

**LEVERAGING EMOTIONAL ENGAGEMENT TECHNIQUES AND
ADULT LEARNING PRINCIPLES TO TRANSFORM SAFETY TRAINING**

by

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ABSTRACT

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Leveraging Emotional Engagement Techniques and Adult Learning Principles to Transform Safety Training

Dissertation directed by Associated Professor Matthew Ryan Hallowell

Safety training despite being the key measure to keeping workers safe within any occupational environment has not kept pace with the significant advancement in the fields of behavioral psychology and education. As a result, researchers have found that the pre-dated safety training techniques on construction sites fail in communicating information in a way that promotes long-term retention of knowledge among adult learners and they also end up generating a negative attitude towards safety among workers. Understanding the psychological antecedents to risk-taking behavior and utilizing prominent adult learning theories to revolutionize safety training could allow academics and practitioners to improve workers' hazard recognition performance and risk assessment skills while promoting risk-averse behavior.

This dissertation therefore aims to (1) test and validate the role of integral and incidental affective arousal in influencing key safety outcomes (hazard recognition performance, valuation of danger, and safety decisions); (2) use the findings to design a safety training program that generates targeted affective arousal but is also rooted in self-directed learning model to facilitate learning; (3) deliver the simulation-based multimedia training module as an intervention to construction workers in a quasi-field experiment to measure changes in affect and situational interest; and (4) apply multivariate statistics to validate if the training environment generated the desired emotional engagement and learning outcomes among workers.

Analysis of the proposed conceptual model showed that the integral negative affective arousal increased perception of risk and promoted risk-averse decision-making in construction safety training context. The quasi-field experiment on 489 construction workers showed that the proposed safety training module generated context-driven negative emotions and also improved situational interest levels regarding safety training which is a primary precursor to learning. Moreover, these results were consistent across all relevant demographical groups common to construction sites in the United States. This work is the first

effort that ascertains the efficacy of various adult learning mechanisms incorporated in the proposed training module and also validates relationship between affect, risk perception, and decision-making in an occupational training environment. Future research should seek to validate the application of this format of safety training for safety training in other domains and study the long-term effects of such training on skills and retention of knowledge of the workforce.

Dedicated to my mother Sapna Bhandari.
This is for you, Mom.

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From dusky roads of Texas to star-studded seminars in Vietnam, Dr. Hallowell gave me opportunities to work with him on projects beyond my core thesis. These opportunities have been priceless for me as they have rounded me to become a better academic, researcher, and consultant. His willingness to share the *behind the scenes* information on how to conduct research, get funding, approach ideas, and make a pitch was unbelievably generous and his advices will always act as my guiding star. Finally, I was not an easy student but Dr. Hallowell's affable nature and never-die optimism held up against my eternal doom approach to work and life. He was always ready to support me, appreciated my work, and instilled me with confidence to get the job done. I am very grateful that he also gave the opportunity to teach under him. His appreciative comments and constructive critiques have already made me a better instructor and I

hope to continue to strive to be someday as good as he is. Dr. Hallowell will always be a role model for me, from both a professional and personal standpoint. I am fortunate to have been advised by him and I hope that the future holds many more collaborations.

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CHAPTER 1: INTRODUCTION

This research validates a new and innovative approach to provide safety training for construction workers by generating emotional engagement through hyper-realistic simulations of injuries and uses adult learning principles to enhance learning.

Observed Problem

A nation's infrastructure is highly reflective of its progress and economic prowess. Between 2005 to 2017, the construction industry contributed an average of \$636.07 billion to the US Gross Domestic Product and currently, employs more than 7 million workers (BEA 2018). Given the size of the industry, it is surprising to note that the means and methods of various construction operations have not changed by much over time. Another facet of the industry that has been stagnant over the past few decades is safety training given to workers. This is a major concern because the fatality rates on construction sites remains unacceptably high and have also started to plateau over the past 5 years (BLS 2018). From a financial standpoint alone, upwards of \$15 billion is spent in direct costs by the industry each year to address occupational injuries (National Safety Council 2016). As high as that is, it does not even begin to reflect the indirect costs for the industry and emotional toll for all associated with the accidents. As researchers focus on various technological systems and design factors to improve overall safety outcomes, they have also examined human factors specifically those associated with a worker's ability to identify and appropriately to respond to threats in their environments.

Haslam et al. (2005) and Hinze (2006) found that poor hazard identification skills and inadequate safety systems were key underlying feature in most construction accidents. It is surprising to note that with the current safety training techniques in place, workers were able to see at best *only half* the hazards present on their site prior to any intervention introduced by researchers (Albert et al. 2013; Albert et al. 2014).

Moreover, these trends are not unique to U.S. as Bahn (2013)'s study based in Australia and Carter and Smith (2006)'s study based in U.K. found that workers were unable to recognize 57% and 10-33% hazards respectively. Thus, understanding how to improve current safety training is essential to long-term safety improvements and well-being of workers on site. The goal is to ensure that workers can identify and respond to the array of unique hazards that they may face in an ever-changing work environment. Furthermore, simply identifying the threat is not sufficient to prevent injuries as robust training must be provided to ensure workers can evaluate the risk involved accurately, while also promoting risk-averse behavior.

Aim and Scope

Though, companies have tried different safety training techniques and modules, the underlying child-focused pedagogical framework has never been fundamentally challenged and altered. That framework is ineffective because compared to children and adolescents, not only are adults different 'types' of learners (e.g., a) *goal-oriented*, b) *activity-oriented*, c) *learning-oriented* learners; Houle 1961), they also have very different learning styles (Merriam 2004) and motivations for engaging in learning process (Fixsen et al. 2005; Russell 2006). Albert and Hallowell (2013) outlined the perils of relying on current child-focused pedagogical approach to training construction workers which uses a traditional one-way lecture delivery approach to transfer knowledge. They called for overhauling the current format of safety training and replacing it with a training module that incorporates the principles from popular adult learning theories. Therefore, the work presented here builds on Albert and Hallowell (2013)'s call for future research and is the first empirically-driven effort to bridge the chasm between adult learning theories and occupational safety training.

To appeal to the wider variety of learning styles, the training module presented here uses a multimedia approach that gives workers somatosensory, auditory, and visual cues to engage their cognitive processing and improve knowledge retention (Badddeley 1992). The current training techniques that use a

'classroom' framework that have been clearly found to be ineffective because it does not present information in manner that is easy to retain for adult learners (Knowles 1984; MacNaughton and Clyde 1990; Willkins 2011) as evidenced by construction workers' behavior and their hazard identification performance levels. Moreover, such training exercises can often leave workers with a negative outlook towards safety also (Haslam et al. 2005). In contrast, multimedia learning allows learners to create mental representations from text and sounds that allow for much advanced understanding of the material. Studies have shown that learners learn better from environments that engage multiple senses compared to situations where only words or pictures are used (Mayer 2009). Furthermore, the 'teacher-student' training framework does not align with the studies that found adults thrive in learning experience that respects their experience (Merriam 2004) and delivers information in accordance to their cultural backgrounds (Hollins and King 1994). The level of engagement from adult learners is primarily determined by their perception regarding the knowledge being provided and whether it will improve their personal or professional lives (Lindeman et al. 1956). The multimedia training module *Naturalistic Injury Simulation* (NIS) proposed in this dissertation incorporates that fact that not only do adults learn selectively, they also want control over how, when, where, and at what pace they want the information provided to them (Baskett 1994).

Beyond the principles of adult learning, the aim of this thesis was also to leverage existing knowledge in the behavioral psychology field to influence workers' perception, performance, and learning. Our affective states and degree of affective arousal can significantly influence our *memory* (Bradley et al. 1992; Buchanan et al. 2006; Cahill and McGaugh 1995), *motivation* (Fassbender et al. 2012; Pekrun 2006; Robinson et al. 2013), and *behavior* (Loewenstein et al. 2001; Nesse and Klaas 1994; Peter and Slovic 1996). There is substantial evidence that shows our affective reactions influence both our perception of risks (Alhakami and Slovic 1994; Finucane et al. 2000; Slovic 1987) and associated decisions (Clare et al. 1994). Generally, negative affective reactions or arousal can reduce the propensity to engage in risky behavior (Johnson and Tversky 1983; Wright and Bower 1992; Constans and Mathews 1993; Peters and Slovic 1996; Gasper and Clare 1998; Loewenstein et al. 2001; Rottenstreich and Hsee 2001). Within

construction domain, Tixier et al. (2014) found positive correlation between negative emotions and risk perception, but how affective arousal influences hazard recognition performance and safety decisions remains nebulous. The work presented in this dissertation presents and validates a conceptual model that examines the associations between unrelated affective reactions and context-driven affective reactions with key safety outcomes such as: hazard recognition, valuation of danger, and decisions regarding safety.

NIS was appropriately designed to generate targeted affective reactions among workers that would appropriately promote risk-averse behavior and improve learning. For the scope of this study, two common hand injuries were simulated: falling object and pinch point injuries. To elicit strong and targeted emotional arousal among workers, a definitive characteristic of NIS was realism. Within the self-directed learning environment, facilitators used framing effect (Slovic et al. 2000) and dread factor (Burke et al. 2011) to generate arousing affective reactions that would increase perception of risk and promote risk-averse decision-making among workers.

The goal was not to simply generate affective response but also generate high arousal. It has been documented that people can recall injuries or other shocking events in sharp detail for years following the events (Peterson and Bell 1996; Peterson and Whalen 2001). In fact, these details are so powerful that people remember the context of the information, time, and how the event impacted them (Christianson 1989). Memory enhancements due to arousal occur when the basolateral nucleus of the amygdala and regions of sensory and mnemonic processing system interact and when there is release of glucocorticoids (McGaugh 2004; Wolf 2008). Interestingly, arousing emotions are also needed to activate motivation for enhanced learning and the development of durable memories (LaBar and Phelps 1998). Arousing information has a mnemonic benefit that tends to increase knowledge retention (Kensinger and Schacter 2008). Thus, the accident and injury simulations were designed to be hyper-realistic and shocking to elicit the targeted emotional response at the desired arousal level to ensure workers remember the details from the training experience.

In summary, the goals of this thesis were to:

Goal [1]: Examine the associations between incidental and integral affective reactions, hazard recognition performance, valuation of danger, and decisions regarding safety.

Goal [2]: Design and develop a new multimedia simulation-based safety training module that is rooted in adult learning principles.

Goal [3]: Deliver and empirically validate the efficacy of the training module on the target population.

Dissertation Format and Contributions

This dissertation is organized in a three-chapter format where each chapter represents a journal paper. Chapter 2 has been published at Journal of Construction Engineering and Management while chapter 1 and chapter 3 are currently under review at Journal of Construction Engineering and Management and Safety Science respectively. Each chapter contains a dedicated abstract, literature review, point of departure, research methods, analysis, theoretical and practical contribution, and future research recommendation. Each subsequent chapter builds on the work from previous chapter where:

Chapter [2]: Empirically validated a conceptual model that outlines the associations between affective reactions and safety outcomes.

Chapter [3]: Outlines the design and delivery strategies of NIS. Also, presents evidence that NIS generated desired emotional arousal across all relevant demographical dimensions.

Chapter [4]: Presents evidence that NIS improved situational interest levels in relation to safety training among workers across all demographical dimensions. In this chapter, exploratory analysis also revealed that change in situational interest was independent of changes in affective arousal among adult learners in non-traditional learning environment.

The 1st paper presented in the dissertation can be found in chapter 2 under the title: *Using Augmented Virtuality to Examine How Emotions Influence Construction Hazard Identification, Risk Assessment, and Safety Decisions*. To establish the associations between emotional responses and safety outcomes, the paper provides a detailed review on how incidental and integral emotional experiences influence our risk perception and decision-making skills. The review highlights the gaps in body of knowledge for construction engineering and management domain and tests hypothesis in a controlled laboratory environment to maintain high internal validity. In total, 73 students were placed in an augmented virtuality environment to test the influence of incidental and integral emotions on key safety outcomes. Applying linear mixed regression technique, results showed that incidental emotional experience does not influence hazard identification performance, risk perception, and decision-making skills. Results also suggest that integral negative emotional experience increases risk perception and tendency to make risk-averse decisions and that individuals trust their subjective (“gut”) evaluations more than objective evaluations when making decisions regarding safety. In conclusion, this paper suggests that targeted integral emotional arousal can be used to reduce risk-taking behavior.

The 2nd paper presented in this dissertation can be found in chapter 3 under the title: *Emotional Engagement in Safety Training: Impact of Naturalistic Injury Simulations on Emotional States of Construction Workers* uses the findings from chapter 1 to propose a new safety training program that uses adult learning principles and psychological agents to generate targeted emotional arousal and improve learning outcomes. The safety training program: *Naturalistic Injury Simulations* (NIS) was developed to give workers the *experience of an injury without actually injuring them*. Design of NIS was based on Garrison (1997)’s self-directed learning model to improve learning among adult learners and utilized hyper-realistic recreation of disabling injuries to generate emotional responses. This training program was delivered to over 1200 construction workers on-site, of which 489 workers were sampled before and after training using previously validated questionnaires to measure the change in emotional states and interest levels. Using paired t-test, results showed that post-NIS workers experienced a surge in negative emotions

and the directionality of results was consistent across all demographical groups sampled. Given the findings presented in chapter 2, the elicitation of integral negative arousal should increase risk perception and risk-averse decisions.

The 3rd paper presented in this dissertation, can be found in chapter 4 under the title: *Making Construction Safety Training Interesting: A Field-based Quasi Experiment to Test the Relationship Between Emotional Arousal and Situational Interest Among Adult Learners* contains the same dataset from chapter 3. However, the hypothesis tested was different. While the paper explores if NIS increased situational interest among construction workers for safety training, it also examines if the change in situational interest was predicted by change in emotional arousal and if the relationship between them is mediated by individual differences. Using paired t-test, results showed that post-NIS workers experienced an increase in situational interest and the directionality of results was consistent across all demographical groups sampled. However, there was no relationship found between change in emotional arousal and change in situational interest among adult learners (i.e., construction workers) in non-traditional learning environment (i.e., safety training). This research challenges hypothesized relationship between emotions and situational interest and shows they are independent of each other. This paper is the first attempt to test adult learning agents in an externally and ecologically valid experimental setting while controlling for the demographic differences.

In summary, this thesis aims to address the long-overdue restructuring of safety training on construction sites. To do so, a thorough examination of psychological antecedents and their influence on key safety outcomes was conducted to incorporate the findings into the new training module. Furthermore, NIS addresses the concerns raised by existing literature (Albert and Hallowell 2013; Haslam et al. 2005; Wilkins 2011) that the current approach to training is not geared towards seamlessly transferring and promoting retention of knowledge among adult learners. NIS is grounded in Garrison (1997)'s self-directed learning model and uses live realistic simulations to generate emotional response that influences risk perception and decision-making while also promoting situational interest among workers. The work in this thesis has

practical implications for industries across all domains providing occupational safety training to their workers and has theoretical contributions to fields to construction safety training, behavioral psychology, and adult learning.

References

1. Albert, A., & Hallowell, M. R. (2013). Revamping occupational safety and health training: Integrating andragogical principles for the adult learner. *Construction Economics and Building*, 13(3), 128-140.
2. Albert, A., Hallowell, M. R., and Kleiner, B. M. (2013). Enhancing construction hazard recognition and communication with energy-based cognitive mnemonics and safety meeting maturity model: Multiple baseline study. *Journal of Construction Engineering and Management*, 140(2), 04013042.
3. Albert, A., Hallowell, M. R., and Kleiner, B. M. (2014). Experimental field testing of a real-time construction hazard identification and transmission technique. *Construction Management and Economics*, 32(10), 1000-1016.
4. Alhakami, A. S., & Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk analysis*, 14(6), 1085-1096.
5. Baddeley, A. (1992). Working memory. *Science*, 255(5044), 556-559.
6. Bahn, S. T. (2013). Mining workers ability to identify hazards using a picture survey. In *Work, employment and employment relations in an uneven patchwork world: Proceedings of the 27th AI ANZ Conference* (pp. 2-10). Fremantle, Australia: Association of Industrial Relations Academics of Australia and New Zealand. Original article available [here](#)
7. Baskett, H.K.M (1994). Self-Directedness in the Workplace. Paper by H.K. Morris presented to the Eighth International Symposium on Self-Directed Learning. Florida.
8. Bradley, M. M., Greenwald, M. K., Petry, M. C., & Lang, P. J. (1992). Remembering pictures: pleasure and arousal in memory. *Journal of experimental psychology: Learning, Memory, and Cognition*, 18(2), 379.
9. Buchanan, T. W., Tranel, D., & Adolphs, R. (2006). Impaired memory retrieval correlates with individual differences in cortisol response but not autonomic response. *Learning & memory*, 13(3), 382-387.

10. Burke, M. J., Salvador, R. O., Smith-Crowe, K., Chan-Serafin, S., Smith, A., and Sonesh, S. (2011). The dread factor: how hazards and safety training influence learning and performance. *Journal of Applied Psychology*, 96(1), 46.
11. Cahill, L., & McGaugh, J. L. (1995). A novel demonstration of enhanced memory associated with emotional arousal. *Consciousness and cognition*, 4(4), 410-421.
12. Carter, G. and Smith S.D. (2006). "Safety hazard identification on construction projects." *Journal of Construction Engineering and Management*, 132(2): 197-205.
13. Christianson, S. A. (1989). Flashbulb memories: Special, but not so special. *Memory & Cognition*, 17(4), 435-443.
14. Clore, G. L., Schwarz, N., and Conway, M. 1994. Affective causes and consequences of social information processing. *Handbook of social cognition*,1, 323-417.
15. Constans, J. I., & Mathews, A. M. (1993). Mood and the subjective risk of future events. *Cognition & Emotion*, 7(6), 545-560.
16. Fassbender, E., Richards, D., Bilgin, A., Thompson, W. F., & Heiden, W. (2012). VirSchool: The effect of background music and immersive display systems on memory for facts learned in an educational virtual environment. *Computers & Education*, 58(1), 490-500.
17. Finucane, M. L., Alhakami, A., Slovic, P., & Johnson, S. M. (2000). The affect heuristic in judgments of risks and benefits. *Journal of behavioral decision making*, 13(1), 1-17.
18. Fixsen, D. L., Naoom, S. F., Blase, K. A., & Friedman, R. M. (2005). Implementation research: a synthesis of the literature.
19. Garrison, D. R. (1997). Self-directed learning: Toward a comprehensive model. *Adult education quarterly*, 48(1), 18-33.
20. Gasper, K., & Clore, G. L. (1998). The persistent use of negative affect by anxious individuals to estimate risk. *Journal of personality and social psychology*, 74(5), 1350.
21. Haslam, R. A., Hide, S. A., Gibb, A. G., Gyi, D. E., Pavitt, T., Atkinson, S., & Duff, A. R. (2005). Contributing factors in construction accidents. *Applied ergonomics*, 36(4), 401-415.

22. Hinze, J. (2006). *Construction safety*, Prentice Hall, New York.
23. Hollins, E. R., & King, J. E. (1994). *Teaching diverse populations: Formulating a knowledge base* (Vol. 1944). SUNY Press.
24. Houle, C. O. (1961). *The inquiring mind*. Oklahoma Research Center for Continuing Professional and Higher Education, University of Oklahoma.
25. Johnson, E. J., & Tversky, A. (1983). Affect, generalization, and the perception of risk. *Journal of personality and social psychology*, 45(1), 20.
26. Kensinger, E. A., & Schacter, D. L. (2008). Memory and emotion. *Handbook of emotions*, 3, 601-617.
27. Knowles, M. (1984). *The Adult Learner: A Neglected Species*. Houston: Gulf Pub. Knowles, M. S., Holton III, E. F., & Swanson, R. A. (2014). *The adult learner: The definitive classic in adult education and human resource development*. Routledge.
28. LaBar, K. S., & Phelps, E. A. (1998). Arousal-mediated memory consolidation: Role of the medial temporal lobe in humans. *Psychological Science*, 9(6), 490-493.
29. Lindeman, E. C., Gessner, R., and Otto, M. (1956). *The simulationcratic man: Selected writings of Eduard C. Lindeman*, Boston.
30. Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological bulletin*, 127(2), 267.
31. MacNaughton, G., & Clyde, M. (1990). *Staffing the Practicum: Towards a New Set of Basics through Clarifying Roles*.
32. Mayer, R. E. (2009). *Multimedia Learning*, 2nd edition, Cambridge; New York: Cambridge University Press.
33. McGaugh, J. L. (2004). The amygdala modulates the consolidation of memories of emotionally arousing experiences. *Annu. Rev. Neurosci.*, 27, 1-28.

34. Merriam, S. (2004). The changing landscape of adult learning theory. In J. Comings, B. Garner, and C. Smith (Eds.), *Review of adult learning and literacy: Connecting research, policy, and practice* (pp. 199- 220). Mahwah, NJ: Lawrence Erlbaum Associates.
35. National Safety Council, "National Safety Council Injury Facts 2016 Edition," National Safety Council, Itasca, IL, 2016.
36. Nesse, R. M., & Klaas, R. (1994). Risk perception by patients with anxiety disorders. *Journal of Nervous and Mental Disease*, 182(8), 465-470.
37. Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational psychology review*, 18(4), 315-341.
38. Peters, E., & Slovic, P. (1996). The Role of Affect and Worldviews as Orienting Dispositions in the Perception and Acceptance of Nuclear Power 1. *Journal of applied social psychology*, 26(16), 1427-1453.
39. Peterson, C., & Bell, M. (1996). Children's memory for traumatic injury. *Child development*, 67(6), 3045-3070.
40. Peterson, C., & Whalen, N. (2001). Five years later: Children's memory for medical emergencies. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, 15(7), S7-S24.
41. Robinson, M. D., Boyd, R. L., & Liu, T. (2013). Understanding personality and predicting outcomes: The utility of cognitive-behavioral probes of approach and avoidance motivation. *Emotion Review*, 5(3), 303-307.
42. Rottenstreich, Y., & Hsee, C. K. (2001). Money, kisses, and electric shocks: On the affective psychology of risk. *Psychological science*, 12(3), 185-190.
43. Russell, S. S. (2006). An overview of adult-learning processes. *Urologic Nursing*, 26(5), 349.
44. Slovic, P. (1987). Perception of risk. *Science*, 236(4799), 280-285.

45. Slovic, P., Monahan, J., & MacGregor, D. G. (2000). Violence risk assessment and risk communication: The effects of using actual cases, providing instruction, and employing probability versus frequency formats. *Law and human behavior*, 24(3), 271-296.
46. Tixier, A. J. P., Hallowell, M. R., Albert, A., van Boven, L., & Kleiner, B. M. (2014). Psychological antecedents of risk-taking behavior in construction. *Journal of Construction Engineering and Management*, 140(11), 04014052.
47. U.S. Bureau of Economic Analysis (2018). Gross-Domestic-Product-(GDP)-by-Industry Data. U.S. Department of Commerce. < https://www.bea.gov/industry/gdpbyind_data.htm>.
48. U.S. Bureau of Labor Statistics, “2016 Survey of occupational injuries and illnesses Charts Package,” U.S. Department of Labor, Washington, DC, Nov. 2017.
49. Wilkins, J. R. (2011). Construction workers’ perceptions of health and safety training programmes. *Construction Management and Economics*, 29(10), 1017-1026.
50. Wolf, O. T. (2008). The influence of stress hormones on emotional memory: Relevance for psychopathology. *Acta psychologica*, 127(3), 513-531.
51. Wright, W. F., & Bower, G. H. (1992). Mood effects on subjective probability assessment. *Organizational behavior and human decision processes*, 52(2), 276-291.

CHAPTER 2: USING AUGMENTED VIRTUALITY TO EXAMINE HOW EMOTIONS INFLUENCE CONSTRUCTION HAZARD IDENTIFICATION, RISK ASSESSMENT, AND SAFETY DECISIONS

Abstract: There is emerging evidence that emotional states influence human decision-making under uncertainty. However, it remains unclear if and how emotions influence our ability to recognize hazards, assess safety risk, or make safety-related decisions. Literature from construction safety, risk perception, and decision science domains was used to create a conceptual model of the influence of incidental and integral emotions on the hazard identification, risk assessment, and safety decision making. The model was then tested via controlled laboratory experiment where participants ($N = 73$) were placed in a high-fidelity augmented virtual construction environment. A mixed-model analyses revealed that contextually-relevant emotional responses to the construction hazards modulated subsequent valuations of risk associated and ultimate safety decisions. However, no direct relationship was found between induced emotional states and hazard identification performance. These results provide preliminary evidence that emotions, not objective evaluations, may be the primary driver of safety-related decision making.

INTRODUCTION

Each year, the construction industry spends \$15 billion in direct costs associated with occupational injuries (National Safety Council 2016). Despite continuous industry and academic effort, there were 991 fatalities on construction sites in 2016 alone (OSHA 2018). In other words, 20% of all occupational fatalities in the US occur in construction. Unfortunately, construction fatality rates have begun to plateau with improvement slowing in the past 5 years (BLS 2017).

Hinze (2006) showed that nearly 75% of construction injuries were the result of unsafe decisions that stem from poor hazard recognition skills and inadequate safety systems. Similarly, Albert et al. (2013) and Albert et al. (2014) found that construction workers identify only half of all the hazards in their

environment. These studies suggest that workers may not be deliberate risk seekers. Rather, workers appear to have difficulty identifying hazards and mis-estimate the risk associated with their actions (Hallowell 2010). Thus, understanding hazard recognition, risk perception, and safety decision making is essential to the improvement of safety training and long-term safety improvements.

The purpose of the present study was to explore construction safety, applied psychology, and decision science literature to build a theoretical model of the relationships among construction hazard identification, risk perception, and safety decision making. Then, using a controlled laboratory experiment in an augmented virtual construction environment, the model was experimentally tested and the role of human emotion in the model was explored. Specifically, the following research questions were addressed via a controlled experiment and statistical hypothesis testing:

- *Does incidental emotional experience impact hazard recognition skill?*
- *Do construction hazards cause emotional responses?*
- *Is there a relationship between hazards identified, total hazards in the environment, and danger assessment?*
- *Is there relationship between emotional experience and danger assessment?*
- *Is there a relationship between hazards identified, total hazard hazards in the environment, danger assessment, and safety decisions?*
- *Is there a relationship between emotional experience and safety decisions?*

This is the first study to explore the relationship of emotion and hazard recognition in any context and the first to model potentially complex relationships among safety decision-making factors in a construction-safety context. Practically, understanding the human decision-making process in constructing safety is important when designing safety training, safety planning and execution, and managing contextual factors that may influence emotional states.

BACKGROUND AND THEORETICAL FRAMEWORK

Emotions are defined as multifaceted responses to a stimuli or event that allow us to engage with our environment adaptively (Oatley et al. 2006). Positive emotions characterize the extent to which a person feels happy, active, and enthusiastic (Watson et al. 1988). Alternatively, negative emotions are closely associated with unpleasant experiences (Stone 1981) that indicate to an individual that something is unsettling (Clore et al. 2001). Compared to positive emotions that lead to more optimistic appraisals of risk (Isen et al. 1978), negative emotions promote risk-averse behavior (Clore et al. 1994; Isen and Patrick 1983) and generate aversive motivation that facilitates long-term retention of knowledge (Lang 2006; Pekrun 2006).

Emotions are differentiated between incidental and integral. Integral emotions are the response that is directly associated with a decision-task or immediate stimulus (Loewenstein and Lerner 2002). Quite simply, humans rely on integral emotions to assess if the current experience or interaction with a given stimuli is good or bad (Kahneman et al. 1997). In contrast, incidental emotions are perceived as not being directly related to the decision-task rather it is a product of other sources (Lerner and Keltner 2000). While integral emotions are the genuine response to the target, incidental emotions can often be misattributed as relevant information even though it bears no connection to decision at hand (Peters et al. 2003). For example, Johnson and Tversky's experiment found that reading newspaper significantly impacted any subsequent and unrelated risk-based decisions (Johnson and Tversky 1983). Studies have shown that both integral (associated to stimulus) and incidental (independent of stimulus yet incorrectly attributed to it; Peters 2006) emotional responses are used by individuals to construct value and preferences, thus influence our judgements and decisions (Lerner and Keltner 2000; Slovic et al. 2002).

The relationships between emotions and occupational safety-related decision making is particularly interesting because it is highly likely that the interaction of a worker with any stimuli prior to beginning work (for instance: interaction with significant other, conversations with crew members, relevant news, or weather) generates an emotional reaction that has the potential to impact risk assessment at work. The aim of this study was to model and test the relationship between emotions and elements of safety decision-making (hazard identification, risk assessment, and decisions) in concert and measure the extent to which theoretical models of decision-making apply to construction safety.

Influence of emotions on risk-taking behavior and decision-making performance

Emotional response to risk is often perceived as information because people consult their feelings (“how do I feel about this?”) when making decisions under uncertainty (Schwarz and Clore 2003). This approach of affect-as-information posits that there is a direct influence between our emotional state and judgements (Clore et al. 2001). Loewenstein et al.’s (2001, p.270) risk-as-feelings hypothesis, “postulates that responses to risky situations (including decision making) result in part from direct (i.e., not cortically mediated) emotional influences”. In other words, although we evaluate risk at a cognitive level (i.e., consider the probability and appeal of potential outcomes), risk as feelings proposes that we also experience emotional response to the risk. These emotional evaluations are not just the product of our cognitive evaluations (or its individual determinants) rather it is also a response to various other factors (e.g., distinctness, proximity, past interactions, mood) that is used by us to compute an overall “feeling” towards risk (Loewenstein et al. 2001).

Given cognitive evaluations do not share the all the variables that enter our emotional evaluations, the risk-as-feelings model considers the possibility that our emotional evaluations could diverge from cognitive evaluations (Loewenstein et al. 2001). Simply, our feelings can have an independent and potentially stronger influence on our behaviors and decisions over our objective assessment (Loewenstein et al. 2001). This means that there are circumstances where behavior may not be congruent with what a

person objectively computes is the best course of action. Thus, on a construction site it is possible there are situations where the emotional response may diverge from cognitive evaluations and influence undesired risk-taking behavior positively or negatively.

Constructing a Conceptual Model Linking Key Safety Outcomes with Emotional Experiences

The risk-as-feelings theory was used to build the conceptual model shown in Figure 1. In this Figure, the black solid lines represent hypothesized relationships in construction safety context based on established literature (relationship between emotions, risk-taking behavior, and judgements) and the light grey lines in Figure 1 represent exploratory examination conducted in this study (e.g., relationship between emotions and hazard recognition). Rigorous investigation of this conceptual model will validate or invalidate the application of current psychological theory to construction safety.

In conceptual model (Figure 1) presented, *Hazards Identified by Participants* is the number of hazards participants in identify in a work environment whereas *Total Hazards in the Environment* is the number of hazards actually present in the environment as determined by team of researchers using the protocols offered by Albert et al. (2014). Total number of hazards was included as a separate variable in this model because the authors wanted to examine if the ‘intuitive sense’ of a dangerous environment influences valuation of risk and safety decisions independent of the hazards explicitly identified. The impetus for measuring intuitive sense is line with the work of Burke and Miler (1999) who found that experts and professionals often rely on intuition when making decisions, especially when judgement needs to be made quickly, information is insufficient, or when there is uncertainty associated with the outcomes.

The *Positive and Negative Emotional Experience* constructs in the conceptual model represent self-reported integral emotional arousal emanating from the work environment. Given that risk-as-feelings

theory posits that emotional evaluations consider subjective factors that an individual believes are relevant to the risk (Loewenstein et al. 2001), the authors hypothesized that the influence of *Positive* and *Negative Emotional Experience* on the subsequent safety outcomes (*Danger Assessment* and *Decision*) to be independent of the cognitive assessment (i.e., *Hazards Identified by Participants* and *Total Hazards in the Environment*). *Danger Assessment* represents the level of risk assigned to threats in the environment and *Decision* is the measure of degree of risk-averse decision made in the face of hazards and danger valuation.

The authors were also interested in controlling for incidental (i.e., unrelated) emotional experience and examine its influences on key safety outcomes. Despite the growing body of literature on the role of emotions in risk perception and decision making, there has been comparatively little attention paid to how unrelated and background emotional experiences influences performance which in this case is the ability to recognize hazards on construction sites. In other words, researchers have explored the extent to which our overall emotional state impacts the *valuation* of risk (i.e., risk perception) but there is a dearth of research into the relationship between emotion and the initial *detection* of danger (i.e., hazard recognition).

Explanation of the Path Model

Figure 1 provides a depiction of the theoretical path model that was created from past literature. Experimentally testing this model allowed the researchers to assess several important relationships. First, by following Path **A** in the model, the authors assessed whether unrelated emotional disposition impact hazard identifications performance. Second, by following paths **B**, **H**, and **I**, the authors could investigate whether emotions (induced and experiential) predict the perception of risk while controlling for the hazards identified and total number of hazards in the environment. Third, following paths **C**, **M**, and **N** elucidates whether emotions (induced and experiential) predict safety decisions, while controlling for hazards identified, total number of hazards in the environment, and perceived risk. Fourth, following paths **E**, **G**, **K**, and **P** shows whether intuitive sense of the environment influences emotional evaluations, valuation of danger, and decisions regarding risk, independent of the objective evaluation. Fifth, following paths **D** and

F measures the extent to which objective evaluation of the threats influences emotional responses. Finally, following paths **J**, **L**, and **O** examines the association between hazard identification performance, danger (i.e., risk) assessment, and safety decisions and tests Tixier et al. (2014)'s model of situational awareness.

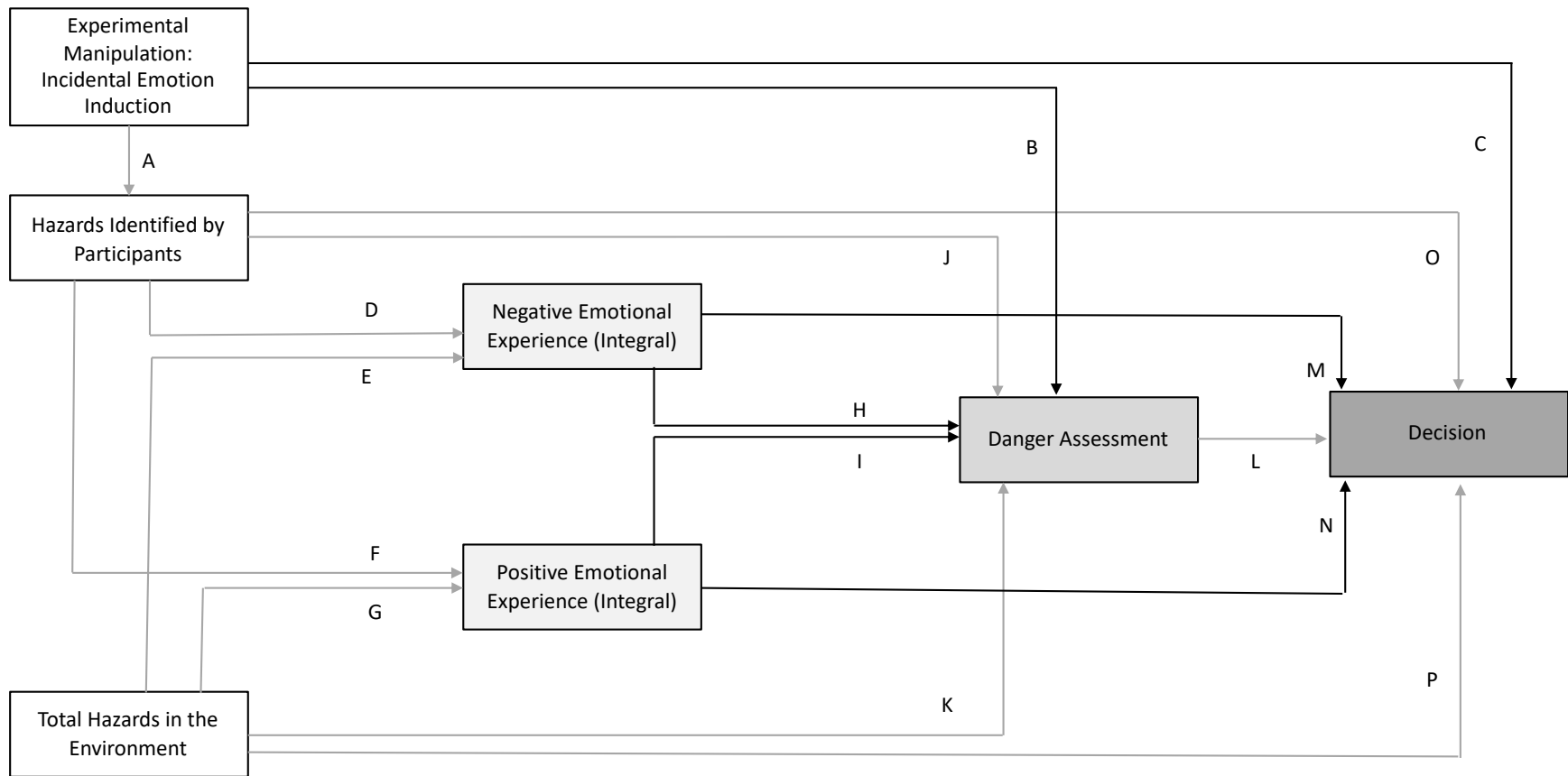


Figure 1: Hypothesized conceptual model showing associations between key safety dimensions and positive and negative emotional experiences

RESEARCH OVERVIEW

To test the path model in Figure 1, an experiment was conducted in a controlled environment where each subject followed the trajectory shown in Figure 2. The experimental objectives were to (1) induce specific incidental emotional states (positive, negative, or neutral) using standardized movie clips validated in previous studies; (2) allow participants to interact with construction hazards in high-fidelity 3D augmented virtual (AV) environment with high ecological validity; (3) measure hazard identification performance, assessment of risk, and emotional reactions; and (4) record the final safety decision. The following section explains each objective and how the experimental setup, data collection process, and strategies adopted to measure each construct (hazard identification performance, perception of danger, emotional reactions, and decisions) helped achieve those objectives.

