Course ID: QAS 515_41_Spring 2008
Title: Workplace Design for Visually Impaired Workers in Nut and Bolt Assembly
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1. Introduction

1.1. Background

Based on a survey published in 1986 by American Foundation for the Blind, it is estimated that there are about 11.4 million people in the United States with some kind of visual impairment. Seventy percent of the severely visually impaired people are 65 years of age or older. Twenty six percent of the severely visually impaired people are in the 18 to 64 year old age. Approximately 37,000 of these are under the age of 18. [1]

"About 117,000 visually impaired people are in the labor force. According to the American Printing House for the Blind, there are approximately 32,000 'legally blind' children in kindergarten through twelfth grade. In addition, according to an estimate by the Office for Blind and Visually Impaired, there are about 6,000 'legally blind' college and university students in the United States." [1].

Throughout the world, blindness and visual impairment affects the daily functioning of many people. Reduced visual functioning has an indirect influence on one's perception of usefulness of his her existence and independence. With limitations, visually impaired people are restricted from participating in social, educational, vocational, and recreational activities. These restrictions, in turn, may lead to lack of self confidences.

The impact of modern technology such as computers with tactile, auditory, and enhanced visual output, electronic travel aids, reading and writing aids, have a beneficial effect upon the blind.

Visually impaired people represent, as a whole, a relatively large population within our society whose contribution potential has neither been realized nor even fully evaluated. Through rehabilitation and training, the vast majority of such individuals can be taught the skills necessary to support and perform many meaningful jobs. This not only will reduce their dependence on society but may also enhance their self-worth and self-respect.

1.2. Problem Statement

Taking into account the large number of visually impaired people in our society today, it becomes apparent that utilizing ergonomics principles in modifying the workplace for visually impaired workers is a social and economic necessity [2]. Although the anthropometric dimensions of the visually impaired are not different from that of the normal population and the actual working dimensions of visually impaired people have not been totally investigated and measured, significant differences exist between the functional dimensions of the healthy and disabled populations [3], such differences exist in the hand motion, eye-hand coordination, two-hand coordination, finger movements, working posture and body movements. These differences clearly indicate that there is a need for specially designing the workplace in which people of limited motor efficiency must function. For this reason, visually impaired people can be

placed in many suitable types of jobs and function efficiently and effectively only if their workplace dimensions are appropriately modified

Much research has been conducted on job and workplace accommodations for normal and handicapped workers. Unfortunately, little has been done to encompass the visually impaired specifically. The application of ergonomics principles to the employment of visually impaired people is important because a person with impaired vision experiences a great reduction in his or her ability to gather information about the external environment through the sense of sight. Through the use of special fixtures and the modifications of workstations, visually impaired people, even with additional handicaps, can be made capable of performing many meaningful jobs.

1.3. The scope

The scope of this project is to highlight the need for designing of the workplace in which visually impaired people can work efficiently and effectively in Nut and Bolt Assembly.

1.4. Description of Nut and Bolt Assembly

The Visually Impaired worker is seated at the bench to retrieve parts, angles, and bolts from bins on the working table. The bolts are bolted into the nut and then the assembled parts are placed in another bin.

2. Design

2.1. Ergonomics in workplace design for the Visually Impaired Assembler

Ergonomics aims to match the task, tools, and environment with human capacities and limitations. The criteria taken into consideration are the worker's productivity, comfort, safety and health [2]. One of goals of workplace design is to make work environment acceptable and comfortable. This can be achieved if a workplace is well designed, integrated, and matched with the physical and mental capacities of workers. Workplace design for visually impaired workers is much more challenging than that for normal workers. It needs to be recognized that the same type of disability may lead to different levels of restrictions and handicaps in different condition. Although loss of vision means that visually impaired workers cannot maintain their work performance as well as normal workers do, it does not mean that visually impaired workers must give up aspirations that relate to their past work history or their willingness to adapt to redesign workplace dimensions within their physical, mental, and sensory capacities [4]. Therefore, ergonomics and job rehabilitators must understand the willingness of visually impaired workers to adapt to different job conditions. Furthermore, individual differences must be given much more consideration. The tasks must be redesigned and the workplace must be modified in order to enable visually impaired individual to master his or her tasks.

