Making Life Meaningful: Designing Workstations for Physically and Cognitively Impaired Adults

Shaheen Ahmed & Kari Babski-Reeves, Ph.D.
Department of Industrial and Systems Engineering
Mississippi State University, PO Box 9542, Mississippi State, MS, USA 39762

Ergonomic solutions for the workplace are important for any employee but especially important for workers with disabilities. This project investigates the workstations of physically and cognitively impaired employees at a state funded work program. Two workstations, a sorting station for coat hangers and a sealing station for flatware packages, were analyzed for inefficiencies and ergonomic hazards. The hanger station was redesigned using anthropometric principles and workstation aids to improve the employees' capability to distinguish and sort the coat hangers. The positioning of the hangers was modified to improve the efficiency of the employees' movements by reducing reach lengths. The sealing station was altered by providing a new platform for aligning flatware packages and installing a lever to control the sealer such that the lever motion conforms better to reduce errors and force requirements. Field tests were performed and the redesigns were proven successful in improving the productivity of the employees.

INTRODUCTION

According to the United States Census Bureau (2008), 41.3 million people (15% of the total population) have some level of disability in the US. The employment-population ratio for persons with disability was only 19.2%, in contrast to a 64.5% employment-population ration for those without a disability in 2009(Bureau of Labor Statistics (BLS), 2010). Persons with disability have higher chance of part time employment compared to those with no disability (BLS, 2010). Research has shown that if provided with meaningful work the quality of life can be improved for persons with disabilities (Heinemann & Pape, 2001).

"In the USA disabled individuals seem to work not only for their daily living but also for the sense of achievement and the meaningful life" (Disability Information Resources, 2001). In order to provide a meaningful work environment, people with disabilities should be treated as well as any other employee. Providing assistive technologies that allow disabled persons to work independently will in turn make them feel important in society (Heinemann & Pape, 2001; Pape, Kim & Weiner, 2002). In disability and assistive technology research, most studies have focused on the elderly. While this research is needed and necessary, research on appropriate accommodations for younger adults with severe cognitive and/or physical limitations is also needed. One study indicates that only 12% of disabled workers received accommodations in their workplace (Workplace Accommodations for People with Disabilities, 2003). Modifications and adjustments to the work, the working environment and other job related matters should be performed to provide necessary accommodations for disabled employees, though this may be a challenging undertaking (The U.S. Equal Employment Opportunity Commission, 2002).

Objectives

This study focused on the redesign of work tasks to accommodate workers within a state funded work program for individuals with documented physical and mental handicaps. Two work tasks, a coat hanger sorting area and a flatware packet sealing station, were evaluated for improvements in the work methods and work station design. Redesign efforts focused on improving worker safety, performance, and satisfaction by: (1) designing tools to help the workers align parts and materials without outside aid, (2) reducing the cognitive load by using simple, redundant cues, and (3) reorienting tools into a comfortable reach envelope.

METHODOLOGY

General Approach

A research team made three visits to a state funded employment facility to understand and identify work tasks for evaluation, conduct formal measurements of the work station, and present working prototypes to the workers.

Task Identification

The research team first visited with the managers of the facility where they were given a tour of the facility, tasks explained, and were provided with concerns by the managers for each task. The managers then identified two main tasks for redesign efforts. These tasks were those that had the poorest productivity (evaluated by error rates), and often required outside assistance from managers to complete. The goal was to develop work method/station redesigns that would promote working independently, reduce errors and increase throughput.

Hanger Station Task Description. Various suppliers provide hanger of various sizes to be sorted based on hanger dimensions prior to return to the facilities. A random assortment of hangers is set on a rack on the floor. Workers have to remove the hangers one by one, surface clean them with a cloth or gloves, and sort them according to size and shape. Once sorted, the hangers are placed at labeled locations on the station wall. Supervisors remove completed, sorted stacks from the workstations and place them back on racks for transport back to customers. Workers are required to pick hangers from the stack (middle picture in figure 1) and then separate four types of hangers (left picture in figure 1): “Baby, “Small,” “Short-Neck,” and “Long-Neck.”