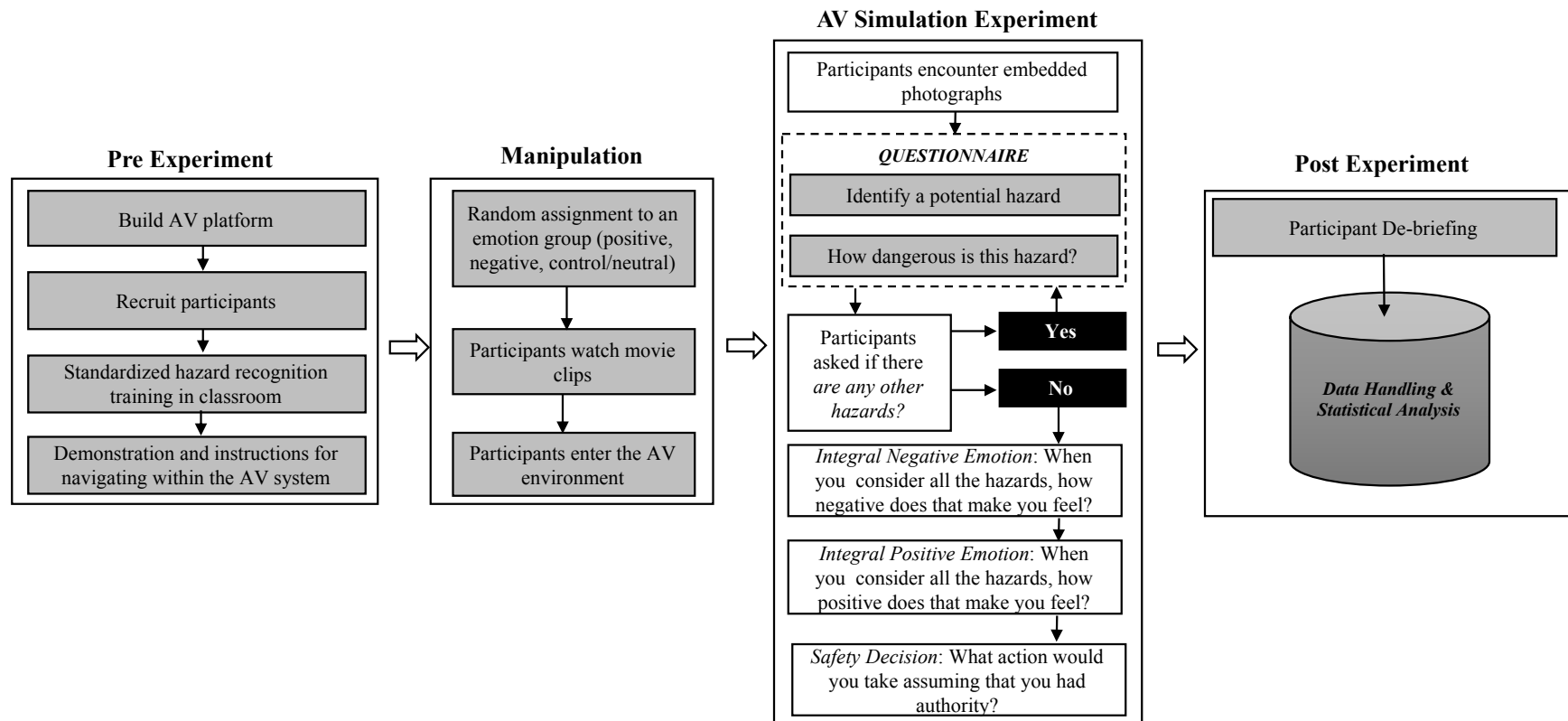


Figure 2: Overview of the Experimental Protocol

Experimental Set-Up

Using High-Fidelity Virtual Construction Environment

An augmented virtual (AV) environment was formed by enhancing a 3-dimensional virtual construction site with real-world images. The AV system was designed to promote ecological validity in the research by placing participants in a realistic work environment where they could be exposed to hazards without exposure to actual harm. Virtual platforms are being increasingly used for safety training purposes (Dickinson et al. 2011; Lin et al. 2011) and have even been used to measure hazard identification performance (Albert et al. 2014; Liaw et al. 2012) and risk assessments (Tixier et al. 2014) in the past. The images embedded in the AV environment depicted workers performing work on an actual construction sites and were either sourced from the internet or taken by members of the research team. The images depicted exposures to both benign hazards (i.e. low energy) and extremely dangerous hazards (i.e. high energy). Screenshot images of the AV construction environment are shown in Figure 3.



Figure 3: Screenshots of the AV environment

Promoting immersion and ecological validity

As subjects navigated the AV environment, they encountered building components and, as they approached the element, the real photograph was displayed for their inspection. To ensure participants had an immersive experience, several features were designed into the system. First, the system included embodied agents, which were virtual co-workers controlled by an independent algorithm (Bailenson and Blascovich 2004). These virtual co-workers added yet another dimension of realism because previous studies have found that subjects in a virtual environment interact with virtual humans as they would with real people (Donath 2007). Participants were only directed to interact with the embedded photographs so interactions with virtual co-workers were incidental. Second, each photograph corresponded directly to an embodied agent or virtual element in the AV environment. For example, an embodied agent is shown pouring concrete was assigned a real photograph of workers pouring concrete for a building component. Such correspondence promoted realism and consistency. Third, to minimize potentially distracting transitions between media, all images and questionnaires were embedded in the AV system itself. Finally, the AV system was designed with a non-repeating soundtrack that captured the typical noise of a construction site to give participants relevant audible stimuli.

Inducing Incidental Emotional Experience with Brief Film Clips

Before commencing the experiment, subjects were randomly assigned into a treatment (positive or negative emotion) or control group. There are various techniques commonly used to induce targeted emotions, ranging from autobiographical recall (Gruber et al. 2009), film-clips (McHugo et al. 1982; Gross and Levenson 1995), hypnosis (Bower 1983), and music (Koelsch 2010). Films were the selected because they are successful across various demographic groups, have a dynamic quality via visual and audio stimuli, and do not involve elaborate descriptions or deceptions (Gross and Levenson 1995). This technique is also, by far, the most popular in emotions research (Gilman et al. 2017) and has been widely tested and validated in literature (Gross and Levenson 1995; Palomba et al. 2000).

Table 1: Movie Clips for Emotion Induction

Target Emotion	Movie Clip (Duration)
Neutral (Control Group)	Denali National Park (3:40)
Negative (Treatment Group 1)	The Champ (3:21)
Positive (Treatment Group 2)	Whose Line is it Anyway? (2:13)

The movie clips in Table 1 generate an array of discrete emotions (Gross and Levenson 1995). For example, *The Champ* (excerpt showing a scene of a young boy crying at the death of his father) generates an overall sad mood (Jeanne et al. 1998) and *Whose Line Is It Anyways* (excerpt showing a comedy skit) generates an overall positive mood (Gilman et al. 2017). The emotions induced by video clips are categorized as incidental since the overall emotional experience from viewing this movie clip has nothing to do with the safety-related tasks in the AV environment. This experimental design allowed the research team to test whether unrelated emotional states can influence hazard recognition performance, valuation of risk, and safety decisions during the task.

Measuring Hazards, Danger Assessment, Emotional Response, and Decisions

After watching the film-clip, participants entered the AV environment and interacted with hazards through the embedded images. All requested data input from the subjects were the same for each image and the data entered by a subject were automatically collected by the system. Once an image appeared, subjects were first asked to identify each hazard by dragging a box around it with the keypad or mouse (both of which were provided to participants) and labeling the hazard by entering text in the space provided. Once a hazard was identified, subjects were asked to rate the danger level of the hazard on a sliding scale of 1-100, where 1 represented ‘not at all dangerous’ and 100 represented ‘extremely dangerous’. The loop of selecting a hazard and assigning it a danger rating continued until participants indicated that they could not identify any new hazards in the system (see Figure 2).

After a subject identified and rated the corresponding danger for the set of detected hazards, they were asked to rate the level of negative and positive emotions experienced when performing hazard recognition and danger assessment. These emotional experience responses were also rated by participants on a 1 to 100 sliding scale, where 1 represented 'not at all' and 100 represented 'extreme'. Participants were asked to make these ratings by considering the all the hazards in image. Given these emotional arousal measures are direct *responses* to the hazards encountered in the AV system, they represent integral emotional state and exist both in contrast to and conjunction with the incidental emotional state induced via film-clips.

After recording the integral emotional experience responses for the image, participants were asked to make a safety decision. They had the option of choosing one option represented on an increasing scale: (1) let work proceed as it is being performed; (2) let work proceed with high caution; (3) stop-work and make minor changes; (4) stop-work and make major changes; and (5) stop-work and note as emergency condition. Once a subject completed this final question, they were placed back to the AV environment where they were free to navigate the work environment and locate a new image, whereupon the process described above would continue for all new images detected until 30 minutes of time had elapsed.

Subject Recruitment and Experimental Controls

A total of 73 student participants were recruited by making class announcements in an upper-level undergraduate Construction Engineering courses at University of Colorado Boulder. Participation was completely voluntary, and a trivial amount of extra-credit was provided as an incentive to bolster recruitment. The goal was to purposely recruit a less experienced subject group who would be less biased from past events, training, and exposures that would threaten the internal validity of a controlled experiment. For example, because of recency bias, experienced workers would be more likely to focus on hazards associated with recent events or exposures and overvalue the risk associated with such hazards

(Cushing and Ahlawat 1996). Given the goal of this paper is to explore if emotional experiences relate to hazard identification, risk assessment, and safety decision-making as a generalized human condition, authors wanted an informed group that would have less potential for bias based on recent or past events, company policies, or established rules and regulations. Thus, this initial experiment focuses on homogeneous sample to reduce demographical and experiential variance.

The authors recognize that the prioritization of internal validity generated some weakness in external validity. Because of resource and practical constraints, the team was not able to test the hypotheses in the field with the same rigor required for an initial experiment. Although future experiments with construction workers is suggested to validate the models, future researchers should be aware that highly controlled experimentation with construction workers is particularly challenging because controlling potentially confounding variables can only be done if a remote laboratory is created and workers are asked to leave the field. That was not reasonably practical for this study.

To control for prior safety knowledge among the recruited subjects, standard hazard recognition training was provided to all subjects as part of their coursework prior to their participation in the experiment. Given Bhandari et al. (2016) found that individuals often confuse hazards (energy sources that can injure) with acts of safety violations (e.g., lack of personal protective equipment), the training session focused on defining the term hazard and providing participants with validated strategies to identify hazards. Specifically, the field-validated energy mnemonic from Albert et al. (2014) was discussed and practiced which provides common definition and understanding of construction hazards.

To enhance validity and minimize bias, several controls were implemented. First, to create a consistent baseline of knowledge, training was delivered by the same instructor for each group and the same material in each session. The instructor for these training sessions was also the primary researcher of the study who was neither blind to the hypothesis nor to the randomization of manipulation conditions. Second,

the training was provided before subjects were recruited and assigned a particular experimental condition. Third, participants from different experimental conditions were given same Institutional Review Board-approved scripted instructions before being assigned a manipulation condition to avoid any undue pressure on a particular participant or a specific condition. Fourth, subjects were given separate rooms that were closed to public access to control to avoid distraction and control for environmental factors. Finally, all participants received the same laptops, headphones, seating, room temperature, and lighting and the rooms were partially shut to give participants privacy.

Before starting the experiment, a brief demonstration was given to each participant on how to navigate the AV system. Following the demonstration, participants were reminded to watch the video (movie clip for incidental emotional experience induction) and then enter the virtual environment both of which were preloaded on their computer screen. To further control for demand characteristics, subjects were informed that the watching the film clip task was for a separate side experiment to assist a colleague in psychology department to avoid response bias (Orne 1962). This was in compliance with Institutional Review Board and other past studies focusing on human behavior research (Harmon-Jones et al. 2007). To further enhance the realism of the cover story, all participants (i.e., construction engineering and management students) underwent experiment in a laboratory in the psychology building. After instructions were provided, the researchers were not physically present during the experiment but were available to answer any procedural questions.

RESULTS

For each photograph, participant's hazard identification *score* was noted to be the total number of hazards correctly identified by a participant. For each photograph, the hazard identification *performance* of a participant was measured by taking the number of hazards identified and dividing it by total number of hazards detectable. The average hazard identification *performance* across the entire sample for all

photographs in this study was 29.8%, which is consistent with the baseline hazard recognition performance observed among workers on construction sites (Albert et al. 2013; Albert et al. 2014). The comparable *performance* level suggests that the sample is representative of the target population in terms of overall skill. Table 2 reports the average hazard recognition *performance* level of each treatment and the control group.

Table 2: Hazard Identification Mean Performance

	Mean	N	Standard Deviation
Positive	29.0%	27	0.13
Negative	31.8%	25	0.14
Control	28.6%	21	0.11

To test all the pathways of the conceptual model shown in Figure 1, the authors conducted a multivariate analysis. The emotion manipulations were contrast coded as linear (-1 = negative, 0 = control, +1 = positive) and quadratic (2 = control, -1 = positive, -1 = negative) conditions. For the analysis process, each participant was treated as within-subject factor and photographs were crossed with the two emotion conditions.

To account for multilevel data, the authors used linear mixed-effects model (LMM) approach to allow for both fixed and random effects (Judd et al. 2017). All variables were continuous in nature except *total number of hazards in a photograph* and *number of hazards identified by a participant*, which represented count data. The continuous variables were scaled and mean centered. Continuous variables that were positively skewed (danger, negative emotional experience, and positive emotional experience) underwent square-root transformations to satisfy the normality requirements of running LMM analysis.

The number of hazards identified by participants (count data) was not transformed since it contained ‘zero’ scores (i.e., some participants did not correctly identify any hazards in a particular image). Transformations of such data are unlikely to yield normally distributed error structures and can often lead to biased estimates (Sileshi et al. 2009; O’hara and Kotze 2010). Further, *generalized* linear mixed effects model (GLMM) which is simply a more general approach and subsumes LMM analysis, allows us to analyze multilevel data without having to transform discrete response variables (Maindonald and Braun 2007). The number of hazards identified by participants did not show overdispersion and was defined in model as following Poisson distribution (O’hara and Kotze 2010).

Does incidental emotional experience lead to variability in ability to detect hazard in a work environment (path: A in Figure 1)?

Emotion manipulation was contrast coded as *linear* (i.e., difference in hazard recognition score of the treatment groups) and *quadratic* (i.e., difference between hazard recognition score of control and treatment groups) conditions. Standard regression analysis revealed that neither linear ($F [1, 625] = 1.28, p = 0.26, 95\% \text{ CI } [-0.11, 0.03]$) nor the quadratic ($F [1, 625] = 0.30, p = 0.58, 95\% \text{ CI } [-0.03, 0.05]$) condition revealed statistically significant differences in hazard recognition *scores* when controlling for total number of hazards in the photograph.

Treating participants as a within-subject factor and crossing the photographs with the two incidental emotion manipulation conditions (linear and quadratic contrasts), the GLMM analysis with Poisson family and log-link function showed that there was no significant difference in hazard recognition score for quadratic contrast condition ($F = 0.025, p = 0.86, 95\% \text{ CI } [-0.09, 0.07]$) or linear contrast condition ($F = 0.54, p = 0.46, 95\% \text{ CI } [-0.18, 0.08]$). It should be noted that the *total number of hazards in the photograph* was not used as a control for this test because its inclusion did not allow the model to converge.

The tests described above imply that incidental emotional experience does not have a significant influence on ability to identify hazards. Therefore, in the conceptual model (see path **A** in Figure 4) there is no direct association between incidental emotion conditions and hazard recognition score. Figure 4 shows only the linear contrast (-1 = negative, 0 = control, +1 = positive) for experimental manipulation findings. Given the statistical power in this analysis, independent replication is suggested to test the assertion that hazard recognition performance is not influenced by extraneous emotion-based information.

The remainder of the statistical tests were performed on continuous variables. Therefore, LMM analysis was used where subjects were treated as random factors and photographs were crossed with the two incidental emotion manipulation conditions (linear and quadratic contrasts). Satterthwaite approximations was used to approximate degrees of freedom.

*Do hazards on a construction site cause emotional reaction (paths: **D**, **E**, **F**, and **G** in Figure 1)?*

After participants noted all hazards in an image, they were asked to report the extent to which they experienced negative and positive emotions during the hazard recognition task (see Figure 2). These data allowed the researchers to explore the extent to which the hazards identified by participants and total number of hazards present in the environment generate an integral emotional response. In other words, the analysis helps to elucidate whether hazards themselves are emotionally-rich stimuli or not. The response variables (negative and positive emotional experience) were regressed separately against the following predictor variables: incidental emotion manipulation conditions (linear and quadratic contrasts), hazards identification score, and total number of hazards in the environment. The predictor variables included in these models showed no significant multicollinearity issues (see Table 3).

Table 3: Correlation matrix of predictor variables (*signifies statistical significance: $p < 0.05$)

	Danger Assessment	Hazards Identified	Total Hazards	Negative Emotion Rating	Positive Emotion Rating
Danger Assessment	1.00	0.46*	0.31*	0.35*	0.01
Hazards Identified		1.00	0.43*	0.18*	0.01
Total Hazards			1.00	0.25*	-0.12*
Negative Emotion Rating				1.00	-0.07
Positive Emotion Rating					1.00

Controlling for total number of hazards in the environment, the analysis revealed that, as subjects identified more hazards, they reported a higher negative emotional experience ($F [1, 571.2] = 5.24; p = 0.02$; path **D**). However, hazards identified by participants did not significantly influence their positive emotional experience ($F [1, 613.5] = 0.01; p = 0.91$; path **F**). This suggests that identifying and interacting with hazards does not significantly change positive integral emotional experience of an individual, but it does increase their negative integral emotional experience. The finding implies that identifying and engaging with hazards can be characterized as negative emotional experience.

When controlling for the number of hazards identified, the total number of hazards in the environment explained both positive ($F [1, 38.8] = 5.45; p = 0.02$; path **G**) and negative ($F [1, 18.2] = 16.0; p < 0.01$; path **E**) emotional experience. That is, as the number of hazards in the photographs increased, *whether explicitly identified by participants or not*, positive integral emotional experience decreased and negative integral emotional experience increased. The influence of the total number of hazards on emotional-based evaluations *independent of hazards explicitly identified* on emotional experience suggests that people may have an intuitive sense of a more dangerous work environment even if they are unable to objectively ascertain the dangers.

There were no statistically significant differences in negative emotion experience for linear ($F [1, 56.5] = 0.05$; $p = 0.83$) and quadratic ($F [1, 62.8] = 0.14$; $p = 0.71$) incidental emotion manipulation conditions. These findings were consistent for positive emotion rating for both linear ($F [1, 72.1] = 0.08$; $p = 0.78$) and quadratic ($F [1, 62.5] = 0.04$; $p = 0.83$) incidental emotion manipulation conditions.

*Is there a relationship between hazards identified, total hazards in the environment, and danger assessment (paths: **J** and **K** in Figure 1)?*

It is largely assumed that there is a relationship between hazards identified and assessment of danger (i.e., risk rating), but the nature and, more importantly, the extent of that relationship is yet to be empirically confirmed. To explore this research question, LMM analysis was conducted where hazards identified, total hazards, incidental emotion manipulation conditions (linear and quadratic contrasts), negative emotion rating, and positive emotion rating were the independent variables and danger rating was the dependent variable. Participants reported a danger rating for each hazard they identified in a photograph. Given that participants were asked to make affective evaluations and decisions on the level of the environment (i.e., photograph), measure of danger needed to be on the same level as well. Thus, relative danger rating for the environment was obtained by averaging the all the individual danger ratings within a photograph. This also resolved the non-independence issue due to sequential nature of the data (Judd et al. 2017).

The analysis showed that the overall danger assessment increases as the number of hazards identified by participants increases ($F [1, 420.8] = 32.0$; $p < 0.01$; path **J**) and total number of hazards in the environment increases ($F [1, 41.9] = 8.67$; $p < 0.01$; path **K**). The former finding is a confirmation on a long-theorized relationship between identifying hazards and evaluating danger and the latter is supported by past research that has found that individuals make assessments of risk without explicit knowledge of the threats (Bechara et al. 1997). In a threatening environment, individuals often rely on intuitive reasoning

(e.g., patterns, cues, and familiarity) to make snap decisions (Klein 2017). Colloquially, this finding confirms that ‘gut feeling’ is a primary driver of danger assessment.

*Is there relationship between emotional experience and danger assessment (paths: **B**, **I**, and **H** in Figure 1)?*

While negative emotion rating was found to strongly influence danger assessment ($F [1, 538.9] = 61.9; p < 0.01$; path **H**), the same could not be concluded for positive emotions ($F [1, 371] = 0.49; p = 0.48$; path **I**). The experimental manipulation did not reveal any statistically significant difference in danger ratings for both linear ($F [1, 37.2] = 0.03; p = 0.86$; path **B**) and quadratic ($F [1, 31.2] = 0.70; p = 0.41$) incidental emotion conditions.

*Is there a relationship between hazards identified, total hazard hazards in the environment, danger assessment, and safety decisions (path **L**, **O**, and **P** in Figure 1)?*

Although there have been studies that have explored hazard identification and danger assessment skills among construction workers, their influence on safety decisions remains an unexamined assumption. Thus, the final analysis was conducted with safety decisions as the response variable and hazards identified, total hazards, negative emotional experience, positive emotional experience, incidental emotion manipulation conditions (linear and quadratic contrasts), and overall danger assessment as predictors.

The results show that controlling for all other predictor variables, safety decisions are strongly influenced by the total hazards in the environment ($F [1, 20.3] = 13.4; p < 0.01$; path **P**). Further, the results show that increased perception of danger supports more risk averse decisions ($F [1, 596.7] = 10.7; p < 0.01$; path **L**). Surprisingly, there was no significant relationship between the number of hazards identified by participants and safety decisions ($F [1, 529] = 2.88; p = 0.089$; path **O**).

Is there a relationship between emotional experience and safety decisions (path C, M, and N in Figure 1)?

The results revealed that negative emotional experience is associated with a propensity to make more risk-averse decisions ($F [1, 604.8] = 32.9; p < 0.01$; path **M**), which is consistent with findings from previous studies (Johnson and Tversky 1983; Loewenstein et al. 2001; Peters 2006). Positive emotional experience ($F [1, 472.6] = 1.50; p < 0.22$; path **N**) and both linear ($F [1, 64.6] = 0.29; p = 0.59$; path **C**) and quadratic ($F [1, 43.6] = 0.05; p = 0.83$) incidental emotion manipulation conditions continue to show no significant relationship.

Figure 4 is an update on the Figure 1 that summarizes the findings discussed above where solid lines represent statistically significant paths with $p < 0.05$. The dashed lines show pathways in the conceptual model that were not statistically significant. Pathways emerging from experimental manipulation in Figure 4 show the only the linear orthogonally planned contrast (-1 = negative, 0 = control, +1 = positive) that compares the two treatment groups.

In summary, experimental results show that induced incidental emotional experience played no significant role in altering hazard identification performance, danger assessment, or decision under risk. That is, key safety outcomes were not influenced by unrelated emotional experiences among construction engineering students. To confirm whether the effect of emotion manipulation dissipated over the course of the experiment, the authors tested the relationship between emotion manipulation and reported emotional experience for just the first photograph encountered by each participant in the AV system. However, there were no statistically significant differences in the reported integral negative emotional experience for quadratic ($F [1, 64.98] = 0.21; p = 0.65$) and the linear ($F [1, 64.43] = 0.17; p = 0.68$) contrast groups. This was again consistent for positive integral emotional experience where linear ($F [1, 65.0] = 0.07; p = 0.79$) and quadratic ($F [1, 65.0] = 0.74; p = 0.39$) contrast groups showed no significant difference. Considering the analysis above, it appears as if the experimental manipulation did not rouse integral emotional response

despite strict conformance to established protocols and direct collaboration with experts in emotion elicitation.

On the other hand, interaction with the hazards (both explicitly identified by participants and present in the environment) was positively associated with an increase in negative emotions. These negative integral emotions and total hazards in the environment also strongly influenced danger assessment and safety decisions made by the subjects. This finding is interesting because the associations between negative emotional, intuitive sense, danger assessment, decision-making existed independent of hazard recognition skill or number of hazards identified (i.e., objective evaluations). That is, emotional experience may influence risk assessment and decisions despite lack of information on the stimuli exhibiting the risk. The relationship between total number of hazards in the environment and decisions regarding risk indicates that safety decisions may be processed more subconsciously (i.e., 'gut feel') rather than consciously or logically. While hazards identified by participants does not directly influences decisions, it does increase negative emotional experience and assessment of danger that, in turn, influence the safety decisions.

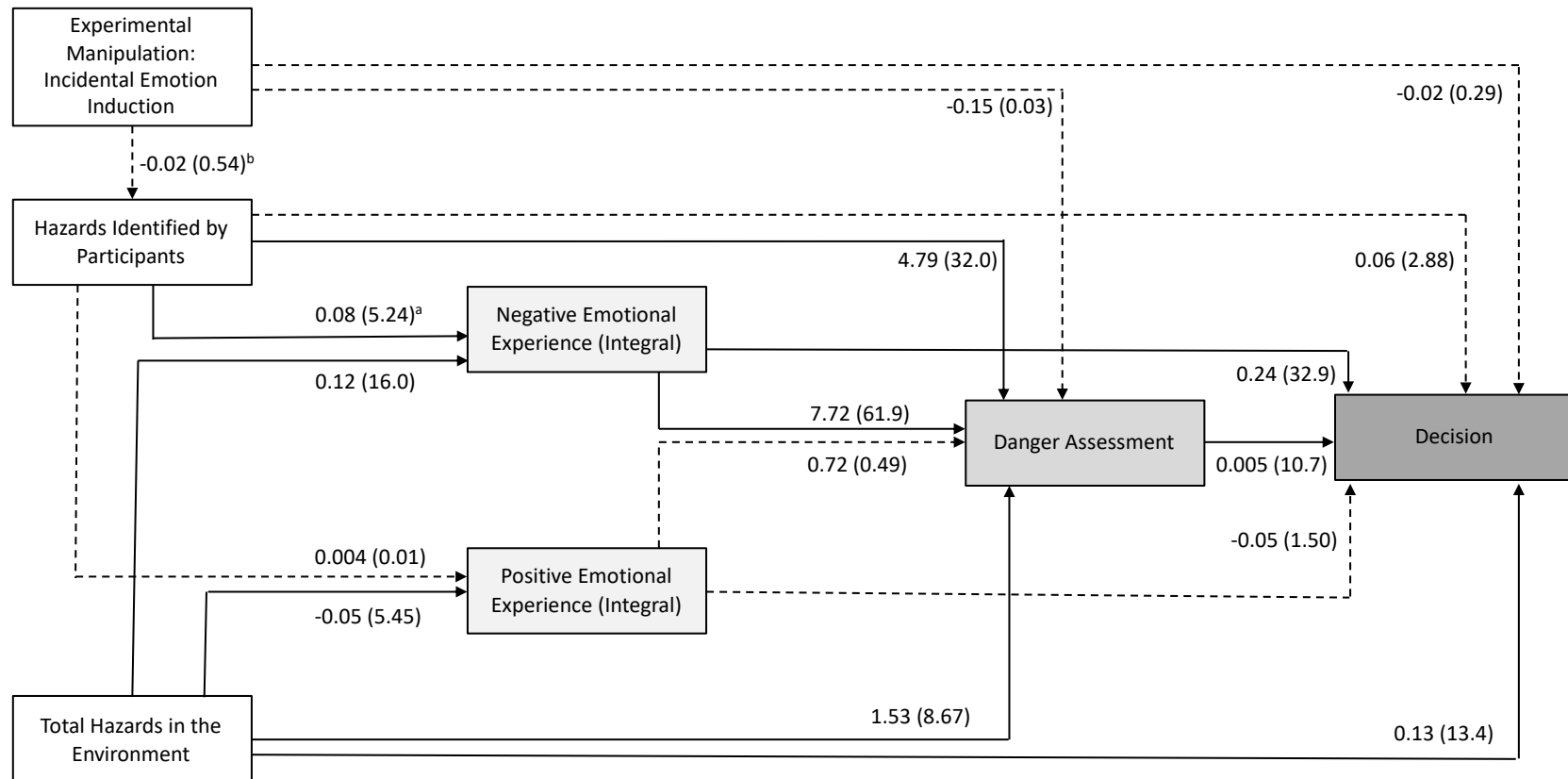


Figure 4: Conceptual Model Showing Associations Between Key Safety Dimensions and Emotional Experiences^c

^a b_0 (F-statistic); b_0 is standardized.

^bPathways from experimental manipulation show the result for emotional manipulation coded linearly i.e., comparison between the two treatment groups (negative and positive).

^cThe broken lines represent relationships that were statistically insignificant whereas solid lines represent the statistically significant pathways.

INTERPRETATION OF FINDINGS

Scholars have long recognized the importance of safety training and have recently called for additional research to explore how psychological antecedents can be incorporated into training programs to improve personnel performance, perceptions, and behavior (Bhandari and Hallowell 2017; Geller 2001; Tixier et al. 2014). Prior to this study the relationship between emotional state and key safety outcomes in construction context has remained mostly unstudied or assumed without scientific evidence. Thus, the goal was to design and conduct an internally-valid experiment to explore a conceptual model that gauges the impact of emotional state on hazard identification performance, perception of danger and decisions. The analysis shows that the overall fit between theorized conceptual model (Figure 1) and patterns of results (Figure 4) was strong.

While both the number of hazards identified by participants and the total number of hazards in the environment directly influence assessment of risk, only total number of hazards in the environment showed a strong association with safety decision which was independent of the number of hazards identified by participants. In fact, number of hazards *actually identified* by participants did not have a direct influence on the final safety decision. This implies that when making decisions regarding risky situation, individuals rely on their intuitive assessment (or “gut feeling” or “sixth sense”; Klein 2017) over their objective assessment of the situation. Individuals use their situational awareness to identify cues, patterns, and past experience to determine a typical situation from an atypical situation and aid rapid decision-making (Klein 2017). According to *fuzzy-trace models of reasoning and decision making*, these gist-based reasonings to aid decision-making are often made unconsciously (Reyna et al. 2005) and although these can hugely beneficial (Slovic et al. 2002), they are also highly susceptible to many cognitive biases (Koehler et al. 2002). Patterns and cues used to make such assessments can often fall prey to miscalibration and cause systemic errors (Stewart et al. 1997; Wagenaar and Karen 1986). Safety training programs and interventions

need to focus on developing understanding over persuasion or literal memorization of facts to promote insightful intuition (Reyna et al. 2005).

The analysis revealed that hazard recognition task and exposure to hazards in the AV environment generated negative integral emotional state among participants which influenced their subsequent risk assessment and safety decisions. Furthermore, while the hazards identified by participants did not alter their positive emotional state, a more hazardous environment (i.e., total number of hazards in the environment) reduced their positive feelings significantly. Thus, hazards in construction environment can be used as an intervention strategy to induce context-driven emotions among workers in future experiments and inquiries.

The results show that negative emotional evaluations can heighten the perception of danger and promote more risk-averse decision-making. These findings are consistent with previous studies that have found negative emotions to promote higher risk perception and reducing risk-taking behavior (Isen and Patrick 1983). As was posited per Loewenstein et al. (2001)'s risk-as-feeling hypothesis, relationship between emotional evaluations and danger assessment was found to be independent of objective evaluations (e.g., hazards explicitly identified or sense of hazards in the environment) in this study. Emotional evaluations can often diverge from objective evaluations and in those cases, our emotions play a more dominating role in controlling our behavior and decisions (Loewenstein et al. 2001). From safety standpoint, this study suggests it is possible for a worker to identify all the hazards in the environment and still partake in risky behavior if the integral emotional experience is not conducive to risk-averse goals. Thus, the finding reiterates the need for training programs to focus on generating targeted context driven emotions to alter perception and behavior on construction sites to cultivate risk-averse practices (Bhandari and Hallowell 2017).

Unexpectedly, the experimental manipulation of incidental emotions did not show any statistically significant relationship in the safety decision pathways (see Figure 4). These results do not replicate some

of the findings presented in previous studies that incidental emotional states influence hazard identification performance (Bhandari et al. 2016) and perception of construction safety risk (Tixier et al. 2014). However, the differences in findings may have been because the conceptual model tested here (Figure 1) is more holistic compared to Bhandari et al. (2016) and Tixier et al. (2014). The lack of such relationship observed here is partially supported by affect-as-information theory that contends emotional states must be linked to the stimuli participants identify, discuss, or encounter to influence the judgment (Clore et al. 2001). Hence, these findings provide some support for the assertion that the sub-optimal hazard identification performance is not a product of fluctuating unrelated emotional states.

LIMITATIONS AND FUTURE RESEARCH

This study has several limitations that require the conclusions be interpreted with caution. First, it is likely that the experimental manipulation with the movie-clips was ineffective but the authors do not have explicit empirical data to confirm this suspicion. It is possible the AV environment acted as an immersive intervention (Riva et al. 2007) or that the movie-clips are outdated (Bartolini 2011). While these methodologies have been widely used and validated in varied experimental domains, it is recommended that future studies should not only reassess the notion that incidental emotional state does not influence safety outcomes but also validate emotion induction techniques on a representation of their sample.

