

Effective Instructional Methods for Providing Safety Training to Construction Workers

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Billions of dollars are spent each year by the construction industry to mitigate risk associated with accidents and fatalities. The highest concern for government and industry is to decrease and eliminate the risk of falls. Tool-box talks are a common on-the-job type of safety training in the construction industry. The purpose of this research was to determine the best method for presenting safety training to construction workers. Research participants consisted of 123 University of Nebraska - Lincoln students which are considered relatively naïve subjects. Three different methods were used to present the same toolbox talk: written only, written with pictures, and written with pictures along with a demonstration. Each method of presentation was given to the participants. The participants were then administered a quiz to determine the amount of information retained. Data from all three methods was analyzed. The results suggested that individuals cognitively retain more information when the presentation method includes written, verbal, and contextual stimuli (e.g. demonstration, images).

Key Words: Safety Training, Cognition, Instructional Methods

Introduction

Despite significant investment by industry in recent years and an increase in regulation by government, construction safety continues to be a concern in the United States (Hallowell, January 2010). In 2011, the Occupational Safety and Health Administration (OSHA) reported 4,188 fatalities in private industry, of which 738 or 17.6% were in construction. Of these 738 fatalities, 259 or 35% were related to falls (U.S. DOL, 2013). Fatalities related to falls represent the highest percentage of all worker fatalities. Many accidents and fatalities often occur in small residential construction companies where a well-established safety program is more unlikely to exist (U.S. DOL, 2013). Even in large construction companies where safety programs are well documented there are still occurrences of injury and fatalities due to falls. The top cited OSHA standard violation in 2012 was fall protection, construction, OSHA standard 29 CFR 1926.501 (U.S. DOL, 2013).

To mitigate risk of injury and fatalities related to falls, OSHA regulations require that safety training be provided for each employee who might be exposed to falls. This training should enable the employee to recognize the hazards of falling and should train the employee to take appropriate steps to minimize risk. Hazard communication is the second highest cited standard violation. In an effort to minimize the accidents and eliminate fatalities, many construction companies provide weekly on-site safety training. However, in many cases, regular safety training is often limited to a five to seven minute toolbox-talk (TbT) at the beginning of the work-week. A toolbox-talk is often delivered in the form of a written page of information relative to the job. Other toolbox-talks may include illustrations or pictures to help trainees better understand the written material. The OSHA website provides numerous resources for developing and delivering toolbox talks, most of which are available in both English and Spanish. In some cases, a demonstration of safety methods may also be made by a foreman or superintendent to enhance the learning of the written material. However the information is delivered, the purpose of the tool-box-talk is to provide safety training that is intended to be cognitively retained and applied in practice by the employee.

The effectiveness of the toolbox-talks may vary depending on several factors, including: the attitudes of the workers, the natural or trained cognitive abilities of the trainee, the communication skills of the trainer and the trainee (considering foreign language), the safety culture that is fostered within the organization, and/or a number of other potentially unknown variables. One hypothesis for this persistent problem may be that the delivery method for safety training does not satisfy the cognitive abilities of the trainee to retain the training information received. There is a need in occupational safety training to understand how individuals with varied experience and exposure to the construction industry learn from different types of TbTs to ensure that the workforce is receiving the best possible safety training.

Considering the need to retain safety training, a pilot study attempted to examine the most effective method for delivering a toolbox-talk. A review of the literature revealed that no specific research to fall-protection and cognitive retention has been performed. There are numerous studies on cognitive retention, and similarly on fall-protection. However, this pilot study found a gap in research addressing cognitive retention related to industrial safety training. A study in Singapore by Goh and Chua found that workers will learn through experience, preparation, and group meetings (Goh & Chua, 2013). Previous research examined working memory constraints and cognitive load theory by presenting safety training via computer-based training modules served as a basis for testing procedures (Wallen & Mulloy, 2006). The findings of this research suggested that workers will cognitively retain information when presented in a combination of text with pictures and audio. As such, can similar principles apply to learning construction safety? Is there a statistically significant difference in the cognitive retention of safety information when presented in different methods? The hypothesis examined in this pilot study was that training which includes written, verbal, and contextual instruction (test 3) is statistically more effective than training that is only written (test 1), or training that is written accompanied with photographic demonstration (test 2). Furthermore, the null hypothesis examined in the pilot study was that there is no statistical difference in the results between test 1, test 2, and test 3.

Methods

In order to determine the best method(s) for presenting on-the-job safety training, or TbTs, three methods were employed during the study. The three methods were similar to tool-box-talk safety training methods used in the construction industry. The research methods attempted to determine statistical significance between three different approaches to presenting material.