Sealing Station Task Description. This task uses a heated sealer to close flatware packages in a plastic bag. The sealing station consists of a wooden box or plastic bin resting on an incline containing the unsealed flatware packets, the sealing device, and a wooden block with simple guides for packet alignment. Flatware packets; consisting of one folded napkin, one fork, one knife, one spoon, and one salt and one pepper packet; were previously prepared and stacked in a bin to the side of the workstation. Workers remove a packet and place it on a platform where the opening of the packet is positioned over the sealers bottom edge. Workers then press down on the sealer lever to seal the packet, ideally about 0.4 inches from the top edge of the packet. Once the packet is sealed it is removed from the platform and placed in another bin, where supervisors check the seal and move the packets to boxes for shipping. Figure 1 below shows a typical sealing station layout.

Figure1. Original Hanger Sorting Station (left two) & Sealing Station Layout

Task Evaluation

Informed Assent/Consent Documents were provided to the managers of the facility approved through the Mississippi State University IRB board prior to data collection. Photographs and video recordings were taken of the workers, their tasks, and their workstations to aid in redesign efforts. Physical measurements were taken of the workstations and of all equipment used in the hanger sorting and sealing tasks using standard tools (tape measures, calipers, rulers, etc.). Efforts were made to record common errors and mistakes, as well as common difficulties encountered during task performance through discussions with managers. For example, detailed photographs were taken of observed points of interest, such as locations where reach envelopes were violated, where awkward postures were assumed, and where most of workers' attention is focused.

Task Redesign Procedures

The research team collaborated and brainstormed possible solutions for observed problems. Videos, photographs, and measurements were reviewed. Rough sketches were drawn, and additional informational needs noted. A second trip to the facility outside of working hours was used to collect more detailed workstation measurements. Further interviews with the supervisory staff were conducted, where the team learned more about worker tendencies. Working prototypes for installation at the employment facility were developed. As the facility had limited funds, all redesigns had to require minimal materials, could be recreated in house, and be easily implemented at a number of workstations.

RESULTS

Coat Hanger Sorting Station Design

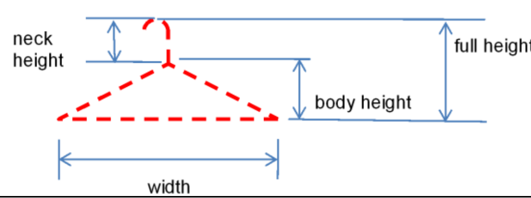
Four station sizes were identified (see Table 1). Dimensions for the largest table type were used in the design process as any design solution could be scaled to the appropriate table size. For the clothes hangers, measurements revealed that the hanger width had the most variation among the “baby” and “small” hangers, and between the “short-neck” and “long-neck” hangers (Table 2).Neck height had very little variance among all the hanger types. Further, the best dimension for differentiating between the “long-neck” and “short-neck” hangers was body height.

Table 1. Dimensions from the facility

Hanger Sorting Station (in Inches)				
Workstation Dimension	Table1	Table2	Table3	Table4
Width	47.00	45.50	47.00	43.25
Depth	34.50	23.00	23.50	21.50
Height	34.00	34.50	34.00	30.00
Station Wall Height = 11.25				
Station Wall Thickness = 0.75				
Height of Chairs (in Inches)				
Adjusted Stool Minimum = 23			Fixed Chair = 18	
Adjusted Stool Maximum = 33				
Hanger Rack Dimensions				
Width = 30	Body Height = 20		Full Height = 10	

Table 2. Clothes Hanger Dimensions

	Long Neck	Short Neck	Small	Baby
Width	17.720 - 18.125	17.750 – 18.000	16.000 – 16.000	14.500 - 14.625
Body Height	4.875- 5.500	4.125- 4.250	4.250 – 5.000	4.375- 4.750
Neck Height	4.300 - 4.700	4.500 - 4.750	3.875- 4.875	4.125- 4.250
Full Height	9.125- 10.125	8.750 - 8.875	8.125- 9.875	8.500 – 9.000



Hanger Station Work Method/Station Concerns/Issues

The reach requirements for most of the hanger sorting tasks required extended reaches above and below the work surface (middle picture in figure 1). Reaching to get hangers from the stack on the floor is physically difficult and places seated workers in a posture that could cause lower back injury or could result in a fall. The workstation wall at the back of the work station, where specific hanger types were stored, also required extended reaches beyond the normal and extended reach envelope of the workers. Therefore, workers were required to either stretch or stand up out of their chair to place hangers in these locations.