Second, the student subjects recruited in this study do not entirely represent construction workers (i.e., ethnicity, age, injury history, or work experience). However, compromising external validity for the promotion of internal validity was intentional as the primary research objective was to conduct a controlled laboratory experiment rather than field-based study. Getting a sample of construction workers in an off-field laboratory setting is often constrained by logistical considerations (Buchholz et al. 1996). Controlled experimental laboratory settings are also not common experience for construction workers and placing them in it could likely cause the Hawthorne effect (Albert et al. 2014) or introduce demand characteristics.

Furthermore, the hazard recognition skill shown by participants of this study matched the baseline skill shown by construction workers in the field (Albert et al. 2014). Finally, as noted previously participants were students in construction engineering and management courses who would likely work or interact with workers on a construction site making them relevant section of the population. Nevertheless, future research needs to examine if the findings presented in this paper are generalizable across construction workers of differing backgrounds.

Third, sample size of 73 is not ideal given the experimental design where participants were crossed with emotional manipulation tasks and had the option of interacting with as many as 16 unique stimuli (i.e. photographs). This limitation was a product of logistical and resource constraints. Although reducing the number of photographs could have increased power, that control was rejected as reducing number of photographs would have decreased the variability of hazards and level of risk exposed to participants.

Finally, the experimental design and using self-reported measures for emotions and risk perception compromises the ability to make causal relationships. Further, the self-report measures of emotions are susceptible to individual biases and misinterpretations that could have caused skewed findings. The conceptual model presented tests strength of relationships and the analysis does not conclusively establish directionality.

CONCLUSIONS

A key practical contribution of this paper is understanding the how emotional state can influence our ability to identify hazards, assess risk, and make decisions within work environment. The construction safety profession has implicitly operated under the assumption that the process of identifying, assessing, and responding to danger in the workplace is based on skill and rationality as evidenced by the design and delivery of traditional safety training programs. Although, the emotions manipulation did not show any

influence on the hazard recognition performance of subjects, the findings suggest that hazards in work environments can generate emotional responses and these emotions-based evaluations can strongly influence risk assessment and safety decisions. Moreover, these emotional evaluations *may have a mind of their own*; i.e., emotions can influence assessment of risk and decisions independent of objective evaluations. That, coupled with the finding that intuitive sense has a direct relationship with decisions regarding safety and risk, suggests safety managers and trainers should not *just* focus on facts, rules, and regulations to promote risk-averse decision-making among workers. Training programs need to facilitate reasoning skills among workers to automatically and unconsciously identify cues in their environment which allows them to understand the risky situations. Further, training programs need to also deliver information in a manner that allows workers to commit information to long-term memory, rapidly access risk-averse values from long-term memory, and implement those values without pondering about the benefits of engaging with the risk (Klein 2017; Reyna and Farley 2006). This study provides preliminary evidence that training programs that heighten contextual relevant emotional arousal can promote risk-averse behavior among personnel.

Theoretically, this study validates the risk-as-feelings proposition that emotional evaluations can diverge from cognitive evaluations. The findings corroborate the assertion that there is a direct influence of emotional evaluations on decisions and subsequent behavior and “the impact of cognitive evaluations on behavior is mediated, at least in part, by affective responses” (Loewenstein et al. 2001, p. 271). Most studies that examine the relationship between emotions and risk perception uses stimuli with invariant or minimally variant uncertainty. By allowing hazards, risk associated with different hazards, and emotional experience to vary across the entire experiment, this study examines risk-as-feelings and affect-as-information theories and validates them ecologically. The authors also validated that the intuitive sense of environment plays a significant role in our perception of risk and willing to engage with risk over and above objective reasoning within construction safety context. Overall, the most relevant and consequential contribution of this study

to the current body of knowledge is testing the application of these theories in a real-world setting: in an occupational safety training environment.

For an industry that is projected to globally spend more than ten trillion dollars each year by 2025 (LePatner 2008), safety and well-being of its personnel are key to its sustainability. The work presented here represents a preliminary effort that confirms that our emotional experiences may play a critical role when assessing risks and making decisions in an occupational safety context. Furthermore, there is evidence that subjective assessments and negative emotional experiences can influence both valuation of risks and subsequent decisions regarding safety independent of the objective assessments we make. These findings underscore the importance of psychological antecedents for occupational training programs especially safety training and show that decisions to engage with risks are not based on purely rational thought process.

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REFERENCES:

- [1]. Albert, A., Hallowell, M. R., and Kleiner, B. M. (2013). Enhancing construction hazard recognition and communication with energy-based cognitive mnemonics and safety meeting maturity model: Multiple baseline study. *Journal of Construction Engineering and Management*, 140(2), 04013042.
- [2]. Albert, A., Hallowell, M. R., Kleiner, B., Chen, A., & Golparvar-Fard, M. (2014). Enhancing construction hazard recognition with high-fidelity augmented virtuality. *Journal of Construction Engineering and Management*, 140(7), 04014024.
- [3]. Bailenson, J.N., & Blascovich, J. (2004). Avatars. In W.S. Bainbridge (Ed.), *Encyclopedia of human-computer interaction* (pp. 64–68). Great Barrington, MA: Berkshire.
- [4]. Bartolini, E. E. (2011). Eliciting emotion with film: Development of a stimulus set.
- [5]. Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, 275(5304), 1293-1295.
- [6]. Bhandari, S., & Hallowell, M. R. (2017). Emotional Engagement in Safety Training: Impact of Naturalistic Injury Simulations on the Emotional State of Construction Workers. *Journal of Construction Engineering and Management*, 143(12), 04017090.
- [7]. Bhandari, S., Hallowell, M. R., Van Boven, L., Gruber, J., & Welker, K. M. (2016). Emotional states and their impact on hazard identification skills. In *Construction Research Congress 2016* (pp. 2831-2840).
- [8]. Bower, G. H. (1983). Affect and cognition. *Phil. Trans. R. Soc. Lond. B*, 302(1110), 387-402.
- [9]. Buchholz, B., Paquet, V., Punnett, L., Lee, D., & Moir, S. (1996). PATH: a work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. *Applied ergonomics*, 27(3), 177-187.
- [10]. Burke, L. A., & Miller, M. K. (1999). Taking the mystery out of intuitive decision making. *Academy of Management Perspectives*, 13(4), 91-99.

- [11]. Clore, G. L., Gasper, K., & Garvin, E. (2001). Affect as information. *Handbook of affect and social cognition*, 121-144.
- [12]. Clore, G. L., Schwarz, N., & Conway, M. (1994). Affective causes and consequences of social information processing. *Handbook of social cognition*, 1, 323-417.
- [13]. Cushing, B. E., & Ahlawat, S. S. (1996). Mitigation of recency bias in audit judgment: The effect of documentation. *Auditing*, 15(2), 110.
- [14]. Dickinson, J. K., Woodard, P., Canas, R., Ahamed, S., and Lockston, D. (2011). "Game-based trench safety education: Development and lessons learned." *J. Inf. Technol. Constr.*, 16, 119–134.
- [15]. Donath, J. (2007). Signals in social supernets. *Journal of Computer-Mediated Communication*, 13(1), 231-251.
- [16]. Geller, E. S. (2001). Behavior-based safety in industry: Realizing the large-scale potential of psychology to promote human welfare. *Applied and Preventive Psychology*, 10(2), 87-105.
- [17]. Gilman, T. L., Shaheen, R., Nylocks, K. M., Halachoff, D., Chapman, J., Flynn, J. J., Lindsey M. M., & Coifman, K. G. (2017). A film set for the elicitation of emotion in research: A comprehensive catalog derived from four decades of investigation. *Behavior research methods*, 49(6), 2061-2082.
- [18]. Gross, J. J., & Levenson, R. W. (1995). Emotion elicitation using films. *Cognition & emotion*, 9(1), 87-108.
- [19]. Gruber, J., Harvey, A. G., & Johnson, S. L. (2009). Reflective and ruminative processing of positive emotional memories in bipolar disorder and healthy controls. *Behaviour research and therapy*, 47(8), 697-704.
- [20]. Hallowell, M. (2010). Safety risk perception in construction companies in the Pacific Northwest of the USA. *Construction management and economics*, 28(4), 403-413.
- [21]. Harmon-Jones, E., Amodio, D. M., and Zinner, L. R. (2007). "Social psychological methods in emotion elicitation." *Handbook of emotion elicitation and assessment*, J. A. Coan and J. J. B. Allen, eds., Oxford University Press, New York, 91–105.

- [22]. Hinze, J. (2006). *Construction safety*, Prentice Hall, New York.
- [23]. Isen, A. M., & Patrick, R. (1983). The effect of positive feelings on risk taking: When the chips are down. *Organizational behavior and human performance*, 31(2), 194-202.
- [24]. Isen, A. M., Shalcker, T. E., Clark, M., and Karp, L. (1978). "Affect, accessibility of material in memory, and behavior: A cognitive loop?" *J. Pers. Soc. Psychol.*, 36(1), 1-12.
- [25]. Jeanne, M., Gross, J. J., Persons, J. B., & Hahn, J. (1998). Mood matters: Negative mood induction activates dysfunctional attitudes in women vulnerable to depression. *Cognitive Therapy and Research*, 22(4), 363-376.
- [26]. Johnson, E. J., & Tversky, A. (1983). Affect, generalization, and the perception of risk. *Journal of personality and social psychology*, 45(1), 20.
- [27]. Judd, C. M., McClelland, G. H., & Ryan, C. S. (2017). *Data analysis: a model comparison approach to regression, ANOVA, and beyond*. Routledge.
- [28]. Kahneman, D., Wakker, P. P., & Sarin, R. (1997). Back to Bentham? Explorations of experienced utility. *The quarterly journal of economics*, 112(2), 375-406.
- [29]. Klein, G. A. (2017). *Sources of power: How people make decisions*. MIT press.
- [30]. Koelsch, S. (2010). Towards a neural basis of music-evoked emotions. *Trends in cognitive sciences*, 14(3), 131-137.
- [31]. Lang, A. (2006). "Using the limited capacity model of motivated mediated message processing to design effective cancer communication messages." *J. Commun.*, 56(S1), S57-S80.
- [32]. Lerner, J. S., & Keltner, D. (2000). Beyond valence: Toward a model of emotion-specific influences on judgement and choice. *Cognition & emotion*, 14(4), 473-493.
- [33]. LePatner, B. B. (2008). *Broken buildings, busted budgets: How to fix America's trillion-dollar construction industry*. University of Chicago Press.
- [34]. Liaw, Y.-L., Lin, K.-Y., Li, M., and Chi, N.-W. (2012). "Learning assessment strategies for an educational construction safety video game." *Proc., of the 2012 Construction Research Congress*, ASCE, VA, 2091-2100.

- [35]. Lin, K. Y., Son, J.W., and Rojas, E. M. (2011). "A pilot study of a 3D game environment for construction safety education." *Electron. J. Inf. Technol. Constr.*, 16, 69–84.
- [36]. Loewenstein, G., and Lerner, J. (2002). The role of emotion in decision making. In Davidson, R. J., Goldsmith, H. H., and Scherer, K. R. (eds.), *Handbook of Affective Science*, Oxford University Press, Oxford, pp. 619–642.
- [37]. Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological bulletin*, 127(2), 267.
- [38]. Maindonald, J. & Braun, J. (2007) *Data Analysis and Graphics Using R – An Example-Based Approach*, 2nd edn. Cambridge University Press, Cambridge.
- [39]. McHugo, G. J., Smith, C. A., & Lanzetta, J. T. (1982). The structure of self-reports of emotional responses to film segments. *Motivation and Emotion*, 6(4), 365-385.
- [40]. National Safety Council, "National Safety Council Injury Facts 2016 Edition," National Safety Council, Itasca, IL, 2016.
- [41]. Oatley, K., Keltner, D., & Jenkins, J. M. (2006). *Understanding emotions*. Blackwell publishing.
- [42]. Occupational Safety and Health Administration. "Commonly Used Statistics." U.S. Department of Labor. Retrieved July 12, 2018, from <https://www.osha.gov/oshstats/commonstats.html>.
- [43]. O'hara, R. B., & Kotze, D. J. (2010). Do not log-transform count data. *Methods in Ecology and Evolution*, 1(2), 118-122.
- [44]. Orne, M. T. (1962). On the social psychology of the psychological experiment: With particular reference to demand characteristics and their implications. *American psychologist*, 17(11), 776.
- [45]. Palomba, D., Sarlo, M., Angrilli, A., Mini, A., & Stegagno, L. (2000). Cardiac responses associated with affective processing of unpleasant film stimuli. *International Journal of Psychophysiology*, 36(1), 45-57.
- [46]. Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational psychology review*, 18(4), 315-341.

- [47]. Peters, E. (2006). The functions of affect in the construction of preferences. The construction of preference, 454-463.
- [48]. Peters, E., Slovic, P., & Gregory, R. (2003). The role of affect in the WTA/WTP disparity. *Journal of Behavioral Decision Making*, 16, 309-330.
- [49]. Riva, G., Mantovani, F., Capideville, C. S., Preziosa, A., Morganti, F., Villani, D., Gaggioli, A., Botella, C., & Alcañiz, M. (2007). Affective interactions using virtual reality: the link between presence and emotions. *CyberPsychology & Behavior*, 10(1), 45-56.
- [50]. Reyna, V. F., & Ellis, S. C. (1994). Fuzzy-trace theory and framing effects in children's risky decision making. *Psychological Science*, 5(5), 275-279.
- [51]. Reyna, V. F., & Farley, F. (2006). Risk and rationality in adolescent decision making: Implications for theory, practice, and public policy. *Psychological science in the public interest*, 7(1), 1-44.
- [52]. Schwarz, N., & Clore, G. L. (2003). Mood as information: 20 years later. *Psychological Inquiry*, 14(3-4), 296-303.
- [53]. Sileshi, G., Hailu, G. & Nyadzi, G.I. (2009) Traditional occupancy-abundance models are inadequate for zero-inflated ecological count data. *Ecological Modelling*, 220, 1764–1775.
- [54]. Slovic, P., Finucane, M., Peters, E., & MacGregor, D. G. (2002). Rational actors or rational fools: Implications of the affect heuristic for behavioral economics. *The Journal of Socio-Economics*, 31(4), 329-342.
- [55]. Stewart, T. R., Roebber, P. J., & Bosart, L. F. (1997). The importance of the task in analyzing expert judgment. *Organizational Behavior and Human Decision Processes*, 69(3), 205-219.
- [56]. Stone, T. W. (1981). Theophylline does not affect morphine inhibition of the isolated vas deferens. *British journal of pharmacology*, 73(3), 787-789.
- [57]. Tixier, A. J. P., Hallowell, M. R., Albert, A., van Boven, L., & Kleiner, B. M. (2014). Psychological antecedents of risk-taking behavior in construction. *Journal of Construction Engineering and Management*, 140(11), 04014052.

- [58]. U.S. Bureau of Labor Statistics (BLS), "2016 Survey of occupational injuries and illnesses Charts Package," U.S. Department of Labor, Washington, DC, Nov. 2017.
- [59]. Wagenaar, W. A., & Keren, G. B. (1986). Does the expert know? The reliability of predictions and confidence ratings of experts. In *Intelligent decision support in process environments* (pp. 87-103). Springer, Berlin, Heidelberg.
- [60]. Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of personality and social psychology*, 54(6), 1063.

CHAPTER 3: EMOTIONAL ENGAGEMENT IN SAFETY TRAINING: IMPACT OF NATURALISTIC INJURY SIMULATIONS ON THE EMOTIONAL STATE OF CONSTRUCTION WORKERS

Abstract: Poor hazard recognition skills and high tolerance for risk are well-known contributing factors to high fatality rates plaguing the construction industry. The prevailing safety training techniques involves one-way delivery of slideshow presentations with written handouts that often describe common hazards and generic solutions. Such delivery does not facilitate active learning, development of contextual examples, or emotional engagement necessary for adult learners to gain new knowledge. To address these limitations, this paper proposes a new multimedia-learning simulation-based training program: Naturalistic Injury Simulation (NIS). NIS involves demonstrating the cause and effect of hand injuries using a hyper-realistic replica of a human hand within realistic scenarios. Out of 1,200 workers that participated, 489 workers were randomly selected for our longitudinal A+B experiment. Change in emotional states among the participants due to the simulations was analyzed across various demographical dimensions. Analysis showed that workers experienced a surge in negative emotions. Findings suggest that NIS will lead workers across the different demographical groups to perceive more risk by being more vigilant and detail-oriented.

INTRODUCTION

Academics and construction practitioners remain perturbed by high injury and fatality rates, which prevail despite targeted research and development. Some have theorized that there are serious fundamental safety issues that are not being addressed by training, written documents, management support and commitment, or safety technologies. For example, Carter and Smith (2006) argued that construction workers are not equipped with necessary skill set to correctly identify potential hazards. This has been empirically supported by Albert et al. (2013) who found that workers are, on average, only able to identify 38% of hazards during typical safety planning and during work execution. Since all safety management activities emanate from a core ability to recognize and respond to danger, these deficiencies are serious

fundamental issues. Thus, there is a need for innovation in safety training and hazard recognition skill development.

Fortunately, recent progress in hazard recognition has been made using an energy mnemonic that facilitates conceptualization and retrieval of hazards from memory. The energy mnemonic, based upon Haddon's (1970) theory, conceptualizes hazards as forms of energy in the environment that, if released, could cause harm. Experimental research has shown that this mnemonic improves hazard recognition skills by approximately 31% when embedded in safety training (Albert et al., 2013) or integrated with pre-job safety planning (Albert et al., 2014). This promising new method may be a technical improvement that transforms safety training and planning activities.

The present paper focuses on the nexus of energy-based safety training and emotional engagement during safety training. Specifically, we designed and tested a field study with 489 workers to test the null hypothesis that *naturalistic injury simulation does not cause emotional arousal during safety training*. Here, we define naturalistic injury simulations (NIS) as scientifically accurate reproductions of past construction injuries using models of actual construction materials, equipment, and tools and hyper-realistic replicas of human body parts. In the design of the NIS, we targeted emotional arousal because it has been strongly tied to learning outcomes (Fassbender et al., 2012; Pekrun, 2006; Pekrun et al., 2009; Pekrun et al., 2002) and because emotional state has been shown to impact construction hazard recognition (Bhandari et al., 2016) and risk perception (Öhman and Mineka, 2001; Clore et al., 1994; Keller et al., 2006; Tixier et al., 2015). Conducting the study in the field with nearly 500 workers allowed us to test our safety training module against varied demographical dimensions greatly enhancing our ecological validity. Also, since demographics have been shown to play a strong role in perception and display of emotions, we examined how ethnicity, age, marital status, education level, past experience with injuries, and years of industry experience relate to the magnitude and direction of observed emotional responses.

LITERATURE REVIEW

In order to test our hypothesis, we needed to create the first NIS tailored to the construction industry and measure the extent to which it can elicit emotional arousal among construction workers. Given that emotions have been linked to learning, retention of new knowledge, and decision-making, understanding how NIS impacts emotions is critical to assess the efficacy of NIS as a new safety training method.

This section describes literature that connects emotion with various factors critical to safety training, namely learning, retention of new knowledge, decision-making, hazard recognition, risk perception, and risk tolerance. It was upon this knowledge that we built the principle hypothesis and made subsequent theoretical links in our discussion and conclusions. We also review literature related to simulation-based training in other industries and the principles of adult learning because it was upon this knowledge base that the NIS were designed and delivered.

Relationship between emotion and risk-based decision-making

Emotions are multifaceted (i.e., behavioral, physiological, and experiential) and each facet serves a different function to help individuals to engage in and adapt to their surroundings (Oatley et al., 2006). A person's emotional state can influence all aspects of hazard identification, valuation, and decision process, as observed in the appraisal of consumer goods (Isen et al., 1978), selection of political leaders (Keltner et al., 1993) and evaluation of losses and gains (Ketelaar, 2004). In particular, research by Clore et al. (1994) and Keller et al. (2006) showed that emotions can strongly affect an individual's perception and tolerance of risk. Interestingly, recent research has suggested that there is a bidirectional relationship between emotions and risk-based decisions as participating in risky behavior also induces emotions (Bonnet et al., 2008).

The connection between emotions and decision-making can be explained by Damasio et al.'s (1996, p.1413) Somatic Marker Hypothesis, which states that, "marker signals influence the processes of response to stimuli, at multiple levels of operations, some of which occur overtly (consciously, 'in mind') and some of which occur covertly (non-consciously, in a non-minded manner)." Alternatively, the hypothesis suggests that conscious and sub-conscious emotional states can sway our assessments of risk and subsequent decisions in environments of uncertainty. This relationship exists physiologically because the amygdala (i.e., the 'emotional computer' of the brain) evaluates the input from external stimuli for its emotional merit (LeDoux, 1998; LeDoux and Phelps, 1993). The emotional value attached to the stimulus then impacts our judgment, which influences our decision on how to act upon it.

Bechara et al. (2000) proposed that individuals make judgments not only by assessing the likelihood of an event and the severity of the potential outcome but also by assessing the emotional qualities of the outcome. Caruso and Shafir (2006) further postulated that an individual will subconsciously make a decision to maintain a positive emotional state or compensate for a negative emotional state via subsequent choices. Slovic and Peters (2006) found this to be true as individuals with positive emotions desire to recreate the environments that led to those emotions and individuals in negative emotional states seek to avoid decisions that could lead to previous disappointment. Mellers and McGraw (2001) specifically explain that, when in a negative emotional state, individuals tend to have feelings of regret or disappointment associated with future events and seek to avoid these risks. Alternatively, individuals in positive emotional states tend to notice the benefits of risk-based decisions and make decisions that they perceive will lead to increases in positive emotions. In sum, prevailing theory is that negative emotional state is associated with risk averse decisions and vice versa. The implication is that the ability of an individual to perceive and act upon safety risk may be compromised as they naturally seek positive emotional states.

In addition to pure theory, researchers have shown empirical evidence for the relationships between emotion and risk-based decision-making. For example, Drevets and Raichle (1998) found evidence that under extreme emotional arousal the blood supply to the brain reduces in the regions of the brain that also process risk. This suggests that the same regions of the brain process risk and emotion and that the two functions are physiologically intertwined. Researchers have also shown experimentally that positive emotion leads to a more positive appraisals of stimuli (Isen and Shalke 1982; Isen et al. 1978) and that the subconscious influence of emotional state on decision-making is more prominent when decisions must be made over short time frames and under pressure (LeDoux 1998).

The major practical problem that emanates from the relationship between emotion and decision-making is that individuals often subconsciously rely on emotional states and become insensitive to true probabilities (Slovic et al. 2005). Mearns and McGraw (2001) showed evidence of this when they found that even individuals working in the same teams and in the same environments had vastly different perceptions of risk, which were explained by differing attitudes, beliefs, motivations, and experiences. They also observed that individuals may comply with established rules or pay attention to warnings quite differently because of varied perceptions of risk. This leads to conflicting perceptions of the organization's safety culture. The relationship between emotions and risk-based decision-making, offers an opportunity to influence safety decisions through emotional arousal or suppression. Since one goal of NIS is to discourage risk taking, we sought to promote emotions related to vulnerability and suppress positive emotions as they relate to dangerous situations.

Relationship between emotion and learning

Multiple studies have shown that emotional experiences during learning have the ability to motivate continued learning (Fassbender et al., 2012; Pekrun, 2006; Pekrun et al., 2009; Pekrun et al., 2002; Robinson 2013). The majority of studies show that positive emotions promote higher levels of learning as they promote curiosity, interest in gaining new knowledge, and desire to improve performance. However,

Pekrun et al. (2007, 2009) suggested that negative emotions can also bring about extrinsic motivation to avoid failure. Therefore, it is not surprising that Chung et al. (2015) found that *both* negative and positive emotions can motivate learners to pursue acquiring new knowledge. Albeit for different reasons, both positive and negative emotions can motivate an individual to achieve the same goals or end results. Thus, there is evidence that emotional valence (i.e., the extent to which emotions are aroused) is the key motivator for learning.

To explain the relationship between emotion and learning motivation, Lang (2006) proposed *Limited Capacity Model of Motivated Mediated Message Processing (LC4MP)* that suggests humans have two types of motivational systems (appetitive and aversive), which are unconsciously driven by emotional tone of the content delivered. Appetitive activation is driven by gaining knowledge or information that would be beneficial, whereas aversive activation focuses on remembering information that would keep the individual safe by avoiding danger. Pekrun (2006)'s control-value theory complements Lang's LC4MP by suggesting that positive activating emotions facilitate critical thinking and creativity while negative activating emotions enhance focus and attention to detail. From safety training standpoint, the aversive motivation system activation should be targeted to make workers remember hazards and mitigation strategies.

In the context of injuries, the relationship between emotional engagement and knowledge retention has been studied indirectly and the relationship appears to be mediated by arousal. It has been documented that people can recall injuries or other shocking events in sharp detail for years following the events (Peterson and Bell, 1996; Peterson and Whalen, 2001; Bahrick et al., 1998). In fact, these details are so powerful that people remember the context of the information, time, and how the event impacted them (Christianson, 1989). Memory enhancements due to arousal occur when the basolateral nucleus of the amygdala and regions of sensory and mnemonic processing system interact and when there is release of glucocorticoids (McGaugh, 2004; Wolf, 2008). Interestingly, arousing emotions are also needed to activate

motivation for enhanced learning and the development of durable memories (LaBar and Phelps, 1998). Arousing information also has a mnemonic benefit that tends to increase knowledge retention (Kensinger and Schacter, 2008). Thus, emotions develop meaningful connections with information provided, promote more accurate recall of details of an event, and help individuals to use knowledge aptly in future decision-making situations (Medin and Ortony, 1989; Thiel et al., 2011).

There are some limitations of using emotional arousal to enhance learning. For example, memories associated with emotional arousal may degrade over time and become less accurate (Kensinger, 2009). Additionally, arousal causes narrowing effects on memory that focuses memory development on only the elements of education that elicited arousal (Buchanan and Adolphs, 2002; Mather, 2007; Reisberg and Heuer, 2004). Interestingly, one may argue that such focus can be advantageous in safety training, especially when traditional material is mundane and routine and an instructor desires to emphasize specific concepts. However, to avoid excessive narrowing of attention, multiple episodic details were avoided to reduce focal enhancement (Kensinger, 2009). When delivering safety training one must not only consider prevailing psychological constructs but also focus upon enhancing learning by considering the distinctive needs of adults.

Principles of adult learning

There is a growing consensus among researchers that adults learn very differently from children and the needs of adult learners must be met when designing any professional education or training session. Compared with pedagogy, which focuses on learning with children and adolescents (i.e. college students), adult learning has received comparatively little attention. Most of the research regarding adult learning is behavioristic and researchers place adults in the same test conditions as children and ignore relevant life-experiences (Merriam, 2004). Wilkins (2011) proposed that the safety training practices are woefully failing in communicating knowledge and skill sets in a manner that would be retained by adults. The simulations aim to address this knowledge gap. There is a strong consensus that adults are active learners and thrive in

learning experiences where information has clear purpose and is delivered in accordance with their experiences and cultural backgrounds (Hollins and King, 1994). Most adult learners bring knowledge and experience as a part of their background, which influences how and why they learn (Cross, 1981). Effectiveness of the adult learning experience is further enhanced in cooperative and collaborative environments where tasks and problems are relevant to their experience (Brillinger, 1990).

Andragogy is one the first adult learning theories to rise to prominence. It is based on assumptions of encouraging self-reflection, eliciting past experience, ensuring readiness to learn, focusing on real-world problems rather than pure theory, and building relevance of knowledge with context (Knowles, 1980; 1984). In short, adults need to be motivated, understand why they are learning something, and see how the material relates to their personal or professional lives. The assumptions of andragogy have been however, criticized by some as generic good practice principles rather than a robust theory (Hartree, 1984). As Merriam (2004) notes, adults are not always motivated learners and techniques must be employed to encourage interest and engagement. Merriam (2004) and Grace (1996) also criticize andragogy for its the lack of context, and a failure to embrace the relevant cultural, social and historical aspects deep rooted in the diverse demographics of the adult learners. Further, typical one-size-fits-all andragogy is limited because Specht and Sandlin (1991) found that adults prefer self-directed learning and learn only what they want to learn. This is true even under threats of coercion (Boyatzis, 2002). Adults learn selectively and also want control over how, when, where, and what pace they want learn the information provided to them (Baskett, 1994).

Incorporating elements of self-directed learning helps to address some of the limitations of traditional andragogy. Self-directed learning is a process that empowers adults to take control of their learning by controlling learning objectives and managing the learning experience (Garrison, 1992). Specifically, the self-directed learning model consists of self-management (contextual control), self-monitoring (cognitive responsibility), and motivational factors (Garrison, 1997). Self- directed learning is an intentional attempt facilitate learning that supports behavioral change (Boyatzis, 2002).

In addition to integrating elements of self-directed learning in NIS, it is critical to consider the culture of the learner. A core component of adult learning is culturally relevant education because learners (especially ones from marginalized backgrounds) care about knowledge that would improve their personal and social well-being (Hollins et al., 1994). In the design of NIS, culture of the workforce was considered in the delivery of new knowledge and in the methods used to elicit emotion.

Relationship between culture and emotion

Emotions are felt and expressed differently across cultures (Markus and Kitayama, 1994; Mesquita, 2003). Matsumoto et al. (2008) sampled 3,386 participants in 23 countries and documented that there are differences in self-reporting of emotions among European American, African, Asian, and Hispanic people. Furthermore, Wierzbicka (1999) suggests that linguistic differences play a pivotal role in our varying understanding of different emotions across cultures. Since, culture governs social behavior and perception of what is ‘socially appropriate’, the elicitors of emotions must consider these factors. Jeanne Tsai’s *Affect Evaluation Theory* reasons that emotions that enhance values and principles of a culture are valued and elicited accordingly (Tsai 2007). In the design of NIS, we aim to understand and address the cultural differences between the two predominant cultures in the US construction industry: Caucasian and Hispanic.

Simulation-based training in other industries

Although the NIS is new to the construction industry, it was important to build upon successes and avoid failures with naturalistic simulations used in other industries. In late 1960’s, full-body mannequin simulators were being used as part of training in the field of anesthesia. Since then, simulation-based training has diffused into various industries and is considered to be superior to lecture-based training in fields including medical, aviation, and military (Steadman et al., 2006; Moorthy et al., 2005).

In most occupations, human performance is largely dependent on interactions with the task and the environment (i.e., situational awareness). To enhance performance, individuals are exposed to simulated scenarios to improve judgment and critical thinking. For example, pilots are often trained in a high-fidelity simulator with working instruments and realistic visual representation of environment (Helmreich, 1997). Flight simulators are used to provide stress training led to participants having greater control of an aircraft, especially in unusual situations (McClernon et al. 2011). Additionally, like aviation, the National Aeronautics and Space Administration and U.S. military built the Crew Resource Management system to improve skills of the crew to manage resources properly (Billings and Reynard, 1984; Jensen and Biegelski, 1989).

McKenna et al. (2006) found that naturalistic simulations improved hazard detection and improved anticipation of danger, thereby reducing risk-taking behavior. The authors suggested that participants may partake in dangerous activities simply because they are oblivious to hazards around them. In those cases, simulated training can be beneficial as they might make participants cognizant of risks without endangering them.

Despite the potential benefits of naturalistic simulation, researchers have not reached consensus with respect to impact of simulations on risk-taking behavior. For example, Kruegar and Dickson (1994) suggests that training increases self-efficacy, which increases risk-taking and Gregersen (1996) demonstrated that the number of accidents after mandatory training increased due to increased confidence. Alternatively, McKenna et al. (2006) found that hazard perception training using video simulations and lab-validated questionnaires led to a reduction in risk-taking while improving drivers' hazard perception. Additionally, Lerner and Keltner (2000; 2001) showed that activities that increase *fear* and *anxiety* enhance risk-aversion. These naturalistic simulations are not just meant to be a tool for safety training but also a means to enhance emotions that would make workers more cautious and retain more knowledge.

RESEARCH QUESTIONS AND CONTRIBUTIONS

The literature review was used to build our research questions and to design our longitudinal experiment. Our null hypothesis was that *naturalistic injury simulation does not cause emotional arousal during safety training*. Our associated research questions were:

1. Do workers experience a strong emotional engagement when participating in NIS?
2. What are the differences in emotional reactions to NIS for various demographics?
3. What are the theoretical implications and observed emotional reactions on risk-taking, learning, and knowledge retention?

RESEARCH METHODS

The research methods involved three steps: (1) strategically building NIS to leverage theories of emotional engagement, foster adult learning, and promote risk aversion; (2) conducting a longitudinal experiment to measure the extent to which worker emotions changed immediately after the NIS; and (3) statistical testing the significance of any observed changes in worker emotions and differences among demographic groups. This section describes the details of these three phases. Emphasis is placed on how and why the NIS were developed in an effort to enhance the reliability and replicability of the study.

Creation and delivery of NIS

NIS were designed to elicit strong emotional reactions that relate to risk aversion and to promote adult learning and retention of new knowledge. The specific design features of the NIS that help to achieve these goals are described as follows and are summarized in Table 4.

NIS delivered to participants on site had the same learning objectives, which were simple and fundamentally related to hazard recognition. By the end of the NIS, the learning objectives were for participants to be able to perform the following for a particular work scenario:

1. Identify potential and kinetic energy in a work environment that has the potential to cause injury or illness
2. Predict and explain how the energy may be released and cause injury;
3. Predict and explain the impact of energy on the human body; and
4. Devise a plan to remove, contain, or otherwise protect against contact with energy.

Table 4: Crosswalk table showing Naturalistic Injury Simulations design and delivery strategies to achieve emotion arousal and learning goals

Strategies used during NIS		Depiction of real, serious injuries	Using Prospect Theory to frame dread	Hyper-realism	Identifying own knowledge gaps	Reflecting on relevant past experience	Group discussions of potential outcomes	Instructors and peers with same cultural identity	Multiple media forms (physical, video, verbal)
Goals	Negative emotional arousal	x	x	x			x		
	Self-reflection	x			x			x	
	Self-management				x	x			
	Self-monitoring					x			
	Motivation				x	x			x
	Social interaction						x	x	
	Cultural relevance							x	
	Address learning styles								x

Eliciting strong emotional responses through strategic design of NIS

Although humans experience emotions at virtually all times, emotional arousal occurs when people feel elevated or even extreme levels of emotion. This typically occurs after an unusual or extreme event or experience. For example, for most people, observing a severe injury in a familiar work environment would represent an extreme event that would elicit arousal. Thus, one of the definitive characteristics of the NIS was that they were so realistic that they virtually equivalent to witnessing a real injury.

To achieve a heightened emotional response, two simulations (injury due to falling objects or pinch points) were designed. The extent to which NIS represents actual injuries was defined by the realism of the injury circumstance, equipment and tools used in the simulation, and synthetic body part. The authors chose two of the most common hand injuries according to the Safety and Health Council of North Carolina (2014), namely those caused by falling objects, and pinch-point injuries (i.e., where a hand is caught between two moving objects).

Artificial hands were built using life-casting techniques primarily used in the fields of dentistry and prosthetics. Specifically, we casted actual human hands using alginate (i.e., the same process used to form a cast of a human tooth), created a negative cast using urethane plastic, and re-created a two-piece positive mold using high-performance silicone rubber. Ultimately, this process yielded a mold that could be used to make multiple replications of the hands and allowed for the placement of internal components within the hands (bones and blood bladder). Each new hand included flesh with nearly exact physical properties of a human flesh, network of veins and arteries, and bones. Some hands were cast in natural flesh color to enhance realism during the initial inspection by the participants and others were cast clear (see Figure 1 and Figure 2) so that the participants could witness the extent of damage to internal hand structures after the simulation was complete.

To illustrate the level of realism achieved in the creation of the hands, Table 5 provides a complete comparison between the fabricated hand and the average adult human hand according to the manufacturer's material data sheets for the products used to make the synthetic hand and the Oxford Handbook of Clinical Medicine (Longmore et al., 2014). As one can see from Table 5 and Figure 5, the hands were sufficiently accurate to serve as a realistic proxy.

