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Usability evaluation of drywall sanding tools

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ABSTRACT

A usability evaluation was performed on four drywall sanding tools and redesign specifications were developed for one, to improve the human-tool interface of the sander that provides the greatest control of drywall dust, a known respiratory health hazard. Sixteen novice participants performed simulated drywall-finishing tasks with each of the four tools: block, ventilated, pole, and wet sponge sanders. Outcome measures of interest were four usability metrics: "ease of use", "ease of learning", "perceived productivity", and "comfort". Scaled questionnaire items were analyzed by MANOVA and responses to open-ended questions were analyzed via content analysis procedures. The block sander, the current industry standard tool, performed best in usability evaluations of "ease of learning" and "ease of use". The ventilated sander, found to be most effective in dust control, performed poorly in terms of "ease of use" and "perceived comfort", but well on "perceived productivity". Findings from content analysis were employed in development of redesign recommendations. Redesign recommendations to improve comfort and ease are presented: reduce tool weight, reduce moment-arm, and improve grip design.

Relevance to industry: Ventilated sanding technology can substantially reduce worker exposure to drywall dust; however, usability problems might be preventing widespread adoption of this technology.

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1. Introduction

1.1. Drywall finishing processes and risks

Respiratory disease among construction workers in general, and plasterers and wall finishers in particular, is a major public health concern. Workers in these trades suffer from disproportionately high rates of respiratory disease and disability (Wang et al., 1999). Drywall-finishing operations have been associated with worker over-exposure to dust that contains known particulate respiratory health hazards, such as silica, talc, and mica (NIOSH, 2000). Kaukiainen et al. (2005) found that construction painters experience a high prevalence of symptoms of upper-airway disease, and that this prevalence was significantly higher than that of other construction-related trades workers. These authors also indicated that exposure to drywall compound dust may be a contributing factor. A Health Hazard Evaluation conducted by the National Institute for Occupational Safety and Health (NIOSH) found that respiratory symptoms are common among drywall finishers and tend to improve when workers were away from the workplace (Miller et al., 1997).

Drywall operations consist of two main tasks: wallboard installation and wall finishing (Pan et al., 2000). Wall finishing tasks, performed by drywall finishers, plasterers, or painters, are the operations with the greatest associated worker dust exposure (Miller et al., 1997). Wall finishing consists of two tasks: taping and sanding. Workers fill joints between wall-boards with joint compound, press tape into the wet compound, and smooth away excess. The joint compound is allowed to dry, the surface is sanded, and an additional coat is applied. This cycle is repeated three times. The final coat, once dry, is sanded until smooth (Pan et al., 2000). The most common sanding tool employed in the drywall-finishing industry is the hand-held block sander (Young-Corbett and Nussbaum, 2009b).

There are additional sanding methods that offer some control of worker exposure to dust from construction drywall-finishing operations: ventilated sanding, pole sanding and wet sanding. All three methods are recommended by NIOSH (2000). Ventilated sanding technology involves a vacuum system attached to the sanding surface. Dust is collected at the point of generation and pulled into a collection basin. In pole sanding, the sanding surface is attached to the end of a pole and the worker holds the other end while performing the operation. This reduces worker exposure to the dust by removing the worker from the point of dust generation. Wet sanding is accomplished in one of two methods. In one method, the drywall compound is allowed to cure and then re-

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wetted. Re-wetting is accomplished either by misting or wiping a damp sponge or cloth over the surface. A second method involves a combination of wet sponge and sand block. Ventilated sanding equipment has been found to produce substantially less dust than the other sanding methods (Young-Corbett and Nussbaum, 2009a).

Despite the existence of engineering and work-practice control technologies for the mitigation of this hazard, worker exposures to dust persist in the drywall-finishing industry (NIOSH, 2000). A survey of owners of drywall-finishing contracting firms revealed that ventilated sanders and wet methods are not employed by most (Young-Corbett and Nussbaum, 2009b). The work presented here is part of a larger effort to identify barriers inherent to the drywall-finishing work system that are preventing the use of highly effective and available dust control technologies. Once probable causes of low usage rates are identified, intervention strategies can be developed and deployed in order to improve controls usage rates in drywall-finishing operations.