Subjects

One-hundred, twenty three (N=123) students at the University of Nebraska - Lincoln participated in the pilot study. The subjects were from a convenient sampling, both males and females, with relatively limited work experience. As such the population was considered a naïve sample with regard to previous training in the training subject matter, fall protection. The majority of student participants were native born Americans (n=120) with English as their primary language. Three participants indicated that they were foreign born and English was a second language (ESL). These ESL students were from European and Asian countries, all of whom had been passed the TOEFL exam and were admitted into university degree programs.

Recruitment of participants occurred by first soliciting approval from university instructors. Administration of the study was scheduled with the instructors for appropriate times when students would not have significant assignments due or exams to prepare for. Participant students were recruited based on their enrollment in courses which were made available to the researchers. Students were given a short overview of the purpose of the study and asked to participate. Students were not obligated to participate, and no risk was associated with the choice to participate or decline participation. Institutional Review Board review and approval was made for all research protocols. In each of the eight classes that participated, for the students who attended the day of the study, 100% participation was observed. No effort was made to determine the number of students absent the day of the study.

Each of the eight classes was presented materials in one of the three methods. Three classes with a total number of thirty eight (38) participants were presented the study using the first method. Three classes with a total number of fifty nine (58) participants were presented the study using the second method. Two classes with a total number of twenty seven (27) were presented the study using the third method. Names or personal identification of participants were not collected.

Research Protocol

Prior to the presentation of the TbT material, participants were asked to complete a simple demographic survey. This survey enquired about the student's gender, age, academic level, and academic major. This survey asked five questions regarding the individual's level of experience and previous training related to the construction industry, occupational safety training, and fall protection. These questions were asked so that a level of prior knowledge and experience could be established for the sample population. Students were also asked to indicate whether English was a second language, and to indicate if they had mountain climbing experience. Familiarity with mountain

climbing harness and equipment is similar in nature and terminology to a personal fall arrest harness and equipment in the construction industry. Five (5) students indicated that they had mountain climbing experience.

The first of the three presentation methods was *text-only* wherein participants (or trainees) are given a two-page written tool-box-talk (TbT). This TbT example includes instructions for the process and requirements of inspecting a personal fall arrest system and a checklist for performing the inspection. No verbal instruction or contextual presentation was used in the administration of this material. Similar to industry methods, participants were given five (5) minutes to review the written material with the expectation that the material would be cognitively retained and applied in practice.

Begin by holding the harness up by the D-ring. Bend the straps in an inverted "U". Watch for frayed edges, broken fibers, pulled stitches, cuts or chemical damage. Check D-rings and D-ring metal wear pads for distortion, cracks, breaks, and rough or sharp edges. The D-ring bar should be at a 90 degree angle with the long axis of the belt and should pivot freely. Inspect frayed or broken strands.

Figure 1: Checklist item for inspecting personal fall arrest system in *text-only* presentation method (millerfallprotection.com, 2013)

"There are several types of fall protection available: personal fall protection devices, guardrails, and safety nets are the most common. Anytime you work at elevated levels of six feet or more you are required to have a personal fall arrest system in place. If there are no guardrails or safety nets, you must wear a personal fall protection device, also known as a personal fall-arrest system."

Figure 2: Method 2, text-with-pictures presentation sample (millerfallprotection.com, 2013)

The second of three methods was a text-with-pictures presentation, wherein participants were given the same text material as the first group, with the addition of photographs to visually contribute to the written content. A series of photographic images was printed next to the written instruction. These images visually demonstrated the written instruction. For example, an image of a harness strap in an inverted "U" shape was shown next to the checklist item that provided instruction on how to inspect a strap. As with the text-only method, no verbal instruction or contextual presentation was used in the administration of the material. Participants were given five (5) minutes to read and review the text-with-pictures material.

A third presentation method was to provide the participants with the two-page, text-with-pictures material, with the addition of a verbal and contextual demonstration. The verbal and contextual presentation included a researcher who read aloud the same material that was provided in written format from the first and second method. A second researcher demonstrated the process of inspecting a personal fall arrest harness in front of the class. Students were also provided the written and picture hand out. Because of the added demonstration, the third method required six (6) minutes to present.