Table 5: Comparison between Real and Simulation Hand

Properties	Fabricated Hand	Actual Human Hand
Specific Gravity	1.070 g/cc	1.067 g/cc
Hardness	10 A	10 A
Tensile Strength	475 psi	421 psi
Elongation at Tear	364%	245%
Die B Tear Strength	102 pli	100 pli
Shrinkage	<0.001 in/in	<0.001 in/in
Bone Shear Strength	70 Mpa	52 Mpa
Bone Breaking Force (index finger)	280 lbs.	267 lbs.

In addition to the realism of the human hands, the two NIS also involved the actual materials and equipment involved in past injuries. The two injury NIS circumstances and the methods of delivery are briefly described below.

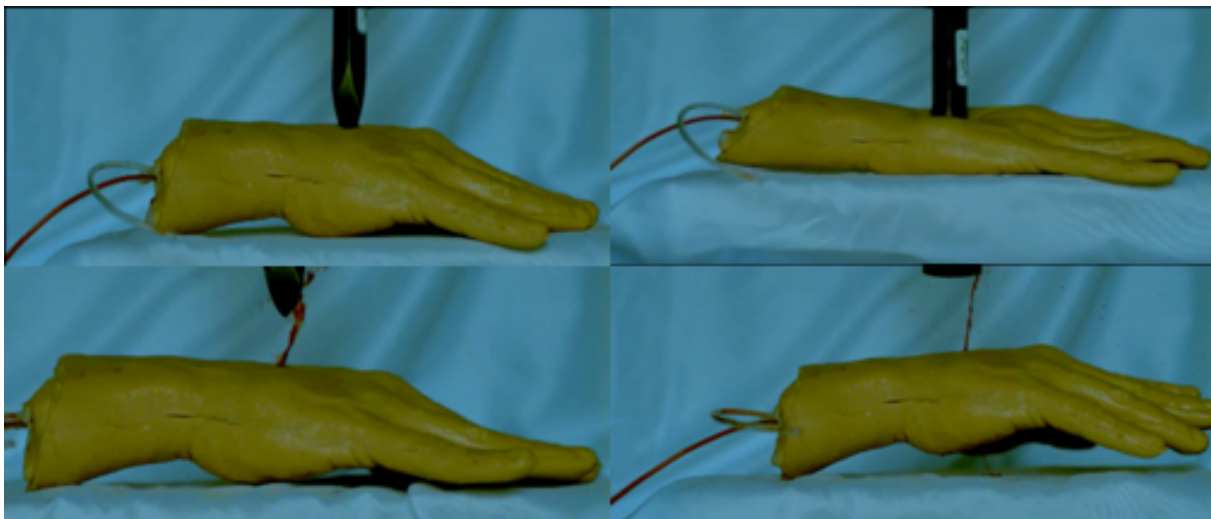


Figure 5 Artificial hand being struck with concrete chisel in the dropped objects NIS shown from screen shots of a single drop

Falling object injury where a worker's hand was struck by a falling concrete chisel This demonstration replicated an actual disabling injury where a carpenter dropped a 1-kilogram concrete chisel from 3 meters when stripping concrete formwork. The falling chisel was dropped by a formwork carpenter who was working at height. The chisel struck the hand of a worker below resulting in three broken phalanges and nerve damage. Ultimately, the injured worker sustained a permanently disabling injury that led to limited use of the hand.

To re-create these circumstances, a simulated work scenario was built in full scale. In the simulation a worker was safely positioned at 3 meters above the ground surface. A synthetic hand, was positioned directly below the worker at height. Using a clear PVC column, the actual 1 KG concrete chisel was dropped onto the synthetic hand. The event was performed live and was also recorded with a high-speed camera at 2,100 frames per second. Once the event occurred, it was replayed for the workers in slow motion so that the release of energy, transfer of energy, and damage to the hand could be clearly viewed. The point of impact and damage to the hand is shown in Figure 5.

Pinch point injury where a worker's hand was caught between a steel pipe and a pipe coupling: This demonstration replicated another hand injury where a worker was in the process of connecting a 3-inch steel pipe to a corresponding pipe coupling. During installation the pipe sling shifted and the worker's hand was pinched between the pipe and the coupling. The result of the injury was a deep flesh wound and nerve damage.

Similar to the falling chisel demo, this demonstration involved a full-scale simulation a section of 3-inch pipe was suspended to a pipe sling and placed adjacent to a 3-inch steel pipe coupling. The physical model was designed so that the sling could be manually released causing the suspended pipe to strike the pipe coupling via horizontal motion. During the simulation, the synthetic human hand was placed in the line of action between the pipe and coupling. The event was captured with the same videography techniques and was shown to the workers as the demonstration as discussed. The point of impact and damage to the hand is shown in Figure 6.



Figure 6 Artificial Hand Caught in the pipe and coupling pinch-point NIS

The two simulations were designed to be as realistic as possible while keeping all participants safe. Participants were encouraged to touch and inspect the physical models and the fabricated hands before the dynamic portion of the simulation. This not only heightened levels of realism for the workers, it also built excitement as the demonstration unfolded. Prevailing literature suggests that the level of realism in these demonstrations coupled with slow-motion videos would lead to arousal of a wide range of emotions.

Promoting risk aversion

When designing these simulations, we targeted arousal of emotions that have been associated with increased perception and lower tolerance of risk. This was important as Hallowell (2010) found that the only personal factor that affects an individual's risk tolerance is their previous personal injury history. Other personal factors like age, experience, marital status, family composition, and others showed null effects. Unfortunately, the logical implication is someone must be injured in order for risk tolerance to change. Therefore, to increase the potential for changed risk perception, the NIS were designed to provide workers with the experience of witnessing a severe injury without actual harm.

The authors used Kahneman and Tversky's (1979) *Prospect Theory* when framing the NIS as a method to maximize potential for risk perception change. This theory suggests that people prefer a risky option over a less variable option when choices are framed in a positive way (e.g., a reward for risk taking) and vice versa. Furthermore, the goal was to frame the proposed training setup to promote dread, which Burke et al. (2011, p.63) defined as, "realization of the dangers associated with ominous hazards and the experienced feelings that one has about the possibility of such events/exposures." Promoting dread is desirable because Burke et al. (2011) also found that workers learn and performed better under high hazardous-event/exposure-severity when engagement during safety training was positive and high. Finally, the authors considered the framing effect discussed by Slovic (2000) and Gordon-Lubitz (2003), which suggests that removing the thrill component from the risky option increases the likelihood of increasing perception and decreasing tolerance of risk because the positive outlook associated with thrill sensation of risk-taking is outweighed by feelings of fear and vulnerability. The review of these theories suggests that NIS should not only induce dread but also reduce thrill component from indulging in risk-taking behavior. Interestingly, stimulating dread was similar to stimulating emotional arousal, which involved replicating an actual event, including actual tools and equipment involved in the injury, reflecting on and discussing similar incidents that participants had experienced in their own past, having participants touch and inspect

the synthetic hand before and after injury, and showing the high-speed video showing the details of the injury (Figure 5 and Figure 6).

Promoting adult learning

Researchers have been testing various factors that improve adult learning in occupational contexts to enhance the effectiveness of training (Billett, 2001; Reio and Wiswell, 2000). They have found that training must involve multiple forms of verbal and visual stimuli that address relevant occupational issues. Furthermore, image and video training provide visual stimuli but lack the tactile nature of a physical simulation. Forms of active learning with tactile sensations learning have been found to be more effective than passive lecture formats and videos (Emerson et al. 2015; Green 2014). Physical demonstrations have been used in classrooms as a means to improve learning (Green 2014) and simulation-based training in a quasi-experimental experimental research by Akhu-Zaheya et al. (2013) has been found to engage, enhance knowledge retention, and improve self-efficacy among students. Naturalistic injury simulation bridges this gap in current safety training within the construction domain by using simulations alongside traditional verbal and visual learning cues.

The NIS were specifically developed and tested using the principles of Generative Theory of Multimedia Learning (Mayer, 1997). As Mayer (1997, p.4) suggests, “multimedia instruction affects the degree to which learners engage in the cognitive processes required for meaningful learning within the visual and verbal information processing systems.” Since adults seek learning approaches with significance to everyday life (Lindeman, 1956), learning was based on relevant safety problems faced in daily working routines. In contrast to generic presentation-based training programs (e.g., PowerPoint slides), multimedia styles of learning like NIS are theoretically more effective as they address a wider variety of learning preferences with physical demonstrations, visual models, discussions, and interaction among participants. As previously discussed, the key features of the NIS were realism, repetitiveness of actual past injuries, and common work environments.

Additionally, when developing the delivery strategy (i.e., interaction between trainers and participants and among participants) the authors used Garrison (1997)'s self-directed learning model comprised of three components: self-management, self-monitoring, and motivational factors. To facilitate *self-management* workers were asked to share their personal experiences of occupational injuries and suggest mitigation strategies for the simulated scenario. This created meaningful context driven conversation by allowing the workers to take control of their learning. Incorporating elements of *self-monitoring* requires constructing relevance and subsequently acquiring new knowledge or enriching previous knowledge (Garrison, 1997). In each step of the NIS the crew was asked to use their existing knowledge to predict the outcome of the simulation. Then, explanations of the physics surrounding the injury were provided to fill knowledge gaps and improve future predictions. This process was designed to help workers gain new knowledge while reinforcing existing fundamental safety concepts. *Motivation*, the final component of the self-directed learning model, involves developing interest in the subject matter (Renninger et al., 1992). A few of the characteristics of the NIS that enhanced motivation were hands-on engagement, novelty, social-interactions, content, and narrative (Bergin, 1999).

Addressing cultural demographics

Since the sample involved a healthy mix of Hispanic and Caucasian workers, we were careful to design the NIS and its delivery to be compatible with the social norms of the two groups. In particular, the authors aimed to provide effective safety training to Hispanic workers who account for an injury and fatality rate that is 48% higher than their Caucasian counterparts (Center of Construction Research and Training, 2013). Through interviews with Hispanic construction workers, Hallowell and Yugar-Arias (2016) found that Hispanic workers felt that safety training was not tailored to their language and other cultural needs. Thus, the NIS were delivered in both English and Spanish so that participants could select the language of their preference. Also, since Brookfield (1995) found that adults learn better when they are taught by

someone of the same ethnic background, the Hispanic groups were trained by a peer from same ethnic background and fluent in Spanish.

Experimental method and data collection

The simulations were delivered to 1,200 construction workers during a one-week period in the Southern United States in 16 different sessions. Out of the 1,200 workers, 489 (~41%) participated in the surveys. Participation was voluntary and uncompensated. The authors opted to promote a natural setting of the construction worksite and actual construction workers over a controlled laboratory environment. This compromised the authors' ability to include a control group and manipulate other experimental controls that discount the effects of confounding variables. In an effort to preserve internal validity we controlled for many external variables. For example, the rooms were well-ventilated, temperature controlled, well lit, there was minimal to no external noise, and the appearance and demeanor of facilitators was consistent across all groups and neutral to avoid any undue influence on participant's emotional state. Additionally, since the NIS were delivered to actual workers in a familiar work environment, we greatly enhanced ecological validity. Finally, the fact that data were from 489 workers over 16 different sessions with a wide variety of demographics allowed us to perform internal consistency checks.

The surveys were administered in two parts: pre-NIS and post-NIS. That is, workers were asked to complete a brief questionnaire prior to the NIS that included demographic questions and an emotional state inventory. After the NIS, the same workers were asked to answer the emotions questions once again. The pre-NIS and post-NIS emotions surveys were identical. To connect the measures over time we requested an anonymous password. A password was used in lieu of a name to ensure confidentiality and anonymity. The participants were also allowed to choose between an English or Spanish questionnaire.

Participants were asked demographic questions about their age, gender, ethnicity, education level, marital status, personal accident history (i.e., if they had ever seen or been injured before), and the number of years of experience in the industry. The key demographics of our sample are as follows:

- 69% married;
- 50% previously witnessed a severe injury first-hand;
- 23% previously injured (recordable injury or more severe);
- 6% have a bachelor's degree or higher, 32% have some college education, 57% completed high school, 4% have no education;
- 70% were Hispanic and 30% were Caucasian;
- Average age was 38 years;
- Less than 1% female

Since the sample contains high variability in the demographics with the notable exception of gender, we were able to generalize findings to a larger population.

Participant's emotional states were measured with a commonly used emotions self-report form. A small sample of the questionnaire is shown in Figure 7. The questionnaire requires participants to self-report and rate the intensity of 18 emotions that include basic (e.g., happiness, anger, sadness) and complex emotions (e.g., guilt, embarrassment) on a 9-point Likert scale. This type of emotion inventory questionnaires has been validated and successfully used in past applied psychological studies (Gross and Levenson, 1997; Lerner and Keltner, 2001; Rottenberg et al. 2007).

It is important to note that emotions can be quite fickle and last from only a few minutes to days (Gilboa and Revelle, 1994). For example, Verduyn et. al. (2009; 2011) found that fear, anger, joy, and sadness are most fleeting and typically last for 10 minutes. Thus, to enhance internal validity, we allowed

no more than a 3-minute lag between the end of the NIS and commencement of post-simulation survey. The survey itself took everyone approximately 5 minutes to complete.

Please indicate the degree to which you are currently feeling these emotions (please fill in dots)									
	1	2	3	4	5	6	7	8	9
	Not At All			Somewhat				Very	
<i>Example</i>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Amusement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Anger	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Anxiety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 7: Sample of questionnaire

RESULTS

To explore the changes in emotions before and after the simulations, we used a paired t-test. Paired t-tests is preferred because the data were normally distributed and the pre- and post-NIS surveys could be linked to one person (McDonald 2014). The paired t-tests aimed to test the null hypothesis that there was no difference in pre- and post-NIS emotional states. The results were considered statistically significant only if the confidence was over 95% ($p < 0.05$).

Table 6 shows the changes in emotions over the entire sample of 489 construction workers. Overall, the workers did experience a strong emotional reaction to the NIS. The results with statistical significance (shown in bold in Table 6) show that immediately after the simulations participants felt less positive and more somber, apprehensive, and vulnerable. Thus, results affirm that the NIS accomplished the stated objectives and reject the stated null hypothesis.

Table 6: Overall changes in emotional states

Emotions	Percent	P-value	Percent	P-value	Percent	P-value
	Change		Change		Change	
			(Hispanics)		(Caucasians)	
Amusement	3.22%	0.42	4.66%	0.33	-0.76%	0.91
Anger	-6.06%	0.26	-9.82%	0.11	-0.61%	0.96
Anxiety	7.78%	0.14	4.52%	0.52	13.9%	0.18
Confusion	-14.3%	<0.01	-12.1%	0.03	-19.0%	0.02
Disgust	10.5%	0.07	8.76%	0.20	12.7%	0.24
Embarrassment	-4.00%	0.50	-5.16%	0.45	-5.88%	0.49
Fear	47.5%	<0.01	39.6%	<0.01	75.6%	<0.01
Guilt	11.2%	0.04	11.8%	0.09	8.73%	0.31
Happiness	-28.4%	<0.01	-27.0%	<0.01	-32.2%	<0.01
Joy	-23.8%	<0.01	-21.0%	<0.01	-31.5%	<0.01
Love	-28.0%	<0.01	-25.2%	<0.01	-34.8%	<0.01
Pride	-21.5%	<0.01	-21.6%	<0.01	-20.3%	<0.01
Sadness	35.9%	<0.01	34.0%	<0.01	38.4%	<0.01
Shame	5.16%	0.38	1.83%	0.81	27.7%	0.02
Surprise	47.3%	<0.01	43.6%	<0.01	68.9%	<0.01
Unhappiness	15.0%	0.03	18.6%	0.03	7.10%	0.49

In addition to general changes in emotion, tests were conducted to observe if there were significant changes in emotions for different demographical dimensions. It is because of the prevailing theory of cultural differences in learning that authors highlighted the differences in emotional responses between Caucasian and Hispanic participants. The various demographic tests are described subsequently.

Changes in emotions of the different demographical subgroups (e.g., Caucasians versus Hispanics, older workers versus younger workers) was also analyzed using a basic two sample t-tests.

Ethnicity

Within the sample of 489 workers, approximately 70% identified as Hispanic and 30% as Caucasian. To explore the potential influence of culture, the authors tested for change in emotional response among Hispanic and Caucasian workers separately. Table 6 shows that both groups experienced an increase in negative emotions and a decrease in positive emotions. Caucasian workers registered high fear and surprise levels and Hispanic workers showed an increase in unhappiness. These results are significant because both ethnic groups reacted to NIS similarly despite major cultural differences. This can be explained by referring to De Leersnyder et al.'s (2011) study, which found immigrants often start feeling emotions the same way as the host culture depending on engagement and amount of exposure. Training through Naturalistic injury simulation will develop strong emotional connection among workers regarding safety that transcends cultural barriers. Although arousal levels varied, both groups showed changes over various emotional dimensions in the same direction.

Age

The average age (38 years) of the study sample is quite similar to the target population's (41.5 years), suggesting a strong ecological validity (CPWR 2014). The participants were divided in two categories of below or equal to 38 (55% of the sample), and above 38 years (45% of the sample). Overall, the changes across both demographics were similar. However, the younger age group registered a significant decrease in anger (refer to Table 7), which is of particular interest because anger stems from evaluations that deem others responsible for errors (LeBlanc et al. 2015) and is linked with high certainty and power over a situation along with an optimistic assessment of future and lower risk perception when compared with fear (Lerner and Keltner 2000).

While the younger group experienced a decrease in anger after the NIS, the older age group experienced an increase in anxiety. This is important because Eisenberg et al. (1998) found that more anxious participants were more risk averse than their low-anxiety counterparts. Anxiety and other stressful emotions are linked with extrinsic motivation to avoid failure in a learning environment (Pekrun et al. 2009; Pekrun et al. 2007).

In sum, we theorize that the NIS promoted slightly different but desirable emotional states among workers across wide age spectrum.

Years of Experience and Marital Status

Although analyzed independently, years of experience and marital status were grouped in this discussion because they showed similar directions and magnitudes of change. Since the median number of the years of construction experience was 9, years of experience was divided into two groups: less than or equal to 9 years of experience (45% of sample) and above 9 years of experience (55%). Also, 69% of our sample consisted of married workers.

Workers with more than 9 years of experience and workers who are married showed significant increase in guilt and disgust (refer to *Table 7*). According to Chapman et al. (2012) disgust gives a stronger reaction than fear when recalling images of an event. Also, disgust tends to persist longer (Rachman, 2004). From the point of view of safety training, this is desirable because disgust improves retention and promote future risk avoidance. Furthermore, workers with more than 9 years of experience also registered a statistically significant increase in shame. Having emotions of guilt and shame suggest there may be a sense of regret regarding actions taken in past. These emotional changes suggest that workers will potentially foster a desire to alter future decisions and actions.

It is important to also note that workers who are single and workers with less experience showed a less intense change in negative emotions compared to their respective counterparts. Interestingly, more experienced and workers who reported they are married showed statistically greater arousal for every negative emotion group (see *Table 7*). For example, the less experienced/single subjects showed no statistically significant change in unhappiness. Thus, it would seem that NIS were more impactful in generating a stronger emotional engagement with more experienced and/or married workers. These findings contradict what would be expected from some of the existing literature. For example, Lawton et al. (1992) and Mroczek and Kolarz, (1998) found that with age comes better emotional control and less negative emotional change. One possible explanation for our observation is that the context and environment of the study caused older, more experienced, and married workers to reflect on their past experiences and the importance of their personal well-being. It has been noted in past literature that workers that are married and/or older will be safer than their counterparts (Cohen, 1977; Choudhry et al., 2009). Thus, the idea that negativity bias decreases with age (Neiss et al., 2009) may not hold in an occupational context where safety is paramount.

Education

Participants were asked to choose from the following options: a) no education, b) high school education, c) some college education, or d) bachelor's degree or higher. Lack of sufficient number of participants in the no education and bachelor's degree or higher meant there were no meaningful comparisons (inadequate power) to report. The sample consisted primarily of 32% workers that had some college education and 57% had completed high school. Both groups showed nearly identical changes decrease in wide array of positive emotions. (refer to *Table 8*). Fang et al. (2006) and Kunar and Bhattacharjee (2006) found that lack of formal education results in higher risk and injury rate. Having a desired similar emotional reaction among both groups with varying education level shows NIS can build engagement with wider audience.

Injury history

As mentioned earlier, participants were asked to choose if they had a) never been injured, b) first-aid, c) lost-work/hospital time, or d) permanent disablement. Also, participants were also asked to choose from the following options: a) have never seen an injury, b) have seen a first aid, c) have seen a lost work time injury, d) have seen a permanent disablement injury, or e) have seen a fatality. In the event that participants have been involved in or have seen multiple injuries of varying severity levels, participants were advised to choose the highest severity injury they sustained or witnessed. One can see from results (refer to *Table 8*) that there were significant differences in emotional reaction among these groups. Workers that never seen or been injured register an increase in disgust and were the only workers to register an increase in unhappiness. A possible explanation is that the NIS challenged these workers the most to form memories that have high shock value and relevance to their well-being. Other workers who have been injured/seen injuries, may have unintentionally desensitized themselves to reduce disagreeable negative emotions to stimuli that produce such emotions (Carnagey et al., 2007)

Participants who had experienced an injury showed a decrease in positive emotions but not a substantial increase in negative emotions. This finding is curious and contradictory to what we expected. According to literature, when survivors are confronted with reminders of a trauma they tend to replay their inceptive response of the event (Keane et al., 1985). Therefore, we expected a heightened emotional response from previously injured workers. A possible explanation for our finding is that participants with previous history of loss or trauma may exhibit emotional dissociation to avoid unpleasant thoughts, emotions, and memories (Weinberger, 1990). This is a critical finding that demands further inquiry.

Table 7: Percent change in emotions for all the demographic groups¹

Emotions	Age		Marital Status		Years of Experience		Education	
	<= 38 yrs.	> 38 yrs.	Single	Married	<= 9 yrs.	> 9 yrs.	High School	Some College Educ.
Amusement	12.8%	-	-	-	-	-	-	-
Anger	-14.7%	-	-	-	-	-	-	-
Anxiety	-	21.2%	-	-	-	-	-	-
Confusion	-13.4%	-15.0%	-	-12.2%	-	-17.6%	-15.1%	-16.7%
Disgust	-	-	-	17.2%	-	16.5%	-	-
Embarrassment	-	-	-	-	-	-	-	-
Fear	28.5%	69.2%	39.6%	55.1%	36.6%	63.3%	42.9%	52.7%
Guilt	-	-	-	16.1%	-	17.9%	-	-
Happiness	-27.0%	-30.2%	-25.1%	-29.4%	-29.5%	-29.3%	-29.4%	-26.65
Joy	-21.1%	-26.3%	-21.4%	-25.2%	-22.4%	-26.1%	-21.8%	-24.4%
Love	-29.7%	-26.6%	-28.1%	-28.6%	-28.4%	-30.3%	-30.2%	-23.1%
Pride	-21.8%	-21.0%	-22.5%	-21.0%	-23.2%	-21.6%	-23.3%	-18.0%
Sadness	20.9%	46.5%	-	47.8%	24.9%	42.2%	38.3%	31.7%
Shame	-	-	-	-	-	24.7%	-	21.7%
Surprise	45.5%	49.7%	50.7%	45.9%	29.6%	62.3%	33.6%	71.6%
Unhappiness	-	25.0%	-	25.5%	-	27.2%	-	-

¹Only statistically significant (p<0.05) values are shown in the table. No value (-) signifies change in emotional state was not statistically significant.

Table 8 Percent change in emotions for all the demographic groups¹

Emotions	Been Injured			Seen Injury			
	Never	First Aid	Lost Work time	Never	First Aid	Lost Work Time	Fatality
Amusement	-	-	-	-	-	-	-
Anger	-	-	-	-	-	-	-
Anxiety	-	-	-	-	-	-	-
Confusion	-13.3%	-	-35.1%	-	-20.8%	-	-
Disgust	14.9%	-	-	16.7%	-	-	-
Embarrassment	-	-	-	-	-	-	-
Fear	43.5%	65.5%	71.4%	47.2%	37.0%	70.1%	34.6%
Guilt	12.5%	-	-	-	-	-	-
Happiness	-28.6%	-25.1%	-32.9%	-29.05	-28.3%	-25.7%	-32.6%
Joy	-23.2%	-26.2%	-	-24.0%	-20.7%	-24.3%	-22.2%
Love	-26.0%	-38.2%	-	-30.0%	-23.9%	-25.6%	-30.7%
Pride	-22.5%	-20.9%	-	-26.4%	-13.8%	-24.4%	-16.6%
Sadness	43.5%	-	-	36.1%	25.6%	43.0%	-
Shame	-	-	-	-	-	-	-
Surprise	42.7%	57.3%	80.6%	34.5%	61.2%	43.4%	45.8%
Unhappiness	24.5%	-	-	20.5%	-	-	-

¹Only statistically significant (p<0.05) values are shown in the table. No value (-) signifies change in emotional state was not statistically significant.

IMPLICATIONS

As mentioned in the theoretical background section, emotions give us information about the riskiness in the environment around us (Johnson and Tversky, 1983) and it is overwhelmingly accepted that positive emotions lead an affinity towards taking risk (Clore et al., 1994; Keller et al., 2006; Gruber et al., 2011). Comparatively, the negative mood leads to more cautious and pessimistic outlook on taking risk (Öhman and Mineka, 2001; Yuen and Lee, 2003). Hence, the implication of these results is that NIS should ultimately lead to future risk-averse decisions.

Since induced emotions are often fleeting (Gilboa and Revelle, 1994; Verduyn et al., 2009; Verduyn et al., 2011), the authors were faced with the question: *will the effect of NIS be fleeting as well?* According to prevailing literature, the answer appears to be yes, but to a lesser extent than typical emotional experiences. According to Brown and Kulik (1977)'s flashbulb memory theory, an emotionally shocking event remains very well preserved in a long-term memory. This detailed recall mechanism is triggered when there is emotionally arousing and/or surprising information. Since we observed a very strong and statistically significant change in surprise and fear, Brown's theory supports the assertion that flashbulb memory did indeed take place. As observed by McClokey et al. (1988), Pillemer (1984), and Christianson (1989), flashbulb memory is still subject to deterioration over time but core information in these memories are less vulnerable to total loss. The authors suggest future research into the long-term impacts of NIS.

Finally, based upon adult learning literature, the implication of the emotional arousal observed is that NIS promoted a high degree of learning and high potential for the retention of new knowledge. Emotional engagement in a learning environment is linked with increased attention and improved memory for learning content (Joëls et al. 2006). As was discussed earlier, the emotions achieved through the NIS cause focal memory enhancement (Kensinger, 2009), instigate extrinsic motivation to continue learning (Pekrun, 2006), and yield a more detail-oriented and cautious approach towards solving problems (Bless

et. al. 1996). Thus, training programs such as NIS that involve emotional engagement are more likely to increase learning, retention, and problem-solving skills.

STUDY LIMITATIONS

As with any field research, there are limitations and trade-offs to the selected approach. Perhaps the most important limitation of this study was the inability to implement extensive experimental controls. As previously mentioned, the authors elected to collect data in a naturalistic setting at a worksite with actual construction workers to preserve ecological validity. The trade-off, however, was that we could not reasonably establish a control group nor could we randomly stage the NIS as an intervention in a longitudinal multiple baseline design. For logistical restricted, the experiment needed to be a before-after test. As such, the authors cannot draw causal inferences. However, as discussed, care was taken to carefully design the NIS to elicit specific emotional responses using guidance from a vast array of literature. Thus, the observed changes can be theoretically, although not experimentally, attributed to NIS.

Second, the data involved self-reporting of emotional state, which intrinsically involves reporting bias. Although self-reporting of emotions is a fast and efficient means of measuring different types of emotional responses, its accuracy is questionable given that it assumes an individual is aware of their emotions and able to distinguish complex emotions from one another. Individuals often generalize their emotional feelings or misinterpret their own emotional state. Although these biases exist, the sample size was large enough and the demographics broad enough that it is unlikely that there were systematic biases in emotions self-reporting. To address this concern, the authors suggest that future researchers include an emotional intelligence questionnaire when collecting self-reported emotions.

Third, there was an inherent discomfort observed by some participants. This discomfort was likely due to the fact that completing an emotions questionnaire may have been strange and confusing for

participants. Although surveys were anonymous, confidential, and voluntary; discomfort with the process could confound the results of some. Fortunately, the same process was implemented before and after the NIS so that any effects of the survey on emotions was likely captured both before and after the NIS.

Fourth, workers were part of large groups in each session (~75). This minimized our ability for trainer-subject interaction and large groups likely made some participants feel uncomfortable answering questions. This could have potentially impacted the learning experience for those workers who are shy and less dominant.

Finally, this study draws logical and theoretical implications of emotional change on learning, retention, memory formation, risk perception, and decision-making based upon a large and mature body of knowledge. However, given more resources, empirically studying these outcomes over an extended period of time would have been preferable. However, the resources required for such an investigation were unavailable to the project team. Training 1,200 workers cost the employers over 3,600 worker hours of productive time.

CONCLUSIONS

The work presented here is an effort to transform safety training practices to improve risk perception and learning by developing an emotional engagement with safety training. Building on established theories from psychology and education, the authors proposed NIS as a new simulation-based training approach that promotes emotional arousal.

From a theoretical standpoint, the results show that NIS is successful in arousing target emotions within the ecologically valid setting of a construction workplace. This is important because most standard safety programs fail to engage the adult workforce, which often leads to a negative outlook towards safety

issues (Haslam et al. 2005). Specifically, there was a surge in arousal of negative emotions that can alter an individual's perception of risk by reducing false optimism (Taylor and Brown, 1988). This condition is known to reduce risk-taking behavior, heighten risk-perception, and increase extrinsic motivation among individuals to learn. All the demographics sub-groups showed significant increase in fear and surprise. While both ethnic groups were quite emotional invested in NIS, Caucasian workers showed more arousal than Hispanics workers. Workers with no injury history and workers who haven't seen an injury showed an increase in complex emotions like disgust, which persist longer and end up leaving more lasting memories. All these changes were generally consistent across different demographic dimensions, suggesting strong generalizability.

Based on the findings there are interesting possibilities for future research. Other studies may build upon NIS by developing different body parts and scenarios, studying short- and long-term impacts on learning and knowledge retention, integrating NIS as a component of typical pre-task planning, measuring the duration of emotional arousal, and isolating the impacts of NIS through controlled experimentation. The findings from the present study suggest that NIS is a promising advancement in safety training that could transform safety training from passive and lecture-based to more effective, interactive and emotionally engaging.

REFERENCES:

1. Akhu-Zaheya, L. M., Gharaibeh, M. K., & Alostaz, Z. M. (2013). Effectiveness of simulation on knowledge acquisition, knowledge retention, and self-efficacy of nursing students in Jordan. *Clinical Simulation in Nursing*, 9(9), e335-e342.
2. Albert, A., Hallowell, M. R., and Kleiner, B. M. (2013). Enhancing construction hazard recognition and communication with energy-based cognitive mnemonics and safety meeting maturity model: Multiple baseline study. *Journal of Construction Engineering and Management*, 140(2), 04013042.
3. Albert, A., Hallowell, M. R., and Kleiner, B. M. (2014). Experimental field testing of a real-time construction hazard identification and transmission technique. *Construction Management and Economics*, 32(10), 1000-1016.
4. Bahrick, L. E., Parker, J. F., Fivush, R., & Levitt, M. (1998). The effects of stress on young children's memory for a natural disaster. *Journal of Experimental Psychology: Applied*, 4(4), 308.
5. Baskett, H.K.M (1994). Self-Directedness in the Workplace. Paper by H.K. Morris presented to the Eighth International Symposium on Self-Directed Learning. Florida.
6. Bechara, A., Damasio, H., and Damasio, A. R. (2000). Emotion, decision-making and the orbitofrontal cortex. *Cerebral cortex*, 10(3), 295-307.
7. Bergin, D. A. (1999). Influences on classroom interest. *Educational psychologist*, 34(2), 87-98.
8. Bhandari, S., Hallowell, M., Van Boven, L., Gruber, J., and Welker, K. (2016) Emotional States and Their Impact on Hazard Identification Skills. Construction Research Congress 2016: pp. 2831-2840. doi: 10.1061/9780784479827.282 .
9. Billett, S. (2001). *Learning in the workplace: Strategies for effective practice*. Allen & Unwin, PO Box 8500, St Leonards, 1590 NSW, Australia.
10. Billings, C. E., & Reynard, W. D. (1984). Human factors in aircraft incidents: results of a 7-year study. *Aviation, Space, and Environmental Medicine*, 55(10), 960-965.
11. Bless, H., Clore, G. L., Schwarz, N., Golisano, V., Rabe, C., & Wölk, M. (1996). Mood and the use of scripts: Does a happy mood really lead to mindlessness?. *Journal of personality and social psychology*, 71(4), 665.
12. Bonnet, A., Fernandez, L., Piolat, A., and Pedinielli, J. L. (2008). Changes in emotional states before and after risk taking in scuba diving. *Journal of Clinical Sport Psychology*, 2(1), 25-40.

13. Boyatzis, R. E. (2002). Unleashing the power of self-directed learning. *Changing the way we manage change*, 13-32.
14. Brillinger, M. F. (1990). Helping adults learn. *Journal of Human Lactation*, 6(4), 171-175.
15. Brookfield, S. (1995). Adult learning: An overview. *International encyclopedia of education*, 10, 375-380.
16. Brown, R., & Kulik, J. (1977). Flashbulb memories. *Cognition*, 5(1), 73-99.
17. Buchanan, T. W., & Adolphs, R. (2002). The role of the human amygdala in emotional modulation of long-term declarative memory. *Advances in Consciousness Research*, 44, 9-34.
18. Burke, M. J., Salvador, R. O., Smith-Crowe, K., Chan-Serafin, S., Smith, A., and Sonesh, S. (2011). The dread factor: how hazards and safety training influence learning and performance. *Journal of Applied Psychology*, 96(1), 46.
19. Carnagey, N. L., Anderson, C. A., & Bushman, B. J. (2007). The effect of video game violence on physiological desensitization to real-life violence. *Journal of Experimental Social Psychology*, 43(3), 489-496.
20. Carter, G., and Smith, S. D. (2006). "Safety hazard identification on construction projects." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2006)132:2(197), 197–205
21. Caruso, E. M., and Shafir, E. (2006). Now that I think about it, I'm in the Mood for laughs: Decisions focused on Mood. *Journal of Behavioral Decision-making*, 19(2), 155-169.
22. Center for Construction Research and Training, 2013. *The Construction Chart Book: The U.S. Construction Industry and its Workers*. Bethesda, MD.
23. Chapman, H. A., Johannes, K., Poppenk, J. L., Moscovitch, M., & Anderson, A. K. (2013). Evidence for the differential salience of disgust and fear in episodic memory. *Journal of Experimental Psychology: General*, 142(4), 1100.
24. Choudhry, R. M., Fang, D., & Lingard, H. (2009). Measuring safety climate of a construction company. *Journal of construction Engineering and Management*, 135(9), 890-899.
25. Chung, S., Cheon, J., & Lee, K. W. (2015). Emotion and multimedia learning: an investigation of the effects of valence and arousal on different modalities in an instructional animation. *Instructional Science*, 43(5), 545-559.

