Abstract

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It is not uncommon to encounter a situation in ergonomic intervention research where there is resistance toward proposed changes to someone's work habits or workstation. Often, this has negative consequences when attempting to study the effectiveness of an intervention. Additionally, research into the implementation of an ergonomic intervention is sparse. Therefore, in an attempt to combat these problems, a study was conducted in the ergonomics laboratory at North Carolina State University. The experiment assessed the effects of positive feedback and reinforcement on the acceptance of an ergonomic intervention.

Two groups of subjects were used; the first, or control, group performed a screwdriving task using an ergonomic intervention without interruption. The second group was the feedback group, who received positive feedback and reinforcement while performing the same task. Significant results from posttest survey questions showed a 29-57% more positive response from the feedback group. Additionally, there was no instance where the feedback group answered significantly less positively. With respect to the two remaining types of data, performance and perceived discomfort, no significant difference was seen either between groups or across the two days of testing.

From these results, it can be seen that the feedback seemed to positively influence the acceptance of the ergonomic intervention. However, it did not negatively affect a person's performance on the task nor did it influence her or his perceived discomfort. The results would indicate that positive feedback during the implementation phase of

ergonomic intervention research has a positive impact on the perceptions of the person working with the intervention. These results are consistent with the body of literature on the positive effects of participatory ergonomics and may lead to more effective techniques for conducting ergonomic intervention research.

Assessing the effects of positive feedback and reinforcement throughout the implementation phase of an ergonomic intervention

By

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Dedication

Throughout my education, I told myself that I would stop attending school the minute I graduated college. I think partially as a child I did not comprehend the importance of an education. More importantly, I did not value learning as much as I should have. Now, nearing the completion of a Master's degree, and contemplating further education, I realize why people should get an education, for personal fulfillment and to teach others. I have always carried with me the ideal that I am capable of doing anything I set my mind to. I have also told myself that I would like to help people through the work that I do. With the selflessness, encouragement and persistence of my parents, Lynne and Larry Brandenburg, to whom I am dedicating this thesis, these ideals are still with me today, and this thesis has become a realization. It was not until I moved away to college that I became conscious of the principles my parents have instilled in me. I finally appreciate my parents' wisdom and I thank them from the bottom of my heart.

Biography

David Brandenburg is the second of four children, the other three being his eldest sister Anne and younger siblings Mark and Mary. His parents, Lynne and Larry Brandenburg, who raised David and his siblings first in Macomb, IL, now reside in Rock Island, IL. After graduating from high school in Rock Island, David eventually received a Bachelor of Science degree in Industrial Engineering from the University of Illinois at Urbana-Champaign. While at the U of I, he had the privilege of working with Dr. Michelle Yeh, who was a graduate student at the time of Dr. Christopher D. Wickens. Immediately following his undergraduate education, he traveled to Raleigh, North Carolina to attend North Carolina State University to work on a Master's degree in Industrial Engineering. While working toward this, David had the honor of working with Dr. Gary A. Mirka, contributing to ergonomic intervention research in the furniture manufacturing industry. In the Summer/Fall of 2002 while working to complete his thesis, David was an ergonomics intern at the University of North Carolina at Chapel Hill, teaming with Riley Splittstoesser in spreading ergonomics across that campus.

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One of the major lessons learned from the experience of completing a thesis is that it is impossible to go it alone. Therefore, I have many people to thank in supporting me during this process. First I would like to thank my advisor, Dr. Gary Mirka. His patience, mentoring, commitment and optimism have been invaluable not only to the success of this project but also to my growth as a person over the last two years. I would also like to thank the two supporting members of my thesis committee, Dr. Carolyn Sommerich and Dr. Mike Wogalter for their support and understanding.

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1.0 Introduction

Since the dawn of civilization, manual labor has been a staple in our working society. Injuries have inevitably accompanied physical exertion. One can think back to the time of the cave dwellers and imagine them dropping a large rock on their foot while transporting it from one place to another. It is also intriguing to envision the construction of such structures as the pyramids of Egypt or Central and South America, or even the Great Wall of China. During these laborious tasks, it is fair to assume that physical injury occurred throughout the process to any number of individuals. What may be less apparent are injuries that may have occurred from overexertion due to lifting rocks from the ground; repetitive motion injuries could have also been prevalent due to repeatedly passing these rocks from person to person. Both of these situations likely posed an excessive amount of stress on the person, an amount that the body might not have been able to cope with. This inability to cope may be either because certain parts of the body can only sustain a limited amount of external force or because other components are not allowed to recover in between small, repetitive exertions. While problems like these found in the workplace have always been apparent, humans have taken many thousands of years to develop the sensitivity to "see" them. This ability, coupled with the task of negating these harms, has evolved into the field of ergonomics.

The following introductory section begins with an overview of ergonomics. Following this, there is a brief explanation of musculo-skeletal disorders and the risk factors that may be involved in their development. The next section covers intervention research, the steps involved in the process, and the construct of participatory ergonomics.

The discussion then deals with problems found during the implementation phase of the intervention research process. Finally, an argument is formed, specifically that using feedback and reinforcement during this phase may help elicit greater acceptance for ergonomic interventions.

1.1 Overview of Ergonomics

The word "ergonomics" comes from the Greek roots of *ergon*, meaning work, and *nomos*, meaning law. Therefore, ergonomics can roughly be translated to mean "the laws of work." This discipline can be more explicitly defined as the "scientific study of the efficiency of man in his working environment" (Oxford English Dictionary, online version). Ergonomics can roughly be divided into two domains of human work, cognitive and physical.

Cognitive ergonomics, or human factors engineering, is concerned with the user's mental understanding of a system and their ability to effectively function within it. An example of this is seen in aviation. It is important that the displays and controls of an airplane cockpit are situated such that the pilot can successfully navigate a plane by obtaining the necessary information without making critical errors.

Physical ergonomics, or simply ergonomics, focuses on the way the human body works within a system in order to develop working environments conducive to their physical well-being. An example of this would be the presence of a mechanical lifting device, such as a hoist, that may take the place of a human needing to bend over to the ground and pick up a heavy object--both of which would place a great deal of stress on the back.

1.2 *Work-related Musculoskeletal Disorders*

The motivation for ergonomics research stems from statistics of the number of recordable workplace injuries and the subsequent amount of money they incur. In 1992, more than 30%, or 705,800 cases, of all OSHA recordable injuries and illnesses were attributed to repetitive motion and overexertion. Over half of these cases concerned injuries to the back. These cases cost industry an estimated $13 to 20 billion annually (NIOSH, 1997). This is mainly due to lost workdays. In 1992, the average repetitive motion case resulted in 18 days away from work while the average overexertion case resulted in 6 to 7 days off. Likewise, according to the Bureau of Labor Statistics, in 1995, 62% of all OSHA recordable illnesses, or 308,000 cases, were from repeated trauma, such as carpal tunnel syndrome (CTS) and tendonitis. Interestingly, going back to 1972, this number was just 23,800. These numbers do not include back disorders; they are recorded as injuries, not illnesses.

Musculoskeletal can be defined as "of, pertaining to, or involving both muscular and skeletal structures" (Oxford English Dictionary, online version) while a disorder can be defined as "a disturbance of the bodily functions; ailment, disease." (Oxford English Dictionary, online version). Melding these two statements yields the following definition for a musculo-skeletal disorder (MSD): a disturbance, ailment or disease of, pertaining to, or involving both muscular and skeletal structures.

MSDs can be produced in a variety and combination of ways, which distinguishes them from an acute injury such as a broken bone. MSDs develop subtly and increase in severity over time as a result of several risk factors, both external and internal. External risk factors, or manifestations of the working environment, include force, repetition, posture, and to a lesser degree environmental factors. Internal risk factors can be anatomical or psychological, which are a result of a person's existing physical and mental characteristics, respectively. These factors, both external and internal, work together in various forms and combinations during the development of an MSD, which may increase the risk (Bhattacharya and McGlothlin, 1996).

External forces exerted on the body become a risk as they increase in magnitude, either singularly or in unison. Magnitude can increase as a result of the job requirement or the person's adopted posture. An example of this can be seen in a job as simple as lifting an object from the ground. With an increase in object weight, the body is required to produce more force to lift it. When multiple objects need to be lifted, as the time-between-lifts decreases, the body is less capable in performing each subsequent repetition as a result of fatigue.

Posture is also a factor during a task such as lifting. The further the object is away from the body, the more force that is required to lift it. Bending, as opposed to squatting, can result in the weight being further from the body than necessary. One thing that should be pointed out is that a person's adopted posture may not necessarily be of her or his own accord. In other words, it could be a result of the workstation setup. For example, if the item to be lifted is behind a table or some other immobile object, the person is forced to bend over the table in order to accomplish the lift.

Environmental conditions are a final group of external risk factors of the workplace (Bhattacharya and McGlothlin, 1996). First of all, as noise increases, a person's hearing is subject to damage. Second, temperature may play a role in increasing risk for developing an MSD. As temperature decreases, the body constricts, reducing characteristics such as a person's range of motion and strength capacity. It is also possible while the elasticity of soft tissues is decreased, they may be more subject to injury (Eastman Kodak Company, 1983). Conversely, in hot environments, perspiration may reduce a person's ability to properly grasp an item. Thus, she or he may have to grip the item tighter to keep control of it (i.e., more exerted force) as the probability for losing control of it increases with the decreased friction.

Research suggests that internal, or personal, risk factors also play a role in the development of an MSD (Bhattacharya and McGlothlin, 1996). To begin with, a person's anatomical makeup may be such that it is more risky for them to perform certain tasks. For example, a taller person is required to bend further over in order to lift something from the ground, which increases the amount of force required to lift her or himself and the item. Two more examples of possible internal risk factors are psychosocial stress (MacLeod, 1995; Devereaux and Buckle, 2000) and personality type (Allread, 2000).

In the context of a working environment, MSDs are also referred to as work-related musculo-skeletal disorders, or WMSDs. Examples of WMSDs are tendonitis or inflammation of the tendon, tenosynovitis or inflammation of the tendon sheath, nerve entrapment or reduced nerve conduction or numbness, low-back pain, chronic neck pain, and muscle strains.

1.3 Intervention Research

The ultimate goal of ergonomics is to be pro-active by designing products and environments initially with the human in mind. However, since the majority of industries came into existence prior to widespread knowledge of ergonomics, there is a need for retrofitting in those areas to reduce and eliminate ergonomic risk factors. Intervention research accomplishes this by studying jobs in the workplace, deciding which ones pose an injury risk to the employees and redesigning the job with the primary aim of reducing the incidence of musculo-skeletal disorders (MSDs).

Goldenhar et al. (2001) provide a 3-step template for intervention research, consisting of development and implementation, as well as studying the effectiveness of a workplace intervention. Although there are other models throughout the ergonomics literature, this one will be adhered to for the following discussion due to its simplicity. Each of the three steps encompasses a wide range of events in the intervention research process.

Development is comprised of everything from initial research of a specific job to designing a final intervention for a job. This includes the analysis of workplace injury data. In some cases, a specific job or task has already been identified, and intervention research will commence specifically at its location. In other cases, company-wide and possibly even industry-wide injury data is examined in order to determine which jobs need to be studied first, or, which tasks have the largest injury rate.

Upon identifying a hazardous job, a more focused study of this specific job will be performed. This examination may include a thorough visual observation of the job, along with video analysis of its tasks and surveying employees regarding the job and their health. The next step is generally a process that includes conceptions of possible solutions. Further efforts will produce an initial prototype, which is then tested in the lab for its functionality as well as productivity, but most importantly to demonstrate that it produces a viable ergonomic benefit to the worker. This could involve focused lab experiments that collect bioinstrumentation data as well as subjective user-input. If the results of this study do not show that the intervention provides a significant ergonomic improvement, the prototype may be modified or a new design can be made and another experiment will be run.

After a prototype is studied and demonstrated to be effective, it is taken out to an actual job site; workers will normally volunteer to use it for a certain period of time. This allows researchers to study the "real-world" effectiveness of the intervention through video analysis, and the volunteers will ideally provide their thoughts regarding the effectiveness. At this point it is likely that the prototype will be modified based on the results from the "real-world" study. It may be apparent that this is an iterative process.

The implementation phase begins following the final modifications when the intervention is taken out to industry for a long-term trial period. Therefore, the assumption is that implementation begins when the final prototype is introduced in the workplace. During this time, employees will be asked to work with the ergonomic intervention in place for a lengthy amount of time, possibly permanently. This may include some sort of education regarding ergonomics and why the intervention is being implemented, as well as a learning phase, which is dependent on the intervention's complexity and the employee's ability and willingness to use the intervention. During this time, and at times in the future, the ergonomist will be recording critical data to determine what kind of impact the intervention has on the employee, namely her or his productivity, and the ergonomic risk factors of the job; the goal is to achieve a positive impact.

The effectiveness study, the third phase of the intervention, is generally long-term in nature and has the goal of determining the success of an intervention. In the short term, data can be collected to assess whether there is an immediate ergonomic impact without significantly affecting the employee's productivity. Ergonomists will analyze a certain job to see if there is an improvement in the ergonomic risk factors. These risk factors may include force, repetition and posture. This can be done with video analysis, bioinstrumentation data, and user feedback, such as satisfaction and perceived discomfort and productivity. In the long term, injury data can be analyzed with the intention of looking for a reduction in injury rates at the redesigned job. This is the type of data that will have the biggest impact, as lower injury rates translate to reduced worker's compensation costs.

One of the major challenges facing ergonomists is overcoming the resistance to change. In other words, it is difficult to get someone to change her or his work habits if she or he has had the same job for a number of years. It is unclear whether the ineffectiveness of the application or the employee's stubbornness is at fault. There are some researchers who claim the former is the case.