Upon completion of the presentation of the safety training material, the students were immediately administered a survey of 18 questions. In all three methods, and in all eight classes, the survey was the same. Each of the participants was given five minutes to complete the fifteen (15) question survey. The survey was written to test the cognitive ability of the participant to retain the information which was presented. The survey required responses to true/false questions (4 questions), fill-in-the-blank questions (9 questions), and multiple choice questions (2 questions). Questions were formulated to require the participant to recall specific terms from the presentation. True/false questions were asked to test the participant's ability to recall and apply information to determine an appropriate action required for inspecting a fall-arrest system. Questions varied in level of difficulty, all of which tested the individual's knowledge of common terms associated with fall protection and fall-arrest systems. Survey questions were written to provide nominal responses, correct or incorrect. Demographic questions however provided both nominal and ordinal responses. Ordinal type questions were asked to determine academic level and previous training and knowledge of fall protection. For example, participants were asked, "have you ever worked in the construction industry before?" This question may indicate some level of previous fall protection training.

Additionally, participants were asked if they had received any Occupational Safety and Health Administration (OSHA) training, if they were familiar with the term "Fall-Arrest System", and if they had received specific training in any kind of fall-arrest systems.

Data Scoring and Testing

The demographic page was attached and the survey was graded for correct answers. One point was scored for correct answers and zero points assigned to incorrect answers. A matrix was created to record and associate demographic responses to each participant's answers to the survey. Classes were grouped according to which instructional method they had experienced (text only = Group 0, text w/picture = Group 1, text w/picture & demonstration = Group 2). This matrix was used in the analysis of the data.

The methods for analyzing data included a reliability test of the survey. Cronbach's alpha is used in statistics to measure internal consistency and is considered an unbiased approach to establish generalizability. An alpha of 0.9 or greater is considered excellent consistency, whereas 0.7< to < 0.9 is considered a good correlation (Field, 2012). Each question of the survey was measured independently for frequency, percent, valid percent, and cumulative percent of correct and incorrect answers. The Cronbach's alpha for this study was determined for the aggregate of all the questions. Subsequently, each question was then measured to determine whether or not the inclusion or exclusion of such would increase or decrease the reliability of the survey as a whole (Leech, Barrett, & Morgan, 2005).

Wanting to determine if age increased the likelihood that any of the other five demographic questions were affirmative, a Pearson's correlation coefficient (PCC) test was performed. The PCC was chosen because this test will determine whether the age (one independent variable) of the participant had a relationship with whether or not participants had answered affirmatively to any of the five (5) experience questions (other independent variables) (Martin & Bridgmon, 2012). This is a two-tailed test with a level of significance set at 0.01. A PCC was also used to measure correlation between each of the demographic questions.

Because of the multiple variables, a reduced regression model was performed with those predictive variables that were considered statistically significant. For the multiple regression tests, an R- squared score is also established to measure the correlation between the predicted values and the observed values. A standard error and degrees were established by the number of respondents, and a p-score < .05.

Wanting to determine if there was a difference in score based solely on group, a one-way ANOVA (analysis of variance, or variance of ratio method) was chosen because it compares the difference in score based solely on group (Creswell, 2012) (Field, 2012). The ratio of the variances (ANOVA) is called the *F*-ratio. In conjunction with the ANOVA, the Tukey's Honestly Significant Difference (HSD) post-hoc test was conducted to determine which group(s) was different. The Tukey's test is used to compare the means of each treatment with the means of the other treatments, (in this case the presentation differences to group 0, group 1, and group 2). The Tukey's HSD test was chosen because we wanted to determine if there was a statistical difference between any of the groups, or categories. This process identifies if there is a difference between any mean scores that is greater than the standard error.

Results

The number of participants in each class varied from five (5) to twenty four (24). The age of the participant ranged from nineteen (19) to fifty three (53). The mean age of the participant student was twenty three (23) with a standard deviation of 4.63. The median age of the participant was twenty two (22). The mode age was twenty one (21). There were twenty six (26) females (21%) and ninety seven (97) males (79%) in the study. Of the eight classes that were administered the study, six of them were offered by the Construction Management Department. One class of (16) participants, and another class of seven (7) participants were offered in the College of Education and Human Sciences. The lowest score on the 18-question survey was one (1) point and the highest score was sixteen (16). The mean score for all 123 participants was 11.91, with a standard deviation of 2.81.

Each survey question was analyzed for frequency, percent, valid percent and cumulative percent of correct and incorrect responses. A reliability test was performed for each question on the survey. The Cronbach's alpha of .8 is generally accepted for cognitive testing (Kline, 1999). The survey instrument was found to have a Cronbach's alpha of 0.702, which is considered to be marginally reliable. After determining the Cronbach's alpha, each survey

question was analyzed for its level of difficulty and its impact on the alpha. Five of the eighteen survey questions were found to increase the alpha if eliminated from the survey.