2.2. Workplace design for the Visually Impaired Assembler

2.2.1. Understanding the Visually Impaired Assembler

A person is defined as 'legally blind' if vision after correction is no better than 20/200 in his or her better eyes. He or she is partially sighted if vision in his or her better eyes after correction is less than 20/70 but better than 20/200. In simpler terms, a person is considered 'legally blind' if he or she can see no more at a distance of 20 feet than someone with normal sight can see at a distance of 200 feet [1]. There is distinction between blindness and partial visual impairment in term of how much assistance and performance aid they needs and what kinds of rehabilitation and training they will receive.

It is important to understand the fact that a person with a visual impairment suffers a great reduction in his or her ability to collect information from visible environment through the sense of sight. Therefore, the sense of hearing and touch plays a significant role for visually impaired people when they are rehabilitated. Furthermore, blind people prefer to receive additional information through their sense of touch rather than through their sense of hearing [5]. On the other hand, for partially visually impaired persons who can still see a little, there are electronics aids available that greatly magnify the image and accentuate the image contrast to enable them to read.

In general, the visually impaired people need more praise and require more training than normal people. The visually impaired have difficulty in changing routines and working at required production rates without environmental and workplace modifications within their residual capacities. Visually impaired workers could be at disadvantageous position in some work situations if they are not provided with the appropriate performance aids and modifications of the workplace.

2.2.2. Special needs of the Visually Impaired Assembler

Today, the technology in assisting visually impaired is available (e.g., robot, intelligent vehicles, intelligent computer-aided instruction, intelligent information-retrieval systems, user-friendly computers, etc.) to keep us living and working better. Unfortunately, these technologies do not implement in assisting visually impaired.

The most urgent and consistently advocated solutions to the problems of accessibility for the visually impaired people are better orientation and mobility instruction and improved electronic or biomedical sensory aids. A proper job match and full integration of employees with their disabilities will make sense financially and socially. Expert system approaches may facilitate the utilization of the current ergonomics knowledge in the field of the prescription of aids and services and improve workplace design for visually impaired.

2.2.3. Development of the Ergonomics in workplace design for the Visually Impacted Assembler

In the course of workplace design, four basic elements need to be considered. These are worker, environment, task, and interaction elements. From the worker's aspect, a workplace designer must consider the worker's anthropometric dimensions, working posture, mobility, sensory ability, and psychological characteristics. From the view of work environment, a workplace designer must consider air temperature and ventilation, humidity, noise, dust, odor, radiation, illumination, vibration, and potential hazards. From the task aspect, it should include mental and physical workload, fine visual judgment, verbal communication requirements, auditory signal detection requirements, tactile discrimination requirements, task frequency and duration, etc. Finally, any potential interaction among these three major aspects must also be considered.

2.2.3.1. Factors to be considered

Please remember the workplace design is for visually impaired people whose working and reaching dimensions are limited as compared to the normal people. Some general factors to be considered in the workplace design are listed below. The factors are categorized under four groups: worker, environment, task, and interaction.

2.2.3.1.1. Worker

- Anthropometry (i.e, body dimensions including static and dynamic).
- Working posture (i.e., seating, standing, or seating and standing)
- Mobility (i.e., stoop, kneel, push and pull, etc.).
- Sensory ability (i.e., hearing, touching, etc.).
- Psychological characteristics (i.e, interest).