In a classic article in Harvard Business Review, Lawrence and Lorsch (1954) deal with this issue of resistance to change. They argue that change in industry is necessary, but does not need to be as difficult as it so often is. Although the change is usually technical, such as redesigned work methods, the resistance is to the accompanying change in the social dynamics of the workplace. The specialists implementing the change, who are chiefly concerned with the technical aspects of the ideas and not necessarily the person who will be working with the change, create some of the resistance. In an effort to counteract these negative aspects, this article discusses employee participation as one method of facilitating change. The authors claim that respecting and listening to employees is necessary for positive results.

In a follow-up article, Lawrence (1969) provides retrospective commentary. He expresses he is less optimistic that his initial hope of management making an effort to include the employees will make a difference in reducing resistance to change. However, Lawrence discusses primarily changes that affect productivity, which could be a result of the writing being published in a business journal.

Although the concept of resistance to change in manufacturing environments was partially spurred by problems with changes in production, it is understood that concern with more than just production levels is important when introducing new technology in the workplace. Nadler and Robinson, in their 1987 publication, discuss the cultural change that may take place when implementing advanced manufacturing technology. They note that culture within organizations is historically stable, and changing the norms can prove to be difficult. Their recommendation, therefore, is to change the cultural norm from stability to continual improvement, similar to the Japanese philosophy of *kaizen*.

Hurley (1992) also explains that introducing new technology can significantly change the workplace. This is evident in ergonomics when an intervention requires the worker to modify her or his work methods. Therefore, when introducing new technology, management needs to understand how this will change their relationship with employees. Hurley provides a model describing the sequences that should be involved in the introduction of new technology, which is reproduced in Figure 1. His first concerns are for the employee to perceive the usefulness of a change and to allow her or him to participate in that change. He argues that acceptance will be greater if employees are immediately informed and involved in the change process. The model in Figure 1 also

Perceived Usefulness
↓
Early Participative Involvement
↓
Pilot Trial
↓
Acceptance
↓
Introduction
↓
Use
↓
Organisation Development and Change

Figure 1: The sequence of processes related to the introduction of new technology (adapted from Hurley, 1992)

shows that acceptance should happen prior to introduction.

Resistance to change in the workplace, specifically with regard to an ergonomic intervention, could be the result of at least four things. First, potentially the employee did not notice a benefit in using the intervention. Second, it is possible that she or he did not try the intervention long enough to become comfortable with it. Third, the employee may not have used the intervention as it was intended or in every appropriate situation. Finally, and most importantly, she or he may not have been as productive using it. In piece-rate working environments, productivity is vital to the employee. If the worker can finish the process faster, she or he will find a way. Relearning the process when asked to use something like an ergonomic intervention can be very frustrating for the worker.

Addressing the above issues regarding the implementation phase and employee resistance to change is clearly necessary. One possible approach may be to incorporate the employee's own ideas into the process of intervention research, and is discussed here.

1.3.1 *Participatory Ergonomics*

As can be seen above, effectiveness studies are necessary in gaining viability for ergonomics. Consequently, it is important to ensure that what leads up to the effectiveness study will produce valid and reliable results. Therefore, studying the preliminary areas of development and implementation in great detail and determining ways to improve those processes are also key measures.

Additionally, in an attempt to achieve the overall goal of lowering the workplace injury rate, intervention researchers have used a number of different techniques in order to facilitate the process of improving ergonomics in the workplace. One approach may have been to provide a training session that will better familiarize the worker with the intervention. An alternative, or supplement, is to give an informational session about ergonomics, during which a worker may be able to understand why the intervention is being implemented. Presently, a common option is to allow the employees to assist in designing the intervention, a process called participatory ergonomics.

In a participatory ergonomics program, the employee actively participates in improving the ergonomics of her or his job (Imada, 1991). The major benefit of this approach is that the employees are the ones who know their job in the most detail. It is also possible that they know what aspect of the job they dislike from the pain or discomfort they feel at work. In addition, the employees may already have some ideas to improve the job. Finally, if the employees are willing to participate in the design, and they invest their time in helping in the design, it often means that they are accepting of an ergonomic intervention (Imada, 1991).

1.3.2 *Importance of Evaluating Quality of Implementation and Effectiveness*

Participatory ergonomics is active in the development stage of an intervention, but it seems to be lacking in the most critical stage of implementation. While the employees who participate in the design are accepting of it, other employees asked to use the intervention may not be. At this point intervention researchers need to communicate the following to the user: what is ergonomically wrong with the workstation, what we as researchers are trying to do about it, how the worker can incorporate the intervention into her or his job over time.

Certain concerns seen during the implementation phase need to be noted. Workers, especially in a piece-rate system, may grow frustrated with the intervention as their ingrained habits are making it difficult to relearn the task. In addition, it is vital to get them to realize that they actually are learning the task and that it is an improvement over their previous set-up. It is also important to help them understand the full functionality of the intervention as well as to ensure that the intervention is used correctly. There are certain questions that arise while trying to understand these situations. Are we as researchers doing enough to help employees with the transition? Are we saying what they need to hear? Do they understand what we are trying to communicate? Why do some employees decide to stop using the intervention after a short period of time? Overall, how can we improve the implementation process?

One method of facilitating implementation, which has not shown up in the ergonomic literature, is the use of feedback and positive reinforcement. It is possible that frustrated employees would benefit from hearing about how we feel they are doing in this learning stage and exactly how we see the intervention helping them. If they can get an understanding of how the intervention is helping them as individuals, their outlook of the job may change and they may become more accepting of intervention research and the intervention process. Ergonomists need not only to be concerned with the proper design of an intervention, but also how to convince people that it will improve the ergonomics of their job. If and when ergonomics becomes completely pro-active, this might be less important, as the job will not need to be changed. However, thinking realistically, it seems that helping facilitate the transition of an ergonomic intervention can improve intervention research productively and beneficially. Positive, direct interaction with someone can be a good way of influencing their perceptions.

In an article addressing the future of intervention research, Rosenstock (1996) argues that researchers must consider behavioral procedures, which attempt to influence worker knowledge, beliefs and behaviors. These procedures may include behavior modification techniques. Rosenstock claims that it is important to consider factors of organizational cultures, which include common attitudes regarding workplace health and safety. She mentions that the success of controlling exposure may be dependent on this knowledge.

Goldenhar and Schulte (1994) reviewed a number of occupational health and safety intervention studies. While the review showed that some of the studies provided behavioral interventions, including education and/or skills training, there was no mention of studies that looked at effects of feedback/reinforcement on performance with or acceptance of an intervention. They do state that an interdisciplinary approach, such as combining an engineering intervention with a behavioral one, strengthens the foundation for developing intervention research.

Likewise, in a 1996 paper, Goldenhar and Schulte state the importance of implementing more than one type of intervention control strategy (e.g., engineering and behavioral strategies used in tandem). They cite seven articles that tried to encourage health and safety related behavior by using behavioral modification techniques like feedback. Unfortunately, the authors do not mention the outcomes of the experiments performed in any of these articles.

Schulte et al. (1996) point out that intervention research can be difficult to carry out as it is linked to social issues in the workplace. The authors note that intervention research needs not only engineers, but also psychologists, sociologists and communication specialists, among others, to be successful. Levenstein (1996) also asserts that intervention research must be built on foundation of social science research. His reasoning is based on the fact that interventions tend to intrude on the employee's workspace.

Zwerling et al. (1997) reviewed numerous occupational injury intervention studies. There were two that looked at feedback and reinforcement as an administrative intervention, and both found positive results. The two studies focused on occupational safety and used the technique of providing feedback to prevent accidents (Cooper et al., 1994) and to reduce laundry linen contamination (Burken et al., 1994). Additionally, there was a number of ergonomic intervention studies reviewed. While three of them applied participatory ergonomics in their study, none seemed to use feedback as a way of influencing satisfaction.

Ironically, in his 1987 publication, Helmreich discusses the idea of increasing the acceptance of new technology in the office. He questions whether the user will realize the full benefits of new technology. Regarding the introduction and training phase, he stresses that users of new office systems need encouragement and support.

Overall, participatory ergonomics has introduced something vital in intervention research: including the employee's input on the design of an intervention. However, it is still critical that the employee's needs be considered after the design process, specifically during the introduction of the intervention into her or his work. As a result, it has been suggested that ergonomists take an interdisciplinary approach to intervention research. In other words, knowledge from the social sciences should be used in the implementation process.

1.3.3 *Lack of Implementation Studies in Ergonomics*

As a result of problems with prior steps such as implementation, it is felt that effectiveness studies can be difficult to carry out for three possible reasons. First, employees change jobs or leave the company. Second, it is possible that the intervention does not hold up under long-term working conditions, and more unforeseen modifications may need to be made. A third explanation is that workers could decide they do not prefer to use the intervention and revert back to the original work methods. In the latter instance, that decision may be due to improper or incomplete methods carried out during the implementation phase.

Goldenhar et al. (2001) recommend that effectiveness studies should not be carried out without properly implementing an intervention. In other words, an effectiveness study may not be useful if it does not have solid ground to support it. The question then becomes, what is the proper procedure for implementing? This can be answered by researching intervention studies and the fidelity of the implementations.

When implementation studies have been done, they often times have been weak or inconsistent (Goldenhar et al., 2001). If this is the case, then it undermines the validity of effectiveness research, as it is dependent on proper implementation. It is assumed that weak and inconsistent implementations studies are a result of their perceived unimportance. A partial explanation of this perception may be that researchers believe the fallacy that introducing an intervention equates to use (Bennis, 1966). In a more abstract sense, Bennis argues that gaining knowledge about something does not necessarily precede a subsequent intelligent action.

In the case of intervention research, it might be assumed that simply introducing an intervention and explaining the rationale for why the intervention may help someone do not necessarily translate into proper use. As a result, the implementation phase may not be effective. Helmreich (1987) also argues that there is a need for research into the introduction of technology. Additionally, in order to gain acceptance in the workplace, new technology needs to be seen as valuable to the employee. A consequence of poorly implementing an intervention, according to Lipsey (1996), is the expectation of weak results from the effectiveness study. It is because of this that the implementation phase needs to be further examined.

1.4 Feedback in Organizations

Ilgen et al. (1979) provide an overview of the elements within the feedback process, which is depicted in Figure 2. Feedback starts at the source; while the source could be a number of entities this discussion assumes that the source is an observer of another individual's behavior. This observer is evaluating the individual's actions and is prepared to provide verbal information to that person.

In processing feedback from the "source," the individual receiving feedback may move through four processing stages. First, she or he perceives the feedback in three

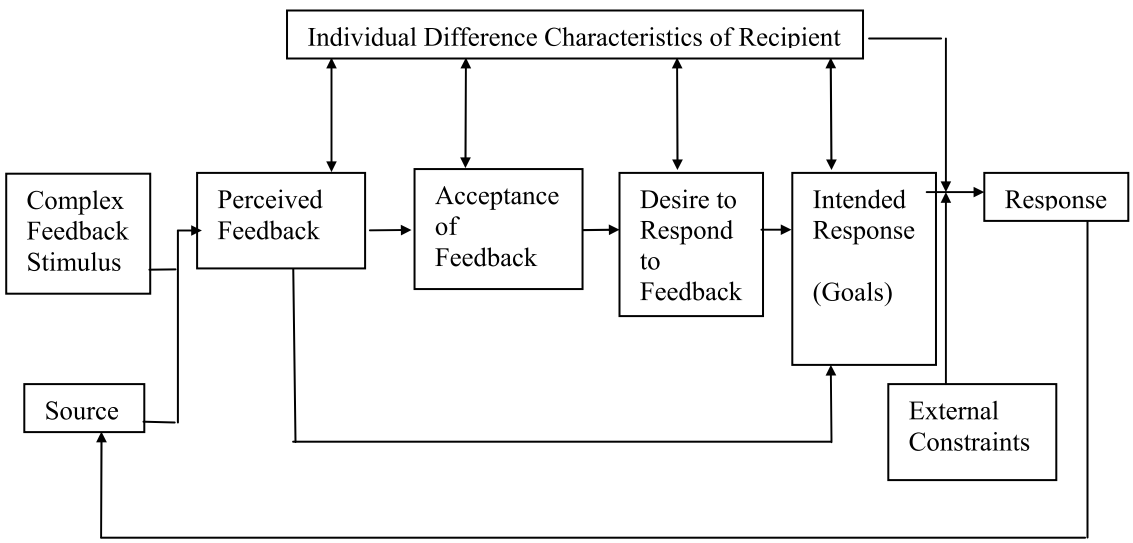

Figure 2: Model of the effects of feedback on recipients (Adapted from Ilgen et al., 1979)

dimensions. Timing is the first dimension, and it refers to the amount of time between the individual's action and her or his receipt of feedback. It is generally felt that feedback is more effective with a shorter time interval (Ammons, 1956). The second dimension of perception is the sign, which can be either negative or positive. Research has shown that positive feedback is perceived more accurately. Negative feedback, on the other hand, is harder for an individual to accept, and it has the tendency to be misperceived. The third dimension of perception is frequency. While Ilgen and his colleagues may not agree that more feedback is always better, they feel that feedback in a work setting is usually too infrequent. Therefore, they suggest providing more feedback, though understanding that it may be possible to administer feedback too frequently.

Once the feedback is properly perceived, the individual decides whether or not to accept the information provided. This decision can be influenced by the source providing the feedback, the message given, or the recipient receiving the feedback. The source is usually the key element in accepting feedback, particularly the individual's perception of the source's expertise. Regarding the message, it again relates back to the sign of the message, meaning that positive feedback is generally more accepted. The recipient is also a key variable in acceptance. A person with an internal locus of control, meaning someone who feels more in control of their actions, is normally more accepting of feedback because of that feeling. Conversely, someone with an external locus of control is less accepting of feedback, possibly because they do not believe the feedback is correct. Additionally, age may play a role in acceptance. Older people, who are generally more experienced in the workplace, are less accepting of feedback and more likely to use their own experience as a source of feedback.

