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Hazard recognition and risk perception in construction

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ABSTRACT

A construction superintendent's ability to recognize hazards and to perceive and assess risk is an essential skill for maintaining safe conditions on their construction sites. In a study that aimed to explore the degree to which construction superintendents are aware of hazards and how well they perceive the associated risks, 61 subjects were asked to identify the hazards in a typical construction project, to assess their risk level, and to estimate the probability and the severity of possible accidents. Some subjects were presented with photographs and construction documents, while others toured a virtual construction site using a 3-sided virtual reality CAVE. The method allowed both for analysis of differences in perception and assessment between distinct populations and for evaluation of the effectiveness of the virtual environment in demonstrating hazardous situations. Results show that construction superintendents with many years of experience are unable to identify all of the hazards in their work environment, and that there are important discrepancies between the way they assess risk levels and the way most formal safety risk assessment methods rate risk levels. Most subjects in the virtual environment assessed higher risk levels to hazards caused by moving equipment. They also identified more hazards correctly than the subjects who studied photographs and documents. Of primary concern is the apparent lack of correlation between hours of safety training and work experience on the one hand, and hazard identification and perception skills on the other hand.

1. Introduction

Most textbooks and guidelines on construction safety list hazard identification and risk assessment as the first steps in safety risk management (e.g., Covan, 1995; Hinze, 1997; HSE, 2011). Yet construction superintendents have difficulty identifying hazards (Sacks et al., 2009). Carter and Smith (2006) found that only 6.7% of method statements in UK construction sites identified all of the relevant hazards. Research in construction operations has shown that familiarity with a task can in fact lead to decreased perception of a hazard, such as painters being 'desensitized' to the risks associated with working on ladders (Zimolong and Elke, 2006).

Furthermore, construction personnel often function in unplanned conditions due to disruption of their regular work. Using an ecological momentary assessment (EMA) method, Menches and Chen (2012) found a high rate of disruptions and that all of the disruptions to a worker's activity required improvisation. Human error is one of the key reasons for construction industry accidents (Saurin et al., 2004). Errors can stem from carelessness or lack of awareness on the part of workers (Abdelhamid and Everett, 2000). According to Rasmussen's model, workers' motivation to achieve high levels of productivity pushes them to work 'near the edge' in terms of their exposure to hazards (i.e. beyond the zone of control or recovery) (Mitropoulos et al., 2005).

In this dynamic work environment, the role of the construction superintendents, who in most countries are responsible for the physical conditions on site, is crucial. They are directly in charge of construction operations and their management on a daily basis. It is the superintendents' duty to organize labour, material, equipment and subcontractors (e.g., Gunderson and Gloeckner, 2011). The role of the foreman or the superintendent has been identified, both by managers and workers, as one of the most powerful influences on the safe work behaviours of workers (Gillen et al., 2004a,b). Sawacha et al. (1999) concluded that operatives "see their superintendent's attitude towards safety as being a major source of influence upon their behavior on site."

Accordingly, improving construction superintendents' hazard recognition and risk perception abilities should improve safety at the site. Numerous studies have shown that hazard recognition and risk perception of workers and drivers can be improved by training intervention. For example, Rethi et al. (1999) prepared a hazard recognition training program with visually degraded stimuli for construction and maintenance activities on mines. The

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training improved the hazard recognition skills of miners (Kowalski-Trakofler and Barrett, 2003) and training that included simulation exercises and used three dimensional slides improved workers' ability to recognize roof hazards (Barrett and Kowalski, 1995). Participants who received video-based road commentary training detected and identified substantially more hazards than control groups, showing that road commentary training seems to be effective (Isler et al., 2009). Additionally, instruction of novice drivers about the deficiencies in their visual search skills or strategies was shown to have positive influence on visual search patterns (Chapman et al., 2002).

