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Designing Universal Workspaces

Gourab KAR[a,1] and Abir MULLICK [a]
[a] *Georgia Institute of Technology, Atlanta, USA*

Abstract. This paper describes a research and design project focused on investigating challenges of work in behind the counter (BhC) workspaces. Present designs of BhC workspaces do not accommodate needs of intended users; and exclude older adults and people-with-disabilities from employment possibilities. The project examined challenges of work in BhC workspaces for the working population in the United States. People-focused and environment-oriented research methods were employed to learn about needs and preferences of employees working in office reception, library checkout, hotel reception and airline check-in counters. A multimodal research methodology helped to map problems from different perspectives; identify user needs and preferences; and generate guidelines to inform design development of inclusive BhC workspaces. The resulting BhC workspace designs incorporate principles of universal design and enable employment opportunities for everyone.

Keywords. Universal Design, Workspace Ergonomics, Behind-the-Counter (BhC) Work, Environmental Design.

Introduction

This project examined challenges of behind-the-counter (BhC) work for older adults and people-with-disabilities. It studied a range of workplaces to focus on important research questions that formed the basis of the project. For example: How can we study degree of *environmental fit* in BhC workspaces? What are minimum and extended work requirements of workers in BhC workspaces? Are there different work needs for older and younger workers; what are consequences of unmet needs? What environmental barriers challenge workers and how do these challenges affect their safety, productivity and wellbeing? Are environmental needs of older workers different from their younger colleagues; do they have different coping strategies? Do accessible workspaces improve functional performance? How can principles of Universal Design be applied to BhC workspaces and enable employment opportunities for everyone?

This paper presents a research and design project dealing with work in BhC workspaces. The project studied how work requirements of intended users affect functional performance; determined how environment design affects safety and usability; identified problems due to lack of *environmental fit* between user capabilities and environmental demands [1]; investigated commonalities and differences in BhC work; generated inclusive design criteria; and informed design development of modular

[1] Corresponding Author: Gourab Kar, Center for Assistive Technology and Environmental Access (CATEA), Georgia Institute of Technology, College of Architecture, 490 Tenth Street, NW, Atlanta, Georgia 30332-0156, U.S.A, E-mail: gourab.kar@gmail.com

workstations that offer safe, usable and inclusive workspaces for everyone. The project took place over two semesters in a university setting and employed a four-stage process of research, analysis, synthesis and evaluation (Table1).

Table 1. Project Stages

Research	Analysis	Synthesis	Evaluation
Literature Review			
Trace Study			
User Observation			
User Interview			
	Design Thinking		
	D. Specifications		
		D. Development	
		Final Design	
			User Feedback
			UD Checklist

1. Research

1.1 Literature Review

Background research employed a variety of sources including journal articles, conference proceedings, books, electronic databases, and other sources of verifiable data. Literature review used following keyword search phrases: workspace ergonomics, disability and work, workstation design, work-related musculoskeletal disorders (WMSDs), aging and work, Universal Design (UD), American with Disabilities Act (ADA), and occupational health. Five broad themes emerged from literature review.

Work & Occupational Health: BhC workspaces feature a mix of stationary and mobile tasks in sedentary and standing postures including over-the-counter interaction. There is increasing evidence that sedentary office work and work requiring constrained sitting or standing postures are associated with a high incidence of WMSDs [2]. Research suggests that work requiring frequent access to and interaction with visual display units (VDU) can cause incompatibility between human element and work technologies; enhanced compatibility and interaction between these two elements are required to minimize risk of WMSDs [3]. Risk factors causing occupational injuries in VDU operators have been linked to both physical [4] and psychosocial factors [5].

Work & Disability: As per the US Census Data [6], 19.1 million people (or 9.9% of working age population) have a disability. Considering that one-tenth of working age population has a disability and this is projected to increase in the near future, there is a critical need to incorporate principles of UD to design of workspaces. This will go a long way to mitigate social and financial disparities caused by excluding certain user groups, and ensure accessible and equitable work opportunities for all users.

Work & Ageing: Demographic trends indicate a significant ‘greying’ of the US workforce over the coming decades. It is estimated that by 2030, one-fourth of the working population in the US will comprise older adults over age of 55 [7]. This makes it imperative to incorporate human-centered approaches to design of workspaces that support physical, perceptual, cognitive and environmental demands of jobs encountered by all workers including older adults.