1.2. Usability

As the role of perceived usability in technology adoption has been documented in the literature (Tornatzky and Klein, 1982), one potential barrier to dust control technology adoption could be a sub-optimal human-tool interface. Therefore, a usability evaluation was undertaken to identify issues inherent to the design of the wet sponge, vacuum, and pole sanders. Indeed, some evidence exists of the need for improvement of the human-tool interface for these sanders. In a study of drywall finisher perceptions of work-related risk factors, Pan et al. (2000) found that pole sanders were associated with physical stress to the neck, shoulders, back and wrists/hands. In a survey of drywall firm owners, human-tool interface problems associated with ease-of-use, learnability and productivity were identified as barriers to the adoption of the vacuum sander and wet sponge (Young-Corbett and Nussbaum, 2009b). More generally, the National Academy of Sciences reported that there is evidence of a link between tool design factors, perceived comfort, and risk of musculoskeletal injury (NRC, 1998). Furthermore, poorly designed tool-user interfaces can contribute to an increase in accident risk, as well as musculoskeletal injury (Aghazadeh and Mital, 1987).

In the present study, a summative usability evaluation was performed to identify any tool-user interface related factors that might prevent adoption and regular use by end-users. Usability is defined as a composite of several attributes, including learnability, efficiency, memorability, error rate, and satisfaction (Hix and Hartson, 1993). Since the sanding technologies being evaluated here are hand tools, usability metrics previously designed to evaluate such tools were employed. Miller (2001) presented several guidelines for conducting usability evaluations of hand-tools, and several metrics were identified: ease of use, force required, comfort levels, likelihood to drop parts, and physical characteristics of the hand tools. Johnson (1999) described the usefulness of subjective usability evaluations of hand tools for comfort, productivity, and ease of use. In a relevant study of usability of orbital sanders, a user-reaction survey was used to evaluate hand/arm discomfort, force required, productivity, and comfort (Spielholz et al., 2001). Based on the metrics established by these previous studies, and the findings of earlier investigations of barriers to adoption, the current study employed the following aspects of usability: ease of learning, ease of use, perceived productivity and comfort.

1.3. Redesign for improved usability

Results of a usability evaluation can help identify aspects of a tool's design or interface that require improvement, and inform the application of established heuristics to the redesign process. Several authors have provided comprehensive approaches to hand tool evaluation and design. A three-dimensional model that emphasized the dimensions of force, precision, and time was developed to classify and analyze work with hand tools (Sperling et al., 1993). In this model, redesign heuristics are prioritized based upon aspects of the tool and the work to be performed. Kuijt-Evers et al. (2007) established a set of comfort predictors for use in improved hand tool design. The Quality Function Deployment (QFD) design method was applied to the ergonomic design of hand-tools by Haapalainen et al. (2000). In this method, user requirements, design parameters, and impacts on ergonomic quality are major inputs into design decisions. A multi-level systems approach to construction tool and process design was proposed by Vedder and Carey (2005). Mital and Kilbom (1992) synthesized the findings of four decades of research pertaining to the ergonomic principles of hand tool design in a set of guidelines for the design and selection of tools. This set included heuristics for the design of tool grips, effective weight, trigger mechanisms, vibration characteristics, user characteristics and general considerations. Physical, physiological, and psychophysical methods of evaluating hand tools were integrated into an evaluation station approach to design in another case (Kadefors et al., 1993). These authors combine usability metrics and established ergonomic criteria into a set of evaluation heuristics, which fall into two general classes (characteristics of the tool and tool effects on operator). In developing a set of redesign recommendations for the ventilated sanding tool in the present study, the guidelines of Kadefors et al. (1993) were applied in the process of evaluating existing tool design and identifying problem areas. In developing recommendations for new design attributes, the specifications developed by Mital and Kilbom (1992) were employed as a framework for guiding design choices.

Based on current industry trends and design heuristics provided by Kadefors et al. (1993), two specific hypotheses were developed regarding the usability of the four drywall-finishing tools. First, it was expected that the block sander would perform better than the other three tools on usability metrics of "ease of use", "ease of learning", "perceived comfort", and "perceived productivity". Second, pole, ventilated, and wet sanders were anticipated to perform worse than the block sander on all usability metrics.

2. Methods

2.1. Experimental design

Participants performed a simulated drywall-finishing task in a laboratory setting, with each participant performing the task four times, once with each sanding technology (tool) of interest. Following each session, participants completed a usability questionnaire concerning the tool just used. Following the entire experimental set of four task sessions, participants completed a questionnaire that assessed tool usability. The experiment was conducted as a mixed-factor design, with one between-subjects factor (gender) and one repeated-measures factor (sanding tool type). Presentation order of the tools was balanced using a 4×4 Latin square design, with two Latin squares for each gender. A total of 16 participants completed the experiment, with equal numbers of males and females.

2.2. Participants

All participants were above the age of 18, had no prior experience with drywall sanding tools, and completed an informed consent procedure approved by the local Institutional Review Board. While a standard method of conducting usability testing is