The aim of this research was to explore the extent to which construction superintendents perceive hazards and how they assess risk. The first hypothesis to be tested (H1) was that their ability to identify hazards and correctly assess risks should exhibit positive correlation with the extent of their work experience and of their formal safety training. This is in line with research demonstrating that more training will lead to better hazard perception (e.g. Kowalski-Trakofler and Barrett, 2003). The influences of accident probability and outcome severity on their risk evaluations were also of interest, because accepted industry practice in safety risk assessment is to multiply separate evaluations of the probability of occurrence and the expected severity of accident scenarios (Gangolells et al., 2010; Hadikusumo and Rowlinson, 2004; Seo and Choi, 2008). The second hypothesis (H2) is, accordingly, that construction superintendents would assess safety risks by multiplying separate evaluations of the probability of occurrence and the expected severity of accident scenarios. The third hypothesis (H3) is that subjects can identify hazards better in a virtual environment than they can using traditional project documents (drawings and schedules) and photographs.

2. Method

The research method was designed to allow comparison of the hazard identification and risk assessment abilities of construction superintendents with those of civil engineering students (who have had no safety training and have no construction site work experience) and with those of company safety directors, (who have had extensive training and have rich construction experience).

Sixty-one individual subjects belonging to the three different groups were asked to identify the hazards and assess the risk levels in a typical construction project. Some were presented with photographs and traditional construction drawings (the *traditional test*), while others were asked to tour a virtual construction site presented using a 3-sided virtual reality CAVE (the *virtual test*). The same set of 48 safety hazards was represented in both test procedures, in which a variety of hazards were present. We used ANOVA tests to compare performance in different groups and across the two test methods.

The virtual reality (VR) construction site method was chosen because it offers a unique solution to the problem of presenting a subject with hazardous conditions. Concern for the physical safety of experimental subjects precludes the possibility of asking subjects to tour a real construction site and to identify all of the hazards they can. In particular, purposefully creating hazardous conditions – such as missing edge protection – would be immoral and unethical. Simulated environments presented in virtual reality tools are commonly used for research in fields as diverse as cognitive processing of traffic signs (Liu et al., 2010), learning in primary school students (Roussou et al., 2006) and physiological response to stress (Kotlyar et al., 2008).

Lucas et al. (2008) succinctly described the fundamental advantage of the cognitive learning that is achieved through virtual reality (VR) training over learning in a traditional classroom in the specific context of safety training for equipment operators. If learning in general can be achieved through use of VR, it is likely that hazard recognition and risk perception, specifically, can be tested using VR. Thus a secondary aim of the research was to explore whether a virtual environment can be used to test hazard recognition and risk perception. Our hypothesis in this regard was that civil engineering students, construction superintendents and company safety directors can identify hazards better in a virtual environment than they can using traditional project documents (drawings and schedules) and photographs.

2.1. Subject population

Twenty-three civil engineering students, 31 construction superintendents and seven company safety directors) were tested. Of the 61, 28 were tested in the virtual test and 33 in the traditional test (see Table 1 for details). The student volunteers were all final year students of construction management from the Technion – Israel Institute of Technology. Their only prior exposure to hazard identification was the minimal content on safety in an introductory construction management course, possible reading in textbooks, and from a site visit during the course of their studies. The construction superintendents and company safety directors were all recruited from companies that are rated at level 5 (the highest possible grade) by the government registrar of construction contractors.

As can be seen in Table 1, the safety directors' group and the superintendents' group had significantly more years of work experience than the students' groups (with overall population means of 21.8, 17.9 and 0.3 years respectively). Almost all of the safety directors (85.7%) and superintendents (92.8%) had received formal safety instruction while only 34.7% of the students had; and the mean of the instruction hours was highest in the safety directors group and lowest in the students group (101.7, 14.2 and 0.7 h respectively). Six of the seven safety directors (86%) had witnessed at least one work accident, as opposed to 72% of the superintendents and only one of the students (4%).

Table 1
Test subject statistics.

Group	Number of subjects	Mean number of years at work	Number of subjects who had received formal safety instruction	Mean number of prior safety instruction hours	Number of subjects injured at work	Number of subjects who witnessed a work accident
Traditional test						
Students	12	0.5	4 (33%)	0.68	1 (8%)	2 (17%)
Superintendents	19	21	17 (89%)	11.3	7 (37%)	13 (68%)
Safety directors	2	33.5	2 (100%)	37.5	1 (50%)	2 (100%)
Virtual test						
Students	11	0	4 (36%)	0.7	3 (27%)	1 (9%)
Superintendents	13	12.6	12 (92%)	19	8 (61%)	10 (77%)
Safety directors	5	19	4 (100%)	85.7	1 (20%)	4 (80%)