Original Article

Usability of cushions designed specifically for car industries' assembly lines

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Abstract

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Background: Ergonomics is a science that provides methods of creating reasonable adaption between occupation and worker by improving usability through consideration of job demands and human ability to satisfy them. A deep understanding of user's thoughts on and attitudes toward utilizing a tool could improve its design. In the present study, two cushions designed particularly for one of car industries' assembly line were tested considering usability.
Materials and Methods: From among the 50 employees of the assembly line, 44 employees were selected randomly to participate in the study. The research tool consisted of a researcher-made questionnaire containing 29 questions in 5 subscales (usefulness, efficiency, effectiveness, satisfaction, and safety). The validity of the questionnaire was estimated by a specialist (CVI = 0.85) and its reliability was calculated using Cronbach's alpha ($\alpha = 0.87$).
Results: The mean scores of the 5 subscales of usefulness, efficiency, effectiveness, satisfaction, and safety were 6.5 ± 0.534, 6.5 ± 0.488, 5.3 ± 0.278, 6.4 ± 0.310, and 6.5 ± 0.534, respectively.
Conclusions: Scores in all dimensions were above moderate and acceptable levels. Workers utilized them satisfactorily, and thus, producers can produce these cushions in large numbers without any problems. The performance of similar studies is recommended in designing other tools and instruments and the application of ergonomic principles in their design.

Keywords: Safety, Satisfaction, Assembly, Industry, Efficiency.

Introduction

The current industrial world has exposed the workforce to various hazards and harmful factors. These factors are integral components of manufacturing and always threaten workers' health. There are many occupations in which employees are exposed to awkward postures and conditions which increase the incidence of musculoskeletal disorders (MSDs) (1).
MSDs involve tendons, tendon sheaths, muscles, nerves, bursae, and vessels (2). Work-related MSDs are considered as the main cause of work time loss, increasing costs, and workforce injuries (3). The estimated costs imposed by these disorders, including workers' compensation, and salary and productivity loss, are 50 billion dollars annually in America (4). The National Institute for Occupational Safety and Health (NIOSH) has reported that 60% of individuals retire early because of spinal column discomforts (5). Ergonomics is a science that is concerned with providing the necessary compatibility between occupations and users with respect to occupational demands and users' mental or physical resources, through usability (6). One way to develop suitable products is to ensure their suitability from the point of view of usability (7). What makes a product usable is the absence of frustration in using it. The concept of usability is concerned with how a product or service is designed. In fact, a thing is usable when the user can perform his or her desired action in the way he/she expects to be

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able to, without hindrance, hesitation, or question (8).

Usability is a complex and multidimensional concept and encompasses the 6 characteristics of usefulness, efficiency, effectiveness, learnability, satisfaction, and accessibility. Usefulness is the degree to which a product enables a user to achieve his or her goals. Efficiency is the rapidity with which the user can reach his or her goal accurately and completely (and usually a measure of time). Effectiveness is concerned with product performance in the way the user expects and its ease of use. Learnability is a part of effectiveness and related to the user's ability to use the product after a training period. It also refers to the ability of infrequent users to learn the system after a period of inactivity. Satisfaction relates to the users perception, feeling, and opinion of the product. Accessibility is obtaining access to the product to reach a desired goal (8, 9).

Usability testing is part of a greater attempt to improve the advantages of products and their compatibility to the costumers. This method enables designers to collect data from users, resolve their complaints, and minimize or eliminate their reluctance to use the designed product (8). For example, in a case study performed by Evans (2003), ergonomic principles were used in designing a new nylon-line garden trimmer. In this study, a researcher-made questionnaire was used to measure user's preferences regarding different types of existent machines and some components like secondary handle for easier lifting and wrist support (10).

There are various ergonomic methods to evaluate human-machine performance, interface demands, and its effects on humans (11). These methods involve checklists, guidelines, observation, interviews, questionnaires, and layout analysis. Selection of the method depends on four main criteria. These criteria consist of the design process, product type, access to the end users, and time restriction (and other resources) (12). The usability questionnaire obtains user's feedback and opinions. In addition, its implementation and scoring is quick and it is cost-effective (13). The content of the questionnaire evaluates usability according to the features, requirements, and categories intended by the examiner and his or her aim of testing (14). Many studies have used custom-made questionnaires to investigate a products' usability. Kuijt-Evers et al. in investigating hand tool comfort and discomfort, used the Comfort Questionnaire and Local Perceived Discomfort Scale to evaluate comfort, subjectively. Their study showed that duration of force exertion is a predictor of comfort and the area under pressure is the best predictor of local discomfort (15). Kortum and Bangor determined the usability rating of 14 ordinary products using an online survey and revealed their main characteristics (16). Zickler et al. performed usability testing on two main applications based on the user-centered design in end users with severe motor paralysis using a custom-made questionnaire (17).