26. Christianson, S. Á. (1989). Flashbulb memories: Special, but not so special. *Memory & Cognition*, 17(4), 435-443.
27. Clore, G. L., Schwarz, N., and Conway, M. 1994. Affective causes and consequences of social information processing. *Handbook of social cognition*,1, 323-417.
28. Cohen, A. (1977). Factors in successful occupational safety programs. *Journal of safety research*, 9(4), 168-178.
29. CPWR (Center for Construction Research and Training). (2014). *The construction chart book: The U.S. construction industry and its workers*, Bethesda, MD.
30. Cross, K. P. (1981). *Adults as Learners. Increasing Participation and Facilitating Learning*.
31. Damasio, A. R., Everitt, B. J., and Bishop, D. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex [and discussion]. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 351(1346), 1413-1420.
32. De Leersnyder, J., Mesquita, B., & Kim, H. S. (2011). Where do my emotions belong? A study of immigrants' emotional acculturation. *Personality and Social Psychology Bulletin*, 0146167211399103.
33. Drevets, W. C., and Raichle, M. E. (1998). Reciprocal suppression of regional cerebral blood flow during emotional versus higher cognitive processes: Implications for interactions between emotion and cognition. *Cognition and emotion*, 12(3), 353-385.
34. Eisenberg, A. E., Baron, J., & Seligman, M. E. (1998). Individual differences in risk aversion and anxiety. *Psychological Bulletin*, 87, 245-251.
35. Emerson, T. L., English, L. K., & McGoldrick, K. (2015). Evaluating the Cooperative Component in Cooperative Learning: A Quasi-Experimental Study. *The Journal of Economic Education*, 46(1), 1-13.
36. Fang, D., Chen, Y., & Wong, L. (2006). Safety climate in construction industry: a case study in Hong Kong. *Journal of construction engineering and management*, 132(6), 573-584.
37. Fassbender, E., Richards, D., Bilgin, A., Thompson, W. F., and Heiden, W. (2012). VirSchool: The effect of background music and immersive display systems on memory for facts learned in an educational virtual environment. *Computers and Education*, 58(1), 490-500.
38. Garrison, D. R. (1992). Critical thinking and self-directed learning in adult education: An analysis of responsibility and control issues. *Adult Education Quarterly*, 42(3), 136-148.

39. Garrison, D. R. (1997). Self-directed learning: Toward a comprehensive model. *Adult Education Quarterly*, 48(1), 18-33.
40. Gilboa, È., & Revelle, W. (1994). Personality and the structure of affective responses. *Emotions: Essays on emotion theory*, 135-159.
41. Gordon-Lubitz, R. J. (2003). Risk communication: Problems of presentation and understanding. *JAMA*, 289(1), 95-95.
42. Grace, A. P. (1996). Striking a critical pose: andragogy--missing links, missing values. *International Journal of Lifelong Education*, 15(5), 382-392.
43. Green, A. (2014). The case for the traditional classroom. *International Review of Economics Education*, 16, 87-99.
44. Gregersen, N. P. (1996). Young drivers' overestimation of their own skill—an experiment on the relation between training strategy and skill. *Accident Analysis & Prevention*, 28(2), 243-250.
45. Gross, J. J., & Levenson, R. W. (1995). Emotion elicitation using films. *Cognition & emotion*, 9(1), 87-108.
46. Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: the acute effects of inhibiting negative and positive emotion. *Journal of abnormal psychology*, 106(1), 95.
47. Gruber, J., Mauss, I. B., & Tamir, M. (2011). A dark side of happiness? How, when, and why happiness is not always good. *Perspectives on Psychological Science*, 6(3), 222-233.
48. Haddon Jr, W. (1970). On the escape of tigers: an ecologic note. *American Journal of Public Health and the Nations Health*, 60(12), 2229-2234.
49. Hallowell, M. (2010). Safety risk perception in construction companies in the Pacific Northwest of the USA. *Construction management and economics*, 28(4), 403-413.
50. Hallowell, M. R., & Yugar-Arias, I. F. (2016). Exploring fundamental causes of safety challenges faced by Hispanic construction workers in the US using photovoice. *Safety science*, 82, 199-211.
51. Hartree, A. (1984). Malcolm Knowles' theory of andragogy: A critique. *International Journal of Lifelong Education*, 3(3), 203-210
52. Haslam, R. A., Hide, S. A., Gibb, A. G., Gyi, D. E., Pavitt, T., Atkinson, S., & Duff, A. R. (2005). Contributing factors in construction accidents. *Applied ergonomics*, 36(4), 401-415.
53. Helmreich, R. L. (1997). Managing human error in aviation. *Scientific American*, 276(5), 62-67.

54. Hollins, E. R., & King, J. E. (1994). *Teaching diverse populations: Formulating a knowledge base* (Vol. 1944). SUNY Press.
55. Isen, A. M., and Shalcker, T. E. (1982). Do you “accentuate the positive, eliminate the negative” when you are in a good mood. *Social Psychology Quarterly*, 45(March), 58-63.
56. Isen, A. M., Shalcker, T. E., Clark, M., and Karp, L. (1978). Affect, accessibility of material in memory, and behavior: A cognitive loop?. *Journal of personality and social psychology*, 36(1), 1.
57. Jensen, R., & Biegelski, C. (1989). Cockpit resource management. In R. Jensen (Ed.), *Aviation psychology* (pp. 176-209). Aldershot, England: Gower Technical.
58. Joëls, M., Pu, Z., Wiegert, O., Oitzl, M. S., & Krugers, H. J. (2006). Learning under stress: how does it work?. *Trends in cognitive sciences*, 10(4), 152-158.
59. Johnson, E. J., & Tversky, A. (1983). Affect, generalization, and the perception of risk. *Journal of personality and social psychology*, 45(1), 20.
60. Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, 263-291.
61. Keane, T. M., Zimering, R. T., & Caddell, J. M. (1985). A behavioral formulation of posttraumatic stress disorder in Vietnam veterans. *Behavior Therapist*, 8(1), 9-12.
62. Keller, C., Siegrist, M., and Gutscher, H. 2006. The role of the affect and availability heuristics in risk communication. *Risk Analysis*, 26(3), 631-639.
63. Keltner, D., Ellsworth, P. C., and Edwards, K. (1993). Beyond simple pessimism: effects of sadness and anger on social perception. *Journal of personality and social psychology*, 64(5), 740.
64. Kensinger, E. A. (2009). Remembering the details: Effects of emotion. *Emotion review*, 1(2), 99-113.
65. Kensinger, E. A., & Schacter, D. L. (2008). Neural processes supporting young and older adults' emotional memories. *Journal of Cognitive Neuroscience*, 20(7), 1161-1173.
66. Ketelaar, T. (2004). Ancestral emotions, current decisions: Using evolutionary game theory to explore the role of emotions in decision-making. *Evolutionary psychology, public policy and personal decisions*, 145-168.
67. Knowles, M. (1980). *The modern practice of adult education: From pedagogy to andragogy* (Rev. and Updated. ed.). Wilton, Conn.: Association Press.

68. Knowles, M. (1984). *The Adult Learner: A Neglected Species*. Houston: Gulf Pub. Kobasa, SC (1982). *The Hardy Personality: Toward a Social Psychology of Stress and Health*. In GS Sanders and J. Suls (Eds.), *Social Psychology of Health and Illness*, 3-32.
69. Krueger, N., & Dickson, P. R. (1994). How believing in ourselves increases risk taking: Perceived self-efficacy and opportunity recognition. *Decision Sciences*, 25(3), 385-400.
70. Kunar, B. M., & Bhattacharjee, A. (2006). Study of Some Occupational and Individual Factors in Coal Miners Injuries. *Journal of Mines Metals and Fuels*, 54(12), 356-361.
71. LaBar, K. S., & Phelps, E. A. (1998). Arousal-mediated memory consolidation: Role of the medial temporal lobe in humans. *Psychological Science*, 9(6), 490-493.
72. Lang, A. (2006). Using the limited capacity model of motivated mediated message processing to design effective cancer communication messages. *Journal of Communication*, 56(s1), S57-S80.
73. Lawton, M. P., Kleban, M. H., Rajagopal, D., & Dean, J. (1992). Dimensions of affective experience in three age groups. *Psychology and aging*, 7(2), 171.
74. LeBlanc, V. R., McConnell, M. M., & Monteiro, S. D. (2015). Predictable chaos: a review of the effects of emotions on attention, memory and decision making. *Advances in Health Sciences Education*, 20(1), 265-282.
75. LeDoux, J. (1998). *The emotional brain: The mysterious underpinnings of emotional life*. Simon and Schuster.
76. LeDoux, J. E., and Phelps, E. A. (1993). Emotional networks in the brain. *Handbook of emotions*, 109-118.
77. Lerner, J. S., & Keltner, D. (2000). Beyond valence: Toward a model of emotion-specific influences on judgement and choice. *Cognition & Emotion*, 14(4), 473-493.
78. Lerner, J. S., & Keltner, D. (2001). Fear, anger, and risk. *Journal of personality and social psychology*, 81(1), 146.
79. Lindeman, E. C., Gessner, R., and Otto, M. (1956). *The simulationcratic man: Selected writings of Eduard C. Lindeman*, Boston.
80. Longmore, M., Wilkinson, I., Baldwin, A., and Wallin, E. (2014). *Oxford handbook of clinical medicine*. Oxford University Press.

81. Markus, H. R., & Kitayama, S. (2001). The cultural construction of self and emotion: Implications for social behavior. *Emotions in social psychology: Essential reading*, 119-137.
82. Mather, M. (2007). Emotional arousal and memory binding: An object-based framework. *Perspectives on Psychological Science*, 2(1), 33-52.
83. Matsumoto, D., Yoo, S. H., & Nakagawa, S. (2008). Culture, emotion regulation, and adjustment. *Journal of personality and social psychology*, 94(6), 925.
84. Mayer, R. E. (1997). Multimedia learning: Are we asking the right question?. *Educational psychologist*, 32(1), 1-19.
85. McClernon, C. K., McCauley, M. E., O'Connor, P. E., & Warm, J. S. (2011). Stress training improves performance during a stressful flight. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 53(3), 207-218.
86. McCloskey, M., Wible, C. G., & Cohen, N. J. (1988). Is there a special flashbulb-memory mechanism?. *Journal of Experimental Psychology: General*, 117(2), 171.
87. McDonald, J.H. 2014. Handbook of Biological Statistics. 3rd ed., Sparky House Publishing, Baltimore, Maryland, USA. This web page contains the content of pages 180-185 in the printed version.
88. McGaugh, J. L. (2004). The amygdala modulates the consolidation of memories of emotionally arousing experiences. *Annu. Rev. Neurosci.*, 27, 1-28.
89. McKenna, F. P., Horswill, M. S., & Alexander, J. L. (2006). Does anticipation training affect drivers' risk taking?. *Journal of Experimental Psychology: Applied*, 12(1), 1.
90. Medin, D. L., & Ortony, A. (1989). Psychological essentialism. *Similarity and analogical reasoning*, 179, 195.
91. Mellers, B. A., and McGraw, A. P. (2001). Anticipated emotions as guides to choice. *Current Directions in Psychological Science*, 10(6), 210-214.
92. Merriam, S. (2004). The changing landscape of adult learning theory. In J. Comings, B. Garner, and C. Smith (Eds.), *Review of adult learning and literacy: Connecting research, policy, and practice* (pp. 199- 220). Mahwah, NJ: Lawrence Erlbaum Associates.
93. Mesquita B. (2003). Emotions as dynamic cultural phenomena. In: Goldsmith H, Davidson R, Scherer K, editors. *Handbook of the Affective Sciences*. Oxford; New York: 2003. pp. 871–890.

94. Moorthy, K., Munz, Y., Adams, S., Pandey, V., & Darzi, A. (2005). A human factors analysis of technical and team skills among surgical trainees during procedural simulations in a simulated operating theatre. *Annals of surgery, 242*(5), 631-639.
95. Mroczek, D. K., & Kolarz, C. M. (1998). The effect of age on positive and negative affect: a developmental perspective on happiness. *Journal of personality and social psychology, 75*(5), 1333.
96. Neiss, M. B., Leigland, L. A., Carlson, N. E., & Janowsky, J. S. (2009). Age differences in perception and awareness of emotion. *Neurobiology of aging, 30*(8), 1305-1313.
97. Oatley, K., Keltner, D., and Jenkins, J. M. (2006). *Understanding emotions*. Blackwell publishing.
98. Öhman, A., and Mineka, S. 2001. Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. *Psychological review, 108*(3), 483.
99. Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational psychology review, 18*(4), 315-341.
100. Pekrun, R., Elliot, A. J., and Maier, M. A. (2009). Achievement goals and achievement emotions: Testing a model of their joint relations with academic performance. *Journal of educational Psychology, 101*(1), 115.
101. Pekrun, R., Frenzel, A. C., Goetz, T., & Perry, R. P. (2007). The control-value theory of achievement emotions: An integrative approach to emotions in education. In P. A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 13–36). San Diego: Elsevier
102. Pekrun, R., Goetz, T., Titz, W., and Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational psychologist, 37*(2), 91-105.
103. Peterson, C., & Bell, M. (1996). Children's memory for traumatic injury. *Child development, 67*(6), 3045-3070.
104. Peterson, C., & Whalen, N. (2001). Five years later: Children's memory for medical emergencies. *Applied Cognitive Psychology, 15*(7), S7-S24.
105. Pillemer, D. B. (1984). Flashbulb memories of the assassination attempt on President Reagan. *Cognition, 16*(1), 63-80.
106. Rachman, S. (2004). Fear of contamination. *Behaviour research and therapy, 42*(11), 1227-1255.

107. Reio, T. G., & Wiswell, A. (2000). Field investigation of the relationship among adult curiosity, workplace learning, and job performance. *Human Resource Development Quarterly*, *11*(1), 5-30.
108. Reisberg, D., & Heuer, F. (2004). Memory for emotional events. In D. Reisberg & P. Hertel (Eds.), *Memory and Emotion* (pp. 3–41). New York: Oxford University Press.
109. Renninger KA, Hidi S, Krapp A, editors. *The role of interest in learning and development*. Hillsdale, NJ: Erlbaum; 1992.
110. Robinson, K. (2013). The interrelationship of emotion and cognition when students undertake collaborative group work online: An interdisciplinary approach. *Computers & Education*, *62*, 298-307.
111. Rottenberg, J., Ray, R. R., & Gross, J. J. (2007). Emotion elicitation using films. In J. A. Coan & J. J.B. Allen (Eds.), *The handbook of emotion elicitation and assessment* (pp. 9_28). New York: Oxford University Press.
112. Safety and Health Council of NC. (2017). "HAND SAFETY in the WORKPLACE." (<http://www.nsc.org/Membership%20Site%20Document%20Library/Recorded-Webinars/Safety%20at%20Hand.pdf>) (Apr. 5, 2017).
113. Slovic, P.: 2000, *The perception of risk*, Earthscan, London, UK.
114. Slovic, P., and Peters, E. (2006). Risk perception and affect. *Current directions in psychological science*, *15*(6), 322-325.
115. Slovic, P., Peters, E., Finucane, M. L., & MacGregor, D. G. (2005). Affect, risk, and decision making. *Health psychology*, *24*(4S), S35.
116. Specht, L. B., & Sandlin, P. K. (1991). The differential effects of experiential learning activities and traditional lecture classes in accounting. *Simulation & Gaming*, *22*(2), 196-210.
117. Steadman, R. H., Coates, W. C., Huang, Y. M., Matevosian, R., Larmon, B. R., McCullough, L., & Ariel, D. (2006). Simulation-based training is superior to problem-based learning for the acquisition of critical assessment and management skills*. *Critical care medicine*, *34*(1), 151-157.
118. Taylor, S. E., & Brown, J. D. (1988). Illusion and well-being: a social psychological perspective on mental health. *Psychological bulletin*, *103*(2), 193.
119. Thiel, C. E., Connelly, S., Harkrider, L., Devenport, L. D., Bagdasarov, Z., Johnson, J. F., & Mumford, M. D. (2013). Case-based knowledge and ethics education: Improving learning and transfer through emotionally rich cases. *Science and engineering ethics*, *19*(1), 265-286.

120. Tixier, A. J. P., Hallowell, M. R., Albert, A., van Boven, L., and Kleiner, B. M. (2014). Psychological antecedents of risk-taking behavior in construction. *Journal of Construction Engineering and Management*.
121. Tsai, J. L. (2007). Ideal affect: Cultural causes and behavioral consequences. *Perspectives on Psychological Science*, 2(3), 242-259.
122. Verduyn, P., Delvaux, E., Van Coillie, H., Tuerlinckx, F., and Van Mechelen, I. (2009). Predicting the duration of emotional experience: two experience sampling studies. *Emotion*, 9(1), 83.
123. Verduyn, P., Van Mechelen, I., and Tuerlinckx, F. (2011). The relation between event processing and the duration of emotional experience. *Emotion*, 11(1), 20.
124. Weinberger, D. A. (1990). The construct validity of the repressive coping style. *Repression and dissociation: Implications for personality theory, psychopathology, and health*, 337-386.
125. Wierzbicka, A. (1999). *Emotions across languages and cultures: Diversity and universals*. Cambridge University Press.
126. Wilkins, J. R. (2011). Construction workers' perceptions of health and safety training programmes. *Construction Management and Economics*, 29(10), 1017-1026.
127. Wolf, O. T. (2008). The influence of stress hormones on emotional memory: Relevance for psychopathology. *Acta psychologica*, 127(3), 513-531.
128. Yuen, K. S., & Lee, T. M. (2003). Could mood state affect risk-taking decisions?. *Journal of affective disorders*, 75(1), 11-18.

CHAPTER 4: MAKING CONSTRUCTION SAFETY TRAINING INTERESTING: A FIELD-BASED QUASI-EXPERIMENT TO TEST THE RELATIONSHIP BETWEEN EMOTIONAL AROUSAL AND SITUATIONAL INTEREST AMONG ADULT LEARNERS

Abstract: Safety training within construction industry is often quite mundane and generic which is a problem for an industry combatting with high fatality rates on job sites for decades. Recent studies have found construction safety training programs severely lacking in developing hazard recognition and risk assessment skills among its workforce. Moreover, techniques used in these training programs are not geared to help adult learners engage or retain information provided. To address these shortcomings, this paper tests the efficacy of a multimedia simulation-based training program: Naturalistic Injury Simulations (NIS) in inducing interest among construction workers. NIS has been empirically shown to elicit strong negative affectivity among construction workers and the work presented here will test if NIS can also generate situational interest in construction workers regarding safety. This paper collected data from 489 construction workers on a construction job-site in an interventional experimental design. Analysis revealed that NIS were able to increase situational interest among workers and that these findings were consistent across all demographic dimensions captured in our study. Multiple linear regression analysis showed preliminary evidence of a relationship between change in affect and increase in situational interest among workers. This work shows that NIS will promote learning among workers by keeping them interested in the safety training process while also generating risk-averse behavioral patterns through emotional manipulation.

Keywords: *Situational Interest, Emotions, Adult Learning, and Safety Training.*

INTRODUCTION

The U.S. construction industry contributes nearly 6% to the entire Gross Domestic Product, accounting for nearly \$1 trillion in annual spending (Huesman et al. 2015); 40% of the nation's primary

energy use (U.S. Dept. of Energy 2012); and 9 million Americans jobs (Dong et al. 2012). Despite its size and importance, it substantially lags behind other industries in safety performance, accounting for the highest injury and fatality rate of any single-service industry (BLS 2016). These trends warrant a deeper introspection on how to improve safety training and performance among workers of this critical industry.

In recent years, many studies have concluded that current safety training techniques fail to develop necessary hazard recognition and risk assessment skills among workers (Albert et al. 2013, 2014a; Carter and Smith 2006). Bhandari and Hallowell (2017) attempted to address this deficiency by developing *Naturalistic Injury Simulations* (NIS), a new safety training program that uses multimedia-based instruction to facilitate experiential learning. NIS were designed to deliver hyper-realistic replications of common workplace injuries to promote emotional arousal during safety training. Initial analysis of the NIS confirmed that they were successful in eliciting an overall negative affective state, especially among young workers and Hispanic workers (Bhandari and Hallowell 2017). But affective arousal only indicates that the NIS has primed individuals for learning. The extent to which NIS promote situational interest - a primary precursor of learning –remains unknown.

The hierarchical relationship between emotional arousal and situational interest has been long theorized (Bergin 1999; Hidi 1990; Hidi and Renninger 2006; Mitchell 1993) and has been mostly studied in traditional learning environments (Benton et al. 1995; Linnenbrink-Garcia et al. 2010; Pekrun et al. 2012; Tobias 1996). However, it is unclear how this relationship operates among adult learners (Consedine et al. 2004) especially in an occupational safety training setting (i.e. non-traditional learning environment). To build comprehensive learning and safety training module for adult learners, it is important to study if, and by how much, emotional arousal supports learning outcomes. Thus, the authors address these knowledge gaps by (1) exploring if delivering NIS using the principles of adult learning generates immediate and sustained situational interest in workplace safety and (2) measuring the extent to which changes in affective arousal predict changes in situational interest among adult learners. The body of

knowledge used to develop these hypotheses and specific points of departure are reviewed in the subsequent section. The aim of the study was to increase knowledge of the mechanisms of adult learning as they pertain to a novel safety training medium designed especially for adult construction workers.

BACKGROUND AND HYPOTHESIS DEVELOPMENT

There is a broad body of literature criticizing traditional lecture-based safety training. However, there is an unfortunate dearth of research into innovative alternatives. In fact, there is very little research aimed to improve the mechanisms of the learning process during construction safety training. This review discusses current limitations of safety training, gaps in knowledge related to the mechanisms of adult learning, and also introduces NIS as a potential alternative grounded in self-directed learning theory and worthy of experimental testing and evaluation.

Shortcomings of the Current Construction Safety Training Techniques

Recent studies have found traditional safety training methods to be highly ineffective because for any given work period, researchers found that workers were only able to recognize and communicate less than *half* of all hazards in their work environment (Albert et al. 2013, 2014a, 2014b; Carter and Smith 2006). One of the main shortcomings of traditional safety training is the reliance on child-focused pedagogical principles when training adult learners, which ignores the wealth of personal experience that adults bring to the learning experience (Albert and Hallowell 2013). In fact, the same principles used to teach university students who are typically 18 to 24 years of age (U.S. Dept. of Education 2013) are applied in construction safety training where the median learner is 43 years of age (BLS 2017). Therefore, it is not surprising that Wilkins (2011) found most standard safety training programs fail to effectively communicate knowledge in a manner that can be retained by the workforce and Haslam et al. (2005) found that most construction workers harbor a strong negative outlook towards safety training.

There is a pressing need to design safety training modules using principles of adult learning (e.g., andragogy, self-directed learning) that initiate and sustain interest in safety among construction workers (Compton et al. 2006; Fairchild 2003; Kazis et al. 2007; Lundberg 2003). To facilitate transfer of skill and knowledge retention, the framework of NIS was designed to incorporate theories of self-directed learning and delivered in an active learning format that facilitates experiential learning and generates targeted emotional arousal (Bhandari et al. 2017).

Emotional Arousal and Learning

Theorists have struggled to assign one universal definition for the term *emotion* given its extensive and heterogeneous usage in the modern lexicon (Griffiths 1997). To provide an operational definition that grounds our epistemological position, the authors adopted the following definition of emotion offered by Lazarus (1991, p. 38): “Emotions are organized psychophysiological reactions to news about ongoing relationships with the environment.” Primary function of emotions is to channel our cognitive processing, focusing our attention to the source of emotional experience, and serve as information for us formulate our behavior and decisions that enhance our well-being, adaptation, and coping mechanisms (Izard 2010). While discrete emotions (such as anger, happiness, sadness, anxiety) are specific and targeted responses, the overall affective state of an individual is characterized by the broad range of positive or negative emotions that they may experience due to some stimuli (Barsade and Gibson 2007). Studies have concluded that emotional responses have been found to impact not only our evaluations of an external stimuli but also our decision-making abilities (Damasio 1996; LeDoux 1998; Bechara et al. 2000; Slovic and Peters 2006).

Emotions are a foundational component of our overall learning process. The decision to acquire a new skill or gain knowledge is significantly swayed by emotions, suggesting that learning is not simply a rational decision (Immordino-Yang 2015). In fact, emotional response can help generate motivation to pursue or continue learning (Isen and Baron 1991; Erez and Isen 2002; Fassbender et al. 2012; Pekrun 2006; Pekrun et al. 2009, 2002; Robinson 2013). Thus, many educators focus on building a learning

environment that promotes emotional arousal since it can heighten curiosity and strengthen desire to improve performance (Konradt et al. 2003). Positive emotions are known to impact cognitive process crucial to learning such as information processing, communication, and decision-making (Erez and Isen 2002; Isen and Baron 1991; Konradt et al. 2003). Specifically, Pekrun (2006) found that positive emotions strengthen our motivation to learn and Isen et al. (1987) found that they make our cognitive processes more flexible, resulting in development of more creative approaches to problem-solving. Although most researchers target the arousal of positive emotions, Pekrun et al. (2007; 2009) showed that negative emotions can elicit extrinsic motivation to avoid failure during the learning process, thereby improving learning outcomes. Similarly, Chung et al. (2015) found that, like positive emotional valence, *activating* negative emotional valence can be effective in generating motivation to learn.

There are several models and empirical studies that explain *why* emotional arousal supports learning. For example, the theoretical relationship between emotional arousal and motivation to learn is explained by the Limited Capacity Model of Motivated Mediated Message Processing (LC4MP), which theorizes that humans are motivated to learn through two motivational systems: *appetitive* when knowledge is perceived to be beneficial and *aversive* when information is about threat or danger (Lang 2006). There is strong physiological evidence to support this model as experimental studies have found that intense emotional experiences act as stimuli for amygdala activation (Canli et al. 1999; Cunningham et al. 2004; Kober et al. 2008), which is important to learning because the amygdala helps classify and characterize information in our memory (Cahill et al. 1996; Hamann et al. 1999) and influences our behavior in risky situations (Hilton and Zbrozyna 1963; Kane et al. 1991; Ledoux 1993).

Situational Interest and Learning

In addition to emotional arousal, research has shown that interest in the subject and learning environment is also a driver of learning (Alexander and Jetton 1996; Garner 1992; Hidi and Renninger 2006). Interest has been linked with cognitive functioning (Ainley 1998; Renninger 2000; Schiefele 1996),

attention (Hidi et al. 2004; McDaniel et al. 2000), goal setting (Harackiewicz et al. 2000; Pintrich and Zusho 2002; Sansone and Smith 2000), and commitment to learning (Alexander 1997; Alexander and Murphy 1998; Hoffmann 2002; Krapp and Fink 1992; Schiefele 1999). Many have theorized that interest is an agent of learning because it is the product of cognition and emotion (Hidi and Berndorff 1998; Hidi et al. 2004; Hidi and Renninger 2006; Krapp 2000). Since interest is the outcome of an interaction between a person and specific content (Hidi and Baird 1986; Krapp 2000), it is not a general predisposition among all learners.

There are two types of interest: *individual interest* and *situational interest*. Individual interest (II) is defined as an enduring disposition to focus on and engage with objects, information, or events with which an individual has developed long-term deep personal connections (Krapp et al. 1992; Renninger 2000; Hidi and Renninger 2006). Alternatively, situational interest (SI), is conceptualized as interest that is generated by an immediate stimulus (Hidi 1990; Hidi and Baird 1986). Although both II and SI are motivating (Hoffmann et al. 1998; Hidi and Renninger 2006), SI is comparatively unstable and can be fleeting whereas II can remain largely consistent across time and context (Rathunde 1998; Schiefele 1991).

Hidi and Renninger (2006) proposed a four-phase model of interest: triggered SI; maintained SI; emerging II; and well-developed II. Triggered-SI is instigated by the environment and is theoretically generated when the learning a stimulus generates attention (Linnenbrink-Garcia et al. 2010). In contrast, maintained-SI is achieved when the individual exhibits persistent effort to acquire knowledge. Triggered SI is typically a precursor to maintained SI. Maintained SI can eventually develop into emerging II and well-developed II when stimuli are pervasive enough (Alexander and Jetton 1996; Hidi and Renninger 2006; Krapp 2002; Silvia 2001). In the context of a discrete learning intervention, SI are most relevant in the short-term. Linnenbrink-Garcia et al. (2010) deconstructed maintained SI into feeling-based and value-based, where value-based SI is a deeper form of interest. In this present study, the authors adopted the Linnenbrink-Garcia et al.'s 3-component SI model (i.e., *triggered-SI*, *feeling-based maintained SI*, and *value-based maintained SI*).

RESEARCH OBJECTIVES

The overarching goal of this study is to improve learning outcomes for construction workers by developing and empirically testing Naturalistic Injury Simulations (NIS) as a novel training tool. The study consisted of the following four distinct objectives:

- [1]. The first objective was to examine if NIS improves triggered, feeling-based, or value-based SI among adult learners. Thus, the experiment was designed to test the null hypothesis: *[H1] there is no change in situational interest levels among construction workers during safety training delivered via NIS*. This hypothesis has both practical and theoretical implications as it tests the extent to which NIS changes the purview of construction workers toward their safety training while building an understanding of the various agents of adult learning.
- [2]. The second objective was to compare changes in SI across demographic groups. Thus, the analysis examines if there is any *difference in situational interest levels among different demographic groups during safety training delivered via NIS*. This analysis addresses the lack empirical research on learning outcomes and typology of workers, which is essential for promoting long-term safety improvements.
- [3]. The third objective of this study examines if there is a relationship between emotional arousal and SI levels. Although it is strongly theorized that emotional arousal is key to generating SI, it has not been empirically established nor has it been studied in the context of adult learning or safety training. This knowledge gap is addressed by testing the hypothesis that *[H2] change in affective state does not predict change in situational interest among adult learners during safety training delivered via NIS*. This hypothesis addresses the nature of SI experienced by adult learners and its possible dependence on emotional arousal. Specifically, this hypothesis empirically investigates if, and the extent to which, emotional arousal predicts SI experienced by workers.

[4]. The final objective is to explore if demographic differences (ethnicity, age, and marital status) attenuate or amplify the relationship between affect and SI. It is difficult to hypothesize the role of demographics in moderating this relationship given the dearth of previous research. Thus, the findings presented in this paper are more exploratory and preliminary in nature and can serve as motivation for future research.

DESIGN AND DEVELOPMENT OF NATURALISTIC INJURY SIMULATIONS

Since SI is context-dependent, a specific learning activity was needed to initiate change in emotion and SI and explore the relationships between emotional arousal and SI. Thus, NIS were used as the intervention because it has been empirically verified to arouse activating negative emotions in the context of safety training (Bhandari and Hallowell 2017). The following sections describe each of the steps required to create and deliver NIS. This step was developmental in nature and was used as the catalyst for change in the experimental process.

Creating of Naturalistic Injury Simulations

The NIS were designed to simulate *actual* past hand injuries, which is one of the most common injury types in construction (Safety and Health Council of North Carolina 2014). Specifically, two simulations were created to demonstrate how the hands of workers were injured by being: (1) struck by a 1-kilogram concrete chisel from 3 meters in height and (2) pinched between moving 3-inch steel pipes. To support the goal of showcasing the most realistic simulation possible, lifelike human hands were fabricated using techniques from prosthetics, special effects, and dentistry.

The hyper-realistic hands created for the simulations were based on life-casting techniques. The procedure detailed by Bhandari and Hallowell (2017) was followed since they were found to represent the physical and tactile properties of an actual human hand almost exactly. First, a negative mold was created

using an actual human hand submerged in alginate. This negative cast was then used to create a resin positive. The resin positive was used as a template to create a two-part negative mold. Finally, the two-part mold was used to place an internal structure of bone and vein proxies and pour flesh material. When struck, the bones on the hand break just as they would in a true hand and, when cut, the hand will appear to bleed. These simulations were designed to highlight how injuries happen and why they cause damage using basic concepts of physical science (e.g., potential and kinetic energy and its transference to the hand).

The falling object demonstration showed how an untethered 1-kilogram concrete chisel falling from a height of 3 meters (~10 ft.) damages a human hand. Prior to the demonstration, workers were asked to describe their own experiences with dropped objects and hand injuries. Then, the concepts of potential and kinetic energy were introduced and the impact force and pressure were estimated. In the physical demonstration, the chisel was dropped on the hand through a clear polyvinyl chloride column to control the energy. During the release of the chisel, the event was recorded on a camera at approximately 2,100 frames per second. After the strike, the synthetic hand was passed around so workers could closely examine the extent of damage (e.g., broken bones, lacerations, and contusions). Then, the high-speed video was shown so that the participants could see the transfer of energy and damage that cannot be detected by the human eye. Finally, the crews discussed solutions that would prevent similar occurrence on their sites. This activity was designed to assist with the projection of the simulation to the workplace. With similar intent, the second demonstration showed a pinch-point injury where a hand was caught between two 3-inch stainless steel pipes commonly used in refinery projects. During the simulation, the workers hold the hand in place using a rod and allow the sling that holds the pipes to slip, causing the pipes to move laterally and strike each other. Again, the event was captured using a high-speed camera, the hand was circulated among the workers, and preventative solutions were discussed.

Both simulations focused on routine construction tasks that had caused actual injuries in the past. Nearly all workers were aware of the nature of accidents being simulated and some personally knew

workers that have been injured as a result. Hallowell (2010) found that personal injury history is the key factor that influences worker's risk tolerance. Thus, the goal of recreating these events with enhanced realism was to give the experience of an injury without causing actual physical harm. Bhandari and Hallowell (2017) found empirical evidence that these demonstrations generate significant negative emotional arousal across relevant demographic groups. These emotional experiences have been connected to improved risk perception and reduced risk tolerance (Alhakami and Slovic 1994; Loewenstein et al. 2001; Keller et al. 2006; Tixier et al. 2014).

Alignment of NIS Delivery with Adult Learning Principles

NIS are proposed as an alternative to current safety training to transition away from child-focused pedagogical delivery techniques (e.g., one-way lectures and slide presentations) that currently dominate the industry. To address common limitations, NIS were designed and delivered using theories of andragogy and application of self-directed learning techniques (Bhandari and Hallowell 2017).

Andragogy helps educators and trainers to better understand the learning needs of adults. Albert and Hallowell (2013) suggested that construction safety training programs should have their foundations based in the following principles of andragogy: a) need to know, b) self-concept of learners, c) experience of learners, d) readiness to learn, e) orientation to learning, and f) motivation (Knowles 1980; 1984). These principles are not robust theory (Hartree 1984; Pratt 1993; Grace 1996; Merriam 2004); however, they are meant to serve as guidelines to build a comprehensive learning module. Knowles et al. (2014) noted that andragogy was never meant to be a vigorous theory but rather principles that should be embedded with other theories with varying sets of goals and purposes. Thus, the delivery of NIS was based on the framework of self-directed learning theory and andragogical principles. By applying the principles of andragogy, common pitfalls associated with child-focused pedagogical learning environment like ignoring the prior experience, cultural background, and knowledge of the adult learners can be avoided (Hollins and King 1994).

Self-directed learning is defined by the extent to which a learner controls their learning experience and later persists in acquiring knowledge when the discrete learning experience ends (Fisher et al. 2001). This form of learning is directly aligned andragogy and is ideally suited to safety training because it allows learners to express prior experience, to define their own knowledge gaps, and shifts control of the learning process from the instructors to the learners (Morrow et al. 1993). Self-directed learning in NIS was achieved by gradually shifting the control from instructors to workers (i.e., from instruction-led brief lecture on physics principles to group-led brainstorming of safety solutions). Specifically, Garrison's (1997) self-directed learning model was used to design the delivery of the NIS. This model includes three components, *self-management, self-monitoring, and motivation*, described below.

Promoting self-management

Self-management refers to giving learners control over multiple aspects of the learning process, thereby enhancing engagement, improving self-efficacy, and sharing resources among the instructors and learners (Garrison 1997). Self-management was specifically achieved by having workers assist in setting up, reflecting on personal experience related to the tools and equipment involved in the physical demonstration, running the simulation (e.g., dropping the concrete chisel onto the hand), and leading discussions. It should be noted that self-directed model does not advocate for complete transfer of control and workers were not expected to be isolated learners (Candy 1991; Garrison 1993, 1997). Rather, a collaborative relationship between workers and facilitators is desired where the traditional boundaries of learner and instructor are blurred and the role of the instructor transitions to that of a facilitator (Candy 1991). Facilitators established the premise, gave context, interjected, and provided momentum to discussion whenever appropriate during the demonstration.