Following the acceptance phase, the individual may or may not have a desire to respond to the feedback presented. This is where the perception of the feedback is integral, meaning that timing, sign, and frequency all play a role in someone's desire to respond. Additionally, credibility of the source can play a role in their desire.

The final step prior to actually responding to the feedback is the individual's formation of an intended response, which can be based on her or his own goals for completing the task. The goals, however, can be affected by the feedback given to the person. It is also noted that specific feedback leads to more specific goals an individual hopes to achieve based on this feedback. Once the processing of the feedback is complete, the individual may or may not provide a response, and the cycle starts over.

1.4.1 *Incorporating Feedback into the Intervention Research Process*

The idea of providing feedback in the workplace has been around for years. Ilgen et al. (1979) claim that feedback is essential for learning and motivation in performance-oriented organizations. This may be true for at least two reasons. First, feedback from a manager or supervisor may prove to be a motivating factor for an employee to increase performance or for making the work environment safer. Second, from an intervention research perspective, it may be possible to increase acceptance for an intervention with simple observational assistance and/or reinforcement for the worker learning the new task.

With regard to the first issue, Becker and Klimoski (1989) performed a field study providing different forms of feedback. Surveys were sent to 152 salaried employees in one particular organization. The researchers reported a positive correlation between feedback from supervisory sources and job performance, while no effect was found with feedback from peers or self. More specifically, positive feedback led to higher job performance.

Pavett (1983) also found positive feedback to be an independent predictor of performance. This study examined the perceptual relationships between feedback, motivation and rated performance. The experiment similarly involved a survey approach, but was performed in a hospital setting with nurses as subjects. Pavett found an effect resulting from frequent positive feedback from three groups of people, including not only supervisors, but peers and patients as well.

A study by Leach et al. (2001) again showed positive effects of feedback. In determining performance, they looked at the change in operator errors on a complex task due to feedback. Specifically, the researchers saw a decreased likelihood of errors along with machine utilization. However, Leach and colleagues saw no change in worker motivation over time.

McAfee, in an article published in 1989 also related to safety, performed a review of 24 studies regarding feedback/reinforcement use in the workplace. In determining articles to review, the authors had four criteria that a study had to meet. First, it needed to be in an industrial setting (although they included four studies involving city employees and one laboratory study) with the goal of improving safety-related behavior through the use of feedback and incentives. Second, the study needed to report statistical data, as opposed to testimonial report. Third, the study had to use a before-and-after design. And finally, since comparisons would be made between studies, there needed to be a sufficient amount of information to do so. A typical study looked at the effects of training, goal setting and feedback or reinforcement on safety-related behavior. Overall, the authors found that in each of the 24 studies, incentives or feedback enhanced safety-related behavior and/or decreased accident rates at least in the short term. They suggest that their conclusion reinforces the theory that rewarded behavior tends to be repeated.

With regard to the second point of acceptance, most feedback studies looked at how it affects performance on the current system, not on introduction of a new system.

Other studies have used feedback to improve worker safety and to reduce error rates. Unfortunately, nothing has been found yet in the area of acceptance or satisfaction of new process/intervention due to positive feedback and reinforcement. In addition, the use of feedback in the work environment is generally non-dynamic, or in survey form, as shown in the above research.

1.5 Interpersonal Communication

The importance of communication is often overlooked, especially in the workplace, which is, in fact, one of the motivating factors of this study. We want to increase the amount of human interaction in the workplace in order to facilitate change. Therefore, it is important to review the domain of interpersonal communication. This section contains a brief overview of interpersonal communication and its important characteristics; the overview is followed by a discussion on how interpersonal communication and feedback was incorporated into the present study.

Wood (1992) describes communication as a systematic, symbolic and dynamic process that involves communicators who personally construct content and a relationship. As opposed to using the traditional expressions of sender/receiver, she uses the term communicator because speakers and listeners are simultaneously communicating with each other. Not only are there verbal cues conveyed by the speaker, there are also nonverbal cues conveyed by both the speaker and listener. For the sake of simplification, this discussion will be divided into two parts, verbal and nonverbal communication.

Verbal communication carries responsibilities along with administering it. Most importantly, it should be audible and clear to the listener. Additionally, the speaker should be aware of misunderstandings and be willing to ask questions to ensure this. The speaker should also be prepared to restate what she or he has said. However, verbal communication not only consists of what is said, but also how it is said; this is referred to as paralinguistics (Tubbs and Moss, 1974).

Paralanguage consists of different voice qualities and unstructured vocalizations, and it can be structured to portray to the listener different aspects of the message. Voice qualities consist of variations in pitch, range, resonance, rhythm, lip control, and articulation control. Vocalizations are noises such as laughing and crying. Examples of variations of these two aspects are as follows: the tone of one's voice can project inferences about feelings; increasing tone, speech rate, volume and fluency may portray a persuasive person; also, increasing loudness, pitch, timbre and speech rate can show intensity of emotion (Tubbs and Moss, 1974).

Verbal communication is regularly coupled with nonverbal communication. In some ways they are equally important. Actually, nonverbal communication can be more trusted, which is likely due to our experience during infancy, where humans live 12-18 months relying strictly on nonverbal cues. Nonverbal communication is used for three reasons, to express meaning, to modify the verbal message, or to regulate the flow of interaction (Trenholm and Jensen, 2000). Important nonverbal cues are facial expressions, because the face is the most noticeable feature of someone when communicating. Other cues include eye contact, body movements such as reactions, hand gestures--the second most important form, and physical appearance (Tubbs and Moss, 1974). Overall, the significance of nonverbal communication is that it allows people to convey a message in more than one way.

In preparation for the current experiment, the experimenter studied the ideas of interpersonal communication along with characteristics of giving feedback. The "Feedback Scripts," shown at the end of section 2.3, included information about the subject's improved neck posture, as well as noticing that she or he was learning the task and beginning to reach her or his productivity level of Day 1. The goal was to be as truthful and positive as possible while not giving the subject too much information to bias the results. For example, when giving feedback about productivity, the participant was told that she or he was getting better and faster at the task, but were not told specifically how much faster. However, what was specifically said is not as important as the delivery of the feedback; with regard to its characteristics and style, delivery was the critical aspect in changing the subject's perception of the new task and its setup.

Kolb et al. (1980) provide a template regarding seven important characteristics of feedback. The characteristics are as follows: feedback should be descriptive, specific, solicited, immediate, checked for clarity, and directed toward behavior that can be controlled. Feedback should also take into account the needs of both parties involved. The feedback scripts and their deliveries from the current study were designed by following these guidelines as closely as possible. Unfortunately, the feedback was imposed by the experimenter, rather than solicited by the subject, at certain points in time.

1.6 Medium for Testing

In choosing an experimental task for the current study, it was important that the task had the following characteristics. First, the task needed to contain at least one risk for musculoskeletal disorders that could be reduced with an appropriate ergonomic intervention. Second, since the experiment was conducted in the laboratory, the goal was to make the base task relatively simple. Third, it was pertinent that the intervention created a certain amount of frustration in the learning process, in order to observe this learning process, as well as force the subject to make a choice at the end regarding acceptance.

Since the goal of the current study was to look at the implementation of an ergonomic intervention, the intervention chosen must show an ergonomic benefit. Therefore, the task used in this study is taken from Lutz et al. (2001), entitled "The use of mirrors during an assembly task: a study of ergonomics and productivity." The goal of the study was to assess the effectiveness of an intervention for reducing non-neutral neck postures. Specifically, the authors looked at a screw-driving task, using power screwdrivers and an aluminum block in which the screws were driven. This was performed in four different configurations. Two of the configurations were more conventional. First, there was the Industry Standard Configuration (ISC) in which the participants performed the task on a table in front of them. The height of the block was such that the elbow was flexed roughly 90° when holding the screwdriver in an inline, vertical orientation. The second conventional set-up was the Pistol Grip Configuration (PGC). In this situation, the subjects performed the task on the wall in front of them. The block was placed at acromion height an arm's length away and the screwdriver was set in the pistol grip configuration.

The remaining pair of configurations featured a visual aid in an attempt to place the person in a neutral neck posture. The first ergonomic configuration was the Mirror

Configuration (MC). In this set-up, the block was placed on the table as in the ISC. However, subjects were asked to look through a mirror located at eye level while completing the task; the mirror reflected a reverse image of the block to the subject. The final configuration was the Periscope Configuration (PC). Resembling the MC with one additional mirror, the two mirrors acted like a periscope, the second mirror reverted the image so the subjects saw exactly what they would see if they looked directly at the block.

These two configurations addressed the non-neutral postures of the ISC and the PGC. In the ISC, subjects were required to flex their neck in order to look down at the table. Conversely, in the PGC, subjects were required to raise their arm up to shoulder height to reach the block. Both of these situations produce static postures that can lead to fatigue, discomfort and reduced blood flow. The effects of static postures could not only lead to a physical ailment, but also a decrease in productivity and quality. Two configurations, MC and PC, place both the shoulder and neck in a more neutral posture.

Lutz et al. considered both ergonomics and productivity as dependent measures in their study. The results of the study do indeed show an ergonomic improvement with both the MC and PC, compared with the ISC and PGC. Significant effects were found in angular deviations, normalized IEMG data, self-reported body discomfort ratings, productivity, and configuration preference. Angular deviations of the neck and head were collected. Deviations were significantly reduced in the MC and PC, compared to the ISC. Also, angular deviation of the shoulder was significantly reduced in the MC and PC, this time compared with the PGC. Normalized IEMG (NIEMG) activity was also collected in the study. NIEMG data show a significant reduction in erector spinae muscle activity with the MC and PC. In the shoulder muscles, compared to the PGC, the PC and MC show a significant reduction in activity. The results of the body discomfort also show a significant effect. In the ISC condition, a significant increase in neck discomfort was reported, compared to the PC and MC. In the PGC condition, a significant increase in shoulder discomfort was seen, compared with the PC and MC.

While the variables discussed above show a positive effect of the visual aids, productivity and preference showed an opposite effect. In terms of average number of seconds per block, the ISC was significantly the most productive workstation. On the contrary, the MC was significantly the least productive workstation. The PGC and PC were not significantly different from each other, but significantly worse than the ISC and better than the MC. It is interesting to note that, in the second experiment where the subjects worked for four hours, three of the eight participants showed that by the end of the four hours they could perform the task as fast with the PC as they could in the ISC. Additionally, 75% of the participants reported a preference for the ISC, assuming they worked on a piece-rate basis.

Among the conclusions of the study, the researchers found that while the two mirror configurations provided the ergonomic benefit of physical relief, they reduced productivity by 13-23%. These mixed results provided another interesting problem for the present study. As stated above, it was important that the task chosen for this study was one that had an empirically proven ergonomic benefit, one that had a visible learning period that may create frustration, and one that was a laboratory study that could be replicated. Since the Lutz et al. (2001) study exhibited all of these characteristics, and along with the productivity issue, the same screwdriving task was chosen for the present study. It was a modified replication, however. Only two of the four configurations were used in the present study, the industry standard configuration and the periscope configuration.

1.7 Goal of the Study

The aim of the present study was to examine the effects of positive feedback and reinforcement during the implementation phase of an ergonomic intervention. There are three main hypotheses of this study. First, it is expected that the feedback will make people more accepting of an ergonomic intervention. Second, it is expected that the use of feedback will prove to be a catalyst in the process of learning to use an intervention. In other words, subjects who receive feedback will learn the new task quicker than subjects who do not receive such feedback. And finally, perceived discomfort will not be affected by providing feedback.

2.0 Methods

2.1 Subjects

Eight males and eight females, ages 19 to 53, were recruited from the university population through the use of fliers as well as word of mouth. Subjects were required to be 18 years of age, have normal or corrected to normal vision, have no history of chronic neck pain, and be able to stand for at least one hour at a time. They were also told prior to participating, that they would be compensated based on their performance of the task; for the 3 hours of work they would receive approximately $20. In addition, at the beginning of each day, subjects were asked to sign a written consent form, shown in Appendix A.

Table 1 displays the anthropometric data, which was compiled at the beginning of

Table 1: Anthropometric Measurements

	Average (cm)	Std. Dev. (cm)
Stature	172.1	10.1
Standing Elbow Height	111.0	6.7
Standing Eye Height	160.6	9.9
Standing Acromion Height	142.6	8.9
Elbow-Fingertip Length	44.3	3.0
Hand Length	18.0	1.1
Hand Breadth	8.3	0.7
Upper Arm Length	31.6	3.3
Forearm Length	26.3	2.3

each subject's first day. The table contains the average and standard deviation of each measurement. The experimenter directly compiled all but two of the measurements shown. Upper-arm length was calculated by subtracting standing elbow height from standing acromion height. Similarly, forearm length was calculated by subtracting hand length from elbow-fingertip length.

