being observed.

Observations of the 5 posture components consisted of whole interval recording. The behavior was observed for 10 second intervals and results were recorded within the next 5 seconds. Each individual posture component was checked as present if and only if it occurred throughout the full duration of the interval without interruption; otherwise it was checked as absent. Each trial consisted of 20 such intervals for a total of 100 (5 components/interval x 20 intervals). Subject behavior checklists were used to record data and a check indicated that the component was present and a minus indicated that it was absent (see Appendix C).

Observations of the hand-wrist positions used a Momentary Time Sample (MTS) procedure. Hand-wrist positions were divided into two categories for ease

of observation: neutral/extension/flexion and neutral/radial/ulnar. The behavior was observed and recorded as it was occurring at the exact moment a 10 second interval ended. Momentary Time Sampling was selected because initial observations revealed that the target behavior occurred at a rate high enough that exact frequency counts would be extremely difficult to record accurately. The short interval (less than 30 seconds) MTS technique has been shown to estimate accurately the percentage time a high frequency behavior occurs (Saudargas & Zanolli, 1990). Each hand was observed separately for each category:

right hand - neutral/extension/flexion;

left hand - neutral/extension/flexion;

right hand - neutral/radial/ulnar;

left hand - neutral/radial/ulnar.

Each session consisted of 5 intervals per category for each hand for a total of 20 (5 intervals x 2 categories x 2 hands). See Appendix C for data recording sheet.

Interobserver Agreement. Observations were conducted simultaneously between the primary observer and the RA to estimate the reliability of the system. Percentages of overall agreement were computed in the

manner described above. Over the course of the data collection, 12 (26%) of baseline sessions and 8 (32%) of intervention sessions were checked for reliability for a total of 20 (29%) of all sessions combined. The overall mean percentage agreement as calculated on a component by component basis for posture was 99.2% (with a range of 86% to 100%) and for hand-wrist position was 91% (with a range of 80% to 100%). The nature of the posture observations (where individual components were scored as either present or absent) allowed percentages of occurrence (both checks and minuses) to be checked for reliability using the same formula as above. Interobserver agreement on occurrence of components had an overall mean of 98.9% with a range from 81% to 100%. Table 1 shows agreement scores.

### Experimental Design

A multiple-baseline across subjects design was used. Each subject began in baseline and received the intervention once she reached stability in baseline. Stability was defined as no new or high points for at least 3 consecutive sessions. The number of sessions of baseline and intervention for each subject were: Subject 1 - 10 baseline, 12 intervention; Subject 2 - 15 baseline, 6

intervention; Subject 3 - 20 baseline, 7  
intervention.

### Procedures

The total of 70 sessions were conducted three times a week for about 15 minutes. On two occasions, double sessions were held on the same day. The Subject came into the office and made themselves comfortable at the computer. Sessions began with the subject entering the office and making herself comfortable at the computer. She then began typing the provided text and observations were initiated within a minute. Behaviors recorded during a session were summarized into separate data points for posture and hand-wrist positions.

Baseline. Data were recorded for each subject and no information about the nature of the observations was shared with the subjects. Data were recorded until stability was reached. Stability was attained when at least 3 consecutive data points remained within the range of previous sessions (no new highs or lows for three sessions).

Intervention. At the end of the last baseline session, the experimenter explained to the subject what was being recorded, showed her the results of the previous observations, and answered any questions

the subject raised. Thereafter, the intervention consisted of privately providing feedback and goal setting immediately after each session.

Feedback. Feedback consisted of informing the subject about her percentage of correct posture items per session and the percentage of time hand-wrist positions that were at neutral per session were provided. Following feedback, as the experimenter observed her, the subject recorded each percentage on a graph following feedback that the experimenter retained.

Goal Setting. During goal setting the experimenter guided the subject in choosing an appropriate goal level for each behavior (posture and hand-wrist positions). The experimenter explained goal setting to the subject and assisted when necessary. Initially, goals were set no higher than the highest data point within the previous sessions of baseline data. Later goals were changed when the pre-specified level had been achieved for at least 3 consecutive observations.