Employees of car manufacturing companies are at risk of MSDs due to their working situations and positions. This industry is one of the largest in our country and has many employees. Factors such as speed of assembly lines, process duration, workstation area, repetitive movements, performance of tasks in awkward postures, material handling, force exertion, and standing for long durations potentiate the incidence of MSDs (18). Therefore, the aim of this study was to evaluate usability of cushions that were designed for performing tasks more comfortably and decreasing reported MSD risk factors.

Material and Methods

In this study that was performed on assembly lines of a car manufacturing company, the ergonomics department detected ergonomic risk factors related to the workstations through periodic assessments. Through observation, the researcher found that workers in some workstations like lamp and headlight assembling, wiring, and inner attachments installation were required to sit on the edges of the car's body and its floor surfaces. To take corrective action in order to supply comfort and prevent MSDs due to awkward working postures over a prolonged period, 2 cushions were designed in collaboration with an industrial design group. These cushions were made of semi-rigid foam covered by a textile ordinarily used by companies producing car seats. Since contact pressure was exerted from both edges and floor of the car body, the design group was asked to design cushions in two shapes; saddle and flat (Figures 1 and 2).

Figure 1: Saddle cushions

Figure 2: Flat cushion

Usability evaluation is a stage of product evaluation with the aim of improving the prototype design before mass production. Therefore, after producing two prototypes of both cushion types, the researcher assessed the usability and appropriateness of samples to the abovementioned tasks. From among the 50 workers who operated in two consecutive shift works and were exposed to inappropriate working circumstances, 44 workers were selected randomly using the Morgan table.

Primary version of the questionnaire was designed according to previous studies and literature review and in interaction with the design team and workers (end users). To improve the questionnaire, a pilot study was conducted. The pilot study enables the determination of redundant questions, completion time, attaining of ideas about future questions, and determination of whether questions seek the correct data or not (17).

Finally, a 29-item questionnaire was designed. The items were scored based on a Likert scale. Based on the kind of product, accessibility to workers, and availability of cushions to end users, content of the questionnaire included cushions' usefulness, efficiency, effectiveness, and characteristics such as shape, dimensions, material, handle, the space required for its use, keeping good posture while using it, safety, and probability of danger (Table 1). Some of the questions in each subscale are provided in the appendix. Cronbach's alpha of the questionnaire was 0.891. Its validity was estimated through specialist confirmation and the content validity index (CVI) was calculated (CVI = 0.95).

Table 1: Summary of scales in each indicator

Indicator	Number of questions	Response categories
Usefulness	3	7-point Likert scale
Efficiency	7	7-point Likert scale
Effectiveness	11	7-point Likert scale
Satisfaction	5	7-point Likert scale
safety	3	7-point Likert scale

Results

All questionnaires were completed and returned. All participants were men, in the age range of 20 to 47 years, and had at least 3 years of work experience. Most of them (40%) were 26-30 years old. The mean scores of the 5 main dimensions of usefulness, efficiency, effectiveness, satisfaction, and safety are given in table 2.

Table 2: Central and distribution indices of usability dimensions

Dimensions	Number	Min	Max	Mean ± SD
Usefulness	44	5.5	7.0	6.5 ± 0.534
Efficiency	44	5.4	7.0	6.5 ± 0.488
Effectiveness	44	4.9	5.8	5.3 ± 0.278
Satisfaction	44	6.0	7.0	6.4 ± 0.310
Safety	44	5.5	7.0	6.5 ± 0.534

Discussion

The aim of this study was to assess the usability of cushions designed for assembly lines to consider end users viewpoints in the design process before mass production. In this research, usability assessment was performed using a custom-made questionnaire including usefulness, efficiency, effectiveness, satisfaction, and safety. This assessment method was similar to that of Kortum and Bangor in usability testing of everyday products, Zickler et al. in studying usability of two applications according to the user-centered design in end users with severe motor paralysis, and Kuijt-Evers et al. in measuring comfort and discomfort of hand tools. Results of central and distribution indices of usability dimensions indicators showed that the cushions were usable and suitable for the workers. They can apply it in a satisfactory manner and suppliers can produce it in large amounts. The restrictions of this research were difficulty in recruiting more workers as participants and producing prototypes of the cushions because of administrative procedures and limitations. Further researches with a larger number of participants may be helpful in the investigation of the cushions' usability and their modification.

Conclusion

Improving usability, results in increaseduse of product by the workers and, of course, minimizing probability of MSDs incidence in non-ergonomic work situations. The performance of usability assessment studies is recommended, because their results provide operational strategies to improve product design, especially in industrial products used by workers who are in the front line of manufacturing.

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