Facilitating self-monitoring

To enable knowledge retention and application, adults must draw their own conclusions through critical reflection and inductive inference (Garrison 1997). This process, known as self-monitoring, is especially important in safety training because it greatly influences the future application of new knowledge in practice. When delivering NIS, an inductive learning strategy was employed where workers were asked to share their predictions of the outcomes of the demonstrations. This enabled the workers to identify any of their own knowledge gaps, access and share their own experiences, and then post-demonstration compare their predictions to actual outcomes. While some predictions were confirmed, the severity of the injury was often underestimated and surprising. This design provided a natural mechanism for critical reflection and discussion.

Facilitating motivation

The delivery of NIS was designed around Garrison's (1997) model of motivation, which included both entering motivation (committing to a task) and task motivation (persisting with the commitment). However, there are varied factors (culture, gender, age, politics, and other environmental factors) that play a critical role in influencing motivation among groups of adult learners (Ahl 2006; Keraka 2002; Sissel et al. 2001; Venter 2003). Thus, the diversity of the crews posed a challenge in addressing motivation. Rather than focus on a single motivational strategy, the NIS were designed to target emotional arousal as a catalyst for motivation (Pekrun et al. 2002; Meyer and Turner 2002). Leersynder et al. (2011) found that individuals can showcase great synergy in how they experience emotions given time and exposure regardless of cultural differences. The levels of emotional arousal measured by Bhandari and Hallowell (2017) showed that NIS had the capacity to trigger aversive motivation in most participants (Lang 2006).

In addition to emotional arousal, the delivery of NIS was also designed to foster motivation through personal story-telling. That is, workers were asked to share their own experiences with hazards, near-misses, or injuries as they related to the demonstrations. Workers were also asked to discuss how they can

use what they have learnt here today to reinforce the value of knowledge they gained. This strategy was adopted because Tough (1979) found that adults are engaged and motivated to learn when there is anticipation of benefits and outcomes. With short-term benefits, such as *satisfying curiosity, being interested in content, and using the newly acquired skill/knowledge* to long-term benefits such as *better understanding of consequences of actions taken today and imparting the knowledge and skills to others* are some of the examples that adult learners expect from their training or learning environments. Thus, by having workers share personal stories and experiences should not only heighten the emotional arousal and interest of their crew members but also reinforces the benefits they can derive from the safety training program should they choose to engage.

Promoting Situational Interest

The NIS were designed to both trigger and sustain interest. Hidi (1990) organized the factors that impact SI in two groups. The first group is generally focused on structure of the subject being taught (e.g., novelty, intensity, and ambiguity). The second group is more individual, focusing instead on the experience of the learner (e.g., sense of belongingness, humor, competence, hands-on, novelty, social-interactions, content, and narrative). One of the principal tenets of the NIS were multiple forms of media and educational activities. This was inspired by Billett (2001) and Reio and Wiswell (2000) who found that training regimens should involve different visual and verbal stimuli to encourage long-term interest in the subject matter and achievement of learning objectives. Baddeley (1992) had also found that working memory retains information by relying on both visual and verbal avenues. Thus, this became another additional reason for including the plethora of complementary media in NIS such as text-based presentation, physical demonstrations, personal stories from workers, and slow-motion videography and different forms of activities during the learning experience over the reasons discussed above.

Table 9 provides a cross-walk of the NIS design techniques and the known triggers of SI summarized by Bergin (1999) and Hidi (1990).

Table 9: Crosswalk table showing how the design and delivery of NIS promotes SI

Strategies		Hands On	Setting Learning Goals	Shock	Aversive Motivation	Novelty	Social Interactions	Humor and Narrative
NIS Design Techniques	Help set up the demo	X	X				X	
	Multiple simulations	X	X	X	X	X		
	Interact with hands	X		X		X		
	Group discussion		X		X		X	X
	Bilingual presentations		X					X
	Personal anecdotes		X		X	X	X	X
	Teaching experience		X				X	X
	Informal setting					X	X	X
	Slow motion video			X	X	X		X
	Emotional tone				X			
	Learning objectives		X					

EXPERIMENT AND DATA COLLECTION

NIS were delivered at the work site to promote ecological validity and authenticity. Also, the experiment was integrated into the daily work routine of the workforce with minimal disruption. The authors elected to promote ecological validity and subject recruitment over experimental control, which would have required a controlled experiment in a laboratory setting. Thus, not all confounding variables could be controlled. The authors took reasonable steps to promote internal validity, including adequate lighting in rooms where surveys were conducted, minimal external noise and interruption, and sufficient

ventilation. The study was approved by the ethics review and the participating organizations. Participants were informed of the risks associated with research protocol and were provided anonymity, opportunity to leave the study at any time, and option of ‘decline to respond’ to any question. These controls were followed and strictly enforced in our study. Alongside the research personnel, the immediate supervisors of the crews co-hosted the training sessions since they understand the background of crew members.

Both simulations were delivered to more than 1,000 workers in southern Texas, U.S. over the course of sixteen, two-hour sessions. The 489 workers who completed the survey were chosen at random and their participation was anonymous, voluntary, and uncompensated. A subset was selected from the larger populations because of limited resources to administer surveys before and after the learning experience. The NIS and accompanying surveys were delivered in both English and Spanish, in accordance of the language preference of the subject.

Quasi-experimental design

The quasi-experiment followed an interventional design where paper surveys gauging emotional arousal and SI levels were administered before and after delivery of the NIS. Demographic questions were asked only in the pre-intervention survey and the two surveys were linked via a password selected by the participants to maintain confidentiality. The simulations were considered an agent that would theoretically cause change and variation in SI so that the primary hypotheses could be tested.

Demographics

In the initial survey, participants were asked questions related to the following demographics: age, years of experience, marital status, education level, ethnicity, accident history, and gender. The participants were also given an option to decline to respond to any demographic questions. Other than gender, the sample involved diverse representation. With respect to gender (less than 1% females), the bias is an unfortunate

though honest representation of the employment characteristics in the US construction industry (BLS 2017).

The key demographics of the sample are as follows:

- 59% married;
- 68% were Hispanic and 30% were Caucasian;
- 22% previously injured (recordable injury or more severe);
- 6% have a bachelor's degree or higher, 33% have some college education, 55% completed high school;
- Average age of 38 years;
- Average years of experience in construction of 9 years.

Demographic data were collected to explore how ethnicity, age, marital status, years of experience, and injury history lead to differences in SI. Ideally, equality in training should be promoted; however, there is evidence that different demographic groups learn differently and behave differently as it relates to workplace safety. For example, adolescents are more likely to engage in risk-taking activities than adults (Arnett 1992; Gardner and Steinberg 2005; Umberson 1987), individuals who have never been married show higher driver levels of aggression in driving (Turner and McClure 2002), and married individuals are more risk averse (House et al. 1988; Litwak and Messeri 1989; Umberson 1987; Rook et al. 1990). Because of these past differences, the authors suspected that individual demographic differences may play a role in change observed in emotional arousal (Bhandari and Hallowell 2017), SI, and the relationships between them.

Measuring emotional arousal

To measure the emotional states of the participants, a self-report emotion inventory was used. These emotion inventory questionnaires have been employed and validated in past studies (Gross and Levenson 1995, 1997; Lerner and Keltner 2001; Rottenberg et al. 2007; Roberts et al. 2007). Unlike physiological measures, the ease of making emotional ratings allows participants to consider past experiences and future

valuations (Robinson and Clore 2002) without experiencing demand characteristics (Barabasz and Barabasz 1992; McCarney et al. 2007; Nichols and Maner 2008). Workers were asked to rate the intensity of 16 distinct emotions on a 9-point Likert scale. Since induced emotions can be fleeting (Gilboa and Revelle 1994) and can wane in as little as 10 minutes (Verduyn et al. 2009; 2011), participants were allowed no more than a 3-minute lag between completion of the NIS and starting post-simulation survey.

Measuring situational interest

The SI questionnaire was derived from Linnenbrink-Garcia et al. (2010) who developed a self-report questionnaire to measure all three SI dimensions: triggered-SI, *feeling*-based maintained-SI, and *value*-based maintained-SI. Since the questionnaire was developed for general education, the wording of the questions was changed to apply to construction safety training setting. For example, the statement, “My math course is exciting” from Linnenbrink-Garcia et. al. (2010, p.665) was changed to “My safety training is exciting”. The SI segment of the survey consisted of all 12 questions from Linnenbrink-Garcia et. al. (2010) and for each statement, participants were asked to report the extent of their agreement on a Likert scale, where 1 represented ‘not at all’ and 5 was a ‘strongly agree’.

RESULTS

This is a within-subject study with repeated measurements on the same subject. The demographic data were both categorical (marital status, education level, and injury history) and continuous (age and years of experience). The data on emotion and SI levels were continuous. Of the 489 subjects, 75 were excluded from the analysis because they did not complete both (pre/post) surveys. For the remaining 414 participants, the *k-nearest neighbor* (kNN) imputation technique (see Batista and Monard 2002 for review) was used to handle missing data (3.6% of the entire dataset). kNN is designed to find ‘k’ nearest variables and imputes missing data by a weighted average (Liao et al. 2014). It has been demonstrated in past literature to be robust and accurate for large datasets (Chen and Shao 2000; Dudani 1976; Troyanskaya et al. 2001). The

dataset of emotions and SI were imputed separately because the variables are on different scales and kNN imputation takes advantage of positive correlations between rows (Troyanskaya et al. 2001). The optimal value of k was determined per Dasarathy (1991) and Lall and Sharma (1996) where k is the square-root of n (number of observations in the dataset). To study if there was statistically significant change in emotions and SI dimensions before and after the NIS, paired t-tests were used. A paired t-test is commonly used to compare means for observations that can be linked to the same subject (Hsu and Lachenbruch 2008). Given that the data are sequential in nature and acquired from each subject over time, using paired t-test is appropriate because it assesses the mean difference between the dependent observations. To account for Type 1 error due to multiple tests, Bonferroni correction was applied ($p = 0.05/52 = 0.001$) to lower the threshold of significance and examine the results conservatively. As reported by Bhandari and Hallowell (2017), NIS caused a significant increase in the negative affective state overall and across the all demographic groups. Specifically, there was a statistically significant increase in *fear* (48%), *disgust* (11%), *guilt* (11%), *surprise* (47%), *unhappiness* (15%) and *sadness* (36%) while a significant decrease was noted in *happiness* (-28%), *joy* (-24%), *love* (-28%), *confusion* (-14%) and *pride* (-22%). Since the present study builds upon Bhandari and Hallowell (2017), we refer the reader to this previous paper for specific statistics and demographical comparisons for change in emotional arousal. This paper focuses on change in SI, demographical differences in experiencing change in SI, and the relationship between observed change in emotional arousal and change in SI.

Change in Situational Interest

Before introducing the intervention, the subjects in the dataset reported high baseline levels of SI for safety training across each dimension (Table 10). This is highly unusual given the findings of previous studies discussed above that found workers generally have a negative outlook towards safety training (Albert and Hallowell 2013; Haslam et al. 2005). It is very likely that workers responses were influenced by the presence of peers, supervisors, and researchers in the room. Any potential demand characteristics or bandwagon effects (Nadeau et al. 1993) could not be logistically controlled for on the construction site.

However, despite workers showing a strong positive predisposition towards safety training, post-intervention means reveal that NIS were able to further increase SI.

Table 10: Means and Standard Deviations for Triggered-SI, Feeling-based and Value-based maintained SI before and after NIS intervention

Situational Interest	Pre-NIS			Post-NIS		
	Triggered-SI	Feeling-based maintained SI	Value-based maintained SI	Triggered-SI	Feeling-based maintained SI	Value-based maintained SI
	Mean	4.32	4.36	4.61	4.61	4.58
Standard Deviation	0.73	0.75	0.64	0.49	0.69	0.60

The paired t-tests analysis shows that there was a statistically significant increase in overall SI and across all the dimensions of SI except *value*-based maintained-SI (Table 11). Overall, the analysis reveals that NIS not only heightened the immediate environment-driven interest (triggered-SI), but also made workers experience sustained interest during training (maintained-SI; Linnenbrink-Garcia et al. 2010). The results support the assertion that, despite the rich diversity within the construction workforce, NIS can generate interest across the dimensions of SI. Despite a lowered threshold of statistical significance due to Bonferroni correction that addresses Type 1 error at the cost of Type 2 error (Gelman et al. 2012), the results are significant. Thus, this analysis allowed the authors to reject the first null hypothesis [H1] that *NIS does not increase SI among construction workers*.

Table 11: Change in Situational Interest

	Percent Change	P-value
Overall	4.60%	<0.001

Triggered SI	6.75%	<0.001
Feeling-based maintained SI	5.07%	<0.001
Value-based maintained SI	2.14%	0.006

To examine if the increase in SI was ubiquitous across all relevant members of the target population, the authors also examine change in SI across each demographic dimension. Table 12 shows the change in SI across each dimension for all demographics recorded in our dataset. Given the exploratory nature of the study, the itemized analysis is done to simply highlight the nature of changes the across different sub-groups of adult learners. In sum, across each sub-group overall there is a significant but variable increase in SI levels. While paired t-test do not allow for comparative analysis between differences in the elevation levels for each individual group, these findings validate the efficacy of adult learning mechanisms included in the live simulation-based multimedia learning framework presented here for occupational safety training purposes. The implications of these findings are further elaborated on in the discussion section.

Ethnicity

Hispanic workers reported an increase on all dimensions of SI including *value*-based maintained SI which suggests that they not only found NIS engaging but they were also making meaningful connections with the subject matter. However, Caucasian workers did not show statistically significant change across *feeling*-based or *value*-based maintained SI but only showed change in triggered SI. This general finding provides clear evidence that NIS generated the interest of Hispanic workers in a more sustained manner, whereas Caucasian workers experienced only immediate interest. This suggests that Hispanic workers made meaningful connections to NIS as indicated by a significant increase in value-based maintained SI.

Age, Years of Experience, and Marital Status

Change in SI across age, years of experience, and marital status were examined independently. The

average age of the subjects was 38 years. The data were dichotomized into workers who were younger than 38 years (representing younger workers) and above 38 years (representing senior workers). As with age, workers were sub-divided into two categories of experience. The median experience was 9 years so the data were dichotomized into less experienced workers (9 or fewer years of work experience) and more experienced workers (more than 9 years of work experience). The data was dichotomized here because the authors wanted to see if the patterns of change noted for overall change (Table 11) were consistent across these sub-groups as well. As shown in Table 12, younger workers showed an increase in SI across all dimensions whereas older workers experienced no change in overall SI, *feeling*-based, and *value*-based maintained SI. Similarly, just like younger workers, less experienced workers registered a significant change in all three dimensions of SI indicating that inexperienced workers were highly invested in the NIS and exhibiting long-term interest in safety. Experienced workers on the other hand, did not show statistically significant change across *feeling*-based and *value*-based maintained-SI and overall SI. Married workers found the framework like younger workers and inexperienced workers beneficial promoting them be attentive and divert cognitive resources accordingly (Iran-Nejad 1987). Despite focus on adult learning in the design of NIS, more mature workers experienced less sustained interest in safety training programs than their younger counterparts. It is possible that classroom environments might not be as effective in non-traditional learning environments for more mature workers.

Education

The before and after SI scores for the following three levels of education were studied independently: no college education and some college education. Less educated workers were more engaged with NIS, with increases in both triggered and feeling-based maintained SI. However, workers with college education only experienced increases on triggered SI. These findings make sense given that the discussions and transfer of knowledge (e.g., potential and kinetic energy) was purposely simplistic. The material may not have been as novel or challenging enough for workers with more advanced education. Workers who have completed college education (N=27) were not included in the analysis because they

represent a very small subset of the dataset.

Injury History

As discussed above, injury history has been shown to be a significant factor affecting construction worker risk tolerance (Hallowell 2010). Workers who had experienced an injury in the past register lower risk tolerance than their counterparts who have never experienced an injury. Given these findings, it was suspected that injury history would play a role in change in SI but the it was unclear which group would show more significant change. The results shown in Table 12 indicate that workers who have never experienced an injury registered a positive and statistically significant change overall and across triggered SI and *feeling*-based maintained SI. Regarding safety training, the design and delivery of NIS was geared towards giving workers experience of an injury without injuring them. This goal is largely supported by the finding that shows workers who have never been injured before were not only interested in NIS but also found greater value in the subject matter. As with workers with college degree, workers who experienced significant injury represented a very small subset (N=29) of the entire sample, therefore, they were not included in the analysis.

Table 12: Change in situational interest by demographic groups¹

Situational Interest	Ethnicity		Age		Marital Status		Years of Experience		Education		Been Injured	
	Caucasian (N=129)	Hispanic/ Latino (N=294)	<= 38 yrs. (N=221)	> 38 yrs. (N=195)	Single (N=125)	Married (N=287)	<= 9 yrs. (N=198)	> 9 yrs. (N=186)	High School (N=242)	Some College Educ. (N=144)	Never (N=329)	First Aid (N=66)
Overall	-	5.1%	6.1%	-	5.1%*	4.6%	6.5%	-	3.6%	-	4.8%	-
Triggered SI	5.6%	7.4%	7.9%	5.5%	7.9%	6.7%	8.6%	4.0%	5.9%	5.5%	7.3%	-
Feeling- based maintained SI	-	4.8%	6.8%	-	-	4.9%	6.5%	-	3.5%*	-	4.9%	-
Value- based maintained SI	-	3.2%	3.8%*	-	-	2.5%*	4.3%	-	-	-	-	-

¹Only statistically significant ($p < 0.001$) values are shown in the table. No value (-) signifies change in SI state was not statistically significant. N does not add up to 489 in some cases because some participants selected “decline to respond” for demographical questions.

* $0.001 < p\text{-value} < 0.005$ (marginal significance)

Investigating the relationship between emotional arousal and situational interest

Once it was established that workers register both emotional arousal and SI during NIS safety training, the following hypothesis was tested: [H2] *change in affective state does not predict change in situational interest among adult learners during safety training delivered via NIS*. The purpose of testing this hypothesis is that it has been long suspected that emotional arousal explains SI, but there is a dearth of empirical evidence, especially for adult learners. If this hypothesis is true, it could indicate that emotional arousal should be the target of adult learning when both short- and long-term interest in the subject matter is desired.

The data set consisted of sixteen discrete emotions, which were reduced using principal component analysis (PCA). The principal components were then regressed against the three components of SI (triggered-SI, *feeling*-based, and *value*-based maintained SI). Since there is a non-independence issue because of time-series data, the difference of the paired observations (i.e. post-NIS score minus the baseline scores) of emotions and SI were used in the entirety analysis process.

Reducing dimensions of the emotions dataset using principal components analysis

PCA is a common technique used to reduce the dimensions and narrow in on the subspaces of the data set that contain most of the variance of the original data set (Jolliffe 1986). To use PCA, at least 10 observations per independent variable are needed (Comrey et al. 1992; Tabachnick and Fidell 2007) and the sample space should be 5-times greater than the independent variables (Hatcher, 1994). With 437 participants and 16 independent emotion variables (ratio of 27.3), the requirement is satisfied. The Kaiser-Meyer-Olkin (KMO) test of global sampling adequacy was 0.79 which is greater than recommended 0.7 and Bartlett's test of sphericity ($p < 0.0001$), indicating that there is a strong relationship between variables proposed for PCA test.

Conducting PCA with oblique rotation (Tabachnick and Fidell 2007) on change scores of emotions, a four-component model was selected based on Kaiser's criteria where components are retained if their eigenvalue is greater than 1. Table 13 shows the pattern matrix that represents the factor loadings on each variable. This table enables for the selection of principal components based upon factor loadings. The selection was straightforward because factor loading of 0.3 is considered significant for this sample size (Hair et al. 1998; Kline 2014; Tabachnick and Fidell 2007).

Since each component consists of a group of emotions, they represent affective state. As mentioned before, affect is defined as overall feelings experienced by an individual. Positive affect is characterized by energy, concentration, and pleasurable engagements and negative affect is characterized by distress and unpleasant experiences (Watson and Tellegen 1985). Here, affect was labeled along the valence (positive and negative) and arousal (high and low) dimensions (Russell 1980). From a theoretical standpoint, the variable loading on component 1 (embarrassment, fear, guilt, sadness, shame, and unhappiness) represents mildly arousing negative affective state; component 2 (happiness, joy, love, and pride) represents mildly arousing positive affective state; component 3 (amusement and surprise) represents highly arousing positive affective state; and component 4 (anger, anxiety, confusion, disgust) represents highly arousing negative affective state seems intuitive and acceptable (Russell 1980). Although the valence of surprise has been long debated, most researchers believe that surprise is a context dependent experience (Barrett 2012; Charlesworth 1969; Oliver 1980) and is often closely linked to the emotion that follows it (Tomkins 1984), in this case amusement. Thus, by accepting this model the dimensionality of the dataset was reduced, and the four principal components (PCs) were used in the testing of the null hypothesis (H2).

Table 13: Principal component analysis pattern matrix

Emotional States	Components			
	1	2	3	4
Amusement	0.165	-0.179		0.682

Anger			0.810	
Anxiety			0.727	
Confusion	-0.156		0.584	0.258
Disgust		0.198	0.506	
Embarrassment		0.388	0.299	
Fear	-0.233		0.542	0.360
Guilt			0.589	0.233
Happiness	0.748	-0.118		0.154
Joy	0.780	-0.181		
Love	0.820			
Pride	0.782	0.222	-0.102	
Sadness		0.749		
Shame	0.118	0.393	0.330	
Surprise		0.204		0.690
Unhappiness		0.764		

Relationship between Change in Emotional State and Change in Overall Situational Interest

The overall change in SI scores were obtained by taking difference between pre- and post-NIS SI scores across three dimensions (triggered-SI, feeling-based maintained SI, value-based maintained SI) and then averaging them. Multiple regression analysis was conducted where the overall change in SI was the dependent variable and the four principal affect groups were the independent variables. The analysis reveals that highly arousing positive emotions [$F(1, 409) = 1.25$; $p = 0.26$], highly arousing negative emotions [$F(1, 409) = 1.59$; $p = 0.21$], mildly arousing positive emotions [$F(1, 409) = 0.17$; $p = 0.68$], and mildly arousing negative emotions [$F(1, 409) = 0.18$; $p = 0.67$] did not show a statistically significant relationship with overall SI.

Relationship between Change in Affective State and Change in Individual Levels of Situational Interest

To further explore the relationship between emotion and SI, the authors explored whether change in affective state predicts change in each *individual* level of SI. The overall change for each dimension (triggered-SI, feeling-based maintained SI, value-based maintained SI) was obtained by taking the

difference of SI scores reported by subjects before and after NIS intervention. Each dimension of SI was then individually regressed on the affective groups. However, no affective group showed a statistically significant relationship with change in triggered-SI and *value*-based maintained SI. However, there was a marginally significant relationship observed between highly arousing positive emotions and change in *feeling*-based maintained SI [$F(1, 409) = 3.40; p = 0.066$]. Also, regressing the four affective groups on the average of change scores across two maintained-SI dimensions (collapsing across feeling and value based), revealed no statistically significant relationship. In summary, these findings provide inconclusive evidence whether contextually-relevant change in emotions generated explains the increase in SI during NIS. Therefore, there is not sufficient evidence to reject the null hypothesis [H2]. In the next section, the role of demographics in moderating this relationship is explored through a series of exploratory tests.

Controlling for Demographical Dimensions

Of the 414 participants, 48 were dropped from this analysis as they declined to disclose information on one or more demographic questions. However, the size of the sample was sufficient to test the relationships between emotion and SI while also controlling for demographic variables. The authors controlled for ethnicity (contrast coded), age, marital status (contrasted coded), and interaction terms (*age* x *marital status* and *ethnicity* x *age*). It should be noted that although age was dichotomized in previous analysis (see Table 12), here it was treated as a continuous variable. When controlling for demographics, the analysis did not reveal any statistically significant relationship between any of the affective groups and the change in overall SI. Although, the test did reveal that as workers get older, the overall change in SI decreases [$F(1, 357) = 4.28; p=0.038$].

Additionally, the relationship between change in affective groups and change in each *individual* SI group was repeated but this time controlling for the relevant demographic groups. Neither change in affective groups nor demographic dimensions showed any statistically significant relationship with change in triggered-SI.

When exploring change in feeling-based maintained SI, the relationship with highly arousing positive emotions group [$F(1, 357) = 2.82; p = 0.09$] was no longer statistically significant, suggesting that the demographic dimensions might play a moderating role. Further, the test revealed that as workers get older, their experience of *feeling*-based maintained SI decreases [$F(1, 357) = 5.05; p = 0.02$]. Similarly, there was no statistically significant relationship observed between *value*-based maintained SI and affective groups, but age showed a statistically significant negative relationship [$F(1, 357) = 3.90; p = 0.049$]. Finally, while controlling for demographic dimensions, the change in overall maintained-SI (collapsing across value and feeling) only showed statistically significant relationship with the variable age where as age increases, the experience of overall maintained SI decreases [$F(1, 357) = 5.2; p = 0.026$]. These tests show that only age was consistently associated with change in SI among construction workers within occupational learning environment.

DISCUSSION

This investigation probes the efficacy of simulation-based safety training that uses adult learning principles and targets emotional engagement to enhance learning. The primary objective was to assess if NIS caused significant changes in SI among construction workers overall and across different demographical dimensions. Results revealed (see Table 11) that after NIS intervention, workers registered an overall increase in SI and that change was consistent across all the dimensions of SI but *value*-based maintained SI ($p < 0.0061$). This confirms that safety training programs that mirror the framework of NIS can foster positivity toward safety training and increased engagement among construction workers (i.e., adult learners). The results also reaffirm the validity of mechanisms used in NIS as tools to promote adult learning since NIS were able to generate interest for a diverse crowd in an unconventional learning environment (see Table 12).

To achieve the secondary objective, the relationship between change in affective arousal groups (arousing positive, mild positive, arousing negative, and mild negative) and SI levels were examined. The results indicated an increase in arousing positive emotions predicted an increase only in *feeling*-based maintained SI, but that relationship was marginally significant. The arousing positive affective group consisted of increases in amusement and surprise (see Table 13). The relationship between ‘surprise’ and SI is not surprising given that increase in SI is closely linked to the shock and novelty of the subject matter (Bergin 1999; Hidi 2000). While this is insufficient evidence to reject the null hypothesis [H2], it is nevertheless the relationship is an interesting finding.

Since NIS were predominantly increasing negative affect among workers, the tentative relationship between positive affect and SI does seem counterintuitive. Although positive and negative affect are independent, they do not represent two ends of a spectrum (MacLeod and Byrne 1996). It is possible that the both positive and negative affective reactions experienced by workers through NIS were context dependent. The link between positive affective (amusement and surprise) and increased *feeling*-based maintained SI among workers could be attributed to adult learners finding the new framework of safety training entertaining. This is supported by research showing that SI is closely associated with curiosity and expectation subversion (Bergin 1999; Hidi and Anderson 1992; Iran-Nejad 1987). In this case, it is strongly tied to surprise possibly associated with use of hyper-realistic hands, authentic accident simulations, and slow-motion graphic videos. Alternatively, the overall increase in negative emotion (fear, disgust, guilt, sadness, and unhappiness) could be associated with discussion on unsafe behaviors, personal stories shared by co-workers on accident history, and reflecting on personal risk-taking habits. It should be noted that researchers delivered NIS in an informal setting using *humor* to keep everyone engaged during simulations and *somber demeanor* during post-simulation discussion to promote risk-averse behavior. So, while surprise could be associated to learning techniques (presentation and information), the overall negative affective reaction may be linked to social or behavioral characteristics of the session (risk-taking habits

discussion, personal stories of injuries). The coexistence and utility of positive and negative affective state in a learning environment with adult learners needs to be confirmed and validated in a future study.

Finally, as discussed in results section, the analysis consistently revealed that as age increased, the interest experienced within NIS training environment reduced. Univariate analysis showed that while NIS facilitate sustained interest among younger and novice workers, not older and experienced workers. This is a highly relevant finding because while there has been a call to incorporate adult learning principles and strategies to enhance learning within construction training environments (Albert and Hallowell 2013), their efficacy had not yet been empirically validated for our domain. This study suggests that the learning mechanisms validated in purely academic settings may not directly translate to occupational safety training environments. Future research needs to modify existing or test new learning mechanisms for construction workers in non-traditional learning environments.

IMPLICATIONS

From an industry standpoint, the NIS design and delivery can present some significant benefits for safety training. As shown in Table 10, subjects sampled in this dataset reported high interest across the three dimensions even before NIS intervention. Nevertheless, the univariate analysis showed that workers still experienced increase across nearly all SI dimensions. This suggests that benefits associated with NIS could be more pronounced on sites with poor safety records or crews with deeper indifference towards safety training. This observation has significant positive implications for construction industry and it could be argued that this format of training could also be beneficial for other high-risk industries as well.

While there was an overall increase in SI observed, each demographical group also revealed statistically significant increase across one or more SI levels post-NIS. Hispanics workers showed statistically significant change across immediate and sustained interest which is highly relevant as they are

more likely to experience injury or fatality compared to their Caucasian counterparts (Center of Construction Research and Training 2013). Research has also shown that Hispanic workers tend to be apathetic towards safety training and are more willing to engage in dangerous work (Yugar-Arias and Hallowell 2016). Thus, the fact that NIS promoted especially high SI and emotional engagement is very encouraging.

From an academic standpoint, efficacy of simulation-based training modules for adult learners is rarely validated in an ecologically valid setting. This study does not find consistent evidence that SI is influenced by change in affect for adult learners in a non-traditional learning environment. The finding allows authors to tentatively suggest that learning agents incorporated in NIS caused an independent increase in SI and negative affective experience among construction workers. Furthermore, the analysis suggests that age may moderate the relationship between affect and SI. While assertions presented in this study are not conclusive, it highlights interesting avenues for future research. Overall, the most relevant and compelling contribution of this study is integrating and examining the adult learning mechanisms and interest generation techniques for adult learners in an occupational learning environment.

LIMITATIONS

There are several limitations in this study due to the design and logistical constraints. First and foremost, this was a quasi-experiment without a control group. The lack of control group or control over the experimental environment limits internal validity and restricts ability to draw conclusive inferences or control for confounding variables. Recognizing that most emotions and situational interest studies are performed in laboratory and classroom settings with high internal validity but low ecological validity, this study promoted ecological validity by studying actual adult workers on active construction sites. The methodology also allowed for the representation of true demographic variability. Such quasi experimental techniques are commonly used in field-based psychology studies (Cunningham 1979; Ganster et al. 1982;

Wagner et al. 2016) and play an important role in exploring the translation of psychological concepts to real-world conditions. The second limitation relates to the use of self-reporting questionnaires in our research design. Although, self-reporting questionnaires are commonly used, the data are often confounded with errors due to participant biases. The third limitation is that while the SI questionnaire has been empirically validated, more research is needed to confirm the psychometric quality of the instruments with older adult population. The Linnenbrink-Garcia et al. (2010) interest survey has not been validated on adult learners before this study to the best of our knowledge. Although, participants in this study were sampled from the same population and therefore, it is likely that their interpretation of survey items was consistent, nevertheless future research should validate the findings of this study to gauge the efficacy of the SI questionnaire in use and include an emotional intelligence questionnaire when collecting self-reported emotions for validation purposes. The fourth limitation is an extension of the previous one where the survey instruments that were used in this study have been validated in literature; however, the effect of translational process on the ambiguity of the questions or words is unclear. The Spanish version of these surveys were translated by native Spanish speakers and vetted by Spanish speaking project leads on site who assisted in delivering NIS and are acutely familiar with the dialect of the crew. However, authors recommend future studies to employ back-translation (Schaffer and Riordan 2003) and pilot testing (Van de Vijver and Leung 1997) to establish semantic equivalence. The fifth limitation is that, despite informing workers that all the surveys are anonymous and confidential, participating in this study was an atypical experience for them. The authors suspect that the emotions questionnaire was awkward and represented a departure from routine for some. Sixth limitation relates the experimental protocol used in this study, which does not allow the authors to test causality between SI and affective arousal. Finally, the authors cite links between SI and learning from past literature, but there was no data collected in this study to empirically test the relationship between the two variables.

CONCLUSIONS

In summary, this study is the first to present a new safety training module that is built on adult learning principles and targets emotional engagement to improve situational interest in safety training. Further, the study involved field testing and validation directly with construction workers to preserve ecological validity. The analyses revealed that the new training method increases SI in adult construction workers across all demographical dimensions. Given that Bhandari et al. (2017) found that NIS increases emotional engagement, the present research also explored if contextually-relevant arousing affective experiences influence SI. Preliminary evidence suggests that arousing positive emotions may influence *feeling*-based maintained SI but *value*-based maintained and triggered SI may be independent of emotional states. Although the conclusions presented in this paper are compelling, they should be challenged and validated by future studies.

REFERENCES

- [1]. Ahl, H. (2006). Motivation in adult education: a problem solver or a euphemism for direction and control?. *International journal of lifelong education*, 25(4), 385-405.
- [2]. Ainley, M. (1998). Interest in learning and the disposition of curiosity in secondary students: Investigating process and context. In L. Hoffman, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Seon conference on interest and gender* (pp. 257–266). Kiel, Germany: IPN.
- [3]. Alexander, P. A. (1997). Mapping the multidimensional nature of domain learning: The interplay of cognitive, motivational, and strategic forces. In M. L. Maehr & P. R. Pintrich (Eds.), *Advances in motivation and achievement* (Vol. 10, pp. 213–250). Greenwich, CT: JAI.
- [4]. Alexander, P. A., & Jetton, T. L. (1996). The role of importance and interest in the processing of text. *Educ. Psychol. Rev.* 8: 89–121.
- [5]. Alexander, P. A., & Murphy, P. K. (1998). Profiling the differences in students' knowledge, interest, and strategic processing. *Journal of Educational Psychology*, 90, 435–447.
- [6]. Albert, A., & Hallowell, M. R. (2013). Revamping occupational safety and health training: Integrating andragogical principles for the adult learner. *Australasian Journal of Construction Economics and Building*, 13(3), 128.
- [7]. Albert, A., Hallowell, M. R., & Kleiner, B. M. (2013). Enhancing construction hazard recognition and communication with energy-based cognitive mnemonics and safety meeting maturity model: Multiple baseline study. *Journal of Construction Engineering and Management*, 140(2), 04013042.
- [8]. Albert, A., Hallowell, M. R., Kleiner, B., Chen, A., & Golparvar-Fard, M. (2014a). Enhancing construction hazard recognition with high-fidelity augmented virtuality. *Journal of Construction Engineering and Management*, 140(7), 04014024.
- [9]. Albert, A., Hallowell, M. R., & Kleiner, B. M. (2014b). Experimental field testing of a real-time construction hazard identification and transmission technique. *Construction Management and*

- Economics, 32(10), 1000-1016. J. Huesman, L. Holland, & T. Langley, "April 2015 construction at \$1,006.1 Billion Annual Rate," U.S. Census Bureau News, Washington, D.C., 01-Jun-2015.
- [10]. Albert, A., & Hallowel, M. R. (2013). Revamping occupational safety and health training: Integrating andragogical principles for the adult learner. *Australasian Journal of Construction Economics and Building, The*, 13(3), 128.
- [11]. Alhakami, A. S., & Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk analysis*, 14(6), 1085-1096.
- [12]. Anderson, A. K., Yamaguchi, Y., Grabski, W., & Lacka, D. (2006). Emotional memories are not all created equal: evidence for selective memory enhancement. *Learning & Memory*, 13(6), 711-718.
- [13]. Arnett, J. (1992). Reckless behavior in adolescence: A developmental perspective. *Developmental review*, 12(4), 339-373
- [14]. Baddeley, A. (1992). Working memory. *Science*, 255(5044), 556-559.
- [15]. Barabasz, A. F., & Barabasz, M. (1992). Research designs and considerations. In E. Fromm & M. R. Nash (Eds.), *Contemporary hypnosis research* (pp. 173-200). New York: Guilford. The preceding paper attributes the concept to Weber, S. J., & Cook, T. D. (1972).
- [16]. Barsade, S. G., & Gibson, D. E. (2007). Why does affect matter in organizations?. *The Academy of Management Perspectives*, 21(1), 36-59.
- [17]. Barrett, L. F. (2012). Emotions are real. *Emotion*, 12, 413429. doi:10.1037/a0027555
- [18]. Bergin, D. A. (1999). Influences on classroom interest. *Educational psychologist*, 34(2), 87-98.
- [19]. Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision-making and the orbitofrontal cortex. *Cerebral cortex*, 10(3), 295-307.
- [20]. Benton, S. L., Corkill, A. J., Sharp, J. M., Downey, R. G., & Khramtsova, I. (1995). Knowledge, interest, and narrative writing. *Journal of Educational Psychology*, 87(1), 66.