The experimenter praised the subject for her progress and for reaching goal levels accompanying this with smiles and other verbal encouragements.

Mastery criteria. The intervention continued until the subject attained at least 90% for at least 3 consecutive trials for each measure.

Consumer satisfaction information was gathered from each participant (see Appendix D).



Table 1. Percentage of Interobserver Agreement Per Session for Each Subject by Condition.

Subject	Posture		Hand-Wrist Position	
	Baseline	Intervention	Baseline	Intervention
S1	100	100	90	90
	86	100	85	95
	98		80	
	100		90	
	100		90	
	100		90	
S2	100	100	90	90
	100	100	80	90
S3	100	100	85	90
	100	100	100	90
	100		95	
	100		100	
	100		95	
	100		95	

## CHAPTER 3

### RESULTS

Figure 1 presents the percentage of posture items performed correctly per session for each subject and the goal levels set during intervention. Figure 2 displays the percentage of time subjects' hand-wrist positions were at neutral per session and the goal levels set during intervention. The mean percentages of each behavior performed correctly by each subject during baseline, the complete intervention and the mean for the last five sessions are provided in Table 2.

Upon introduction of the intervention, each subject displayed a rapid increase in the percentage of behaviors performed correctly for both posture and hand-wrist position. All subjects stabilized at 100% correct posture items within 3 sessions (see Figure 1). Once this level of performance was attained, it did not waiver. The hand-wrist position data were more variable than the posture data, as can be seen in Figure 2. Subject 1 achieved the highest level of stability (100%) followed by Subject 2 and then by Subject 3, with 95% and 90% respectively.

By the end of intervention, the mean percentage for the last five sessions for posture was 100% for 2

subjects and only slightly less for the third. Each subject's mean percentage for the last five sessions for hand-wrist data was slightly less, ranging from 88% to 97% (see Table 2).

Table 2. Mean Percentage of Behaviors Performed Correctly During Baseline, Intervention and the Last 5 Sessions of Intervention.

<u>Subject</u>	<u>Behavior</u>	<u>Baseline</u>	<u>Intervention</u>	<u>Last 5 Sessions</u>
S1	Posture	78.6	99.9	100.0
	Hand-Wrist	44.5	92.1	97.0
S2	Posture	60.8	99.7	99.6
	Hand-Wrist	60.7	92.5	95.0
S3	Posture	58.7	97.0	100.0
	Hand-Wrist	47.5	84.2	88.0