ADA & Workspace Design: The *ADA* mandates employers to *"provide a reasonable accommodation to a qualified applicant or employee with a disability, within certain limitations"*. ADA Accessibility Guidelines (ADAAG) has detailed provisions for design of checkout counters in business, mercantile, and civil spaces [8]. These guidelines specify basic dimensions, provisions for equivalent facilities and minimum number of counters for wheelchair access. While these are minimum standards that are legally enforceable, both workers and employers will benefit from an approach based on UD. An inclusive perspective will offer equitable workspaces that are flexible, modular and cater to needs of a broad range of users in an egalitarian, non-discriminatory way.

Universal Design & the Workspace: Universal Design is defined as: *"The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design"* [9]. The need for social inclusion is urgent, and requires that products, services, and environments be designed to reflect diverse demands of today's users and include needs of an increasingly greying demographic [10]. In context of BhC workspaces, the multifaceted challenges posed by convergence of occupational health issues; disability statistics; demographic projections and legislative mechanisms suggest need for a paradigm shift in the conceptual point-of-view regarding workers, work and workspaces. A holistic approach employing human-centered research methods to investigate environment-behavior issues can inform design of inclusive BhC workspaces that provide benefits of supportive design for everyone.

1.2 Contextual Enquiry

Four BhC workspaces were carefully chosen to represent work practices and work environments commonly occurring in public spaces. These workspace types are - library circulation counter, hotel check-in counter, airport check-in counter and office reception counter. Each workspace was studied using three research methods: (1) Trace Study, (2) User Observation, and (3) User Interviews of BhC Workers. A total of 10 users were observed at work and interviewed subsequently; of these users, four were in library check-in counter and two each in other BhC workspaces. Intended to study a wide range of users, participants were carefully selected to represent young and old users and their ages ranged from 25 - 57 years; and number of years of experience in BhC Workspaces varied from 3 – 34 years. The Institutional Review Board (IRB) of the University approved the research protocol; user consent was obtained in writing prior to the study. While the research methods employed have been described previously [11], this paper focuses on the evidence-based-design process that connects research findings to design outcomes. The following sections describes in detail, each of the three research tools employed.

1.2.1 Trace Study

Trace study (TS), offers a means to analyze environmental traces derived from observation and offer causal inferences rooted in human behaviour, environmental deficiency and lack of person-environment fit. The method employs visual means and annotations to conduct analysis and outline design specifications [12]. For environment-behavior researchers, TS offers a means to overlay an analytical structure over visual traces, identify issues of *environmental fit*, and analyze them to gain insights into meaning and use of environments by people. The role of TS is to provide an evidence-based method grounded in analysis and help design better environments. Trace Study, a sequential process, is rooted in three stages – Observation, Analysis and Inference [13]. Observation includes identifying environmental traces and recoding information using visual means like photographs (Figure.1). Analysis implies systematically examining environmental traces to determine causal conditions. Inference lists outcomes of analysis and outlines design specifications.

The BhC Workspaces research employed TS to four workspace types mentioned previously. Photographs of environmental traces were annotated to study existing conditions, assess problems and determine issues of importance to design. Each workspace was observed for two separate days during a workweek and daily observations were made two times; half-an-hour before start of work and half-an-hour after end of the workday. Those workspaces busy round-the-clock were photographed during transition time between change of shifts. Photographs of traces in work environments were studies in three stages - Observation, Analysis and Inference. The process involved making: (1) Observations in work environments, (2) Document traces that result from person-environment interaction, (3) Conduct visual analysis of environmental traces, (4) Gain insight into possible causes for traces, and (5) Outline design adequacy and limitations.

Figure 1. Trace Study of Library Counter

1.2.2 User Observation

User Observation was employed to evaluate four types of workspaces mentioned earlier; each work environment was observed for two separate days in a typical workweek. The researcher adopted a marginal participant vantage point for the study. On each day, observations were made for two hours - an hour during peak work period (as reported by users) and another hour during lean work period between peaks. The sequence of observations provided an accurate representation of the nature of work, and peaks and troughs of activity over a typical workday. The study involved taking notes related to BhC work, and making annotated diagrams of environment and activities. Digital photographs and video recordings complemented notes and annotated diagrams. The observation of workers in work situation developed a comprehensive picture of activity patterns and environmental relationships between worker, work and workspace. Observation study resulted in - (1) Spatial audit of BhC Workspaces, (2) Analysis of over-the-counter interactions, (3) Diagramming movement patterns of users in workspace and (4) Understanding environmental variables (such as noise, illumination levels, glare and degree of privacy) that affect work. (Figure 2)