- [21]. Bhandari, S., & Hallowell, M. R. (2017). Emotional Engagement in Safety Training: Impact of Naturalistic Injury Simulations on the Emotional State of Construction Workers. *Journal of Construction Engineering and Management*, 143(12), 04017090.
- [22]. Billett, S. (2001). *Learning in the workplace: Strategies for effective practice*. Allen & Unwin, PO Box 8500, St Leonards, 1590 NSW, Australia.
- [23]. Candy, P. C. (1991). *Self-Direction for Lifelong Learning. A Comprehensive Guide to Theory and Practice*. Jossey-Bass, 350 Sansome Street, San Francisco, CA 94104-1310.
- [24]. Canli, T., Zhao, Z. U. O., Desmond, J. E., Glover, G., & Gabrieli, J. D. (1999). fMRI identifies a network of structures correlated with retention of positive and negative emotional memory. *Psychobiology*, 27(4), 441-452.
- [25]. Cahill, L., Haier, R. J., Fallon, J., Alkire, M. T., Tang, C., Keator, D., Joseph Wu, & Mcgaugh, J. L. (1996). Amygdala activity at encoding correlated with long-term, free recall of emotional information. *Proceedings of the National Academy of Sciences*, 93(15), 8016-8021.
- Cunningham, W. A., Raye, C. L., & Johnson, M. K. (2004). Implicit and explicit evaluation: fMRI correlates of valence, emotional intensity, and control in the processing of attitudes. *Journal of cognitive neuroscience*, 16(10), 1717-1729.
- [26]. Center for Construction Research and Training, (2007). *The Construction Chart Book: The U.S. Construction Industry and its Workers (4th ed.)*. Retrieved June 21, 2016, from [http://www.cpwr.com/sites/default/files/research/CB4_Final for web.pdf](http://www.cpwr.com/sites/default/files/research/CB4_Final%20for%20web.pdf)
- [27]. Charlesworth, W. R. (1969). The role of surprise in cognitive development. *Studies in cognitive development*, 257-314.
- [28]. Chen, J., Shao, J., 2000. Nearest neighbor imputation for survey data. *Journal of Official Statistics* 16, 113–132.
- [29]. Chung, S., Cheon, J., & Lee, K. W. (2015). Emotion and multimedia learning: an investigation of the effects of valence and arousal on different modalities in an instructional animation. *Instructional Science*, 43(5), 545-559.

- [30]. Clore, G. L., Schwarz, N., and Conway, M. 1994. Affective causes and consequences of social information processing. *Handbook of social cognition*,1, 323-417.
- [31]. Compton, J. I., Cox, E., & Laanan, F. S. (2006). Adult learners in transition. *New directions for student services*, 2006(114), 73-80.
- [32]. Comrey, A. L., and Lee, H. B. (1992). *A first course in factor analysis*, Erlbaum, Hillsdale, NJ.
- [33]. Consedine, N. S., Magai, C., & King, A. R. (2004). Deconstructing positive affect in later life: A differential functionalist analysis of joy and interest. *The International Journal of Aging and Human Development*, 58(1), 49-68.
- [34]. Cunningham, M. R. (1979). Weather, mood, and helping behavior: Quasi experiments with the sunshine samaritan. *Journal of Personality and Social Psychology*, 37(11), 1947.
- [35]. Damasio, A. R., Everitt, B. J., & Bishop, D. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex [and discussion]. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 351(1346), 1413-1420.
- [36]. Dasarathy, B. V. (1991). Nearest neighbor ({NN}) norms: {NN} pattern classification techniques.
- [37]. De Leersnyder, J., Mesquita, B., & Kim, H. S. (2011). Where do my emotions belong? A study of immigrants' emotional acculturation. *Personality and Social Psychology Bulletin*, 0146167211399103.
- [38]. Dudani, S. A. (1976). The distance-weighted k-nearest-neighbor rule. *IEEE Transactions on Systems, Man, and Cybernetics*, (4), 325-327.
- [39]. Erez, A., & Isen, A. M. (2002). The influence of positive affect on the components of expectancy motivation. *Journal of Applied psychology*, 87(6), 1055.
- [40]. Fairchild, E. E. (2003). Multiple roles of adult learners. *New directions for student services*, 2003(102), 11-16.
- [41]. Fisher, M., King, J., & Tague, G. (2001). Development of a self-directed learning readiness scale for nursing education. *Nurse education today*, 21(7), 516-525.

- [42]. Frijda, N. H., & Mesquita, B. (1994). The social roles and functions of emotions. In S. Kitayama and H. R. Markus (Eds.), *Emotion and culture: Empirical studies of mutual influence* (pp. 51-87). Washington, DC: American Psychological Association.
- [43]. Ganster, D. C., Mayes, B. T., Sime, W. E., & Tharp, G. D. (1982). Managing organizational stress: A field experiment. *Journal of Applied Psychology*, 67(5), 533.
- [44]. Gardner, M., & Steinberg, L. (2005). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: an experimental study. *Developmental psychology*, 41(4), 625.
- [45]. Garner, R., Brown, R., Sanders, S., and Menke D. J. (1992). "Seductive details" and learning from text. In Renninger, A., Hidi, S., and Krapp, A. (eds.), *The Role of Interest in Learning and Development*, Lawrence Erlbaum, Hillsdale, NJ, pp. 239–254.
- [46]. Garrison, D. R. (1997). Self-directed learning: Toward a comprehensive model. *Adult Education Quarterly*, 48(1), 18-33.
- [47]. Garrison, D. R. (1993). An analysis of the control construct in self-directed learning. *Emerging perspectives of self-directed learning*, 27-44.
- [48]. Gilboa, È., & Revelle, W. (1994). Personality and the structure of affective responses. *Emotions: Essays on emotion theory*, 135-159
- [49]. Grace, A. P. (1996). Striking a critical pose: andragogy--missing links, missing values. *International Journal of Lifelong Education*, 15(5), 382-392.
- [50]. Gross, J. J., & Levenson, R. W. (1995). Emotion elicitation using films. *Cognition & emotion*, 9(1), 87-108.
- [51]. Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: the acute effects of inhibiting negative and positive emotion. *Journal of abnormal psychology*, 106(1), 95.
- [52]. Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (1998). *Multivariate data analysis* (Vol. 5, No. 3, pp. 207-219). Upper Saddle River, NJ: Prentice hall.

- [53]. Hallowell, M. R. (2010). Safety risk perception in construction companies in the Pacific Northwest of the USA. *Construction management and economics*, 28(4), 403-413.
- [54]. Hallowell, M. R., & Yugar-Arias, I. F. (2016). Exploring fundamental causes of safety challenges faced by Hispanic construction workers in the US using photovoice. *Safety science*, 82, 199-211.
- [55]. Hamann, S. B., Ely, T. D., Grafton, S. T., & Kilts, C. D. (1999). Amygdala activity related to enhanced memory for pleasant and aversive stimuli. *Nature neuroscience*, 2(3), 289.
- [56]. Harackiewicz, J. M., Barron, K. E., Tauer, J. M., Carter, S. M., & Elliot, A. J. (2000). Short-term and long-term consequences of achievement: Predicting continued interest and performance over time. *Journal of Educational Psychology*, 92, 316–330.
- [57]. Hartree, A. (1984). Malcolm Knowles' theory of andragogy: A critique. *International Journal of Lifelong Education*, 3(3), 203-210
- [58]. Haslam, R. A., Hide, S. A., Gibb, A. G., Gyi, D. E., Pavitt, T., Atkinson, S., & Duff, A. R. (2005). Contributing factors in construction accidents. *Applied ergonomics*, 36(4), 401-415.
- [59]. Hoffmann, L. (2002). Promoting girls' learning and achievement in physics classes for beginners. *Learning and Instruction*, 12, 447–465.
- [60]. Hoffmann, L., & Häußler, P. (1998). An intervention project promoting girls' and boys' interest in physics. In L. Hoffmann, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Seeon conference on interest and gender* (pp. 301–316). Kiel, Germany: IPN.
- [61]. Hollins, E. R., & King, J. E. (1994). *Teaching diverse populations: Formulating a knowledge base* (Vol. 1944). SUNY Press.
- [62]. House, J. S., Landis, K. R., & Umberson, D. (1988). Social relationships and health. *Science*, 241(4865), 540-545.
- [63]. Hidi, S. (2000). An interest researcher's perspective: The effects of extrinsic and intrinsic factors on motivation. *Task· contingent rewards (co/lti" ued)*, 328, 83.

- [64]. Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research*, 60, 549–571.
- [65]. Hidi, S., & Anderson, V. (1992). Situational interest and its impact on reading and expository writing. *The role of interest in learning and development*, 11, 213-214.
- [66]. Hidi, S., & Baird, W. (1986). Interestingness—A neglected variable in discourse processing. *Cognitive Sci.* 10: 179–194.
- [67]. Hidi, S., & Berndorff, D. (1998). Situational interest and learning. In L. Hoffman, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Secon conference on interest and gender* (pp. 74–90). Kiel, Germany: IPN.
- [68]. Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational psychologist*, 41(2), 111-127.
- [69]. Hidi, S., Renninger, K. A., & Krapp, A. (2004). Interest, a motivational variable that combines affective and cognitive functioning. In D. Y. Dai & R. J. Sternberg (Eds.), *Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development* (pp. 89–115). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- [70]. Hilton, S. M., & Zbrożyna, A. W. (1963). Amygdaloid region for defence reactions and its efferent pathway to the brain stem. *The Journal of physiology*, 165(1), 160-173.
- [71]. Hsu, H., & Lachenbruch, P. A. (2008). Paired t test. *Wiley Encyclopedia of Clinical Trials*.
- [72]. Immordino-Yang, M. H. (2015). *Emotions, Learning, and the Brain: Exploring the Educational Implications of Affective Neuroscience* (The Norton Series on the Social Neuroscience of Education). WW Norton & Company.
- [73]. Iran-Nejad, A. (1987). Cognitive and affective causes of interest and liking. *Journal of Educational Psychology*, 79(2), 120.
- [74]. Isen, A. M., & Baron, R. A. (1991). Positive affect as a factor in organizational-behavior. *Research in organizational behavior*, 13, 1-53.

- [75]. Isen, A. M., Daubman, K. A., & Nowicki, G. P. (1987). Positive affect facilitates creative problem solving. *Journal of personality and social psychology*, 52(6), 1122.
- [76]. Izard, C. E. (2010). The many meanings/aspects of emotion: Definitions, functions, activation, and regulation. *Emotion Review*, 2(4), 363-370.
- [77]. Kane, F., Coulombe, D., & Miliareisis, E. (1991). Amygdaloid self-stimulation: A movable electrode mapping study. *Behavioral neuroscience*, 105(6), 926.
- [78]. Kline, P. (2014). *An easy guide to factor analysis*. Routledge.
- [79]. Konradt, U., Filip, R., & Hoffmann, S. (2003). Flow experience and positive affect during hypermedia learning. *British journal of educational technology*, 34(3), 309-327.
- [80]. Kazis, R., Callahan, A., Davidson, C., McLeod, A., Bosworth, B., Choitz, V., & Hoops, J. (2007). Adult learners in higher education: Barriers to success and strategies to improve results. Employment and Training Division Occasional Paper, 3.
- [81]. Keller, C., Siegrist, M., and Gutscher, H. 2006. The role of the affect and availability heuristics in risk communication. *Risk Analysis*, 26(3), 631-639
- [82]. Kerka, S. (2002). *Teaching Adults: Is It Different? Myths and Realities*.
- [83]. Knowles, M. (1980). *The modern practice of adult education: From pedagogy to andragogy* (Rev. and Updated. ed.). Wilton, Conn.: Association Press.
- [84]. Knowles, M. (1984). *The Adult Learner: A Neglected Species*. Houston: Gulf Pub. Kobasa, SC (1982). *The Hardy Personality: Toward a Social Psychology of Stress and Health*. In GS Sanders and J. Suls (Eds.), *Social Psychology of Health and Illness*, 3-32.
- [85]. Knowles, M. S., Holton III, E. F., & Swanson, R. A. (2014). *The adult learner: The definitive classic in adult education and human resource development*. Routledge.
- [86]. Krapp, A. (2000). Interest and human development during adolescence: An educational-psychological approach. In J. Heckhausen (Ed.), *Motivational psychology of human development* (pp. 109–128). London: Elsevier.

- [87]. Krapp, A., & Fink, B. (1992). The development and function of interests during the critical transition from home to preschool. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 397–429). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- [88]. Krapp, A., Hidi, S., & Renninger, K. A. (1992). Interest, learning, and development. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 3–25). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- [89]. Lall, U., & Sharma, A. (1996). A nearest neighbor bootstrap for resampling hydrologic time series. *Water Resources Research*, 32(3), 679-693.
- [90]. Lang, A. (2006). Using the limited capacity model of motivated mediated message processing to design effective cancer communication messages. *Journal of communication*, 56(s1), S57-S80.
- [91]. Lazarus, R. S. (1991). *Emotion and adaptation*. Oxford University Press on Demand.
- [92]. LeDoux, J. E. (1993). Emotional memory systems in the brain. *Behavioural brain research*, 58(1-2), 69-79.
- [93]. LeDoux, J. (1998). *The emotional brain: The mysterious underpinnings of emotional life*. Simon and Schuster.
- [94]. Lerner, J. S., & Keltner, D. (2001). Fear, anger, and risk. *Journal of personality and social psychology*, 81(1), 146.
- [95]. Liao, S. G., Lin, Y., Kang, D. D., Chandra, D., Bon, J., Kaminski, N., ... & Tseng, G. C. (2014). Missing value imputation in high-dimensional phenomic data: imputable or not, and how?. *BMC bioinformatics*, 15(1), 346.
- [96]. Linnenbrink-Garcia, L., Durik, A. M., Conley, A. M., Barron, K. E., Tauer, J. M., Karabenick, S. A., & Harackiewicz, J. M. (2010). Measuring situational interest in academic domains. *Educational and Psychological Measurement*.

- [97]. Litwak, E., Messeri, P., Wolfe, S., Gorman, S., Silverstein, M., & Guilarte, M. (1989). Organizational theory, social supports, and mortality rates: A theoretical convergence. *American Sociological Review*, 49-66.
- [98]. Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological bulletin*, 127(2), 267.
- [99]. Lundberg, C. A. (2003). The influence of time-limitations, faculty, and peer relationships on adult student learning: A causal model. *Journal of Higher Education*, 665-688.
- [100]. MacLeod, A. K., & Byrne, A. (1996). Anxiety, depression, and the anticipation of future positive and negative experiences. *Journal of abnormal psychology*, 105(2), 286.
- [101]. McCarney, R., Warner, J., Iliffe, S., Van Haselen, R., Griffin, M., & Fisher, P. (2007). The Hawthorne Effect: a randomised, controlled trial. *BMC medical research methodology*, 7(1), 30.
- [102]. Merriam, S. (2004). The changing landscape of adult learning theory. In J. Comings, B. Garner, and C. Smith (Eds.), *Review of adult learning and literacy: Connecting research, policy, and practice* (pp. 199- 220). Mahwah, NJ: Lawrence Erlbaum Associates.
- [103]. Meyer, D. K., & Turner, J. C. (2002). Discovering emotion in classroom motivation research. *Educational psychologist*, 37(2), 107-114.
- [104]. Mitchell, M. (1993). Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of educational psychology*, 85(3), 424.
- [105]. Morrow, L. M., Sharkey, E., & Firestone, W. A. (1993). *Promoting independent reading and writing through self-directed literacy activities in a collaborative setting*. National Reading Research Center.
- [106]. Nadeau, R., Cloutier, E., & Guay, J. H. (1993). New evidence about the existence of a bandwagon effect in the opinion formation process. *International Political Science Review*, 14(2), 203-213.
- [107]. Nichols, A. L., & Maner, J. K. (2008). The good-subject effect: Investigating participant demand characteristics. *The Journal of general psychology*, 135(2), 151-166.

- [108]. Öhman, A., and Mineka, S. 2001. Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. *Psychological review*, 108(3), 483.
- [109]. Oliver, R. L. (1980). A cognitive model of the antecedents and consequences of satisfaction decisions. *Journal of marketing research*, 460-469.
- [110]. Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational psychology review*, 18(4), 315-341.
- [111]. Pekrun, R., Elliot, A. J., & Maier, M. A. (2009). Achievement goals and achievement emotions: Testing a model of their joint relations with academic performance. *Journal of educational Psychology*, 101(1), 115.
- [112]. Pekrun, R., Frenzel, A. C., Goetz, T., & Perry, R. P. (2007). The control-value theory of achievement emotions: An integrative approach to emotions in education. In P. A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 13–36). San Diego: Elsevier
- [113]. Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational psychologist*, 37(2), 91-105.
- [114]. Pekrun, R., & Linnenbrink-Garcia, L. (2012). Academic emotions and student engagement. In *Handbook of research on student engagement* (pp. 259-282). Springer, Boston, MA.
- [115]. Perlman, A., Sacks, R., & Barak, R. (2014). Hazard recognition and risk perception in construction. *Safety science*, 64, 22-31.
- [116]. Pintrich, P. R., & Zusho, A. (2002). The development of academic self-regulation: The role of cognitive and motivational factors. In A. Wigfield & J. S. Eccles (Eds.), *Development of achievement motivation* (pp. 249–284). New York: Academic.
- [117]. Pratt, D. D. (1993). Andragogy after twenty-five years. *New directions for adult and continuing education*, 1993(57), 15-23

- [118]. Rathunde, K. (1998). Undivided and abiding interest: Comparisons across studies of talented adolescents and creative adults. In L. Hoffman, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Seon conference on interest and gender* (pp. 367–376). Kiel, Germany: IPN.
- [119]. Reio, T. G., & Wiswell, A. (2000). Field investigation of the relationship among adult curiosity, workplace learning, and job performance. *Human Resource Development Quarterly*, 11(1), 5-30.
- [120]. Renninger, K. A. (2000). Individual interest and its implications for understanding intrinsic motivation. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 375–407). New York: Academic.
- [121]. Roberts, N. A., Levenson, R. W., & Gross, J. J. (2008). Cardiovascular costs of emotion suppression cross ethnic lines. *International Journal of Psychophysiology*, 70(1), 82-87.
- [122]. Robinson, M. D., & Clore, G. L. (2002). Episodic and semantic knowledge in emotional self-report: evidence for two judgment processes. *Journal of personality and social psychology*, 83(1), 198.
- [123]. Rook, K. S., Thuras, P. D., & Lewis, M. A. (1990). Social control, health risk taking, and psychological distress among the elderly. *Psychology and Aging*, 5(3), 327.
- [124]. Rotgans, J. I., & Schmidt, H. G. (2017). Interest development: Arousing situational interest affects the growth trajectory of individual interest. *Contemporary Educational Psychology*, 49, 175-184.
- [125]. Rottenberg, J., Ray, R. R., & Gross, J. J. (2007). Emotion elicitation using films. In J. A. Coan & J. J.B. Allen (Eds.), *The handbook of emotion elicitation and assessment* (pp. 9_28). New York: Oxford University Press.
- [126]. Russell, J. A. (1980). A circumplex model of affect. *Journal of personality and social psychology*, 39(6), 1161.
- [127]. Safety and Health Council of NC. (n.d.). HAND SAFETY in the WORKPLACE. Retrieved April 21, 2017, from <http://www.safetync.org/>. Retrieved from

<<http://www.nsc.org/Membership%20Site%20Document%20Library/Recorded-Webinars/Safety%20at%20Hand.pdf>>

- [128]. Sansone, C., & Smith, J. L. (2000). Interest and self-regulation: The relation between having to and wanting to. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 341–372). New York: Academic.
- [129]. Schaffer, B. S., & Riordan, C. M. (2003). A review of cross-cultural methodologies for organizational research: A best-practices approach. *Organizational research methods*, 6(2), 169-215.
- [130]. Schiefele, U. (1999). Interest and learning from text. *Scientific Studies of Reading*, 3, 257–280.
- [131]. Schiefele, U. (1996). Topic interest, text representation, and quality of experience. *Contemporary Educational Psychology*, 21, 3–18.
- [132]. Schiefele, U. (1991). Interest, learning, and motivation. *Educational psychologist*, 26(3-4), 299-323.
- [133]. Silvia, P. J. (2001). Interest and interests: The psychology of constructive capriciousness. *Review of General Psychology*, 5, 270–290.
- [134]. Sissel, P. A., Hansman, C. A., & Kasworm, C. E. (2001). The politics of neglect: Adult learners in higher education. *New Directions for Adult and Continuing Education*, 2001(91), 17-28.
- [135]. Slovic, P., & Peters, E. (2006). Risk perception and affect. *Current directions in psychological science*, 15(6), 322-325.
- [136]. Tabachnick, B. G., and Fidell, L. S. (2007). *Using multivariate statistics*, 5th Ed., Pearson Allyn and Bacon, Upper Saddle River, NJ.
- [137]. U.S. Bureau of Labor Statistics, “2017 Labor Force Statistics from the Current Population Survey” U.S. Department of Labor, Washington, DC, Jan. 2018.
- [138]. U.S. Bureau of Labor Statistics, “2016 Survey of occupational injuries and illnesses Charts Package,” U.S. Department of Labor, Washington, DC, Nov. 2017.

- [139]. U.S. Department of Education, National Center for Education Statistics. (2013). Digest of Education Statistics, 2012 (NCES 2014-015), Retrieved from:
<http://nces.ed.gov/programs/digest/d12/>.
- [140]. US Department of Energy, "Buildings Energy Data Book," Building Energy Data Book, March 2012. [Online]. Available: <http://buildingsdatabook.eren.doe.gov/ChapterIntro1.aspx>. [Accessed: 25-May-2016].
- [141]. Wilkins, J. R. (2011). Construction workers' perceptions of health and safety training programmes. *Construction Management and Economics*, 29(10), 1017-1026.
- [142]. Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics*. Allyn & Bacon/Pearson Education.
- [143]. Taylor, S. E., & Brown, J. D. (1988). Illusion and well-being: a social psychological perspective on mental health. *Psychological bulletin*, 103(2), 193.
- [144]. Tixier, A. J. P., Hallowell, M. R., Albert, A., van Boven, L., & Kleiner, B. M. (2014). Psychological antecedents of risk-taking behavior in construction. *Journal of Construction Engineering and Management*, 140(11), 04014052.
- [145]. Tobias, S. (1995). Interest and metacognitive word knowledge. *Journal of educational psychology*, 87(3), 399.
- [146]. Tough, A. (1979). *The Adult's Learning Projects. A Fresh Approach to Theory and Practice in Adult Learning*.
- [147]. Tomkins, S. S. (1984). Affect theory. *Approaches to emotion*, 163(163-195).
- [148]. Troyanskaya, O., Cantor, M., Sherlock, G., Brown, P., Hastie, T., Tibshirani, R., Botstein, D. & Altman, R. B. (2001). Missing value estimation methods for DNA microarrays. *Bioinformatics*, 17(6), 520-525.
- [149]. Turner, C., & McClure, R. (2003). Age and gender differences in risk-taking behaviour as an explanation for high incidence of motor vehicle crashes as a driver in young males. *Injury control and safety promotion*, 10(3), 123-130.

- [150]. Umberson, D. (1987). Family status and health behaviors: Social control as a dimension of social integration. *Journal of health and social behavior*, 306-319.
- [151]. Van de Vijver, F., & Leung, K. (1997). *Methods and data analysis of comparative research*. Allyn & Bacon.
- [152]. Venter, K. (2003). Coping with isolation: The role of culture in adult distance learners' use of surrogates. *Open Learning*, 18(3), 271-287.
- [153]. Verduyn, P., Delvaux, E., Van Coillie, H., Tuerlinckx, F., and Van Mechelen, I. (2009). Predicting the duration of emotional experience: two experience sampling studies. *Emotion*, 9(1), 83.
- [154]. Verduyn, P., Van Mechelen, I., and Tuerlinckx, F. (2011). The relation between event processing and the duration of emotional experience. *Emotion*, 11(1), 20.
- [155]. Wagner, V., Klein, J., Hanich, J., Shah, M., Menninghaus, W., & Jacobsen, T. (2016). Anger framed: A field study on emotion, pleasure, and art. *Psychology of Aesthetics, Creativity, and the Arts*, 10(2), 134.
- [156]. Watson, D., & Tellegen, A. (1985). Toward a consensual structure of mood. *Psychological bulletin*, 98(2), 219.
- [157]. X. S. Dong, J. A. Largay, & X. Wang, "New trends in fatalities among construction workers," *Cent. Prot. Work. Rights CPWR Data Brief*, vol. 3, no. 2, Jun. 2014.
- [158]. Zhang, S. (2012). Nearest neighbor selection for iteratively kNN imputation. *Journal of Systems and Software*, 85(11), 2541-2552.

CHAPTER 5: SUMMARY AND CONCLUSIONS

Construction industries use safety training to provide workers with skills to identify threats and risk associated in their work-environment accurately and to condition their risk-taking behavior such that they become make risk-averse decisions. On the surface, the increasing rate of fatalities and injuries on construction sites is baffling statistic because of increasing focus on safety research within the academic community and rigorous implementation regulations from industries. However, as pointed in various chapters above, the industry has not kept pace with advancement in field of learning and behavioral psychology to improve safety training. This has likely resulted in safety training programs failing to generate intrinsic motivation to avoid risk (Haslam et al. 2005) nor has it improved their hazard recognition skills (Albert et al. 2013; Albert et al. 2014). This thesis addresses the calls to improve safety training program (Albert and Hallowell 2013) by empirically testing its efficacy in improving learning outcomes and eliciting precursors that catalyze risk-averse behavior.

CHAPTER 2 SUMMARY

There are primarily two affective experiences: incidental and integral. While integral affect is affective reaction directly associated with decision-task or immediate stimuli, incidental affect is caused by external stimuli which is unrelated to the decision-task at hand or immediate stimuli. In this chapter, the objective was to examine to what extent, if at all, does incidental and integral affective responses (positive, negative, and neutral) independently influence the ability to identify hazards, assess danger, and make safety decisions within construction safety context. The analysis conducted also examines the linear linkages between hazard recognition, risk perception, and safety-related decision making that has been previously theorized in Tixier et al. (2014)'s situational awareness model but has not been empirically examined. The analysis also explores whether participants value subjective feelings (i.e. "gut feeling") over objective evaluations when taking safety decisions.

A controlled laboratory experiment was conducted where participants (N= 73) were randomly assigned to an experimental manipulation to induce incidental affective state and then immersed in an augmented virutality (AV) environment. Within the AV environment, participants were exposed to various construction-tasks where they were tasked to identify all the hazards, rate the danger level associated with each hazard, and report the level affective arousal on a self-report sliding scale of 1-100 where 1 represented 'not at all' and 100 represented 'extremely.' Finally, the participants were asked to make a safety decision for the presented scenario.

Analysis and Key Findings

Given the experimental design, each participant had to treated as a within-subject factor and the photographs encountered by participants in the AV environment were crossed with the experimental manipulations (i.e. induced affective state). To account for multilevel data, linear mixed-effects model analysis was used to allow for both fixed and random effects. The key statistically significant highlights from the analysis were:

1. Hazards explicitly identified and subjective feel of the environment generated negative integral affect among participants.
2. Controlling for all the hazards identified by the participants, total hazards in the environment, and the experimental manipulations (i.e., induced incidental affect), negative integral affective experience increased the overall perception of risk.
3. Controlling for all the hazards identified by the participants total hazards in the environment, assessment of danger, and the experimental manipulations, integral affective experience increased risk-averse decision-making among participants.
4. Subjective evaluations (i.e., total hazards in the environment) influenced affective experiences, assessment of risk, and safety decision independent of objective evaluations (i.e., hazards identified by participants).

5. While there was direct association between number of hazards identified by participants with assessment of risk, there was no evidence found to support a direct relationship between number of hazards identified by participants influenced their decisions regarding safety.

Limitations

There were several key limitations associated with the work presented:

1. The study was underpowered (N=73) and did not capture the demographical variability found on construction sites. Future studies should attempt to recruit construction workers to capture and control for demographical differences in their analysis such as: culture, age, and relevant experience data
2. The results presented show correlation because the experimental design did not allow the researchers to test for causality.
3. There was reason to believe that the experimental manipulation did not work despite following validated experimental protocols. The author recommends future researchers to cross validate the selected emotion induction technique on the representative sample before running the complete experiment.
4. While the AV environment was immersive virtual environment, there is very little evidence to support that individuals' perception and behavior noted in AV environment align with real-world environment. There is a need to conduct a field-based quasi experiment to cross validate the findings presented here.

The work presented here confirms that a training module that generates context-driven emotions can influence valuation of danger positively and also promote risk-averse decision-making within construction safety context.

CHAPTER 3 SUMMARY

Apart from improving hazard recognition skills among workers, general philosophy behind NIS was to give workers the experience of injury without actually injuring them. This is in accordance with Hallowell (2010) who found that the only personal factor that affects a worker's risk tolerance is their previous personal injury history. NIS was therefore defined as scientifically accurate live multimedia-based reproductions of past accidents that uses hyper-realistic replicas of human body parts and actuals tools, equipment, and materials to simulate various injuries.

The training module was grounded in popular adult learning theories: andragogy and self-directed learning to promote active and experiential learning among workers. In NIS, the principles of andragogy were embedded with the self-directed learning model proposed by Garrison (1997). The self-directed learning technique is much more effective in delivering information and engaging with learners that have significant past experiences. The design and delivery of NIS was focused on promoting the three components of Garrison's (1997) model: *self-management*, *self-monitoring*, and *motivation*.

NIS was delivered to over 1200 workers in Kenedy, TX on a ConocoPhillips site over the course of sixteen two-hour sessions. The researchers randomly selected 489 workers to complete a survey that capture their demographics, emotional arousal, and situational interest. The surveys were administered before and after the intervention (i.e., NIS) and participation was anonymous, uncompensated, and voluntary. The quasi-field experiment intentionally contrasts with the controlled lab-environment experimental strategy of chapter 2 to confirm the effectiveness of the training module on construction workers. A large dataset from the target population such as this yielded a high external and ecological validity to the findings and conclusions presented.

Analysis and Key Findings

Changes to the emotions before and after the training intervention are presented in this chapter. Since the before-after data was linked to one subject and was found to be normally distributed, paired t-test analysis was used to examine if there was a statistically significant difference in pre-NIS and post-NIS emotional states. The key statistically significant highlights of the analysis were:

1. Overall, across all 489 workers, there was statistically significant increase in negative emotions (e.g., fear, guilt, sadness, and unhappiness) and significant decrease in positive emotions (e.g., happiness, joy, love, and pride).
2. Though level of arousal varied, both Hispanic and Caucasian workers showed changes in similar directions, despite cultural differences suggesting NIS was emotionally engaging for both primary cultures found on construction sites in North America.
3. NIS was able to decrease levels of anger among younger workers whereas older workers experienced an increase in anxiety.
4. Married workers showed a strong increase in disgust and guilt whereas more experienced workers felt an increase in shame post-NIS intervention.
5. The findings suggest that NIS was emotionally more impactful and engaging for older or married workers compared to younger or single workers.
6. Workers who have never experienced an injury showed visceral reactions to NIS whereas workers with injury experience were more muted in their emotional response.

Limitations

There were several limitations to the work presented in this chapter:

1. While the rich data from the field experiment lends high external validity, the lack of controlled testing environment to test change in emotions due to intervention reduces the internal validity. The researchers could place only limited control for confounding variables. Future studies should examine these findings in a laboratory experiment for cross-validation purposes.

2. Workers were asked to self-report their emotional responses which is unusual experience that can cause discomfort and confusion. Future exploration should use objective (physiological) alongside self-report measures to confirm the findings.
3. The goal of this study was to examine if NIS generates an emotional response across all demographical dimensions. The analysis conducted does not allow for comparative analysis or interpretations. Examining the differences between each demographical group was beyond the scope and objective of this study.

Building from the findings presented in the previous chapter, here the focus was on developing a safety training program that uses adult learning framework to transfer knowledge while also generating context-driven emotional responses. In **chapter 2**, the analysis showed that integral negative emotions are positively correlated with high perception of risk and tendency to make safer decisions. In this chapter, analysis shows that NIS generates desired context-driven negative emotions among construction workers. In the following and final chapter of this dissertation, analysis is conducted to examine whether a) NIS increases situational interest levels among construction workers and b) whether the emotional responses generated by NIS predict the change in situational interest observed.

CHAPTER 4 SUMMARY

Traditional safety training is often perceived to be mundane and unengaging (Albert and Hallowell 2013; Haslam et al. 2005). As simple as it sounds, one of the primary objectives of NIS was to generate interest among workers for safety training. Interest and emotional experiences have been found to be immediate precursors to intense learning experiences (Hidi and Renninger 2006; Pekrun 2006). For this study, the focus was only on situational interest because it is representative of the learners' cognitive functioning (Ainley 1998; Renninger 2000; Schiefele 1996), attention (Hidi et al. 2004), and commitment to learning (Alexander and Murphy 1998; Schiefele 1999) with respect to the immediate material and

learning environment. Situational interest therefore, is the ideal variable to gauge the level engagement among workers who are interacting with a new safety training program.

The data on situational interest was collected during the field-experiment described above where both pre-NIS (i.e., measured situational interest regarding traditional safety training) and post-NIS (i.e., measured situational interest regarding NIS) situational interest levels were recorded using a questionnaire validated by Linnenbrink-Garcia et al. (2010). Linnenbrink-Garcia et al. (2010)'s survey measured triggered situational interest, feeling-based maintained situational interest, and value-based maintained situational interest where the triggered situational interest is characterized as fickle interest and can be a precursor to maintained situational interest which is a comparatively deeper and sustained form of interest. The wording of the questions from the questionnaire in Linnenbrink-Garcia et al. (2010) were appropriately modified to match the context of this study (i.e. occupational safety training).

Analysis and Key Findings

The question explored in this chapter was to what extent, if at all, does NIS promote situational interest among workers and what are differences in the experience of interest across different demographical dimensions. Further, exploratory analysis was conducted to empirically examine whether the change in affect predict change in different situational interest dimensions (triggered, feeling-based, and value-based) among adult learners while controlling for the demographical differences. Paired t-tests were used as before to gauge the statistical significance of the change in situational interest before and after the intervention across all interest dimensions. To study the relationship between change in emotions and situational interest, principal component analysis was used to reduce the dimensions of emotions dataset where 16 unique emotion were distributed into 4 principal components: highly arousing positive, highly arousing negative, mildly arousing positive, and mildly arousing negative emotions. The key statistically significant highlights of the analysis were:

1. Across all demographical groups, there was an increase in overall situational interest. Increase in situational interest was observed across all dimensions (triggered, feeling-based maintained, value-based maintained) suggesting framework of NIS is appropriate for adult learners.
2. Adult learners in NIS training environment experienced change situational interest which was independent of the change in emotional arousal.
3. Relationship between change in affect and situational interest is likely mediated by individual differences.