2.2 Equipment

2.2.1 *Testing Apparatus*

The task performed in the experiment, discussed in more detail in Section 2.3, consisted of driving and removing screws from an aluminum block using a cordless power screwdriver. The task was performed on a height adjustable table as seen in Figure 3. This figure also depicts a person performing the screw-driving task. The

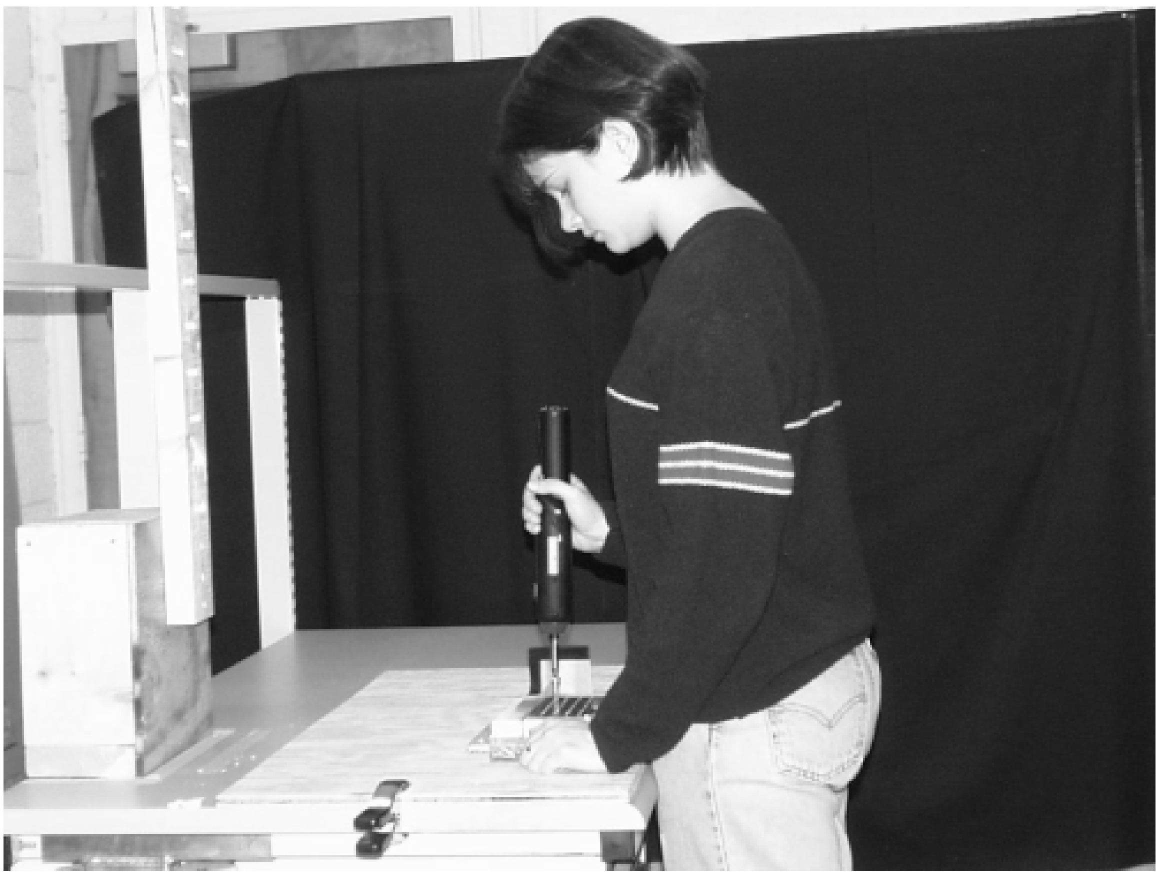

Figure 3: Picture of height-adjustable table and person performing screw-driving task

figure also shows the type of screwdriver used, which can be seen more clearly in Figure 4. All were of the same type: Sears Craftsman, Model 315.11690. The screwdrivers contained a 3.6 Volt battery [the battery life was approximately 45 minutes], had two speeds (low = 130 rpm, high = 400 rpm), and had adjustable torque. Each one was left on its charger overnight to ensure maximum battery life.

Figure 4: Cordless screwdriver

Not as obvious in Figure 3 are the aluminum block and screws used in the experiment. Figure 5 depicts these more clearly. The dimensions of the block were 6" long X 3" wide X 1" thick. It contained a 4 X 9 grid of pre-drilled and tapped holes. For each testing session, 18 screws measuring 3/4" long, 1/4" diameter and 20 threads per inch were used.

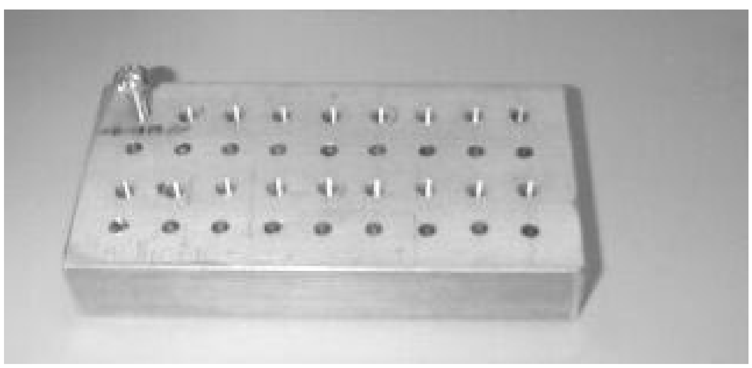

Figure 5: Aluminum block and type of screw used

On the second day of the experiment, the subject performed the task while looking into a "periscope" mirror configuration, as opposed to looking directly at the work surface. Figure 6 provides an illustration of this. The periscope configuration was created with a wooden support stand (seen on the left of the picture). A vertically oriented “two-by-four” block was used with slots cut through it (approximately 2” vertically apart), measuring approximately ½” high X 2” wide. These slots were used to

Figure 6: Person performing task while using periscope

place the two mirrors. Each mirror measured 12” X 12” with a rotating arm glued on the back, which was placed in a specific slot relative to the subject’s height.

To get a better understanding of how the mirrors work, further explanation is needed. Further examination of Figure 6 shows a horizontally oriented mirror, which is downward facing to capture the image of the block from the work surface. A second mirror is tilted approximately 45° from vertical and facing the participant; this captures the inverted image from the mirror above, reverts the image, and displays it in front of the forward-looking subject. Notice the difference in neck flexion of the person between Figures 3 (Day 1) and 6 (Day 2).

2.2.2 *Data Collection Instruments*

2.2.2.1 Hardware

Seven body dimensions were recorded with an anthropometer. These include standing height, standing eye height, standing elbow height, standing acromion height, hand length, elbow to fingertip length and finally hand breadth. Standing elbow height was important in determining table height while standing eye height was necessary for configuring the periscope on the second day.

The subject was recorded on video in the sagittal plane on both days of the study. This was used to determine more precise times for each completed block and for analyzing posture, bodily "fidgets" and technique throughout the two hours of testing. A stopwatch for recording minutes and seconds was used by the experimenter to monitor the duration of the task and also cycle times in order to provide feedback (described in section 2.3) to one of the two groups of subjects. During post-experimental data collection, a television and videocassette recorder were used to more accurately record the time-to-completion of each block.

2.2.2.2 Surveys

The remaining data collected during the experiment was via self-reported paper surveys. All surveys used can be found in Appendix B. Subjects were presented a "Body Discomfort Survey" at the beginning and end of each day, asking them to rate physical discomfort at that moment. This document depicts an outline of a body, from the front and back as well as close-up portrayals of the front and back of both hands. The subjects were instructed to label each spot on the body where they currently felt discomfort and rate it from 1 (slight discomfort) to 10 (unbearable pain). For persons without discomfort, there was a space for them to indicate so. This survey was also administered each day at the conclusion of testing to gauge change in their perceived discomfort during the testing period.

A post-test survey, "Employee Survey 1," was also administered at the end of both sessions, following the second body discomfort survey. This survey asked subjects to rate (on a five point Likert scale) the following four categories: ease of use, comfort, accuracy and productivity. The five points of the scale were as follows: strongly disagree, disagree, neutral, agree, and strongly agree. Therefore, one statement read: "The workstation configuration allowed me to easily complete the task." They were instructed to give their level of agreement to the question by circling one of the five choices, answering according to their experience of performing the task using the configuration on each day.

On the second day of experimentation, subjects completed two additional surveys. The first was "Employee Survey 2," designed nearly identical to the previous survey, but this time the subject was asked to compare the two workstation set-ups using the same four categories as above. As a result, the example above was reworded to the following: "The periscope configuration allowed me to more easily complete the task." Again, they were asked to provide their level of agreement by circling one of the five choices, from strongly disagree to strongly agree. Two supplemental questions were asked; the first regarded the support of the "ergonomist" (the experimenter) and the other regarded their preference toward the periscope. These were worded differently than the first four questions on the survey; the subjects were asked strictly about their experience on Day 2.

The Subjects were then asked to fill out a "Final Comparison Survey," which queried the subjects on their preference of workstation setup, also based on the same four categories as the first survey. This survey, however, was constructed differently. They were asked to pick their preference between the industry standard configuration from Day 1 and the periscope configuration from Day 2. Finally, the subjects were asked to answer one comprehensive question: whether they would be willing to use the periscope configuration for the next two months, imagining that the task of screw driving was their real job.

2.3 Protocol

The experiment was administered to each subject over a two-day period. The second session in each case was within a week of the first, though not on consecutive days. Each session lasted approximately one and a half hours, which included one hour for each testing period, and then a half-hour on both days for preliminary and post-test activities. Appendix C contains a protocol checklist that lists each activity performed, listed in brief below:

1. The subject filled out administrative forms and a discomfort survey.
2. Anthropometric data was collected (only on the first day) and the workstation was subsequently set up.
3. The subject tested for one hour (drove and then removed screws).

4. The subject filled out another discomfort survey and any other surveys required for that day.
5. The subject was thanked and given payment (only on the second day).

Day 1

Upon arriving at the laboratory, the procedures of the experiment were briefly explained to the participant, and she or he was shown the workstation and tools used. The participant was subsequently asked to read the Informed Consent form. Those who wished to continue signed and dated it and provided it to the test administrator. If the participant wished to retain a copy of the unsigned consent form she or he was provided one to keep. There was a specific section in the form that queried the subject on whether or not she or he had chronic neck pain, and if not, to sign her or his initials in an area provided.

The subject was then asked to complete a "Body Discomfort Survey," asking her or him about any current bodily discomfort. The next preliminary activity was the compilation of anthropometric measurements. With the use of standing elbow height, the workstation height was established. The key in this adjustment was to set the table height so that the subject's fingers were horizontal without wrist deviation in either the radial or ulnar direction when performing the task. Therefore, the height was such that while the subject held the screwdriver in hand over the aluminum block, the elbow was in a position a few degrees above horizontal. More importantly, this table height was recorded in order to reproduce the set-up on the second day.

Once the workstation was in order, the "Introductory Script" was read out loud to the subject as follows:

> "You are an employee at a major auto manufacturing facility. Your job assignment is to assist in building the engine block. During this task you will be using the cordless screwdrivers to drive and then remove screws in rows one and three on the block, alternating between each row. It is important that you approach the task as if you were actually working in a manufacturing facility. Imagine that you just arrived at work and that you are to work for the next hour until your morning break. For the first part of the hour, I will ask that you do as thorough a job as possible, not worrying too much about how long it takes you to do the work. During the second half of the hour, you will get paid based on the number of blocks completed, so the more you produce the more you get paid."

Following the reading of this script, the subject was taken to the workbench, and the experimenter demonstrated how to perform the screw-driving task. At this stage, the subject was informed that there were various ways of performing this task. The experimenter also explained the reasoning for keeping the driver vertical while driving screws, which was to ensure that the screw went in vertically and without resistance.

The subject then practiced the task for thirty minutes. Prior to beginning, she or he was told how to perform the task, specifically to drive and then remove 18 screws alternating between rows one (the top row in Figure 3) and three (second from the bottom row of Fig. 3). The participant was also notified that there was no time pressure to complete the task, and she or he should develop an efficient work method, as the second half-hour of the session was piece-rate.

While training, the subject was allowed to adopt her or his own style, provided the screwing-in pattern was alternating between rows one and three. The training period was videotaped to better observe each individual method as well as each subject's learning progression.

At the end of those thirty minutes, the subject was stopped and read the Day 1 "Performance Script" as follows:

> "During this task you will be using the cordless screwdrivers to drive and then remove screws in rows one and three on the block, alternating between each row. For the next half-hour, you will get paid based on the number of blocks completed, so the more you produce the more you get paid. I will be observing you as you work. Ready? You may begin."

This reminded the participant of the task objectives and explained to her or him that they perform the task under "simulated" working conditions for the second half-hour. In other words, the participant was paid $.60 for each block finished within the allotted time. The number of completed blocks was tabulated and recorded on the "Compensation Form" by the experimenter while casually observing from a chair across the room. Upon completion of the testing session, the subject was asked to fill out a second "Body Discomfort Survey," asking her or him about any current bodily discomfort.

The final task of Day 1 was for the subject to answer an "Employee Survey 1," asking her about her perception of the workstation setup. The subject was then thanked, reminded of the date and time for the second day of the study, and told that she or he would be paid for an hour of work on that day.

Day 2

Each subject participated in a second experimental data collection session that lasted an hour and a half. On this day the workstation set-up contained the periscope, and the subject was randomly assigned to one of two groups, determined before the experiment began. The task goal was the same, to drive and remove 18 screws from the aluminum block; however, the subject was instructed to look through the periscope while completing the task. The ergonomic benefit to using a periscope was the reduction and/or elimination of forward neck flexion, as shown in Figure 6. Another departure from the first day was that the subject received a five-minute introduction to ergonomics; she or he was given a brief explanation on the need for ergonomics and how it benefits people in the workplace. A third deviation from the activities of Day 1 was the absence of a training period. Participants on Day 2 tested for the whole hour. This was done to mirror real working conditions, in that workers normally do not get a training period following the introduction of an ergonomic intervention. Finally, Groups 1 and 2 differed during this testing period; Group 2 received brief periods of positive feedback and reinforcement throughout the testing session on Day 2.

Group 1: The Control Group

The control group did not receive any feedback during the experiment as they drove the screws into the aluminum block. This is often how an ergonomic intervention is introduced to an industrial worker. As shown in the "Introductory Script," the subject in this group was first reminded of his imagined work environment, task objectives and the testing duration. The next topic of discussion was ergonomics. After a brief definition, she or he was given specific examples of why an ergonomic intervention might be implemented and what benefits it brings to the typical laborer. The participant was also given reasoning for the workstation redesign.

Prior to the subject's arrival, the periscope workstation set-up was already in place. The most important task for the experimenter was to set the workstation height at the same level as during the subject's first day. Upon arrival, the participant was greeted, immediately shown the new workstation configuration, and explained that she or he would be performing the same task while using the periscope.