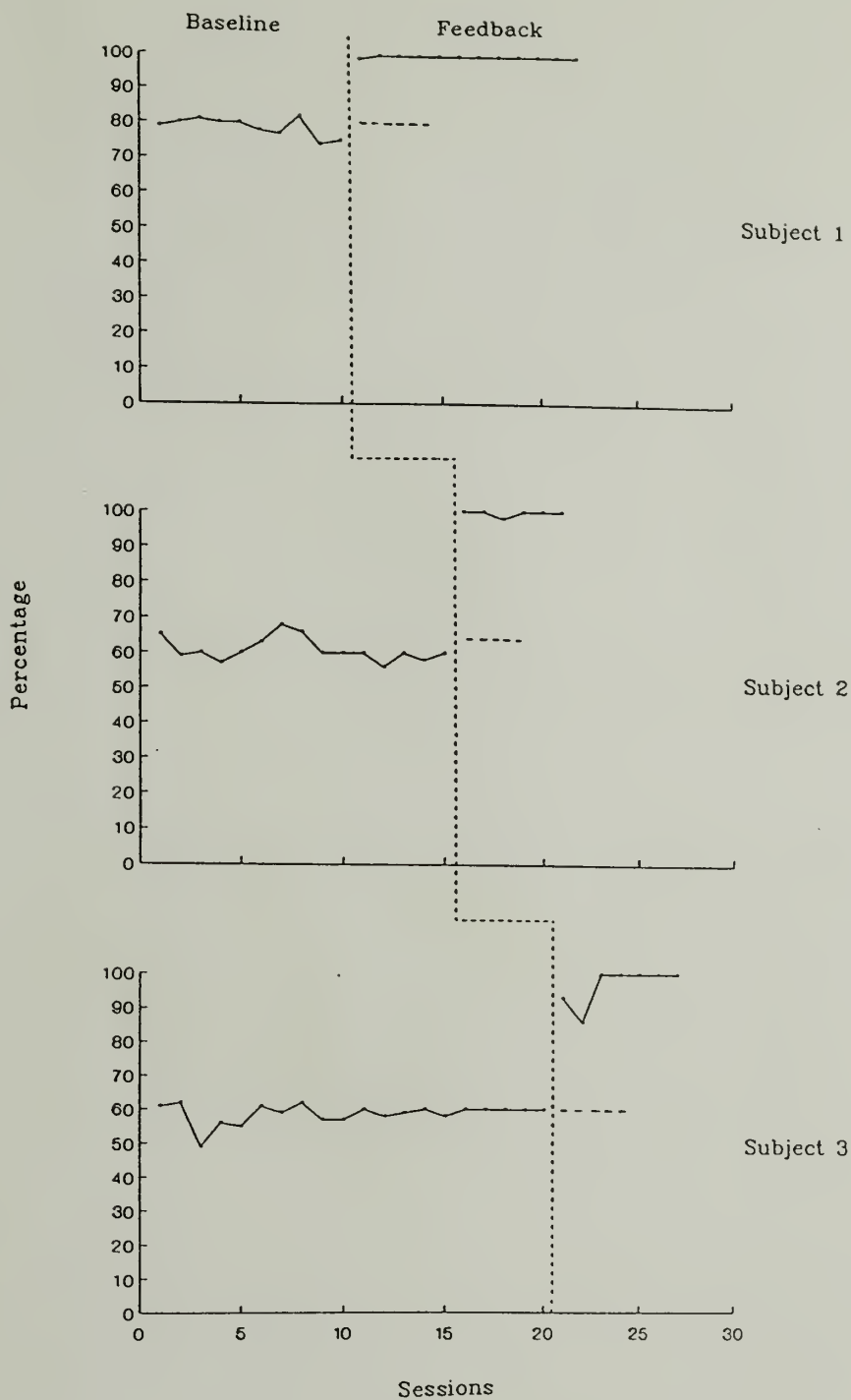


Figure 1. Percentage of Intervals During Which Posture Components Were Performed Correctly Per Session. Horizontal Dashed Lines in Intervention Indicate Goal Selections.