2.2.3.1.2. Environment

- Air temperature and air movement
- Humidity
- Radiation
- Noise
- Dust
- Odor (i.e., chemical agents, etc.)
- Illumination
- Hazards

2.2.3.1.3. Task

- Mental load (i.e., accurate movement, complexity off decision, etc.).
- Physical load (i.e., heavy muscular work).
- Fine visual judgment
- Verbal communication requirement
- Auditory signals detection requirement
- Tactile discrimination requirement
- Frequency and duration of the task

2.2.3.1.4. Interaction

- Interaction between the worker and the environment (e.g., distraction, glare, etc.)
- Interaction between the worker and the task (e.g., protection devices).
- Interaction between the task and the work environment (e.g., adequate work space)

2.2.3.2. Checklist of Ergonomics Information Analysis for the Visually Impaired Assembler

2.2.3.2.1. Physical characteristics and capacities

a. Basic Physical Stamina
   - Height
   - Weight
   - Lift Strength
   - Visual acuity

b. Physical Characteristics
   - Stoop, Kneel
   - Reach, Handle
   - Talk, Hear
   - Push, Pull

c. Work Environments
   - Wet or humid
   - Noise or Vibration
   - Extreme temperature changes
   - Standing for long periods
   - Indoor or Outdoor activities

2.2.3.2.2. Workplace

a. Workstation
All potential workstation hazards and interference with the human working on it must be properly identified.

b. Seating
The seat dimensions and the elements of seating comfort are carefully recorded.

c. Task Analysis
The complexity of the task and the corresponding hand/body movements are thoroughly analyzed

d. Manual Material handling
A lifting belt will be provided if workers perform lifting/lowering weight that is greater than 20 lb.

2.2.3.3. Workplace Design System

The physical dimensions in the design of a workstation for Visually Impaired worker are of major importance from the view point of production efficiency and safety effectiveness. Small changes in workstation dimension can have a considerable impact on worker productivity and occupational health and safety. Inadequate posture caused by an improperly designed workstation causes static muscle efforts, eventually resulting in acute localized muscle fatigue.

To design a workstation for Visually Impaired worker, it is necessary to obtain relevant information or data on task performance, equipment, working posture, and environment

2.2.3.3.1. Collecting Anthropometric Dimensions for Visually Impaired Assembler

Body Part	Width (mm)	Length (mm)	Depth (mm)
Head			
Neck			
Chest			
Abdomen			
Upper Arm			
Lower Arm			
Hand			
Thigh			
Lower Leg			
Foot			
Arm Length			
Shoulder Height			
Elbow Height			

2.2.3.3.2. Determining Workstation Dimensions

a. Work Height
   - Height of the working surface should maintain a define relationship with the operator's elbow height
   - All possible the work-surface height should be adjustable to fit individually dimensions and preferences

b. Normal and Maximum Reaches

   The normal reach is defined by the tip of the thumb while the forearm moves in a circular motion on the table surface. The maximum reach can be considered as the boundary on the work surface in front of an operator that he/she can reach without flexing his/her torso.

c. Lateral Clearance

   The minimum lateral clearances at waist level are determined by adding 2cm on both sides.

2.2.3.3.3. Seating

Improper design of chairs and seats can affect the work performance of people and can contribute backaches and back problems. Therefore, the following items must be taken into consideration while selecting seats

- The clearance between the seat and the underside of the work surface should accommodate the thighs of the largest worker.
- Promote lumbar lordosis
- Minimize disc pressure
- Minimize static loading of back muscles
- Reduce posture fixity
- Provide for easy adjustability

2.2.3.3.4. Environmental conditions

a. Illumination

The following should be considered while designing lighting for Visually Impaired workers:

- A suitable level of illumination
- A balance of surface luminances
- Avoidance of glare
- Temporal uniformity of lighting

b. Climate
Variations in climatic conditions will be with us forever and undoubtedly. Therefore, a good understanding of the effects of temperature, humidity, and air flow on human health and performance, as well as the effectiveness of various protective measures is essential for efficient and safe design. The following factors must be taken into account in order to maintain proper working environment
- Heat exposure limit
- Heat exchange
- Humidity
- Heat stress
- Cold stress

c. Noise
The effects of noise on performance are not clear-cut; however, to prevent from hearing loss, the following subjects must be identified:
- Noise exposure measurement
- Methods for reducing noise levels at the source and along the path to the worker

d. Motion
- Limits for exposure to whole-body vibration

2.2.3.4. Testing

The following tests are used to measure the visually impaired worker's residual capabilities in performing nut, clip, and bolts assembly task

2.2.3.4.1. Achievement Test

This Test is designed to measure the worker's reading (e.g., word recognition and pronunciation), written spelling, and arithmetic computation skill level. It reflects the worker's achievement and aptitude characteristics.