Following the introduction, the subject was asked to re-read and sign a second informed consent form. Provided she or he consented to another day of experimentation, the subject was presented with a "Body Discomfort Survey." Upon completion of this survey, the subject was taken to the workstation, and the experimenter recited the "Introductory Script" for Day 2 presented below:

"To refresh, you are an employee at a major auto manufacturing facility. Your job assignment is to assist in building the engine block. During this task you will be using the cordless screwdrivers to drive and then remove screws in rows one and three on the block, alternating between each row. It is important that you approach the task as if you were actually working in a manufacturing facility. You will get paid based on the number of blocks completed for the entire hour; so the more you produce the more you get paid.
Imagine that you just arrived at work and that you are to work for the next hour until your morning break. Today, however, you will be asked to perform the same task at a newly configured workstation. The new workstation is an attempt to improve the ergonomics of your job.
As plant ergonomist, I would like to educate you a little on exactly what ergonomics is. What do you know about it? (pause and wait for an answer)
(Based on answer, respond accordingly including the following): The job of the plant ergonomist is to make sure that the workstation setup is such that the employee is not at risk of developing an injury over time. Certain risk factors that are important to observe would be high force requirement, high repetition rate, awkward postures, and any combination of the three.
Certain examples of injuries are low-back injuries, which could be attributed to long hours spent in a bent over position or repetitive heavy lifting; or, shoulder tendonitis, which might be due to repetitive and/or forceful above the head reaching. The workstation that you are going to use today is specifically designed to reduce neck and shoulder discomfort by reducing the static, awkward posture of the neck while you do this task. Do you have any questions? (pause to wait for answers, and respond accordingly)
You will be asked to look through the periscope in order to perform the task, which allows you to maintain a neutral neck angle. Only look down if you have dropped a screw or the screwdriver and need to locate it. Otherwise, keep your eyes directed at the mirror. You will be asked to work as efficiently as possible, as you will be paid for each piece that is finished within the allotted time."

During the introductory discourse, the subject was allowed to ask any questions before beginning. The experimenter then started the videotape, verified that the subject was ready and told her or him to begin working. During the testing hour, the experimenter observed as the "ergonomist" from across the room, but did not interact with the subject for the duration of the test session. At the 30-minute mark, both screwdrivers were replaced, one at a time, with fully recharged screwdrivers to ensure that the subject worked with fully charged screwdrivers for the whole hour. Thirty minutes was chosen as the switching point due to the battery life of the screwdrivers being approximately 45 minutes.

At the end of the hour, the subject was stopped, allowed to sit down and asked to fill out a final "Body Discomfort Survey." The participant was then presented with an "Employee Survey 1," which asked about her or his perceptions of the workstation set-up, and an “Employee Survey 2,” which asked the subject to compare her or his perceptions between the workstation set-up of Day 1 and 2. Two additional questions on this survey queried the participant’s impression of the assistance given to her or him by the ergonomist and her or his overall sentiment regarding the periscope.

The subject was then asked to fill out the “Final Comparison Survey” that first asked about her or his preference of workstation setup. The culminating question on this survey asked the participant how willing she or he would be to use the periscope for a two-month period, as opposed to the industry standard configuration and given that she or he worked within a piece-rate system. This question was representative of what real employees in furniture manufacturing have been asked following the introductory use of an ergonomic intervention. The final phase of the experiment included recording the number of blocks completed on the second day, calculating the total monetary reward, thanking the subject for participating, and directing her or him to the administrative assistant for payment.

Group 2: The Feedback Group

Group 2, the “feedback” group, was the experimental group. The protocol for this group was nearly identical to Group 1 with the exception of the ergonomist’s role during the testing session. The “Introductory Script” for Group 2 is presented below (Note: additions to the script for Group 2 are highlighted in bold for the reader’s benefit. These phrases were not emphasized during presentation to subject):

> “To refresh, you are an employee at a major auto manufacturing facility. Your job assignment is to assist in building the engine block. During this task you will be using the cordless screwdrivers to drive and then remove screws in rows one and three on the block, alternating between each row. It is important that you approach the task as if you were actually working in a manufacturing facility. You will get paid based on the number of blocks completed; so the more you produce the more you get paid.
> Imagine that you just arrived at work and that you are to work for the next hour until your morning break. Today, however, you will be asked to perform the same task at a newly configured

workstation. The new workstation is an attempt to improve the ergonomics of your job, which will be discussed before you begin. **In addition, throughout the morning, I will be discussing the new workstation set-up with you as you work to help you get accustomed to it.**
As plant ergonomist, I was hoping to educate you a little on exactly what ergonomics is. What do you know about it? (pause and wait for an answer)
(Based on answer, respond accordingly including the following): The job of the plant ergonomist is to make sure that the workstation setup is such that the employee is not at risk of developing an injury over time. Certain risk factors that are important to observe would be high force requirement, high repetition rate, awkward postures, and any combination of the three.
Certain examples of injuries are low-back injuries, which could be attributed to long hours spent in a bent over position or repetitive heavy lifting; or, shoulder tendonitis, which might be due to repetitive and/or forceful above the head reaching. The workstation that you are going to use today is specifically designed to reduce neck and shoulder discomfort by reducing the static, awkward posture of the neck while you do this task. Do you have any questions? (pause to wait for answers, and respond accordingly)
You will be asked to look through the periscope in order to perform the task, which allows you to maintain a neutral neck angle. Only look down if you have dropped a screw or the screwdriver and need to locate it. Otherwise, keep your eyes directed at the mirror. You will be asked to work as efficiently as possible, as you will be paid for each piece that is finished within the allotted time.
I understand that learning a new routine can be difficult, especially after being so used to a previous method and now required to relearn the process. Therefore, throughout the morning, I will be talking with you at various times in an attempt to make the transition easier."

The difference in this script is these subjects were informed that at various times during the test session the experimenter, or ergonomist (as he was imagined to be), would be offering verbal comments in order to help facilitate the transition of learning to use the periscope.

To be more specific, the experimenter made five verbal comments throughout the hour with the expressed interest of relieving the frustration of learning a new task. In doing this, the experimenter would reveal to the subject that the periscope was helping her or him physically and that her or his productivity was getting better, or back to the level that she or he experienced on the first day. The five scripts are shown below:

Script 1: [recited five minutes after they begin working (at 5 min)]
"Well I can definitely see an improvement in your neck posture."

Script 2: [recited ten minutes after the first script (at 15 min)]
"I can see you're starting to develop a technique now. You're movements are becoming more fluid."

Script 3: [recited 15 minutes after the second script (at 30 min)]

"So how are you feeling? (pause and wait for answer) I hope the periscope is making things more comfortable for you."

Script 4: [recited 15 minutes after the third script (at 45 min.)]
"I've been keeping track of your productivity, and I can really see an improvement across the hour. And I think you're still getting faster!"

Script 5: [recited 10 minutes after the third script (at 55 min.)]
"So how are you feeling? (pause and wait for answer) You look pretty comfortable with the task and your productivity is still getting better!"

It is important to note that the scripts were not recited verbatim, as it was intended to make them sound like casual observations, not a recited script. Overall, however, each subject in the Feedback group received the same content at each point in time.

2.4 Preparing for Experiment

In designing the feedback, certain principles of interpersonal communication were adhered to. The overall goal was to provide the subject with immediate and succinct information that had a positive effect (on her or his impression of the intervention and willingness to use it). For that reason, feedback was always positive, directed toward the subject's behavior such as her or his improved technique, and given intermittently throughout the hour. More specifically, feedback was given at the 5, 15, 30, 45, and 55 minute marks. This schedule was chosen arbitrarily and at various intervals. The intervals were chosen for the following reasons: feedback was given as soon as possible to get the subject consciously thinking about the task, less frequently through the middle of the hour to allow for a rhythm to develop, and then directly prior to the end of the hour to keep them on track as they finished. The goal was that it be interspersed across the whole hour, but not be too frequent (Fedor and Buckley, 1987).

The style of delivery of the feedback was also prepared. In keeping with the research of interpersonal communication, a variety of verbal as well as nonverbal cues were studied and incorporated into the experiment. First, the experimenter recited the scripts loudly and clearly to reduce the ambiguity of what was said. Paralanguage was also used to provide vocal cues. These cues may have included tone, articulation, fluency, and rate of speech. Additionally, occasional vocalizations such as laughter were used in an attempt to keep a relaxed atmosphere.

Second, the construct of proxemics was adhered to. In other words, the experimenter was relatively close to the subject. Additionally, he stayed in the same place in the room, which was in front of the subject, so she or he would know from where the feedback was coming. This was also important with regard to eye contact, if the subject were to glance at the experimenter. Third, the experimenter sat in an upright, attentive posture to assure the subject of his interest. In addition, the experimenter relayed positive facial expressions to the subject, such as a noticeable smile and arched eyebrows. Finally, the experimenter was relaxed and casual in demeanor and dress. He also avoided wearing a hat in order to allow the subject to notice the eye contact. This was also a personal decision by the experimenter to avoid portraying a reserved feeling to the subject.

A few aspects of communication were not used during the experiment, namely hand gestures, kinesics, and touch. It was felt that hand gestures would require the subject to divide her or his visual attention between the task and the experimenter. A possible consequence of this visual distraction may have been excess frustration. By the same token, it would likely have been distracting to touch the participant during the experiment.

To successfully portray positive reinforcement, the experimenter was required to practice the task of giving feedback. Since providing feedback in a situation like this did not come naturally, he practiced the scripts to a point that the delivery sounded more natural rather than rehearsed. The experimenter also videotaped himself while practicing in order to improve the aforementioned nonverbal cues. Videotaping provided the opportunity to gauge how clearly and positive the feedback would sound to the subject.

2.5 Independent Variables

Group type was the independent variable in the experiment. This variable consisted of two levels: the control group and the "feedback" group.

2.6 Dependent Variables

Two types of dependent variables were collected during the study. The first dependent variable quantified performance on the screw-driving task. Along with collecting the number of blocks completed each day, "time-to-completion" data was also compiled. In other words, the amount of time to complete the task (screwing in and removing screws) was recorded for each block. The second type of dependent variable was a group of responses on the four subjective surveys, consisting of the body discomfort survey and employee surveys 1, 2 and 3.

Four "Body Discomfort Surveys" were administered to each subject, two on each testing day. One was given at the beginning of the testing session and one was given at the end of the session. Discomfort was rated for each body part from "slight discomfort" to "unbearable pain," translating in scores from 1 to 10.

Two "Employee Survey 1" surveys were given, one during each session. There were four questions asking subjects to rate their level of agreement to a statement. Answers ranged from "strongly disagree" to "strongly agree," which produced scores on each question ranging from 1 to 5.

One "Employee Survey 2" was given on the second day. The questions were fashioned similarly to the first employee survey, and scoring was identical. Two additional questions were added to this survey and were designed the same way.

One "Final Comparison Survey" was also meted out on the second testing day. For the first five questions on preference, scores ranged from 1 to 3. The final question concerning willingness varied in score from 1 to 10. All data were collected and stored with a unique identifier number for each subject.

2.7 Data Processing

2.7.1 *Performance Data*

In order to gauge time-to-completion accurately, the videotapes from each subject were more closely analyzed using a television and videocassette recorder, and data was entered into a spreadsheet. In processing the performance data, a difference in performance across days was to be determined. Since only half of the time on Day 1 was recorded, it was compared to the last half of the second day. In calculating this difference in performance, the average time to complete one block in minutes from Day 1 was subtracted from the average time from Day 2. The difference was calculated this way to represent an increase in performance from Day 1 to Day 2 as a positive number. It was also of interest to look at performance across Day 2, to see the improvement across the hour. Therefore, the number of blocks completed in four fifteen-minute intervals was compiled for each subject, and the trend was compared between groups.

2.7.2 *Survey Data*

The survey data, consisting of the body discomfort data as well as the three employee surveys, were compiled in a spreadsheet. The discomfort data was separated by body part, and each body part had a rating from 0 to 10. Zero was the value given if a subject did not report discomfort in a certain area. For each day, the difference in discomfort was calculated for each of the body parts by subtracting the pre-discomfort value from the post-discomfort value. An overall discomfort score was then obtained by subtracting the discomfort value on Day 2 from discomfort on Day 1. The overall score was calculated this way to show a decrease in discomfort from Day 1 to Day 2 as a positive value.

"Employee Survey 1," which was also administered on both days, was similarly calculated in order to achieve a difference from Day 1 to Day 2. As described previously, the survey questions had five choices to answer from. The lowest choice "strongly disagree," was given a score of 1. Each choice was given a value of one higher than the previous, up to "strongly agree," which was given a score of 5. Additionally, a total score was calculated by adding the scores of the four questions together, with a possible score ranging from 4 to 20. Finally, as with the discomfort data, the difference in each score between days was calculated.

The questions from "Employee Survey 2," which asked the subject to directly compare the set-ups between the two days, were scored similarly to the first survey. Each question received a score between 1 and 5, with a sum total of the first four questions also calculated. Again, the sum total had a possible score between 4 and 20. This survey culminated with two additional questions. These questions regarding support and overall satisfaction with the periscope were not included in this survey's total score because they only referred to Day 2.

The final survey asked about similar information regarding the experimental setups, but was unique to the other two surveys in that the first five questions asked the subjects to pick their preference between the two configurations. Choosing the industry standard configuration resulted in a score of 1 while preferring the periscope resulted in a score of 3 for each question. They were also given the option of indifference, which resulted in a score of 2. While the first four questions asked about ease of use, comfort, accuracy and productivity, the fifth question queried their overall preference. Therefore, the sum total for this survey was between 5 and 15. The culminating question that asked the subjects about their willingness to work with the periscope had a possible score between 1 and 10, "not willing" at all to "very willing", respectively. Overall, with the survey data, score was positively correlated with the subject's acceptance of the periscope configuration.

2.8 Statistical Analysis

2.8.1 *Statistical Model*

The current study contained two statistical models, and the following equation can be considered the first statistical model of the experiment:

$$y_{ijk} = \mu + \tau_i + \beta_j + \varepsilon_{ij} \quad ; (i = 1\text{-}2, j = 1\text{-}16) \text{ (eq.1)}$$

This model is a mixed model with τ being a fixed variable of group type, 1 or 2, and β being a random variable of subject, 1 to 16.