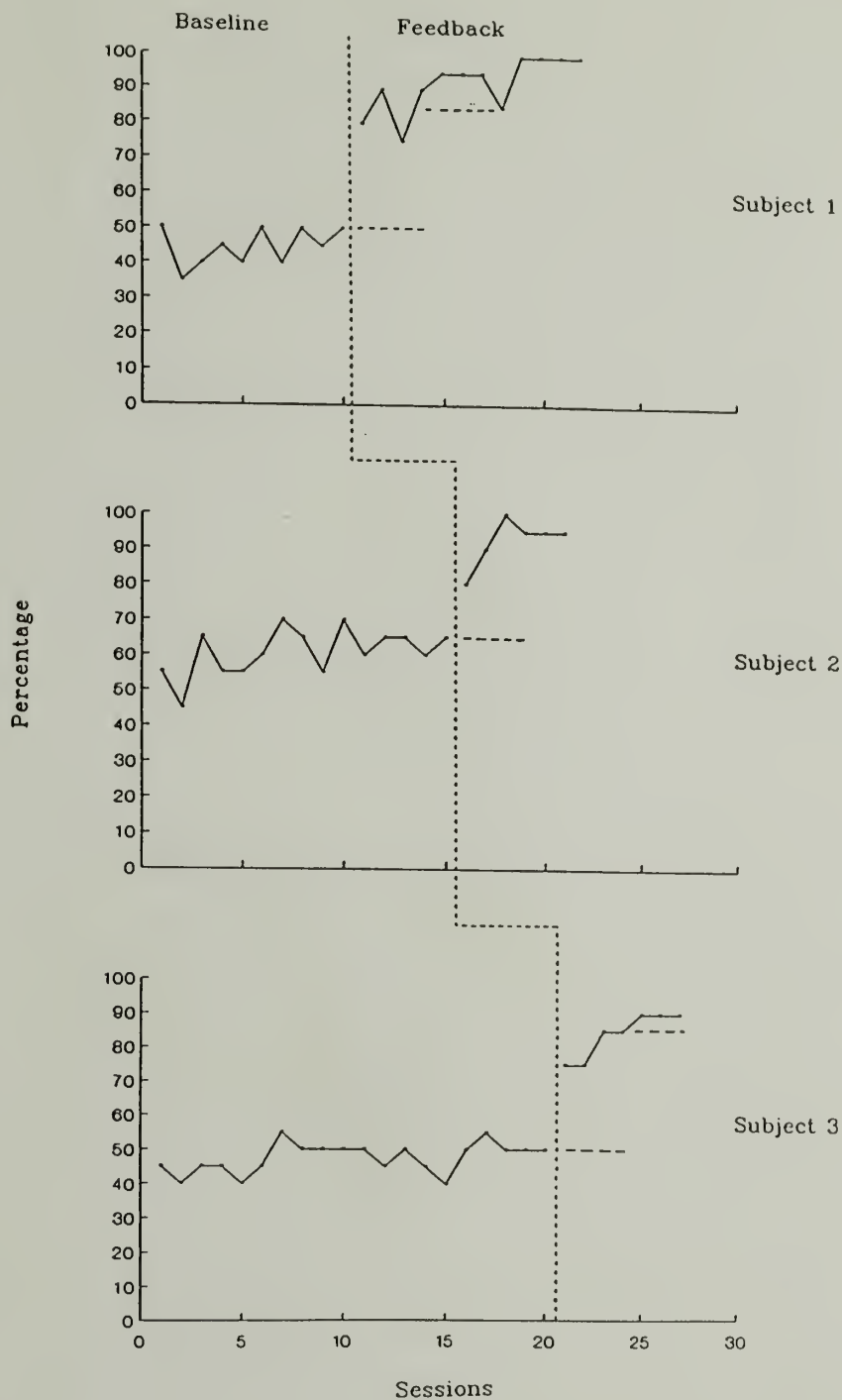


Figure 2. Percentage of Time Hand-Wrist Positions Were Recorded Each 10 Seconds at Neutral Per Session. Horizontal Dashed Lines in Intervention Indicate Goal Selections.

## CHAPTER 4

### DISCUSSION

#### Experimental Purpose and Goals

The current study had two goals: 1) to develop a reliable observational system targeted at subject posture and hand-wrist positions; 2) to implement an intervention consisting of intensive feedback on those measures which would hopefully result in an improvement of those behaviors. It was further intended that the results of the current work serve as the basis for a more comprehensive approach toward the risk reduction of Carpal Tunnel Syndrome in VDT users in an applied setting. The above two goals were met quite successfully and optimism concerning their utility in an actual work environment is indicated.

The system implemented was highly reliable, as indicated by the consistently high percentages of inter-observer-agreement sampled throughout the course of the observations. During training, there was little disagreement between the observers regarding the definitions of the various posture items, and calculated indices of agreement during data collection rapidly approached and stabilized at 100%. The data collection method was relatively

simple to use and the observers mastered it rather quickly. The posture items primarily consisted of gross motor behaviors which were easily discerned (i.e., feet flat on the floor). Reliable and valid observations of such behaviors have been demonstrated numerous times in the literature. Alavosius and Sulzer-Azaroff (1986, 1990), for example, accurately measured lifting and client positioning behaviors of institutional direct care staff through direct observations and brought about changes in those behaviors with great success.

Observations of the second target behavior, hand-wrist positions, were also easily mastered, although the discrepancies between the observers were slightly higher on this measure than was the case for posture. The measurement of correct hand-wrist positions was on a finer motor behavior than posture and was not as stable. Items of posture, for example, back straight, were most often exhibited by the subject for long durations; frequently, once in a certain position the subject did not significantly alter that position for the entire session. However, the hands and wrists were constantly in motion due to the nature of the task (typing) and the observers were required to observe diligently each and every



motion in anticipation of the momentary time sample auditory cue. Thus, the assessment of hand-wrist positions was more rigorous than that of posture. Accordingly, this difference is reflected by the slightly lower indices of inter-observer-agreement on this item. However, an average of 91% agreement is still remarkably high.