Another major issue was the ability of the workers to correctly sort the four hanger types. Discerning between hanger types was confusing because the hangers have very minute variances in their sizes and shapes. Two methods for sorting the hangers were currently being used. The first method involved taping example hangers for each type on the workstation surface and having workers visually compare hangers to be sorted by placing the hanger over the example. This method was believed to impose a high cognitive load on the workers by requiring workers to draw conclusions from comparisons, especially when the differences in hanger lengths were extremely small. The second method used cardboard with the outlines of hanger types drawn in permanent marker placed in non-permanent locations on the workstation surface. A hanger could be laid within the outline to determine hanger type. This method imposes the same cognitive load problems as method one. Additionally, with both of these methods there was an organizational space issue. Even the largest workstation did not have space for all four hanger guides to be seen by the workers from the seated position.

A third issue was the placement of sorted hangers. Once hangers were identified as a type, they were to be placed at specific locations on the wooden dividers of the workstation. Some workers consistently placed hangers in the wrong places since the workstation only has small, hand-written tags for hanger placement and many workers cannot read. On occasion, workers would disrupt the work of neighboring workers when attempting to place sorted hangers on common walls. Additionally, each employee had different preferences for sorted hanger locations. As workers rotated between workstations, this introduced error and worker frustration.

Hanger Station Redesigns

To address extended reaching to the hanger racks on the floor, platforms were designed to raise the hanger racks to a more acceptable level between knuckle and shoulder height. Because seating ranged from a fixed chair with a seat pan height of 18 inches and an adjustable stool with a minimum seat pan height of 23 inches and a maximum height of 33 inches, platform designs were based on known anthropometric data. The mid-shoulder height of the 50th-percentile male/female population is 23.6 inches and the elbow rest height is 9.3 inches (Kroemer, 2010). Given that the 30-inch hanger racks should not come within 6 inches of the top of the shoulder, to prevent multiple reaches over shoulder height, the platform height corresponding to the minimum chair height (18 inches) was 5.6 inches (figure 2). The platform height corresponding to the maximum chair height (33 inches) was 20.6 inches. When the platforms are in place, the elbow rest height should be about 8.3 inches below the top of the hanger rack (figure 2). All platforms were square/rectangular wood structures.

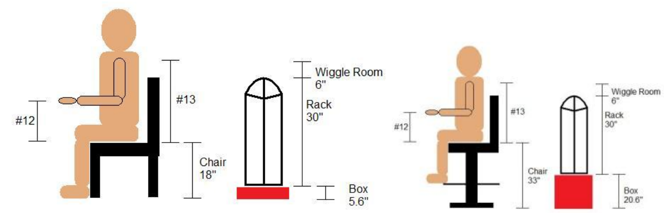


Figure 2. Measurements for Minimum and Maximum Platform Heights (Kroemer, 2010)

A sorting apparatus was constructed to assist in distinguishing between hanger types (figure 3). The designed comparison station contained wooden guides where the hanger is to be placed. Colored regions are located at each end of the apparatus, symmetric from the center. When the hanger is secured, the colored regions on the guide identify the hanger type according to where the leftmost or rightmost tip of the hanger lies. The two regions provide a redundancy check in case the hanger may have been placed within the guides incorrectly or if the hanger is bent on one side.