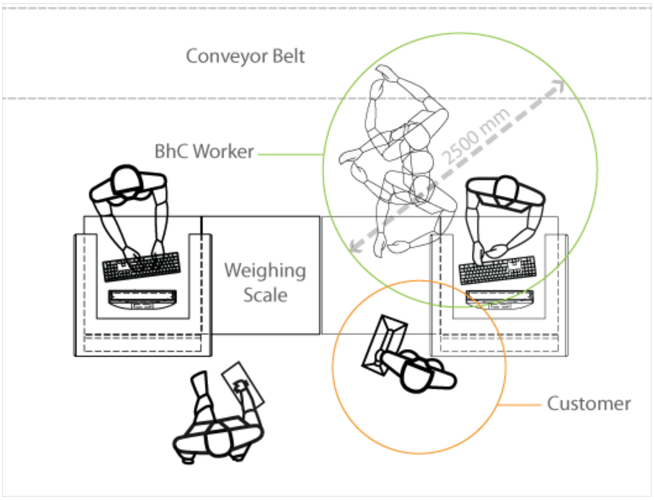

Figure 2. Airport Counter Movement Pattern

1.2.3 User Interviews

The study employed user interviews in all four types of workspaces mentioned previously. Prior to interview study, a set of talking points was developed from analysis of user behaviour in trace and observation studies. Semi-structured interviews were conducted with ten (10) workers in their respective work environments. Each interview lasted around half-an-hour and was video recorded with user consent. Interviews provided means to validate information obtained in trace and observational studies, confirm exact problems users encountered at work, and learn about new problems. Users shared anecdotal insights about problems at work, workarounds devised and suggestions for redesigns. The user interviews helped to - (1) Identify coping strategies workers develop to overcome environmental barriers and perform work, (2) Confirm/reject/modify initial inferences made during the trace and observation studies (3) Generate new insights and inferences from users about their work practices, (4) Offer a user-centered perspective on usability conflicts in BhC work. The application of three tools in sequence helped identify environmental-behaviour issues and confirm these at each stage. This method also allowed for user responses to be integrated into the research process, and helped to develop the design specifications.

2. Analysis

2.1 Design Thinking

Design thinking refers to methods and processes for investigating ill-defined problems, acquiring information, analyzing knowledge, and positing solutions in design and planning fields. As a style of thinking, it is considered as the ability to combine empathy in a problem, creativity in the generation of insights and solutions, and rationality to analyze and fit solutions to the context [14]. Trace Study, Observation and User Interview informed design of a new range of BhC workspaces. Inferences were synthesized into preliminary design specifications (Fig.3). The process of synthesis transformed ideas into practical design outcomes. For example: In hotel, airport and library counters, seating was either absent or hardly used due to the dynamic nature of work. Staff complained about pain in lower limbs due to long hours of standing on-the-job. Video analysis revealed coping strategies and postural shifts to relieve pressure on the legs by partially resting hands on the counter and frequently shifting body weight from one leg to another. As a potential solution, we thought of developing a body support feature that allowed occasional resting during breaks at work. The inference in this case was to reduce stress on the lower limbs, conceptualizing a body support was the design specification.