The next equation shown below reflects the second model of the study:

$$y_{ijk} = \mu + \tau_i + \phi_j + \beta_k + \varepsilon_{ijk} \; ; (i = 1\text{-}2, j = 1\text{-}4, k = 1\text{-}8) \text{ (eq. 2)}$$

This model refers only to the performance across Day 2, between the two groups. Again, τ is a fixed variable of group type, 1 or 2. ϕ Is another fixed variable referring to the four different fifteen-minute intervals across Day 2. β Is a random variable of subject, 1 to 16.

2.8.2 *Performance Data*

The performance data was analyzed through a one-way analysis of variance (ANOVA), comparing performance between groups across days as well as across Day 2 only. There was also an analysis of the entire subject pool across Day 2. Throughout, the analysis, a probability of less than .05 indicated a significant difference between what was being compared, either between groups or between time intervals.

2.8.3 *Survey Data*

As the surveys are subjective and can be classified as ordinal scales, a non-parametric ANOVA was performed. Namely, the Kruskal-Wallis test was used for the analysis. Again, a probability of less than .05 means that a variable is significantly different between groups 1 and 2, the Control group and Feedback group, respectively.

3.0 Results

The results are presented in three sections. Section 3.1 covers the three employee surveys and the significant results found. Section 3.2 presents the data on performance between subjects as well as performance across Day 2. Finally, section 3.3 explains the data from the Body Discomfort Survey.

3.1 Employee Survey Data

Table 2: Kruskal-Wallis Test for Employee Surveys Between Groups

Survey	Dependent Variables	Chi-squared statistic	Pr > Chi-squared	
ES 1	Ease of Use	0.50	0.48	
ES 1	Comfort	0.00	0.96	
ES 1	Accuracy	2.39	0.12	
ES 1	Quickness	0.00	0.96	
ES 1	Total (of ES1)	0.34	0.56	
ES 2	Ease of Use	3.79	0.05	
ES 2	Comfort	0.85	0.36	
ES 2	Accuracy	6.80	0.01	**
ES 2	Quickness	3.91	0.05	**
ES 2	Total (of ES2)	6.43	0.01	**
ES 2	Support (#)	5.00	0.03	**
ES 2	Overall (#)	0.44	0.51	
ES 3	Ease of Use	1.53	0.22	
ES 3	Comfort	0.29	0.59	
ES 3	Accuracy	2.41	0.12	
ES 3	Quickness	0.89	0.35	
ES 3	Overall	0.28	0.60	
ES 3	Total (of ES3)	1.75	0.19	
ES 3	Willingness (#)	0.29	0.59	

** denotes significantly different variable (Pr < .05)
# denotes a variable that was *not* included in its respective survey's total score

Table 2 displays the results from the data analysis of each employee survey. Note that all of the significant variables from Table 2 were from Employee Survey 2 (ES 2). The table shows the results for each question of each survey as well as a total score for each survey in the dependent variables column. The degrees of freedom were equal for all variables as the analysis was performed by condition, and there were two conditions, or groups. The final two columns of Table 2 display the results from the Kruskal-Wallis test, with the chi-squared test statistic shown first followed by the corresponding probability value.

The first significant variable discussed from Table 2 is the total score (Pr = .011) for ES 2. This total score is comprised of the four questions regarding ease of use, comfort, accuracy, and quickness. Recall, from the Appendix, that the first four ES 2 questions were worded "more easily," "more comfortably," etc., and that the subjects were asked to directly compare the periscope setup to the industry standard setup. The final two questions on ES 2 were asked on a separate page, and were only asking subjects to rate what happened on Day 2. These two questions asked them first to rate the support they received from the ergonomist on Day 2, and then their overall satisfaction with the periscope. Therefore, these questions were not part of the total score for ES 2.

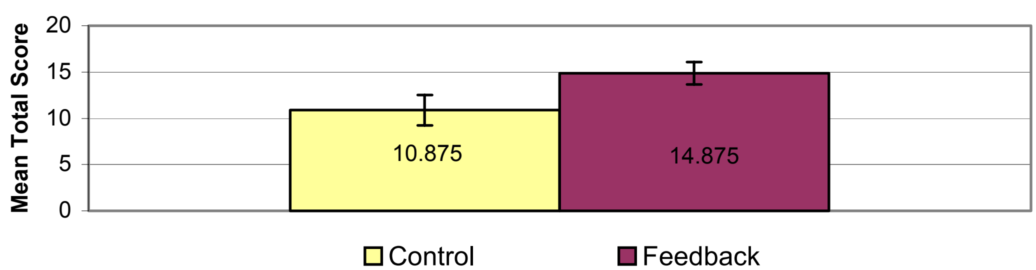

Figure 7: Employee Survey 2, Total Score

Figure 7 is an illustration of the difference in total scores from ES 2 between groups 1 and 2. The means and standard errors are displayed in the figure as vertical bars and vertical lines, respectively. In addition to noticing a clear difference in average total score, it is interesting to note in this figure the clear difference in variance that the standard error lines point out. It is also interesting to point out that the sum total of "neutral" scores from ES 2 is 12, which lands in between the scores from the two groups.

The second significant variable discussed from Table 2 is the accuracy question (Pr = .009) from ES 2. Recall that the question asked the participants if they thought they could "more accurately" perform the task using the periscope, and they had five choices to pick from. The choices ranged from "strongly disagree," which was a score of 1, to "strongly agree," which was a score of 5. The mean perceived accuracy scores for ES 2 are presented along with their respective standard errors are shown in Figure 8. Again, there is a clear increase in average score for Group 2. In other words, the feedback group agreed significantly more with the question. Also notice that the two scores are clearly on opposite sides of the "neutral" score of 3.

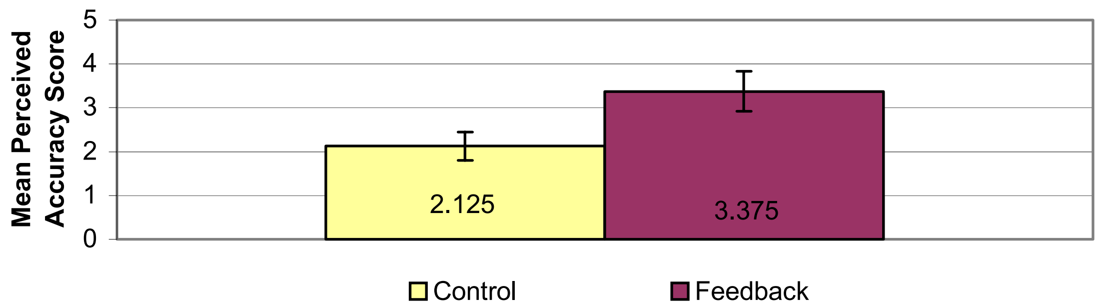

Figure 8: Employee Survey 2, Accuracy

The Quickness question (Pr = .048), also from ES 2, was the third question that showed a significant difference between groups. Table 2 shows the results from the Kruskal-Wallis test. This question was similar to the accuracy question, although it asked subjects if they felt the periscope allowed them to "more quickly" complete the task, compared to the industry standard configuration. Figure 9 shows the average quickness scores and standard errors for both groups. This figure also shows that Group 2 significantly agreed more with the respective question than Group 1, which is depicted by the larger average score. Note also that the "neutral" score again separates the two groups' scores.

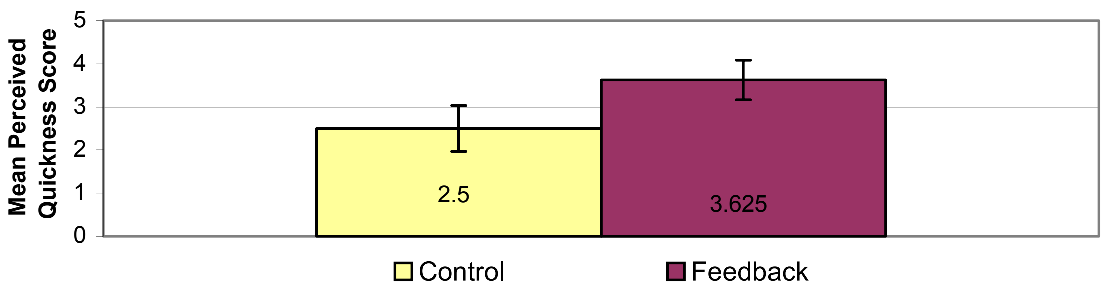

Figure 9: Employee Survey 2, Quickness

The final significant question, also from ES 2, was the question regarding support (Pr = 025). The chi-squared statistics for this variable are also displayed in Table 2. Recall that this was an independent question, and it asked the subjects whether they thought the support from the ergonomist was helpful while getting used to using the periscope. Figure 10 illustrates the increase in score of the feedback group over the control group. Also notice the small variance shown by Group 2. In fact, every subject from this group selected either a 4, which corresponded to "agree," or 5, which corresponded to "strongly agree," when answering the question.

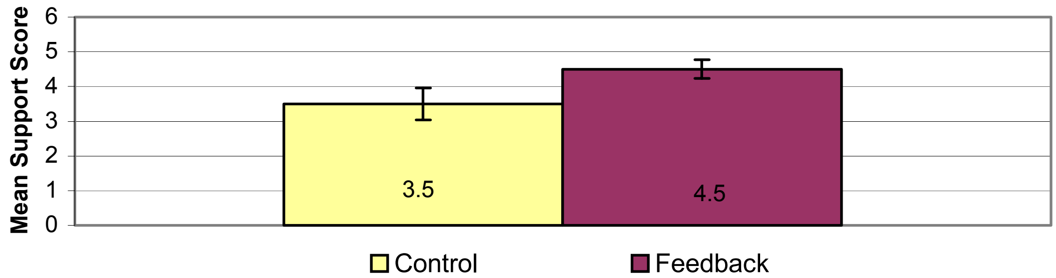

Figure 10: Support From Ergonomist

3.2 Performance Data

Table 3: ANOVA Test for Performance Between Groups

Dependent Variables	df	F statistic	Pr > F
Performance	1	0.06	0.81

Table 3 displays the results of the ANOVA test for performance between the two groups. In determining the performance variable, each subject's difference between days was taken, and this difference between days of both groups was compared. Table 4 shows the performance data for both groups. The mean difference was taken by

Table 4: Performance Difference Across Days (day2 - day1)

Group	mean difference (# of blocks)	std. dev (# of blocks)
1	-0.30	0.24
2	-0.34	0.30

subtracting the number of blocks finished on the first day from the number of blocks on the second day. The data show that there was a performance decrement when using the periscope, and as Table 3 shows, there was no significant difference in that decrement between groups.

Although there was an overall performance decrement on Day 2, an improvement was seen across the hour. Table 5 shows the mean minutes per block of all subjects for four fifteen-minute intervals on Day 2. A Duncan test was performed on this data, which

Table 5: Day 2, Duncan Test for Four Fifteen Minute Intervals

Time (Min)	N	Tukey Grouping	Mean (Min./Block)	Std. Dev. (Min)
15	16	A	3.21	0.50
30	16	B	2.84	0.45
		B		
45	16	B	2.80	0.40
		B		
60	16	B	2.81	0.43

*Means with the same letter are not significantly different

shows a significant difference between performance during the first fifteen minutes and performance during the rest of the hour ($p = .03$). A significant improvement was seen after the first fifteen minutes, with asymptotic performance over the remaining 45 minutes. This can be seen visually in Figure 11 below. It is apparent that the greatest improvement was made during the second fifteen-minute interval, and subjects subsequently began to asymptote during the last thirty minutes.

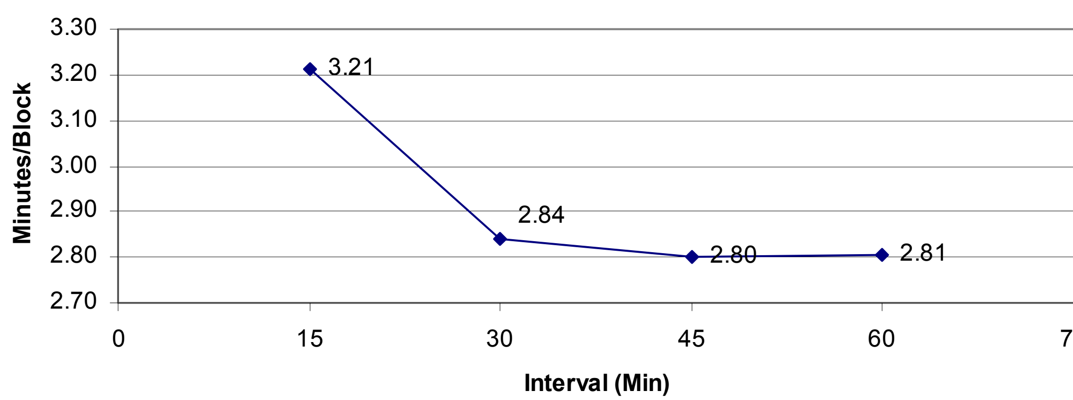

Figure 11: Day 2, Average Time per Block at Four Points During the Testing Hour

Table 6 shows looks at performance, not only across the hour of Day 2, but also with respect to group type. Performance refers to number of blocks completed across the four different time intervals, and condition refers to the two different groups. The table shows that there was no significant difference between the two groups. In other words, the 2 groups did not improve across the hour in a significantly different manner.