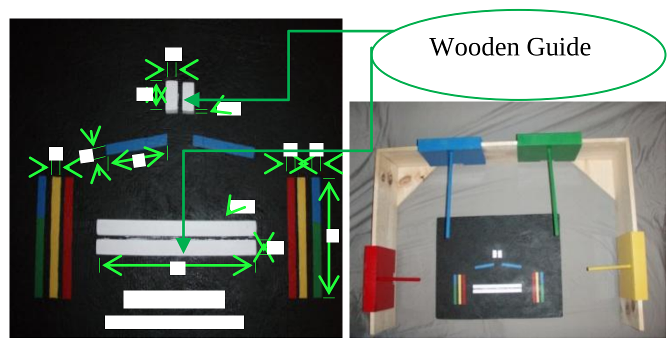


Figure 3. Hanger Comparison Station on the left and the complete work station

Once identified, the hanger is removed from the sorting apparatus and placed on the corresponding-colored dowel rod. These rods were built into wooden fixtures that mounted on the side walls and rear wall of the workstation. Four rods and fixtures were built; two were placed on the rear wall, colored blue and green, and are used for the "Long-Neck" and "Short-Neck" hanger types respectively. The other two were placed on the side walls, one each. On the left is the red-colored dowel for the "Baby" hanger type. The use of the rods reduced the need for extended reaches as workers needed only to get the hanger over the end of rod. The rods were constructed at an angle of fifteen degrees above the horizontal, so workers could place the hangers at the ends, and they would slide to the back towards the wall with the help of gravitational force.

This arrangement was chosen in order to help the workers correlate larger hangers with the rear wall and smaller hangers with the side walls. The green rod is also not adjacent to the red rod to provide separation in case a colorblind worker would be assigned to the workstation (Hoffman, 1999). Because of the dimensions of the workstations, the blue and green rods mounted on the rear wall are nine inches longer than the rods at the sides in order to prevent the worker from having to make an uncomfortable reach to place a hanger on the rod.

The reach envelope used for the redesign of this station was determined using the workers' functional pinch distance, which for the 50^{th}-percentile male/female person is 24.1 inches (Kroemer, 2010). The average mixed population measurements were chosen since no specific anthropometric data was collected on the target population and all parts of this workstation design can be adjusted for the comfort of the individual employee. Workers are estimated to sit with their bodies about six inches away from the edge of the workstation. Therefore, the reach envelope depth that exists over the surface of the workstation is 18.1 inches. The workstation depth of 34.5 inches and rear-wall dowel rod length of 18 inches result in an approximate 2-inch operational variance for the workers to place the hangers on the rod. A rod length of 8 inches was used for the side panels since these rods are already contained within the reach envelope, and a longer rod would protrude too far into the working space and cause interference.

The elevated dowel rods also allow for a visual check of the hangers already placed on it. If the hangers are properly sorted, they should form an even sloping pattern while on the dowel rod. Any incorrectly-placed hangers will be easily seen because of their differing body shape or neck length. This visual check was not possible in the old method where the hangers were hung directly on the workstation walls at oblique and inconsistent angles.

Sealing Station Design

Two models of sealers were used at the sealing station. The variance between the dimensions of these sealers was deemed negligible in the redesign of workstation/task.

Sealing Station Work Method/Station Concerns/Issues

The flatware packets have approximately 1 inch of available space for sealing. Some workers would cause an error by sealing too far down from the top edge of the packet, which would trap the napkin. Another common mistake is sealing the packet at an angle, which would result in a hole in the packet. The existing wooden platforms were custom-made to fit against the sealers, but they were not precision-made to match the lengths of the packets. This would cause confusion for the workers, who could not comprehend the amount of distance needed to slide the packet on the platform such that 0.4inches of the packet would be underneath the sealer contact surface.

The sealer handle itself required excessive force during activation and resulted in forearm pronation and wrist flexion. The repetitive application of force in this posture has been found to increase injury risk previously (Chaffin, 2006).

Sealing Station Redesigns

The wooden platforms used to align the unsealed packets under the sealer were redesigned to minimize the two sealing errors common with the current design (figure 4). The length of the platform was set such that the necessary 1 inches of packet will always be hanging off the edge of the platform and in the path of the sealing contact surface. Platform walls were installed to prevent improper placement and alignment of the packet. The platform was also tilted 22 degrees below the horizontal; this helps the packet slide against the rear wall reducing the need for exact placement of the packet for sealing and the associated cognitive load associated with aligning the packet to more than 2 points (sealer, walls, and back edge). A drawback is that the horizontal distance of the sealable area of the packet is reduced because of the angle, but the increased accuracy from the packets sliding against the rear wall to the pre-measured platform length compensates for the drawback.