The second goal, to effect an improvement in the target behaviors through the delivery of feedback, also was achieved. All subjects demonstrated a rapid and dramatic improvement in both posture and hand-wrist positions upon receipt of the intervention; the rate of the change was remarkable. The results indicated that the implementation of a dense schedule of specific feedback combined with goal setting was, as expected, extremely effective and dramatically improved performance was the outcome. This was not surprising, as the efficacy of such interventions has been demonstrated time and again. Balcazar, Hopkins and Suarez (1986), Alavosius and Sulzer-Azaroff (1986, 1990), Saari and Näsänen (1989), Komaki, Heinzman and Lawson (1980) and many others all provide research which clearly supports the utility of feedback in applications to industrial safety. The rapidity of change was not unusual considering

the circumstances under which sessions were conducted. Sessions were brief (approximately 10 minutes total) and the feedback was delivered immediately following each session after baseline measures were complete. The brevity of session length may have facilitated rapid change because the salience of the observations probably remained high during each session. If a less dense schedule had been used, the change rate would probably not be as pronounced, although there is a good probability that the magnitude of change ultimately would be the same.

#### Implications for CTS Research

An actual assessment of risk reduction cannot be made from this study. First, the subjects did not represent a population at occupational risk, such as full time VDT workers. Second, because of the chronicity of the syndrome and the lack of clear diagnostic tools, the measurement of risk reduction would require long term longitudinal group data in an applied setting. Therefore, although the results do not speak directly at the reduction of risk, significant steps toward this goal were made.

As previously reviewed, no direct causal links between biomechanical factors, specifically constrained posture and hand-wrist deviations, and

the contraction of RSIs have been established. There is, however, strong correlational evidence linking the above behaviors to an increased risk of such injuries (Armstrong et al., 1987; Arndt, 1987; Silverstein, Fine, & Armstrong, 1987). The results of the current research indicate that those biomechanical factors can be measured objectively and are subject to modification. Both categories of behaviors, posture and hand-wrist positions, changed from less than optimal (constrained posture and frequent wrist deviations) to the recommended topographies (unconstrained posture and infrequent deviations). This research also provides the initial link called for by Blair and Bear-Lehman (1987) in the bridge between ergonomics and training for behavioral change.

Optimal environmental design through ergonomics and the identification of biomechanical factors which impinge on the risk of contracting RSIs are critical components in research aimed at the reduction of such injuries. The current research begins to explore the issue of training which is so important to combine with the above as a comprehensive preventive tool. Once the biomechanical risk factors have been identified, ergonomic guidelines dictate an

environment such that the incidence of risky behavior is minimized. The design of a work station (in the current context, a VDT setup) attempts to minimize the need for repetitive motions, extreme joint deviations, excessive force levels and stereotyped movements by the worker (Meagher, 1987; Putz-Anderson, 1988).

Ideally, once the environment is designed to support optimal behaviors workers will automatically comply. Unfortunately, this is not always the case, and an effective training tool is required to take the preventive process one step further and maximize the beneficial aspects of such a program. The current data address this aspect. Although not conducted in an applied setting with a population at risk, the data indicate that the behaviors targeted by the medical and ergonomic fields in relation to CTS can be modified in a straightforward training program.

An important aspect of this training methodology, feedback, is that it is relatively easy to import into an applied setting. Alavosius and Sulzer-Azaroff (1990) and Saari and Näsänen (1989) both implemented similar packages in applied industrial settings. The technique is learned rather

easily and the time investment required by those overseeing such a program is minimal. Behaviors can be measured in many different ways, including computer aided measurements of specific angles of hand-wrist deviations and other body positions. However, in an applied setting, the benefit of a measurement tool needs to be balanced against the time and effort it requires from the user. The current system is simple, requires no specialized training or tools and in a laboratory setting yielded extremely promising results. The methodology of the study, however, is not without comment.