Table 6: Day 2, Performance Across Groups

Performance vs.	F Value	Pr > F
Condition * Time	0.25	0.86

3.3 Body Discomfort Data

Table 7: Kruskal-Wallis test for Discomfort Between Groups

Dependent Variables	df	Chi-squared statistic	Pr > Chi-squared	
Neck	1	0.42	0.52	
Head	1	0	1	
Chest	1	0	1	
Abdominals	1	0	1	
Upper back	1	4.00	0.05	**
Mid-back	1	0.04	0.85	
Low-back	1	0.57	0.45	
Right Thigh	1	0	1	
Left Thigh	1	0	1	
Right Knee	1	0	1	
Left Knee	1	0	1	
Right Calf	1	1.00	0.31	
Left Calf	1	1.00	0.31	
Right Foot	1	1.88	0.17	
Left Foot	1	2.13	0.14	
Right Shoulder	1	0.21	0.64	
Left Shoulder	1	0	1	
Right Upper-arm	1	0	1	
Left Upper-arm	1	0	1	
Right Elbow	1	1.00	0.32	
Left Elbow	1	0	1	
Right Forearm	1	1.00	0.32	
Left Forearm	1	0.01	0.93	
Right Wrist	1	1.22	0.27	
Left Wrist	1	1.00	0.32	
Right hand	1	1.64	0.20	
Left hand	1	1.00	0.32	
Right Fingers	1	0.84	0.36	
Left Fingers	1	1.00	0.32	

** denotes significantly different variable (Pr < .05)

Table 7 displays the Kruskal-Wallis results for the Body Discomfort Data. Recall that the Body Discomfort Survey asked subjects to rate each area of the body where they had discomfort by rating it from 1, slight discomfort, to 10, unbearable pain. Also, they filled out a total of four surveys, at the beginning and end of each testing session. As the table shows, one variable, the upper-back region, showed a significant difference between groups. This difference is illustrated in Figure 12. The figure depicts the average difference in discomfort between Day 1 and Day 2, which was calculated in two steps. First, the change in discomfort for each day was calculated by subtracting the pre-discomfort data from the post-discomfort data. Second, the difference in discomfort across days was calculated by subtracting the discomfort value on Day 2 from the

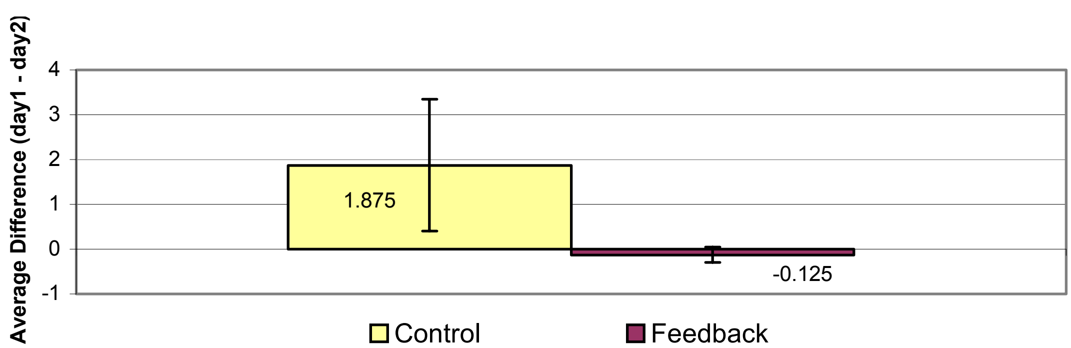

Figure 12: Upper-Back Discomfort, Difference between Day 1 and Day 2

discomfort value on Day 1. The overall discomfort difference for each body region of each subject was calculated in this way to show that a positive value meant discomfort was less on Day 2. Therefore, looking again at Figure 12, Group 1 showed an average positive change in discomfort from Day1 to Day 2, while Group 2 showed an average negative change. Notice also the large standard error of Group 1. Moreover, it is interesting to point out that only five subjects reported upper-back discomfort on Day 1 and Day 2 combined.

4.0 Discussion

The following discussion is divided into three sections. The first section deals with the significance of the results presented in the previous section, what these results imply, how these results tie into previous ergonomic research, and what they mean to the field of ergonomics. The second section presents the limitations of the study, and the third sections describes how these limitations as well as the results can lead to future research along the same line.

4.1 Significance of Results

Recall that there were three areas of results presented, consisting of the three employee surveys' data, the performance data, and the body discomfort survey data. While none of the areas yielded a great deal of significant difference between groups or workstation setups, and even as Employee Survey 2 (ES 2) showed the majority of the significant data, the fact that the rest of the data was non-significant actually makes for an interesting argument, that positive feedback and reinforcement did have a positive effect on acceptance of the ergonomic intervention. In formulating this argument, the three groups of data are discussed separately, followed by an encompassing discussion regarding how the data tie together.

4.1.1 *Discussion of the Employee Surveys*

Among the three employee surveys, ES 2 was the only survey that produced meaningful results. The significance shown leads us to believe that there, in fact, was a direct effect of the feedback that Group 2 received. However, not every component of the survey was significant. Actually, three of the questions were significant while the remaining three were not. The significant questions were those regarding perceived accuracy, perceived quickness, and support. The other three questions asked subjects about ease of use, comfort, and overall feeling of the periscope. Along with the former three variables, a seventh variable, the total score from the questions on accuracy, quickness, ease of use and comfort, was shown to be significant. The total score was interesting because it showed that the feedback group was generally more positive toward the periscope.

The final significant question on ES 2 was that of "support." The subjects were directly asked whether they felt the support from the ergonomist was helpful when getting used to the periscope. The feedback group significantly answering more positively shows a direct influence of the feedback given to them.

The accompanying two surveys did not show significance, which was unexpected; but it can possibly be explained. With respect to Employee Survey 1 (ES 1), the data used in the analysis came from the difference in scores between Day 1 and Day 2. The nonsignificance of this survey may be due to the unreliability in comparing the results of two subjective surveys. The fact that ES 2 was significant warrants the argument that a survey fashioned in this way is better than one fashioned similar to ES 1.

Regarding Employee Survey 3 (ES 3), the subjects were asked to pick their preference between the periscope configuration (PC) and the industry standard configuration (ISC). The nonsignificance of this survey may be attributed to the limited number of choices for the first five questions. For ES 3, there were three possible choices, as opposed to five possible choices from the other two surveys. With only three choices, the differences between groups became subtler, as the overall variance is smaller. It is possible that only having two choices may have made a difference, however. Had the middle choice of “no preference” been taken out, it would have forced subjects to choose between the two configurations, and a significant difference may have emerged.

The final question on ES 3 was the “willingness” question. This question asked subjects to rate their willingness, from 1 to 10, to use the periscope for the next two months, assuming this was their actual job, they worked in a piece-rate system, and the alternative was to work in the ISC. It was surprising to see a nonsignificant result between groups. The assumption was if the feedback group was truly affected by their treatment, then they would be more accepting of the intervention. The reason the assumption turned out to be false was that the majority of *all* subjects, regardless of group, were willing to use the periscope. In fact, 13 subjects, or 81%, chose at least a 6 out of 10 regarding willingness.

Another sign of this general willingness is evident in the “overall” question from ES 2. The question asked the subjects if they agreed that they preferred the periscope. Ten subjects, or 63%, chose either “agree” or “strongly agree” for this question, and 14 subjects, or 88%, chose at least “neutral" when answering the question. It may have been that the participants largely valued comfort over performance. However, none of the three perceived comfort questions (one from each survey) showed a significant difference between groups.

4.1.2 *Discussion of Performance Data*

Regarding the performance data, the feedback did not demonstrate a significant effect on performance. In other words, both groups experienced a decrement in performance from Day 1 to Day 2, and the decrement between groups was not significant. Comparing the performance data as a whole to the Lutz et al. (2001) experiment, it appears to mirror the reduction in performance they saw as well. Additionally, as the hour progressed, the feedback did not have a significant effect on subjects' performance. It was hoped that the performance data would show an indication of increased motivation from the feedback group, but this does not appear to be the case.

4.1.3 *Discussion of Body Discomfort Data*

The body discomfort data confirm one significant variable, the upper-back. The significance in Figure 12 illustrates that Group 1 felt significantly less discomfort from Day 1 to Day 2 than Group 2. This was a surprising result (noted by the negative average difference), especially given the fact that on Day 2 subjects in Group 2 felt more back discomfort. Although, with the variability in Group 1 being so large, and given that only five subjects even reported back discomfort, the significance of this result is muted. In fact, a more interesting result is the overall body discomfort. Aside from the upper-back, Groups 1 and 2 were not significantly different in the discomfort that they reported.

4.1.4 *Correlation of Results*

Overall, the results tell a story of three parts. First, the results confirm a direct influence of feedback on perception. Also, the question regarding support shows that the

feedback given by the ergonomist was sufficient enough that the subjects in Group 2 thought it was helpful. Second, the performance data did not correlate with this positive perception of the intervention. This could be a factor of motivation.
The feedback may have not been strong enough to change the motivation of the participants to try to work faster, or it may be that external feedback in general is not effective in influencing someone's internal motivation. It is also possible that the periscope configuration would not allow subjects to attain the same level of performance due to its design. The third interesting observation seen in the results pertains to the correlation of the survey data to the discomfort data. Although the feedback group was positively affected by the feedback, they were not affected in the way they rated their discomfort. This was a positive result in that the subjects did not misperceive the information given.

In a general sense, it appears that this study produced favorable results. Since the results of one survey showed a significant difference in scoring between groups, but that difference was not seen in either the performance or discomfort data, it is assumed that acceptance of the intervention was positively affected by providing feedback. These results seem to reinforce the belief that feedback is essential for learning and motivation in performance-oriented organizations (Ilgen et al., 1979). However, the results are also inconsistent with previous research that regarded feedback as being a predictor or an influence in performance (Becker and Klimoski, 1989; Pavett, 1983; Leach, 2001, McAfee, 1989). This inconsistency may be a result of the present study being performed in a laboratory with volunteer participants.

Even though this study conflicts the theory of feedback improving performance, the findings can be helpful when performing intervention research. While implementing an intervention, it is necessary to think of the person performing the task, not just in a physical sense, but in a cognitive one as well. It might be best for the researcher to imagine her or himself as the employee, and try to empathize with that person. Change can be very stressful for someone, especially when factors such as money are involved.

4.2 Limitations

This study had limitations that, if considered, can prove to make viable research to further knowledge regarding this important issue of acceptance of ergonomic interventions. The limitations can be seen in a number of ways, including problems with the experimental setting, limitations to the experimental approach, and confounders to the study. The most important limitation was the laboratory setting. It was difficult to get the participants to feel and act as they were at work. Also, it is felt that acceptance would be different had this been a task performed by someone for years, as opposed to one hour. Of course, with a lab study, we were able to focus on one main difference between groups. Time and cost were also a factor in the decision to perform the experiment in the laboratory.

Second, subjects picked up the task quickly, but there is a chance that there was a learning curve in performing the task across the two days. In other words, it is possible that subjects in general did not reach steady state in their performance on Day 1. Another problem seen with performance is that error rate was not recorded during the study to keep the data analysis as simple as possible. It is possible that this may have shown a significant difference between groups.

Third, it is possible that the feedback was not as influential as it could have been. This is possible, as the experimenter was self-taught in giving feedback. Ideally, an ergonomist that would do this in the field should consider getting trained in interpersonal communication. However, the constraint of time and resources led to the self-teaching approach. Additionally, although the experimenter trained himself to give feedback, it was felt that he became more comfortable in giving feedback, and that he may have been more effective during the later testing sessions. Also, recall that a majority of subjects were willing to use the periscope. This may be due the simplicity of the task, or that frustration was not experienced, because they only used the periscope for one hour.

Finally, certain subjects seemed internally motivated while performing the task. This is often called an internal locus of control issue, and there is evidence that some people prefer not to have or do not need external feedback (Ilgen et al., 1979). In fact, it was observed that some subjects were actually distracted by the feedback, and it affected their productivity. Conversely, some subjects could have used much more feedback. It is likely that these people had an external locus of control. Research has shown that this type of persona may require more external feedback to improve performance (Ilgen et al., 1979).

4.3 Future Research

Even with these limitations, this study could influence positive change within the field of ergonomics. The impacts of this study can change not only how intervention research is conducted in the future at North Carolina State University, but on ergonomic intervention research as a whole. However, the idea likely needs to be tested at least with actual workers in the laboratory or in a field setting. It is suggested that the same approach be taken initially with regard to providing feedback. The benefit to using actual employees of a job is that these people already know how to perform their current job very well. Therefore, it provides a bigger hurdle when trying to convince them that an ergonomic intervention will actually work.

A second step in future research, provided the real-world testing is promising, would be to formally train ergonomists in administering positive feedback and reinforcement. The benefits of this will likely be more influential communication with the employees. This is also important in order to properly adhere to the current practices in the field of feedback and interpersonal communication.

Moving forward with this research may ultimately gain further respect for the field of ergonomics. This respect can be gained from users of the interventions, by increasing their acceptance and understanding. Additionally, the act of providing feedback opened the lines of communication between the "ergonomist" and "employee." They were willing to discuss their issues with the workstation while working. This is a very positive result seen from the experiment, as it seemingly made the subjects feel more comfortable during the testing session.

Regarding the amount of feedback given to the subjects, it should be based on the person and how much they need or could use. This goes back to the idea of locus of control; some people seemingly could use more feedback than others. In the future, a post-interview or focus group might be beneficial as well. This would allow for even more information from "workers" on their feelings and really understanding them.

With respect to working in a piece-rate environment, it is hypothesized that non-piece-rate settings would facilitate acceptance for an intervention. Piece-rate workers are driven by productivity. Additionally, companies should reward people for willingly improving their work methods ergonomically and otherwise. They should allow them to take their time to learn it as opposed to working piece-rate. Not only does the acceptance rate likely diminish, this does not allow them to properly learn the task, as they are so focused on working quickly.

I propose a study that requires more practice time along with multiple days of using the intervention. The subjects were given what seemed to be a sufficient amount of time to get used to the task, but some of them did not look to improve their method. If they had multiple days to work with the intervention, they would be able to learn the "ins and outs" of the job. This in turn would make the changeover to the intervention more challenging. This would be a daunting lab study. Therefore, as mentioned above, it might be valuable instead to test the idea with actual employees either in the lab or in a real work setting. It would also be prudent to try the feedback strategy with a more complex task. This could increase the utility of feedback due to a possible increase in frustration level.