The Pearson Correlation Coefficient test showed that there was a low or non-significant correlation between age and the five demographic questions, suggesting that age did not affect whether participants had received any previous experience or exposure to safety training. For correlation to each of the demographic questions and age, D1(Have you ever worked in the construction industry before?) = -0.59, D2 (Have you ever received OSHA training?) = .096, D2 (Do you have an OSHA 10-hr, or 30-hr certificate?) = .109, D3 (Are you familiar with the term "Fall-Arrest System?) = .055, and D5(Have you ever received training of any kind in Fall Arrest systems?) = .051. Measuring the correlation between each of the demographic questions the highest score was found between questions D2 to D3 (PCC = .672) and D4 to D5 (PCC = .678). As such, no significant correlation was determined between any demographic question, including age.

The multiple regression analysis found three variables, besides group number, to be predictive. The R-squared score of 0.2966 was determined. Additionally the standard error of 2.358 on 117 degrees of freedom was found. The multiple regression analysis was used to determine which, if any, of the questions were considered predictive. Demographic question number 3 asked the participants if they had received the Occupational Safety and Health Administration (OSHA) 10-hour certificate. This question was found to be negatively correlated to participant scores. However, this negative correlation may be a function of the limitations of the pilot study. Demographic question number 4 asked participants if they were familiar with the term *Fall Protection*. This question was found to have a positive correlation to participant scores. The most significant predictor was ESL. ESL students are predicted to score 7.792 points lower on the test than non-ESL students when holding the other predictors constant.

Next the categorical level of group was considered. This was performed independent of other variables because there were actually three levels. Group 0 (Text only) was used as a reference level to determine whether the other groups were significant. Group 2 (Text with pictures and demonstration) was significantly better than Group 0. Group 1 (Text with pictures) was not significantly different than Group 0. The one-way ANOVA was used to determine if there was a difference in score based solely on group. The test, where *F*-ratio= 3.919, df = 2 & 120, p = 0.022, suggests that at least one group had a difference score.

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	59.110	2	29.55	3.919	0.022
Within Groups	904.906	120	7.541		
Total	964.016	122			

Table 1: One-Way ANOVA

The Tukey's HSD post hoc test then found that there was a difference between group 0 and group 2, where p = 0.016. Participants in group 2 scored, on average, 1.604 points better than the group 0.

		Mean Difference			**95 % Confidence Interval**	
(I) Group	**(J) Group**	**(I – J)**	**Std. Error**	**Sig.**	**Lower Bound**	**Upper Bound**
Text Only	Text and Pictures	-0.941	0.691	0.364	-2.581	0.698
	Text and Demonstration	-1.604	0.573	0.016	-2.964	-.244
Text and Pictures	Text Only	0.941	0.691	0.364	-.698	2.581
	Text and Demonstration	-0.662	0.639	0.556	-2.181	0.855
Text and Demonstration	Text Only	1.604	0.573	0.016	.244	2.964
	Text and Pictures	0.662	0.639	0.556	-.855	2.181

Table 2: Multiple comparisons using Tukey's HSD

Conclusions

This pilot study attempted to identify the most effective method for providing safety training related to the construction industry and more specifically, fall protection. The methods used in the collection and analysis of data revealed a statistical significance between the text-only method of presenting material and the verbal and written

presentation of the same material companioned with pictures and demonstration. Furthermore, the results disproved the null hypothesis that test 1, test 2, and test 3 are statistically indifferent. The results of the study suggested that individuals cognitively retained information that was presented in a combination of methods that included written, verbal, and contextual stimuli. The central hypothesis of the study, therefore, was found to be true.

This study also concluded that three other variables were found to be statistically significant for retaining safety training, variable 1) participants with English as a second language showed a negative correlation for cognitive retention, variable 2) participants with familiarity with the term, "Fall Protection" had a positive correlation to cognitive retention, and variable 3) participants that had previously received OSHA training had a small, but statistically significant negative correlation to cognitive retention for safety training.

Limitations

As a pilot study there were a number of limitations that were recognized. Considering population validity, the sample for this pilot study was a convenient sample of university students enrolled in courses made available to researchers. The participants of this study do not necessarily represent the demographic of the typical construction worker. The negative correlation between previous OSHA 10-hr training and participant scores should not infer any causal relationship. The limitations of this pilot study did not ask participants the length of time since their OSHA training, or which topics were specifically emphasized. Future research needs to address this question more specifically. Age and post-secondary educational training may all have an impact on the cognitive abilities to retain information. Gender may also contribute to potential demographic differences between the typical university student and the typical construction worker. However, the typical student enrolled in a construction management program may be more closely aligned with the percentage of males versus females in the construction workforce.