#### Methodological Issues

External Validity. External validity refers to the degree to which the results of an empirical system may be applied to other groups, measurement variables, treatment variables and settings (Cambell & Stanley, 1963). Threats to external validity can significantly limit the generality of the research. A major threat in the current research was reactivity.

Reactivity was a factor because direct observations were used during each session; often times there were two observers present. Subject reactivity to the observation procedures was expected

and although participants reported that after the initial sessions they ignored the presence of the observers, it is unlikely that this reduced the reactivity completely. The sessions were conducted in a rather small office, therefore, the observers were never more than a few feet away from the subject. Consequently, nothing is known of the behaviors in question in the absence of the observers.

Limitations to Generality. Because of the profound effects of reactivity, the generality of the current research remains to be demonstrated. Subjects performed the behavior almost exclusively within the context of the experiment. The behavior of the subjects was under tight environmental stimulus control. All observations occurred under identical stimulus conditions and, as the subjects reported, it was often the only environment in which the typing behavior occurred on a reliable basis. The subject population precluded any generalization probes of the behavior outside the experimental setting. A solution to the problem of reactivity and an assessment of generality should be sought. One method of accomplishing this would be to replicate

the procedure across different settings and determine the effects of the intervention.

Another approach would be to identify a subject population who engage in the target behavior on a regular basis; for example, a telephone operator who works full time at a VDT. This population would permit more frequent and less intrusive observations of the target behaviors in an less artificial setting and lend support to the generality of the procedure. One such method might utilize a video recorder as a permanent fixture in the environment. Frequent samples of the behaviors could be recorded without the subjects' knowing when their performance was being recorded and although reactivity would continue to be an issue, it would be far less of a threat to external validity than in the current study.

Maintenance. A recognized omission in the current study is a lack of maintenance data. Although all subjects were proficient typists, none regularly engaged in the behavior as a predictable part of their days. Indeed, because the participants were enrolled full time at the University and had various other commitments, it was difficult to schedule observation times.

## Future Directions

One logical progression of this research is to expand the system to demonstrate long term maintenance and generality of the results among a population who use VDTs for a good part of the working day. Once this is accomplished, a critical assessment of the impact such behaviors have on the risk of contracting CTS could be made.

As previously mentioned, the using of video recorders and cameras to facilitate observations is an extremely useful direction the research could take. Not only might this equipment reduce the level of reactivity, but it would also allow for a more rigorous assessment of reliability. A major concern in the current study was the reliability of the measurement system as estimated by inter-observer-agreement, and although this agreement was high, obtaining dual measures often proved difficult due to schedule conflicts among the subjects and research staff. The observational system required that the primary observer and the RA observe simultaneously and receive auditory cues from the same source. Video tapes and photographs would significantly decrease the scheduling problem because estimates of



agreement would not need to occur during actual sessions.

Video or photographic equipment would also permit a more rigorous assessment of the target behaviors; particularly of hand-wrist positions. Exact angles of deviation were not measured in the current study because the direct observation of hand-wrist positions relied upon subjective visual judgments. Observers probably could learn to record angles, but most would find such fine discriminations very difficult. However, joint markers, applied to the hands and wrists would allow an assessment of finer categories of deviations than were attempted by the author. For example, a permanent record of the behavior (such as videotapes and/or photographs) would allow the category of "extension" to be further broken down: 5-10 degrees, 10-15 degrees, etc. As a result, specificity of feedback would also increase and the effect of the intervention probably would be more powerful. Only a systematic study incorporating the above suggestions can yield specific advantages.

Modeling. Another function video tapes could serve would be as part of a modeling package. Videotape modeling has been shown to be an extremely effective training tool in business and in bringing

about changes in both gross and fine motor behaviors (Carroll & Bandura, 1982; Hultman, 1986; Miller & Gabbard, 1988; Rosenbaum, 1984). Subjects could view samples of tapes depicting a typist displaying optimal performance (unconstrained posture and neutral hand-wrist positions). The investigator could discuss and point out the desired behaviors to the subjects and then provide them with feedback about their own performance. It is also possible that subjects could eventually view and rate their own performance. This would maximize the effect of modeling because the effectiveness of modeling increases with the number of characteristics the subject shares with the model; self-modeling capitalizes on this factor (Dowrick & Dove, 1980; Dowrick & Hood, 1981).