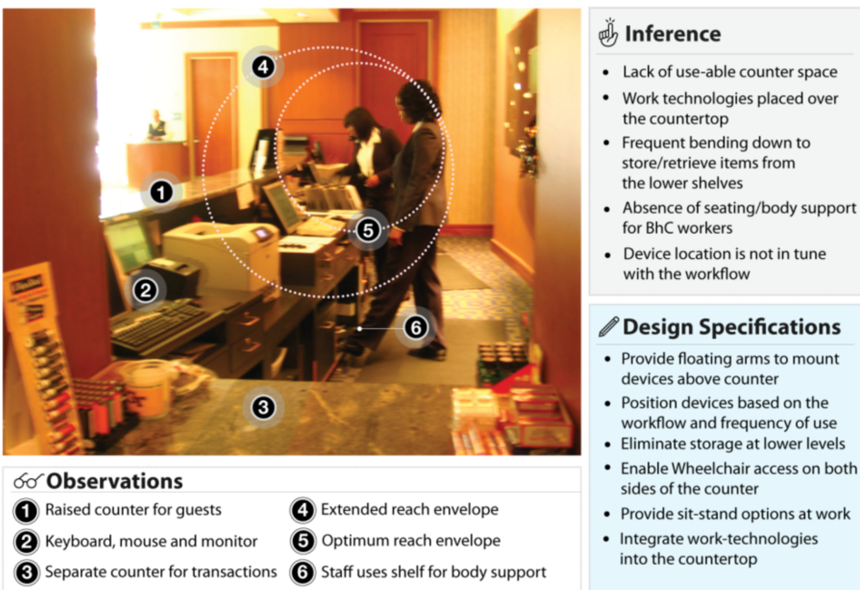

Figure 3. Hotel Reception Counter Work

2.2 Design Specifications

Inferences and insights from research translated into design specifications. These were categorized under four headings: Access, Flexibility, Integration, and Environment.

Access. User research indicates need for equitable access in all workspaces. While access for people-with-disabilities is mandated by ADAAG, equal access to workspace envelope can be achieved for all intended users through a UD approach. Accessibility issues of primary concern include: (a) wheelchair access on both sides of counter, (b) storage / retrieval zones within optimum reach envelope of users, (c) ease of use in material exchange (documents, books, and luggage) across counter space, (d) familiarity with devices and modes of interaction with work technologies.

Flexibility. Contextual enquiry highlights the need for users to customize workspaces to suit their individual and collective needs. Customizing physical workspace can improve job productivity; and research studies have been able to quantify benefits of improved design on task performance and comfort [15]. Flexibility in use can be provided through: (a) variable working heights (through height-adjustable counters), (b) adjustable split-level surfaces allowing independent use on both sides, (c) flexibility in device and storage locations, (d) sit-and-stand options for work at counter.

Integration. Studies reveal lack of integration between work technologies and physical environment, which adversely affects work performance. Technologies integrated into work surface facilitate an efficient workflow and improve work performance. Primary issues in the technology-environment domain include the need for - (a) positioning devices based on frequency of use, (b) providing for cable management and/or wireless networks and charging docks, (c) integrating devices into work surfaces, and (d) combining devices to aid workflow.

Environment. Environmental parameters like degree of enclosure and workspace layouts have significant impact on work performance. Specific environmental design features to aid performance are: (a) provision of screens and surfaces for visual privacy, (b) sound absorbing materials to reduce environmental noise and (c) design of superstructure to integrate building services such as lighting, heating ventilation and air conditioning (HVAC), security cameras etc.

3. Synthesis

Mapping common features across range of workspaces facilitated development of a systems thinking approach for the design scheme [16]. Common features translated into design specifications for a basic module, with provision to add-on features for specific work requirements. The basic module forms the basis for library, registration, and hotel counters. Additional features like extra storage module for office-counters and weighing scale for airport-counters can be integrated as required. Common design specifications offered a framework to develop ideas into initial concept sketches. Various concepts were explored and prototyped iteratively to refine ideas into three-dimensional prototypes. Prototyping simulated assembly sequence and enabled understanding of materiality, structure, appearance and performance. Designs explored concepts for inclusive access, variable work-heights, sit-stand body support, technology integration, modularity, and flexibility.

Prototypes developed through three rounds of iterations were benchmarked against four parameters of Access, Flexibility, Integration, and Environment. Concepts were refined to develop a final solution providing optimum balance between all four parameters. The final concept, modeled in a Computer-Aided Design (CAD) program, enabled quick and accurate visualizations of design scheme. This basic module included variable work heights; work in sit-stand postures, and wheelchair access on both sides of counter. Critical dimensions (working height, counter width, clearance and reach, etc) were determined from published anthropometric data sources [17, 18] and ADAAG guidelines. Common features include storage below counter level, monitor on floating arms, ridge at counter-edge as a device dock. The counter surface has provisions to integrate work technologies like book demagnetizer and barcode scanner. Office reception counters have additional storage zone and a printer dock. The modular design allows for parts to be easily arranged, swapped, and reconfigured; offering a range of layout possibilities by permutation and combination. The airport check-in counter comprises of the standard module along with a weighing scale. The design integrates work-technologies into the counter surface and provides for information display screens on floating arms. Counter staff is able to customize workspace for greater safety, convenience and productivity; and avoid environmental misfits that result from incompatibility between user needs, work-technologies and environmental design. Modules work both as stand-alone workspace units, and in linear configurations featuring multiple units (Fig. 4).