2.2.3.4.2. Behavior Identification Test

This test is designed to identify the worker's behavior related to different job activities, e.g., work steadiness and consistency, reactions to changes in work assignment, ability to cope with work problems. It reflects the worker's temperament characteristics

2.2.3.4.3. Flexibility Test

This test is designed to measure the vision-impaired worker's ability to work at different work situations. It reflects the worker's physical and mechanical skill characteristics

3. Summary/Recommendations

3.1. Summary

A comprehensive approach would begin with the assessment of the workplace environment factors leading to the workplace design. Workplace environment factors include control of workplace temperature, noise, humidity, odor, illumination, and cleanliness. For workplaces to be designed in terms of the abilities of disabled people, the field of human factors should play an important role. To get the best out of a visually impaired person, it becomes necessary to have an effective workplace design system. Placement follow-up analysis in terms of job satisfaction, on-the-job training and retraining, productivity, quality, and safety are also important factors which need to be considered as well.

3.2. Recommendations

3.2.1. Material Handling

- Design the job based on lifting guidelines
- Provide back belt for lifting
- Tools and assembly parts must be pre-positioned
- Use supports under elbows, forearms or hands
- Provide back and leg rests
- Avoid seating too long
- Train the workers prior to task positioning
- Analyze worker's comfortability during the task
- Fool-proof the part design to ensure proper assembly
- Maintain neutral wrist posture

3.2.2. Workstation

- Design a preventive maintenance program
- Provide an adjustable desk which can be tilted or angled
- Provide raised edge working table to keep materials from falling
- Provide tactile map of work area
- Height adjustable motorized table
- Place light objects against a dark background
- Position work objects so as to eliminate static neck postures
- Avoid static shoulder elevation

3.2.3. Seating

- Ensure a proper seating posture such as knees and hips are bents at approximate 90 degree
- Ensure that the feet are flat on the floor are footrest
- Ensure that arms are comfortably placed at sides with elbows at 90 degrees
- Provide a padded seat that is adjustable for height and angle
- Provide a suitable adjustable backrest for lumbar support
- Adjustable foot rest
- Pneumatic height adjustable chair
- Provide a 4 cm thick lumbar support
- Provide a reclined backrest
- Adjustable seat height: 41 to 52 cm
- Seat pan angles of 0° to 10° backward tilt
- Seat depth: 38 to 43 cm
- Seat width: 45 cm
- Seat back angle: 90° to 105° with the seat pan
- Seat back width: at least 30 to 32 cm
- Seat back height: a minimum of 50 cm

3.2.4. Task Analysis

- Ensure that the hands are working in symmetrical directions and circular motions
- Reduce the number of motions each hand goes through
- Provide gravity bins and drop delivery to reduce reach and move times
- Pre-position objects for easy grasp
- Move finished bins closer to the worker
- Other objects are within reach of the worker
- The reach requirements should not exceed the maximum reach limit
- Avoid mental stress
- Limit repetitive movements
- Spend no more than 50% of time doing the same task

3.2.5. Workplace Environment

- Provide proper illumination between 400 and 600 lux
- Provide ear protection devices to the worker
- Provide safety mats
- Provide air conditioning, fans, and/or dehumidifiers
- Maintain proper clothing in cold and hot environments

- Place mirrors so that lighting doesn't reflect off them and create glare
- Select luminaires with low Discomfort Glare Rating (DGR)
- Using several low-intensity luminaires of a few very bright one
- Position luminaires as far from the line sight as feasible
- Increase the luminance of the area around any glare sources
- Keep the luminance level of luminaires as low as feasible to reduce reflected glare

3.2.6. Workplace design system

- A workplace design analysis system should be developed to analyze the dimensions of an existing workplace design and provide consultation based on the reach requirements of Visually Impaired Worker
- A workplace design information system should also be developed for handling anthropometric data and company information

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