Self-Monitored Performance. Self-monitored performance would be a useful addition to a training package as well as a convenient maintenance tool. One such method might be incorporated into the computer program the subject uses (for example, into a word processing package). Such a program could ask subjects to self report on various aspects of their behavior and at the same time prompt them to perform

optimally. The illustration below provides an example of such a program.

Subjects are informed about the desired behaviors (correct posture items and hand-wrist positions). The computer periodically interrupts the program the subject is using and asks the subject to self report on one of the behavioral components. A pool of relevant questions could be formed such as: "Are your feet flat on the floor?"; and, "Is your back straight?". If the subject responds with an optimal answer (i.e., YES - indicating that the feet are in the correct position), feedback would be given such as "Great!", the normal computer program would resume where it left off and the next prompt would occur at some predetermined interval. If the subjects' answer indicates that the behavior is not optimal (that feet were not flat on floor), appropriate feedback would be given and the program would resume. However, the interval following an incorrect response would decrease from the previous interval. If the normal interval were 30 minutes, an incorrect response would be followed by a 25 minute interval and the same question would be asked. If the response were again in the unwanted direction, the interval would subsequently decrease from 25 to

20 minutes and the question would be presented again. Thus, undesirable responses would be consequted by more frequent interruptions. This process would continue until the subject provided the desired response. Once this occurred, the interval would return to its original length (30 minutes) and a new question would be asked.

Several important aspects of the proposed self monitoring method must be considered. First, the nature of process is potentially aversive; subjects would be interrupted periodically during their work. Therefore, it would be very important to identify specific times at which interruptions would be least aversive. If the subject was typing text, for example, an interruption at the end of a paragraph might be less aversive than one in mid-sentence. Second, the accuracy of self-reports must be considered. The reliability of these reports would need to be measured. This could be accomplished through the comparison of self reports to more objective data gathered either through live observations or the video-camera set up previously discussed. The accuracy of self appraisal is maximized when subjects are made aware that their reports are being monitored (Hayes, Rosenfarb,

Wulfert, Munt, Korn, & Zettle, 1985). The program could be further bolstered by reinforcing subjects for accurate self reports. This would increase the utility of the program as well as make it more palatable to the participants.

#### Summary

It was hoped that the behaviors presumably implicated as risk factors for CTS could be measured and changed, and these expectations were fulfilled. As discussed, no direct assessment of risk reduction would be made based on the data in the present study. It is not known whether the procedures presented would reduce subjects' risk of contracting CTS. Besides the limitations inherent in the present study (e.g., brief intervals, highly structured setting, etc.), the chronicity of the syndrome and the lack of causal evidence linking it to specific behaviors prevent such a conclusion. The long range potential implications of the procedures used in the study, however, are promising.

The immediate and future consequences of cumulative trauma are only beginning to be realized. Technological advances are being developed at extraordinary rates and with them comes a host of new industrial injuries appear to be accompanying them.

This project explored a system which integrates the ergonomic, biomechanical, training and management components recommended to reduce the risk of CTS and other RSIs. It is anticipated that OSHA soon will issue guidelines that target these injuries. At that time, the need for comprehensive safety programs in this area will be enormous, and the field will be ripe for wide scale interventions such as those outlined above.

## APPENDIX A

### INFORMED CONSENT FORM

As you may know, technological advances have resulted in many individuals spending their entire day at work in front of a computer and keyboard. Although it may not appear to be dangerous, hazards associated with prolonged use of such equipment are being identified. One of these is Repetitive Strain Injury (RSI). RSIs result from rapid repeated motions over extensive periods of time. In data entry, the hands, wrists, and arms are prone to such injuries. Many people, including doctors, physical therapists, and engineers are trying to find ways to decrease the risk of people getting RSIs.

I believe that one way to do this is to get people to change their behavior in small ways while they are working. That is why I am asking for your cooperation and contribution to this project. The more research that can be done, the better off we are in fighting this occupational injury.