Contextual limitations must be considered for generalizability. As of 2012, in the United States, one in six workers was foreign born (U.S. BLS, 2013). As such, a survey of actual construction workers may also find differences in percentages of ESL participants. Other contextual limitations would include the environment in which university students learn versus construction workers. Considering the training has to do with life safety, a construction worker may potentially apply more interest and attention to learning the material than a student that may never have a practical application of the knowledge. As such, this pilot study readily recognizes that cognitive retention may be affected by the context of the training.

This pilot study recognizes limitations in the methodology and intervention. The survey instrument used in this pilot study had not been previously tested for reliability. Questions which are found to lower the reliability of the survey would need to be changed or deleted. Refining the survey will help establish greater reliability for which the study can be repeated in additional samples of the population. An empirical study that addresses this same research question would survey a broader population of individuals. Such a study would also attempt a more random sampling of the population. Additionally, a comparison group of construction workers that has received extensive safety training would also provide a reference point for measuring the reliability of the results taken from a random sampling.

Discussion

Considering the finding that individuals will retain safety training best when presented in combination of written, verbal, and contextual presentation methods, industry professionals should explore possibilities for delivering safety training in such a manner. This study suggests that a more effective method for delivering safety training can be achieved in the same amount of time, with minimal amount of additional effort, but demonstrate significant improvements. Surprisingly, students that had received the OSHA 10-hour certificate did not demonstrate an increased ability to retain safety information. This suggests that students may not be receiving sufficient instruction regarding fall protection. Additionally, as it was found that participants with some familiarity with fall protection cognitively retain information more effectively, training should be reoccurring, or repeated regularly. This process will reinforce the terms and the safety principles necessary to improve personal safety on the job.

This pilot study was performed to gather some initial data in order that a more thorough study may be designed for future studies. This discussion is intended to serve as a catalyst for research design related to safety training and cognitive retention of the workforce. Future studies should consider the effect of a 'pre-task' training approach, wherein workers receive safety training related to tasks scheduled for immediate application. One consideration for

future research would be a mixed-methods sequential explanatory study (Creswell, 2012) wherein the participant is asked qualitative questions to consider how they best learn information and use the results of the instrument to determine if there is consistency between their responses and the results. Future research studies will utilize stratified subject samples, a larger study population and subgroup sample sizes, detailed subject selection and classification criteria, and more advanced statistical methods that can accurately detect differences and significance between groups and within groups.

Future study might consider a longitudinal approach to repeated measures testing. Such a study may help better understand the impact of building on knowledge previously gained. Studies should further explore the need to address bilingual or ESL workers. Ultimately, this pilot study was intended to serve as a method for discovering a more effective method for presenting safety training. As such, this pilot study, though limited, may be considered successful. This research demonstrates that there is a statistical significant improvement for teaching with demonstration.

References

Creswell, J. W. (2012). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research.* Boston, MA: Pearson Education, Inc.

Field, A. (2012). *Discovering Statistics Using IBM SPSS Statistics, 4th Edition.* Thousand Oaks, CA: Sage Publications, Ltd.

Goh, Y. M., & Chua, D. (2013). Neural network analysis of construction safety management systems: a case study in Singapore. *Construction Management & Economics*, Vol. 31, Issue 5, p460-470.

Hallowell, M. (January 2010). Cost-effectiveness of construction safety programme elements. *Construction Management and Economics*, 28, 25-34.

Inspection and Maintenance. (2013). Retrieved October 9, 2013, from Miller by Honeywell: https://www.millerfallprotection.com/smart-solutions/guide-to-fall-protection/inspection-and-maintenance

Kline, P. (1999). *The Handbook of Psychological Testing, 2nd Edition.* London: Routledge.

Leech, N. L., Barrett, K. C., & Morgan, G. A. (2005). *SPSS for Intermediate Statistics: Use and Interpretation.* Mahwah, New Jersey: Lawrence Erlbaum Assiciates, Inc.

Martin, W. E., & Bridgmon, K. D. (2012). *Quantitative and Statistical Research Methods: From Hypothesis to Results.* San Francisco, CA: John Wiley & Sons, Inc.

U.S. BLS. (2013, May 22). *Labor Force Characteristics of Foreign-Born Workers Summary*. Retrieved October 8, 2013, from Bureau of Labor Statistics: http://www.bls.gov/news.release/forbrn.nr0.htm

U.S. DOL. (2013). *Commonly Used Statistics*. Retrieved October 8, 2013, from Occupational Safety & Health Administration: https://www.osha.gov/oshstats/commonstats.html

Wallen, E. S., & Mulloy, K. B. (2006). Computer-based training for safety: Comparing methods with older and younger workers. *Journal of Safety Research*, 461-467.

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