A lever system was developed to reduce forces required during sealer activation and to promote better wrist positioning (figure 4). This lever places the wrist in a pronated position and allows for more force to be delivered to the sealer handle with minimal stress or pinching of the median nerve in the wrist.

Figure 4. Lever System with Redesigned Platform

REDESIGN IMPLEMENTATION

When the workstation prototypes were delivered to the employment facility, the workers had left for the day. Facility managers were allowed to view and use the prototypes and ask questions of the research team. Though specific usability or user perception data was not collected, reactions were positive. Several informal comments on the portability and adjustability of the hanger sorting apparatus were made.

In a phone interview conducted a few days after prototype delivery, the lead supervisor reported that all of the designs were working with very minimal adjustments required. The apparatuses designed for the hanger sorting station were being replicated for installation on all the hanger sorting stations. Small changes to the to the colored rods were to be implemented to allow for multiple rods to be placed on adjacent station walls. The wooden guide designed for the sealing station was not a proper fit, so the prototype built could only be used as a proof of concept for the design of a better fitting model. The lever arm was tested with a worker that had use of only one arm. The lever base needed some minor modifications to prevent the sealer from sliding, but after those changes were made its use was successful in modifying the worker's posture and ability to operate the sealing device.

DISCUSSION

Many of the issues encountered with the tasks of interest were driven by workstation issues. Because of low funding, many of the workstations were developed by taking donations from other businesses or creating their own workstations in house. This resulted in an inconsistent workplace in which workers may work on any workstation within the facility. The goal of this study was to develop low cost solutions that improved working conditions and addressed the known physical and cognitive limitations of the current work force.

Hanger Station Discussion

Specific hanger station issues addressed in the redesign were extended reaches and non-neutral postures, and hanger discrimination. The redesign solutions focused mainly on repositioning working within normal or extended reach distances to reduce extended reaches beyond the work envelope. Additionally, designs to reduce cognitive load associated with comparisons and decision making were implemented to increase worker independence and reduce common hanger sorting errors. Finally, the redesigns promoted the idea of a single workstation and a single work method, which would be beneficial in a work environment where workers float among work stations.

Prior to implementation of the workstation modifications, workers at the hanger sorting workstation had to reach 34.5 inches to the far wall, 16.4 inches beyond their normal reach envelope. With the dowel rods in place, the maximum reach distance was reduced to within their forward functional pinch range. Keeping the reach distances within the reach envelope helps to reduce the risk of injury and reduces the time required to place hangers on the correct colored rod, thereby increasing productivity. The wooden fixtures also provide a convenience to the supervisors who must remove the stacks of completed hangers to prepare for shipment. To prevent any permanent modification to the current work area, in case it needed to be reconfigured for a different job, all of the redesigned fixtures can be lifted or slid off the workstation with relative ease.

Sealing Station Discussion

Station redesigns for the sealing station focused on reducing sealing errors and force and wrist postures during sealer activation. The design proposed, while not completely successful, removed cognitive loading associated with product orientation. Further refinements of the activation handle should focus on limiting sealer movement and reorienting the hand to a handshake position to eliminate deviated wrist postures.

Results from this effort illustrate that inexpensive and simple solutions can have major impacts on worker independence and productivity. Moreover, populations with limited physical and cognitive abilities (e.g. children, pregnant women, older) can also benefit from this type of study.

Limitations

The anthropometric data used in this study may not represent the actual population. Because of physical disabilities, forward reach distances may be much shorter than in traditional anthropometric tables (Kroemer, 2006), special consideration should be given to workstation/work tasks designs that address the specific needs of this user population. Also, this study did not collect formal performance data prior to or following the implementation of any design modifications. While the authors recognize the need for this type of data collection, the facility supervisors were not concerned with collecting this data. Their goals in allowing the authors to complete this study were to minimize errors, but considered observational data sufficient to evaluate the design modifications. Even without this data, however, the focus on specific needs by individuals with disabilities is a consideration of ergonomics.

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