Figure 4. Scaled Down Model

4. Evaluation

Evaluation of design by actual users is fundamental to the human-centered design process. It provides an opportunity to examine how a particular solution influences actual context of use [19]. CAD visualizations of BhC workspace designs were used to elicit user responses (Fig.5). A handout comprising visualizations of new BhC workspace designs with explanation of design features and modes of operation was circulated among representative users from four workspace types. After perusing the handout, respondents had to answer three open-ended questions:

- What in your opinion are the strengths of the design?
- What in your opinion are the weaknesses of the design?
- Do you have any suggestions for improving the design?

Fifteen (15) BhC workers responded to the survey. Analysis of the feedback provided a qualitative understanding of user response. Recognizing the busy nature of BhC work, users were briefed on the handout and given a day to respond in writing to the three questions. The user responses have been categorized as being positive, negative, and suggestive. User responses to specific features is as follows:

Positive. Features that elicited positive responses include – Provision of wheelchair access on both sides, variable height counters for sit-stand work, usable work surfaces unencumbered by device clutter, flexibility in positioning devices, integration of work technologies into the counter surface, and body support place of seating solutions.

Negative. Aspects that were not deemed to be of value or potentially affecting work performance include – Counter depth may restrict across the counter reach, Controls for height adjustment not evident, Ridge at counter edge may hinder transaction, Device integration may affect repair and maintenance, and Staff side counter width may be inadequate for some workspaces.

Suggestive. Users responded to the design visualizations with a range of suggestions ranging from overarching thematic approaches to specific component detailing. Salient points for design improvement suggested by users include – Provision for additional storage zones for all counter spaces, Castor wheels on the frame for ease of transport and relocation, Provisions to facilitate multi-user collaborative work, Ease of repair and routine maintenance, Customizable and thematic aesthetics, and Need for stand-alone devices in addition to surface integrated work-technologies.

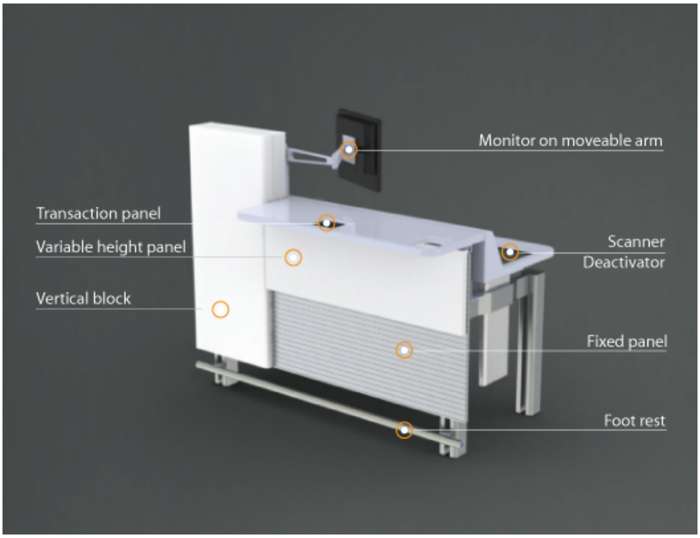

Figure 5. Basic Workspace Module

5. Conclusion

Looking back, there are definite answers to some research questions, while other questions can be answered after validating design through full-scale simulations with representative users. First, in response to need for UD approach, design outcomes have been successful in proving that a modular design incorporating UD principles offer performance benefits for all users. Modularity allows for customization according to individual needs; adoption of UD principles enables designs to be accessible to and equitable for older adults and people-with-disabilities. Second, adopting a modular approach to design appears to be a step in the right direction. People-centric research methods were successful in identifying commonalities; and informed design specifications that meet minimum and extended needs of all users. Third, the multimodal research approach successfully identified degree of *environmental fit* between user capabilities and environmental demands. Fourth, design allows for customizations that enable individuals to personalize workspaces according to their needs and preferences. In conclusion, this project shows that UD philosophy in combination with human-centered research methods can create equitable, accessible, empowering workspace solutions that benefit everyone. Future work for this project should include a broader range of service environments, and lead to the creation of full-scale functional prototypes of inclusive workspaces that are tested with all users including older adults and people-with-disabilities.

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