As discussed above, the experimenter was self-taught in delivering the feedback. It would likely be more effective to either receive training in motivational speaking, or even call on an expert in interpersonal communication to administer the feedback. Additionally, it might be advantageous to make the surveys more anonymous, as the subjects may have answered differently. The surveys could also be tested and redesigned to make them more reliable and/ or valid as necessary, or current surveys that have more validity/reliability could be used.

The field of ergonomic intervention research is complex, and as it has evolved, people have realized that not only the engineering and design is important, but that understanding the worker and working closely with her or him can have positive results and help make for an effective study. If someone is not willing to use an ergonomic intervention, then it is essentially useless. Everything can be improved, and the key to change is proper communication, no matter what the setting. Especially as ergonomics is designing for the human, it is a field that should have an even greater sensitivity to all human needs.

5.0 Conclusion

A study was conducted in the ergonomics laboratory at North Carolina State University. The experiment assessed the effects of positive feedback and reinforcement on acceptance of an ergonomic intervention. Two groups of subjects were used, one was the control group and the second was the feedback group. Out of three surveys administered, one survey, Employee Survey 2, found significant differences between the two groups of subjects. From this survey, the question regarding accuracy in performing the task showed a 57% increase in perceived accuracy from the control group to the feedback group when using the ergonomic intervention. Likewise, with regard to quickness, a 45% increase in perceived quickness was seen. The total score from this survey also exhibited an increase of 29% from the control group to the feedback group. Finally, with regard to support received from the ergonomist while getting used to working with the intervention, the feedback group showed a 37% increase in satisfaction with the support. Additionally, there was no instance where the feedback group answered a survey question significantly less positively when compared to the control group. With respect to the two remaining types of data, performance and perceived discomfort, no significant difference was seen either between groups or across the two days of testing.

From these results, it can be seen that the feedback seemed to positively influence the acceptance of the ergonomic intervention. However, it did not negatively affect a person's performance on the task nor did it influence her or his perceived discomfort. These results would indicate that positive feedback during the implementation phase of ergonomic intervention research has a positive impact on the perceptions of the person working with the intervention. These results are consistent with the body of literature on the positive effects of participatory ergonomics and may lead to more effective techniques for conducting ergonomic intervention research.

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Appendix A: Informed Consent Form

North Carolina State University
INFORMED CONSENT FORM

Title of Study: Assessing the effects of an ergonomic intervention during an assembly task.

Principal investigator: David Brandenburg **Faculty Sponsor:** Dr. Gary A. Mirka

You are invited to participate in a research study. The purpose of this study is to assess the effects of an ergonomic intervention during an assembly task. YOU MUST BE 18 YEARS OF AGE OR OLDER to participate in this study.

INFORMATION

The experimental task that you will be asked to perform is a simple screw-driving task. You will be using an electric, cordless screwdriver to drive screws into an aluminum block and then take them back out again. This is the basic task that will be performed in both the training and testing sessions of the experiment. All experimental procedures will be videotaped. The following is a chronological list of activities we will be performing over the two days (about 3 hours total):

Day 1

- Introduction to study, procedures etc. / signing of informed consent & compensation form
- Collection of body measurements (height, standing eye height, standing elbow height)
- Survey completion (body discomfort survey)
- Training session of 30 minutes driving screws into blocks with no time pressure
- Testing session of 30 minutes driving screws into block on an incentive system (paid by the piece)
- Survey completion (body discomfort survey, post-test survey asking questions about the work task)

Day 2

- Experiment refresh
- Survey completion (body discomfort survey)
- Testing session of one hour driving screws into block on an incentive system (paid by the piece)
- Survey completion (body discomfort survey, post-test survey asking questions about the work task and a comparison survey asking you to compare two work environments)
- Gathering of payment information and "Thanks for Participating"

RISKS

Individuals with chronic or current neck pain should not perform this experiment. Initial here to indicate that you do not have chronic or current neck pain: ___________. There may be some discomfort from standing for an extended period of time while performing the tasks. This discomfort from fatigue may be in the legs and the neck/shoulder region but should subside in a couple of hours after the experiment.

BENEFITS

Results of the study will increase our knowledge of techniques involved in ergonomic intervention research.

CONFIDENTIALITY

The information in the study records will be kept strictly confidential. Data will be stored securely and will be made available only to persons conducting the study unless you specifically give permission in writing to do otherwise. No reference will be made in oral or written reports that could link you to the study. All videotapes will be secured and destroyed upon completion of data analysis and report writing.

COMPENSATION

For participating in this study you will be paid $0.60 for each block completed over a 1.5-hour period. On average, participants will receive approximately $20.

CONTACT

If you have questions at any time about the study or the procedures, you may contact the researcher, David Brandenburg at 637-2951 or in Riddick 341 (phone #: 515-7210). If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 8101, NCSU Campus, (919-513-1837).

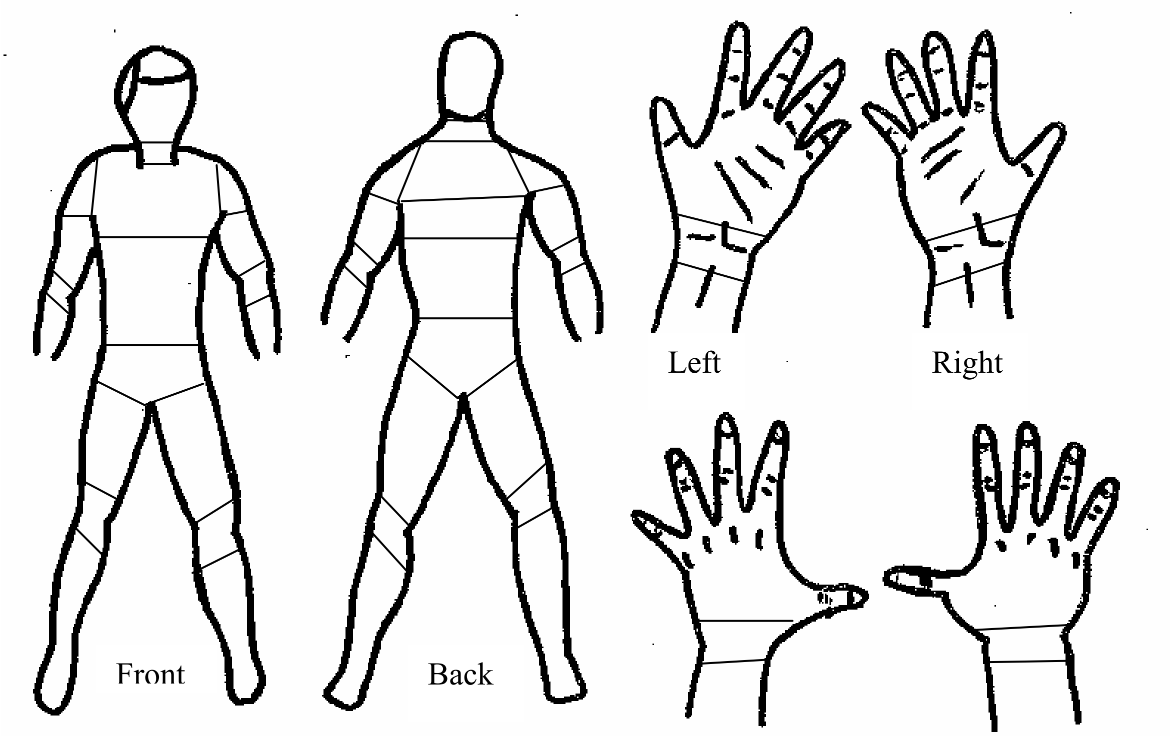
PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed.

CONSENT

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study."

Subject's signature____ Date _________________
Investigator's signature____ Date _________________



Body Discomfort Survey

Instructions

- Place an X in each area of the body where you *currently* feel discomfort.
- Indicate the level of discomfort at each location by rating it from 1 (slight discomfort) to 10 (unbearable pain). Write this number next to the appropriate X. **If you currently don't have pain, check here:______**

Pre___ Post___

Day 1 2 Subject______

Appendix B: Employee Surveys

Employee Survey 1

Instructions

- Read each statement
- Please indicate your *level of agreement* by circling the corresponding number.

1) The workstation set-up allowed me to *easily* complete the task.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

2) The workstation set-up allowed me to *comfortably* complete the task.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

3) The workstation set-up allowed me to *accurately* complete the task.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

4) The workstation set-up allowed me to *quickly* complete the task.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

Day 1 2 Subject______

Appendix B: Employee Surveys

Employee Survey 2

Instructions

- Read each statement
- Please indicate your *level of agreement* by circling the corresponding number.
- When answering questions, *compare* the periscope set-up to the industry standard set-up from Day 1.

Compared to Day 1:

1) The periscope workstation set-up allowed me to *more easily* complete the task.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

2) The periscope workstation set-up allowed me to *more comfortably* complete the task.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

3) The periscope workstation set-up allowed me to *more accurately* complete the task.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

4) The periscope workstation set-up allowed me to *more quickly* complete the task.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

Day 1 2 Subject______

Please answer the following questions:

5) While getting used to the periscope, the *support from the ergonomist* was helpful.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

6) *Overall*, I would prefer to work with the periscope workstation set-up.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Comments:____

____

Day 1 2 Subject______

Employee Survey 3

Instructions

- Read each statement carefully
- Please circle which workstation setup (**periscope** or **industry standard**) you prefer based on the italicized words.
- If you are equally satisfied with both configurations, then circle both choices.

1) It was *easier* to complete the task using the (**periscope** / **industry standard**) workstation set-up.

2) I was *physically more comfortable* using the (**periscope** / **industry standard**) workstation set-up.

3) I was able to *more accurately* complete the task using the (**periscope** / **industry standard**) workstation set-up.

4) It was *quicker* to complete the task using the (**periscope** / **industry standard**) workstation set-up.

5) *Overall*, I would prefer to work with the (**periscope** / **industry standard**) workstation set-up.

For this question, circle the number corresponding to your feelings

6) Looking at all aspects of the screwdriving task (ease of completion, comfort, accuracy and speed), how willing would you be to *use* ***the periscope set-up*** *for the next two months* while performing this task (assuming the other alternative would be the industry standard set-up)?

1 2 3 4 5 6 7 8 9 10

(Not at all willing) (Very Willing)

Day 1 2 Subject______

Appendix C: Experimental Checklist

Subject_____
Date_______

Day 1

- ❑ Introduction to workstation (screws, screwdriver, block)
- ❑ Informed Consent (ask if they want a copy)
- ❑ Compensation Form
- ❑ Body Discomfort Survey 1
- ❑ Anthropometric Measurements (cm)

Standing Height	
Standing Elbow Height	
Eye Height	
Floor-to-Acromion Height	
Elbow-to-Fingertip Length	
Hand Length	
Hand Breadth	

- ❑ Adjust work surface
- ▪ Standing with screwdriver in hand, getting the forearm a little above horizontal.
- ❑ Read “Introductory Script A”
- ▪ You are an employee at a major auto manufacturing facility. Your job assignment is to assist in building the engine block. It is important that you approach the task as you would if you were actually asked to perform it in the workplace. You will be given specific instructions prior to the task.
- ▪ Imagine that you just arrived at work and that you are to work for the next two hours until your morning break. Initially, I will ask that you do as thorough a job as possible, not worrying about the time it takes to complete. After the initial training period, I will ask that you perform the task as if you were paid for each finished piece.
- ❑ Training session (30 min)
- ▪ **Demonstrate Task** and answer any questions subject has
- • Show them different ways to perform the task (and also where to stand)
- • Explain to them that it’s good to try to keep the screw and driver vertical and together
- ▪ Have subject perform task for 30 min., to get comfortable with task
- ▪ During this task you will be using the cordless screwdrivers to drive and then remove screws in rows one and three on the block, alternating between each row.
- ▪ The object of this training session is to learn the task well, because during the second half of the hour, you’ll be paid for each block finished, so the more efficient of a method you can develop now, the better.
- ▪ [Start Video Tape]
- ▪ Instruct them when to begin and when to stop

Appendix C: Experimental Checklist

Subject_____
Date_______

- ❑ Testing session (30 min)
- ▪ Exchange screwdrivers
- ▪ Simulated working conditions
- ▪ **<u>Day 1 Script:</u>** During this task you will be using the cordless screwdrivers to drive and then remove screws in rows one and three on the block, alternating between each row. You will be paid for each piece that is finished within the allotted time (.$60 per piece) so it is to your benefit to work as quickly as possible. During this session, you will be asked to perform this as if this were your actual job. I will be observing you as you work.
- ▪ You may begin
- ▪ (1 hour later) Okay, you may stop working.
- ▪ [Stop Video Tape]
- ❑ Body Discomfort Survey 2
- ❑ Post-Test Survey
- ❑ Enter # of blocks completed on Compensation Form
- ▪ Running tally of completed blocks______________________________

Appendix C: Experimental Checklist

Subject_____
Date_______

Day 2

- ❑ Greeting
- ❑ 2nd Informed Consent
- ❑ Body Discomfort Survey 1
- ❑ Reading of Introductory Script (Determine which group)
- ❑ Workstation Set-up
- ❑ Performance Script (based on group number
- ❑ Testing Session (1 hour)
  - ▪ Remember to exchange screwdrivers at ½ hour mark
  - ▪ $.60 per piece
- ❑ Body Discomfort Survey 2
- ❑ Post-Test Survey
- ❑ Post-Intervention Survey
- ❑ Enter # of blocks completed on Compensation Form and sign it
- ❑ Thank them

Tally of blocks completed (record times to gauge productivity improvement)

1	13
2	14
3	15
4	16
5	17
6	18
7	19
8	20
9	21
10	22
11	23
12	24