This research project is designed to determine the specific motions of the hand and wrist which are normally used when entering information on a computer keyboard. Participation is purely voluntary.

The project will consist of two phases. During the first phase you will be observed by myself and/or a trained research assistant for a brief duration while you are working at your computer.

In the second phase, I will talk to you about the specific motions we are interested in and share with you the results of the initial observations. Following this, the observations will continue and you will be provided with frequent feedback on exactly what we have recorded.

Your decision to participate or not to participate is entirely your own. The main advantage is the contribution you may make ultimately toward preventing job related injuries.

Should you choose to participate, you will be given a summary of the project upon its completion. The data from this study will be used by me in partial fulfillment of my graduate school requirements and may be used for publication in professional journals and/or for presentation at professional conferences. As in all research such as this, neither participants' names nor any identifying characteristics will be made public

from this study without their explicit consent at the time.

The project will last for approximately 4-6 months. Your participation is totally voluntary. Therefore, while I hope you would plan to participate for the duration of the study, you should feel free to withdraw at any time without any penalty. If you have any questions at all regarding this project, feel free to call me at the number below.

Thank you for your time and consideration.

I have read the above and agree to participate in this study. I understand that I may withdraw at any time.

Kathleen E. Blake  
(413) 545-0794

---

Name (please print)

---

Signature

---

Date



## APPENDIX B

### SUBJECT SCREENING QUESTIONNAIRE

Please answer all of the following questions either YES or NO. All answers are strictly confidential and you can discontinue at any time. Thank you for your cooperation.

1. Do you now, or have you ever had Carpal Tunnel Syndrome?
2. Do you have arthritis in either hand, wrist, or arm?
3. Do you have tendonitis in either hand, wrist, or arm?
4. Are you pregnant?
5. Do you have a history of problems with edema (swelling and water retention)?
6. Have you ever broken or sprained either hand or wrist?
7. Do you have diabetes?
8. Have you experienced any of the following within the past 3 months?
  - persistent tingling in your hands or fingers
  - numbness in your hands or fingers
  - nocturnal pain in your arms, hands, or fingers
  - weakness/clumsiness in your hands or fingers

## APPENDIX C

### SUBJECT BEHAVIOR CHECKLISTS

#### Subject Behavior Checklists

#### POSTURE

- + item present
- item absent

Interval

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Back straight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Shoulders relaxed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Neck straight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feet flat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Forearms parallel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

TOTAL (+) = \_\_\_\_\_

#### HAND-WRIST POSITION

Right Hand

Left Hand

Interval

Interval

1 2 3 4 5

1 2 3 4 5

Neutral

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Extension

Flexion

1 2 3 4 5

1 2 3 4 5

Neutral

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Ulnar

Radial

## APPENDIX D

### CONSUMER SATISFACTION SURVEY

It would be very helpful for me to get some feedback concerning your participation in the study. I am interested in what you liked, disliked and what improvements should be made. Please take a few minutes to answer the questions below. Thank you.

1. The duration of the study was
  - a) shorter than I expected
  - b) longer than I expected
  - c) about what I expected
  
2. The amount of time and effort required of you was
  - a) very little
  - b) a little
  - c) a large amount
  
3. Please rate your reaction to the following:

1	2	3	4	5
(-)				(+)

  - a) being observed

1	2	3	4	5
---	---	---	---	---
  
  - b) receiving feedback from the graphs

1	2	3	4	5
---	---	---	---	---
  
  - c) receiving feedback from the experimenter

1	2	3	4	5
---	---	---	---	---
  
  - d) the close proximity of the observers

1	2	3	4	5
---	---	---	---	---
  
4. How useful did you find the information you learned (i.e., correct posture and hand positions)?
  - a) very useful
  - b) somewhat useful
  - c) not useful
  
5. How do you feel other people would respond to the process you participated in?
  - a) very well
  - b) adequate
  - c) not at all well

6. Do you feel that the original explanation of the study was accurate and sufficient enough that you knew what to expect? If not, please comment.
7. Any comments you have, good or bad, or suggestions would be appreciated.

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