Limitations

The limitations associated with this chapter were:

1. This chapter shares internal validity issues discussed above for chapter 2 given the constraints present in field-experiments to control for confounding variables.
2. Furthermore, the relationships represent correlational relationships and the experimental design does not support any causal inferences.
3. As with emotion questionnaire, the situational interest questionnaire adopted in this study represents self-report data and there were no controls in place to account for cognitive or social biases. Future studies need to replicate the experimental process to cross-validate and confirm the exploratory nature of the findings presented in this chapter.
4. Current analysis does not support any inferences regarding long-term effects of NIS on learning.

It is very *interesting* that while NIS focuses on generating context-driven negative affect among workers, it was increase in arousing positive emotions (surprise and amusement) that showed a marginally significant relationship with change in situational interest. It is possible that the arousing negative (fear, guilt, sadness, shame, and unhappiness) generated by NIS could be associated with social and behavioral characteristics of the training session (e.g., personal stories of injuries from crew members, post-simulation injury discussion, reflecting on personal risk-taking habits) that decreases risk-taking behavior, whereas the

arousing positive (amusement, surprise) emotional response could be associated with novelty associated with using artificial hands, graphic demonstration of accidents, and curiosity that increased interest in the safety training. However, the results suggest that adult learners can experience increase in situational interest which is independent of change in their emotional experiences and the relationship between change in situational interest and emotional experience is mediated by demographic differences.

Figure 8 summarizes the research objectives, approach, and key findings of the entire thesis.

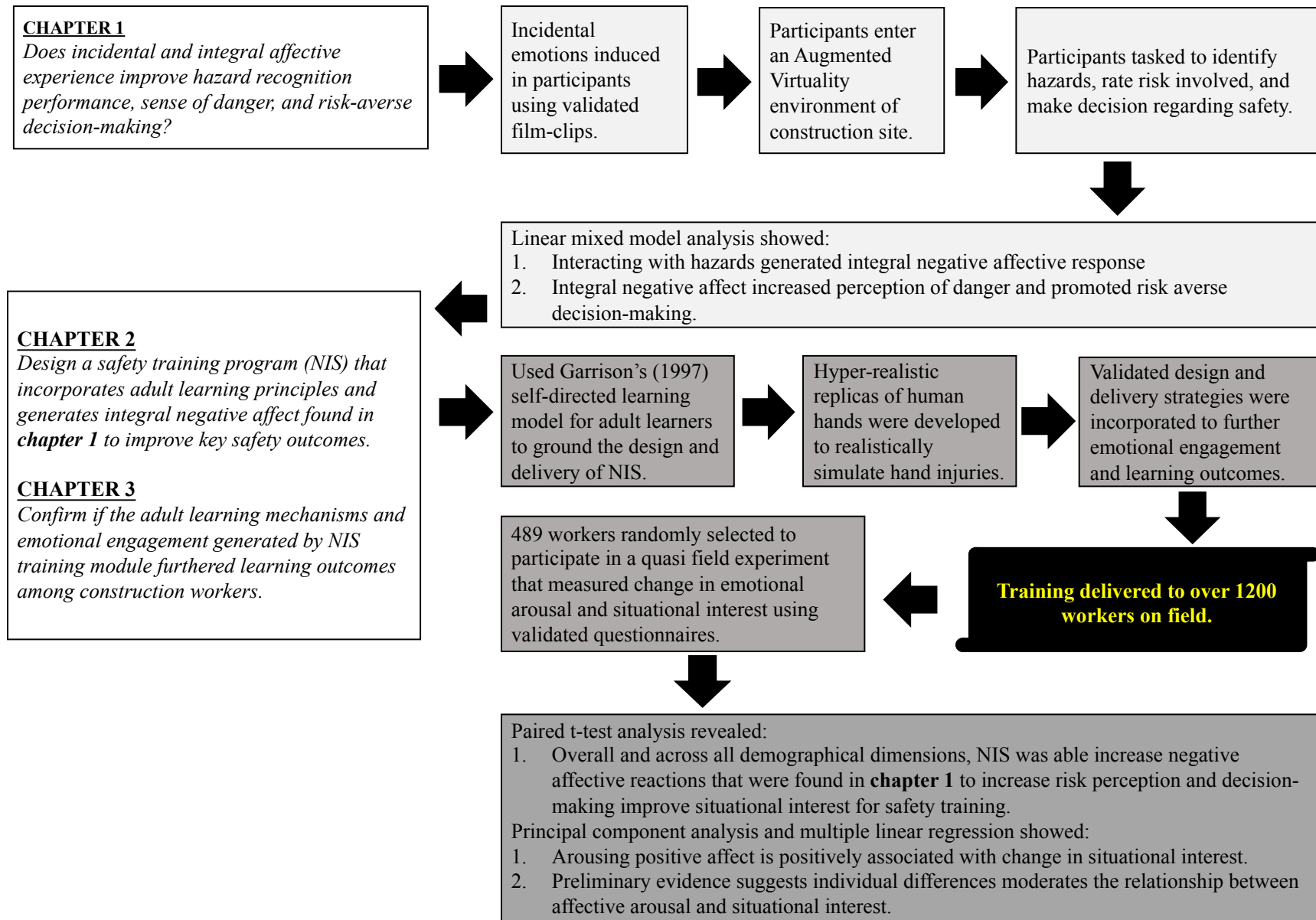


Figure 8: Thesis Summary

FUTURE RESEARCH

First and foremost, future studies should look to address the limitations and challenge the assumptions made in this thesis. For instance, while this thesis validates that relationship between affective experiences and safety outcomes (chapter 2) in construction safety context, it does not test these relationships on construction workers. Findings presented in chapter 2 need to be validated among construction workers while controlling for typical individual differences. Similarly, the discussed effects of training intervention such as NIS (chapter 3 and chapter 4) need to be tested in a controlled laboratory environment to control for any confounding effects that may not have been accounted for in quasi-field experimental approach adopted by author in the work presented here. These challenges to current work are critical to establish the generalizability and reliability of the findings presented in this thesis.

While, emotional arousal and situational interest measured in this study are indicators of learning and motivation, long-term benefits of NIS in improving skills and conditioning behavior cannot be concluded based off the work presented in this thesis. Future researchers should look seek to understand if NIS promotes long-term retention of knowledge and increases risk perception among construction workers. While, this thesis uses validated findings from previous studies, it cannot make any causal claims regarding learning or risk-taking behavior. This line of inquiry is essential to further justifying investment into training modules such as NIS, which are time and resource intensive compared to traditional training approach.

The lack of relationship between change in situational interest and change in affect among adult learners is also curious. Most studies in learning literature do not focus on adult learners especially adults learning in an occupational environment. The finding that as age increased, the change in situational interest decreased (see chapter 4) challenges adult learning agents used within NIS design and delivery. There is a need to explore learning agents for adult learners gaining technical skills in a non-traditional classroom

environment. Those explorations should be used to improve and enhance the effectiveness of training programs such as NIS.

Finally, with growing globalization, most construction companies are becoming multinational which means they have workforces across the world that bring a unique skill set, experience, social structure, and cultural values that would make standardizing safety training programs challenging. It is unlikely that application of NIS in any construction safety context would be equally effective. There is a need to study how effective a multimedia safety training format would be for workforces that are not predominantly Caucasians and Hispanics. Future researchers should consider validating adult learning and emotion elicitation agents for different cultures to allow companies to revise safety training programs to be more effective.

References

1. Ainley, M. (1998). Interest in learning and the disposition of curiosity in secondary students: Investigating process and context. In L. Hoffman, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Seon conference on interest and gender* (pp. 257–266). Kiel, Germany: IPN.
2. Alexander, P. A., & Murphy, P. K. (1998). Profiling the differences in students' knowledge, interest, and strategic processing. *Journal of Educational Psychology*, 90, 435–447.
3. Albert, A., & Hallowell, M. R. (2013). Revamping occupational safety and health training: Integrating andragogical principles for the adult learner. *Construction Economics and Building*, 13(3), 128-140.
4. Albert, A., Hallowell, M. R., and Kleiner, B. M. (2013). Enhancing construction hazard recognition and communication with energy-based cognitive mnemonics and safety meeting maturity model: Multiple baseline study. *Journal of Construction Engineering and Management*, 140(2), 04013042.
5. Albert, A., Hallowell, M. R., and Kleiner, B. M. (2014). Experimental field testing of a real-time construction hazard identification and transmission technique. *Construction Management and Economics*, 32(10), 1000-1016.
6. Garrison, D. R. (1997). Self-directed learning: Toward a comprehensive model. *Adult education quarterly*, 48(1), 18-33.
7. Hallowell, M. (2010). Safety risk perception in construction companies in the Pacific Northwest of the USA. *Construction management and economics*, 28(4), 403-413.
8. Haslam, R. A., Hide, S. A., Gibb, A. G., Gyi, D. E., Pavitt, T., Atkinson, S., & Duff, A. R. (2005). Contributing factors in construction accidents. *Applied ergonomics*, 36(4), 401-415.
9. Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational psychologist*, 41(2), 111-127.

10. Hidi, S., Renninger, K. A., & Krapp, A. (2004). Interest, a motivational variable that combines affective and cognitive functioning. In D. Y. Dai & R. J. Sternberg (Eds.), *Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development* (pp. 89–115). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
11. Linnenbrink-Garcia, L., Durik, A. M., Conley, A. M., Barron, K. E., Tauer, J. M., Karabenick, S. A., & Harackiewicz, J. M. (2010). Measuring situational interest in academic domains. *Educational and psychological measurement, 70*(4), 647-671.
12. Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational psychology review, 18*(4), 315-341.
13. Renninger, K. A. (2000). Individual interest and its implications for understanding intrinsic motivation. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 375–407). New York: Academic.
14. Schiefele, U. (1996). Topic interest, text representation, and quality of experience. *Contemporary Educational Psychology, 21*, 3–18.
15. Schiefele, U. (1999). Interest and learning from text. *Scientific Studies of Reading, 3*, 257–280.
16. Tixier, A. J. P., Hallowell, M. R., Albert, A., van Boven, L., & Kleiner, B. M. (2014). Psychological antecedents of risk-taking behavior in construction. *Journal of Construction Engineering and Management, 140*(11), 04014052.

BIBLIOGRAPHY

- [1]. Ahl, H. (2006). Motivation in adult education: a problem solver or a euphemism for direction and control?. *International journal of lifelong education*, 25(4), 385-405.
- [2]. Ainley, M. (1998). Interest in learning and the disposition of curiosity in secondary students: Investigating process and context. In L. Hoffman, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Seon conference on interest and gender* (pp. 257–266). Kiel, Germany: IPN.
- [3]. Akhu-Zaheya, L. M., Gharaibeh, M. K., & Alostaz, Z. M. (2013). Effectiveness of simulation on knowledge acquisition, knowledge retention, and self-efficacy of nursing students in Jordan. *Clinical Simulation in Nursing*, 9(9), e335-e342.
- [4]. Alexander, P. A. (1997). Mapping the multidimensional nature of domain learning: The interplay of cognitive, motivational, and strategic forces. In M. L. Maehr & P. R. Pintrich (Eds.), *Advances in motivation and achievement* (Vol. 10, pp. 213–250). Greenwich, CT: JAI.
- [5]. Alexander, P. A., & Jetton, T. L. (1996). The role of importance and interest in the processing of text. *Educ. Psychol. Rev.* 8: 89–121.
- [6]. Alexander, P. A., & Murphy, P. K. (1998). Profiling the differences in students' knowledge, interest, and strategic processing. *Journal of Educational Psychology*, 90, 435–447.
- [7]. Albert, A., & Hallowell, M. R. (2013). Revamping occupational safety and health training: Integrating andragogical principles for the adult learner. *Australasian Journal of Construction Economics and Building*, The, 13(3), 128.
- [8]. Albert, A., Hallowell, M. R., & Kleiner, B. M. (2013). Enhancing construction hazard recognition and communication with energy-based cognitive mnemonics and safety meeting maturity model: Multiple baseline study. *Journal of Construction Engineering and Management*, 140(2), 04013042.

- [9]. Albert, A., Hallowell, M. R., Kleiner, B., Chen, A., & Golparvar-Fard, M. (2014a). Enhancing construction hazard recognition with high-fidelity augmented virtuality. *Journal of Construction Engineering and Management*, 140(7), 04014024.
- [10]. Albert, A., Hallowell, M. R., & Kleiner, B. M. (2014b). Experimental field testing of a real-time construction hazard identification and transmission technique. *Construction Management and Economics*, 32(10), 1000-1016. J. Huesman, L. Holland, & T. Langley, "April 2015 construction at \$1,006.1 Billion Annual Rate," U.S. Census Bureau News, Washington, D.C., 01-Jun-2015.
- [11]. Alhakami, A. S., & Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk analysis*, 14(6), 1085-1096.
- [12]. Anderson, A. K., Yamaguchi, Y., Grabski, W., & Lacka, D. (2006). Emotional memories are not all created equal: evidence for selective memory enhancement. *Learning & Memory*, 13(6), 711-718.
- [13]. Arnett, J. (1992). Reckless behavior in adolescence: A developmental perspective. *Developmental review*, 12(4), 339-373
- [14]. Baddeley, A. (1992). Working memory. *Science*, 255(5044), 556-559.
- [15]. Bahn, S. T. (2013). Mining workers ability to identify hazards using a picture survey. In *Work, employment and employment relations in an uneven patchwork world: Proceedings of the 27th AI ANZ Conference* (pp. 2-10). Fremantle, Australia: Association of Industrial Relations Academics of Australia and New Zealand. Original article available here
- [16]. Bahrnick, L. E., Parker, J. F., Fivush, R., & Levitt, M. (1998). The effects of stress on young children's memory for a natural disaster. *Journal of Experimental Psychology: Applied*, 4(4), 308.
- [17]. Bailenson, J.N., & Blascovich, J. (2004). Avatars. In W.S. Bainbridge (Ed.), *Encyclopedia of human-computer interaction* (pp. 64–68). Great Barrington, MA: Berkshire.
- [18]. Barabasz, A. F., & Barabasz, M. (1992). Research designs and considerations. In E. Fromm & M. R. Nash (Eds.), *Contemporary hypnosis research* (pp. 173-200). New York: Guilford. The preceding paper attributes the concept to Weber, S. J., & Cook, T. D. (1972).

- [19]. Barsade, S. G., & Gibson, D. E. (2007). Why does affect matter in organizations?. *The Academy of Management Perspectives*, 21(1), 36-59.
- [20]. Barrett, L. F. (2012). Emotions are real. *Emotion*, 12, 413429. doi:10.1037/a0027555
- [21]. Bartolini, E. E. (2011). Eliciting emotion with film: Development of a stimulus set.
- [22]. Baskett, H.K.M (1994). Self-Directedness in the Workplace. Paper by H.K. Morris presented to the Eighth International Symposium on Self-Directed Learning. Florida.
- [23]. Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision-making and the orbitofrontal cortex. *Cerebral cortex*, 10(3), 295-307.
- [24]. Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, 275(5304), 1293-1295.
- [25]. Benton, S. L., Corkill, A. J., Sharp, J. M., Downey, R. G., & Khramtsova, I. (1995). Knowledge, interest, and narrative writing. *Journal of Educational Psychology*, 87(1), 66.
- [26]. Bergin, D. A. (1999). Influences on classroom interest. *Educational psychologist*, 34(2), 87-98.
- [27]. Bhandari, S., & Hallowell, M. R. (2017). Emotional Engagement in Safety Training: Impact of Naturalistic Injury Simulations on the Emotional State of Construction Workers. *Journal of Construction Engineering and Management*, 143(12), 04017090.
- [28]. Bhandari, S., Hallowell, M. R., Van Boven, L., Gruber, J., & Welker, K. M. (2016). Emotional states and their impact on hazard identification skills. In *Construction Research Congress 2016* (pp. 2831-2840).
- [29]. Billett, S. (2001). *Learning in the workplace: Strategies for effective practice*. Allen & Unwin, PO Box 8500, St Leonards, 1590 NSW, Australia.
- [30]. Billings, C. E., & Reynard, W. D. (1984). Human factors in aircraft incidents: results of a 7-year study. *Aviation, Space, and Environmental Medicine*, 55(10), 960-965.
- [31]. Bless, H., Clore, G. L., Schwarz, N., Golisano, V., Rabe, C., & Wölk, M. (1996). Mood and the use of scripts: Does a happy mood really lead to mindlessness?. *Journal of personality and social psychology*, 71(4), 665.

- [32]. Bonnet, A., Fernandez, L., Piolat, A., and Pedinielli, J. L. (2008). Changes in emotional states before and after risk taking in scuba diving. *Journal of Clinical Sport Psychology*, 2(1), 25-40.
- [33]. Bower, G. H. (1983). Affect and cognition. *Phil. Trans. R. Soc. Lond. B*, 302(1110), 387-402.
- [34]. Boyatzis, R. E. (2002). Unleashing the power of self-directed learning. *Changing the way we manage change*, 13-32.
- [35]. Bradley, M. M., Greenwald, M. K., Petry, M. C., & Lang, P. J. (1992). Remembering pictures: pleasure and arousal in memory. *Journal of experimental psychology: Learning, Memory, and Cognition*, 18(2), 379.
- [36]. Brillinger, M. F. (1990). Helping adults learn. *Journal of Human Lactation*, 6(4), 171-175.
- [37]. Brookfield, S. (1995). Adult learning: An overview. *International encyclopedia of education*, 10, 375-380.
- [38]. Brown, R., & Kulik, J. (1977). Flashbulb memories. *Cognition*, 5(1), 73-99.
- [39]. Buchanan, T. W., & Adolphs, R. (2002). The role of the human amygdala in emotional modulation of long-term declarative memory. *Advances in Consciousness Research*, 44, 9-34.
- [40]. Buchanan, T. W., Tranel, D., & Adolphs, R. (2006). Impaired memory retrieval correlates with individual differences in cortisol response but not autonomic response. *Learning & memory*, 13(3), 382-387.
- [41]. Buchholz, B., Paquet, V., Punnett, L., Lee, D., & Moir, S. (1996). PATH: a work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. *Applied ergonomics*, 27(3), 177-187.
- [42]. Burke, M. J., Salvador, R. O., Smith-Crowe, K., Chan-Serafin, S., Smith, A., and Sonesh, S. (2011). The dread factor: how hazards and safety training influence learning and performance. *Journal of Applied Psychology*, 96(1), 46.
- [43]. Burke, L. A., & Miller, M. K. (1999). Taking the mystery out of intuitive decision making. *Academy of Management Perspectives*, 13(4), 91-99.

- [44]. Cahill, L., Haier, R. J., Fallon, J., Alkire, M. T., Tang, C., Keator, D., Joseph Wu, & Mcgaugh, J. L. (1996). Amygdala activity at encoding correlated with long-term, free recall of emotional information. *Proceedings of the National Academy of Sciences*, 93(15), 8016-8021. Cunningham, W. A., Raye, C. L., & Johnson, M. K. (2004). Implicit and explicit evaluation: fMRI correlates of valence, emotional intensity, and control in the processing of attitudes. *Journal of cognitive neuroscience*, 16(10), 1717-1729.
- [45]. Cahill, L., & McGaugh, J. L. (1995). A novel demonstration of enhanced memory associated with emotional arousal. *Consciousness and cognition*, 4(4), 410-421.
- [46]. Candy, P. C. (1991). *Self-Direction for Lifelong Learning. A Comprehensive Guide to Theory and Practice*. Jossey-Bass, 350 Sansome Street, San Francisco, CA 94104-1310.
- [47]. Canli, T., Zhao, Z. U. O., Desmond, J. E., Glover, G., & Gabrieli, J. D. (1999). fMRI identifies a network of structures correlated with retention of positive and negative emotional memory. *Psychobiology*, 27(4), 441-452.
- [48]. Carter, G. and Smith S.D. (2006). "Safety hazard identification on construction projects." *Journal of Construction Engineering and Management*, 132(2): 197-205
- [49]. Carnagey, N. L., Anderson, C. A., & Bushman, B. J. (2007). The effect of video game violence on physiological desensitization to real-life violence. *Journal of Experimental Social Psychology*, 43(3), 489-496.
- [50]. Caruso, E. M., and Shafir, E. (2006). Now that I think about it, I'm in the Mood for laughs: Decisions focused on Mood. *Journal of Behavioral Decision-making*, 19(2), 155-169.
- [51]. Center for Construction Research and Training, 2013. *The Construction Chart Book: The U.S. Construction Industry and its Workers*. Bethesda, MD.
- [52]. Center for Construction Research and Training, (2007). *The Construction Chart Book: The U.S. Construction Industry and its Workers* (4th ed.). Retrieved June 21, 2016, from [http://www.cpwr.com/sites/default/files/research/CB4_Final for web.pdf](http://www.cpwr.com/sites/default/files/research/CB4_Final%20for%20web.pdf)

- [53]. Chapman, H. A., Johannes, K., Poppenk, J. L., Moscovitch, M., & Anderson, A. K. (2013). Evidence for the differential salience of disgust and fear in episodic memory. *Journal of Experimental Psychology: General*, 142(4), 1100.
- [54]. Charlesworth, W. R. (1969). The role of surprise in cognitive development. *Studies in cognitive development*, 257-314.
- [55]. Chen, J., Shao, J., 2000. Nearest neighbor imputation for survey data. *Journal of Official Statistics* 16, 113–132.
- [56]. Choudhry, R. M., Fang, D., & Lingard, H. (2009). Measuring safety climate of a construction company. *Journal of construction Engineering and Management*, 135(9), 890-899.
- [57]. Christianson, S. A. (1989). Flashbulb memories: Special, but not so special. *Memory & Cognition*, 17(4), 435-443.
- [58]. Chung, S., Cheon, J., & Lee, K. W. (2015). Emotion and multimedia learning: an investigation of the effects of valence and arousal on different modalities in an instructional animation. *Instructional Science*, 43(5), 545-559.
- [59]. Clore, G. L., Gasper, K., & Garvin, E. (2001). Affect as information. *Handbook of affect and social cognition*, 121-144.
- [60]. Clore, G. L., Schwarz, N., and Conway, M. 1994. Affective causes and consequences of social information processing. *Handbook of social cognition*, 1, 323-417.
- [61]. Cohen, A. (1977). Factors in successful occupational safety programs. *Journal of safety research*, 9(4), 168-178.
- [62]. Compton, J. I., Cox, E., & Laanan, F. S. (2006). Adult learners in transition. *New directions for student services*, 2006(114), 73-80.
- [63]. Comrey, A. L., and Lee, H. B. (1992). *A first course in factor analysis*, Erlbaum, Hillsdale, NJ.
- [64]. Consedine, N. S., Magai, C., & King, A. R. (2004). Deconstructing positive affect in later life: A differential functionalist analysis of joy and interest. *The International Journal of Aging and Human Development*, 58(1), 49-68.

- [65]. Constans, J. I., & Mathews, A. M. (1993). Mood and the subjective risk of future events. *Cognition & Emotion*, 7(6), 545-560.
- [66]. CPWR (Center for Construction Research and Training). (2014). *The construction chart book: The U.S. construction industry and its workers*, Bethesda, MD.
- [67]. Cross, K. P. (1981). *Adults as Learners. Increasing Participation and Facilitating Learning*.
- [68]. Cunningham, M. R. (1979). Weather, mood, and helping behavior: Quasi experiments with the sunshine samaritan. *Journal of Personality and Social Psychology*, 37(11), 1947.
- [69]. Cushing, B. E., & Ahlawat, S. S. (1996). Mitigation of recency bias in audit judgment: The effect of documentation. *Auditing*, 15(2), 110.
- [70]. Damasio, A. R., Everitt, B. J., & Bishop, D. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex [and discussion]. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 351(1346), 1413-1420.
- [71]. Dasarathy, B. V. (1991). Nearest neighbor ({NN}) norms: {NN} pattern classification techniques.
- [72]. Dickinson, J. K., Woodard, P., Canas, R., Ahamed, S., and Lockston, D. (2011). "Game-based trench safety education: Development and lessons learned." *J. Inf. Technol. Constr.*, 16, 119–134.
- [73]. De Leersnyder, J., Mesquita, B., & Kim, H. S. (2011). Where do my emotions belong? A study of immigrants' emotional acculturation. *Personality and Social Psychology Bulletin*, 0146167211399103.
- [74]. Donath, J. (2007). Signals in social supernets. *Journal of Computer-Mediated Communication*, 13(1), 231-251.
- [75]. Drevets, W. C., and Raichle, M. E. (1998). Reciprocal suppression of regional cerebral blood flow during emotional versus higher cognitive processes: Implications for interactions between emotion and cognition. *Cognition and emotion*, 12(3), 353-385.
- [76]. Dudani, S. A. (1976). The distance-weighted k-nearest-neighbor rule. *IEEE Transactions on Systems, Man, and Cybernetics*, (4), 325-327.

- [77]. Eisenberg, A. E., Baron, J., & Seligman, M. E. (1998). Individual differences in risk aversion and anxiety. *Psychological Bulletin*, 87, 245-251.
- [78]. Emerson, T. L., English, L. K., & McGoldrick, K. (2015). Evaluating the Cooperative Component in Cooperative Learning: A Quasi-Experimental Study. *The Journal of Economic Education*, 46(1), 1-13.
- [79]. Erez, A., & Isen, A. M. (2002). The influence of positive affect on the components of expectancy motivation. *Journal of Applied psychology*, 87(6), 1055.
- [80]. Fairchild, E. E. (2003). Multiple roles of adult learners. *New directions for student services*, 2003(102), 11-16.
- [81]. Fang, D., Chen, Y., & Wong, L. (2006). Safety climate in construction industry: a case study in Hong Kong. *Journal of construction engineering and management*, 132(6), 573-584.
- [82]. Fassbender, E., Richards, D., Bilgin, A., Thompson, W. F., & Heiden, W. (2012). VirSchool: The effect of background music and immersive display systems on memory for facts learned in an educational virtual environment. *Computers & Education*, 58(1), 490-500.
- [83]. Finucane, M. L., Alhakami, A., Slovic, P., & Johnson, S. M. (2000). The affect heuristic in judgments of risks and benefits. *Journal of behavioral decision making*, 13(1), 1-17.
- [84]. Fisher, M., King, J., & Tague, G. (2001). Development of a self-directed learning readiness scale for nursing education. *Nurse education today*, 21(7), 516-525.
- [85]. Fixsen, D. L., Naoom, S. F., Blase, K. A., & Friedman, R. M. (2005). Implementation research: a synthesis of the literature.
- [86]. Frijda, N. H., & Mesquita, B. (1994). The social roles and functions of emotions. In S. Kitayama and H. R. Markus (Eds.), *Emotion and culture: Empirical studies of mutual influence* (pp. 51-87). Washington, DC: American Psychological Association.
- [87]. Ganster, D. C., Mayes, B. T., Sime, W. E., & Tharp, G. D. (1982). Managing organizational stress: A field experiment. *Journal of Applied Psychology*, 67(5), 533.

- [88]. Gardner, M., & Steinberg, L. (2005). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: an experimental study. *Developmental psychology*, 41(4), 625.
- [89]. Garner, R., Brown, R., Sanders, S., and Menke D. J. (1992). "Seductive details" and learning from text. In Renninger, A., Hidi, S., and Krapp, A. (eds.), *The Role of Interest in Learning and Development*, Lawrence Erlbaum, Hillsdale, NJ, pp. 239–254.
- [90]. Garrison, D. R. (1997). Self-directed learning: Toward a comprehensive model. *Adult Education Quarterly*, 48(1), 18-33.
- [91]. Garrison, D. R. (1993). An analysis of the control construct in self-directed learning. *Emerging perspectives of self-directed learning*, 27-44.
- [92]. Garrison, D. R. (1992). Critical thinking and self-directed learning in adult education: An analysis of responsibility and control issues. *Adult Education Quarterly*, 42(3), 136-148.
- [93]. Gasper, K., & Clore, G. L. (1998). The persistent use of negative affect by anxious individuals to estimate risk. *Journal of personality and social psychology*, 74(5), 1350.
- [94]. Geller, E. S. (2001). Behavior-based safety in industry: Realizing the large-scale potential of psychology to promote human welfare. *Applied and Preventive Psychology*, 10(2), 87-105.
- [95]. Gilman, T. L., Shaheen, R., Nylocks, K. M., Halachoff, D., Chapman, J., Flynn, J. J., Lindsey M. M., & Coifman, K. G. (2017). A film set for the elicitation of emotion in research: A comprehensive catalog derived from four decades of investigation. *Behavior research methods*, 49(6), 2061-2082.
- [96]. Gilboa, È., & Revelle, W. (1994). Personality and the structure of affective responses. *Emotions: Essays on emotion theory*, 135-159
- [97]. Gordon-Lubitz, R. J. (2003). Risk communication: Problems of presentation and understanding. *JAMA*, 289(1), 95-95.
- [98]. Grace, A. P. (1996). Striking a critical pose: andragogy--missing links, missing values. *International Journal of Lifelong Education*, 15(5), 382-392.
- [99]. Green, A. (2014). The case for the traditional classroom. *International Review of Economics Education*, 16, 87-99.

- [100]. Gregersen, N. P. (1996). Young drivers' overestimation of their own skill—an experiment on the relation between training strategy and skill. *Accident Analysis & Prevention*, 28(2), 243-250.
- [101]. Gross, J. J., & Levenson, R. W. (1995). Emotion elicitation using films. *Cognition & emotion*, 9(1), 87-108.
- [102]. Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: the acute effects of inhibiting negative and positive emotion. *Journal of abnormal psychology*, 106(1), 95.
- [103]. Gruber, J., Harvey, A. G., & Johnson, S. L. (2009). Reflective and ruminative processing of positive emotional memories in bipolar disorder and healthy controls. *Behaviour research and therapy*, 47(8), 697-704.
- [104]. Gruber, J., Mauss, I. B., & Tamir, M. (2011). A dark side of happiness? How, when, and why happiness is not always good. *Perspectives on Psychological Science*, 6(3), 222-233.
- [105]. Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (1998). *Multivariate data analysis* (Vol. 5, No. 3, pp. 207-219). Upper Saddle River, NJ: Prentice hall.
- [106]. Haddon Jr, W. (1970). On the escape of tigers: an ecologic note. *American Journal of Public Health and the Nations Health*, 60(12), 2229-2234.
- [107]. Hallowell, M. R. (2010). Safety risk perception in construction companies in the Pacific Northwest of the USA. *Construction management and economics*, 28(4), 403-413.
- [108]. Hallowell, M. R., & Yugar-Arias, I. F. (2016). Exploring fundamental causes of safety challenges faced by Hispanic construction workers in the US using photovoice. *Safety science*, 82, 199-211.
- [109]. Hamann, S. B., Ely, T. D., Grafton, S. T., & Kilts, C. D. (1999). Amygdala activity related to enhanced memory for pleasant and aversive stimuli. *Nature neuroscience*, 2(3), 289.
- [110]. Harackiewicz, J. M., Barron, K. E., Tauer, J. M., Carter, S. M., & Elliot, A. J. (2000). Short-term and long-term consequences of achievement: Predicting continued interest and performance over time. *Journal of Educational Psychology*, 92, 316–330.

- [111]. Harmon-Jones, E., Amodio, D. M., and Zinner, L. R. (2007). "Social psychological methods in emotion elicitation." *Handbook of emotion elicitation and assessment*, J. A. Coan and J. J. B. Allen, eds., Oxford University Press, New York, 91–105.
- [112]. Hartree, A. (1984). Malcolm Knowles' theory of andragogy: A critique. *International Journal of Lifelong Education*, 3(3), 203-210
- [113]. Haslam, R. A., Hide, S. A., Gibb, A. G., Gyi, D. E., Pavitt, T., Atkinson, S., & Duff, A. R. (2005). Contributing factors in construction accidents. *Applied ergonomics*, 36(4), 401-415.
- [114]. Helmreich, R. L. (1997). Managing human error in aviation. *Scientific American*, 276(5), 62-67.
- [115]. Hoffmann, L. (2002). Promoting girls' learning and achievement in physics classes for beginners. *Learning and Instruction*, 12, 447–465.
- [116]. Hoffmann, L., & Häussler, P. (1998). An intervention project promoting girls' and boys' interest in physics. In L. Hoffmann, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Seon conference on interest and gender* (pp. 301–316). Kiel, Germany: IPN.
- [117]. Hollins, E. R., & King, J. E. (1994). *Teaching diverse populations: Formulating a knowledge base* (Vol. 1944). SUNY Press.
- [118]. House, J. S., Landis, K. R., & Umberson, D. (1988). Social relationships and health. *Science*, 241(4865), 540-545.
- [119]. Hidi, S. (2000). An interest researcher's perspective: The effects of extrinsic and intrinsic factors on motivation. *Task· contingent rewards (co/lti" ued)*, 328, 83.
- [120]. Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research*, 60, 549–571.
- [121]. Hidi, S., & Anderson, V. (1992). Situational interest and its impact on reading and expository writing. *The role of interest in learning and development*, 11, 213-214.
- [122]. Hidi, S., & Baird, W. (1986). Interestingness—A neglected variable in discourse processing. *Cognitive Sci.* 10: 179–194.

- [123]. Hidi, S., & Berndorff, D. (1998). Situational interest and learning. In L. Hoffman, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Seeon conference on interest and gender* (pp. 74–90). Kiel, Germany: IPN.
- [124]. Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational psychologist*, 41(2), 111-127.
- [125]. Hidi, S., Renninger, K. A., & Krapp, A. (2004). Interest, a motivational variable that combines affective and cognitive functioning. In D. Y. Dai & R. J. Sternberg (Eds.), *Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development* (pp. 89–115). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- [126]. Hilton, S. M., & Zbrożyna, A. W. (1963). Amygdaloid region for defence reactions and its efferent pathway to the brain stem. *The Journal of physiology*, 165(1), 160-173.
- [127]. Hinze, J. (2006). *Construction safety*, Prentice Hall, New York.
- [128]. Hollins, E. R., & King, J. E. (1994). *Teaching diverse populations: Formulating a knowledge base* (Vol. 1944). SUNY Press.
- [129]. Houle, C. O. (1961). *The inquiring mind*. Oklahoma Research Center for Continuing Professional and Higher Education, University of Oklahoma.
- [130]. Hsu, H., & Lachenbruch, P. A. (2008). Paired t test. *Wiley Encyclopedia of Clinical Trials*.
- [131]. Immordino-Yang, M. H. (2015). *Emotions, Learning, and the Brain: Exploring the Educational Implications of Affective Neuroscience* (The Norton Series on the Social Neuroscience of Education). WW Norton & Company.
- [132]. Iran-Nejad, A. (1987). Cognitive and affective causes of interest and liking. *Journal of Educational Psychology*, 79(2), 120.
- [133]. Isen, A. M., & Baron, R. A. (1991). Positive affect as a factor in organizational-behavior. *Research in organizational behavior*, 13, 1-53.
- [134]. Isen, A. M., Daubman, K. A., & Nowicki, G. P. (1987). Positive affect facilitates creative problem solving. *Journal of personality and social psychology*, 52(6), 1122.

- [135]. Isen, A. M., & Patrick, R. (1983). The effect of positive feelings on risk taking: When the chips are down. *Organizational behavior and human performance*, 31(2), 194-202.
- [136]. Isen, A. M., and Shalcker, T. E. (1982). Do you “accentuate the positive, eliminate the negative” when you are in a good mood. *Social Psychology Quarterly*, 45(March), 58-63.
- [137]. Isen, A. M., Shalcker, T. E., Clark, M., and Karp, L. (1978). “Affect, accessibility of material in memory, and behavior: A cognitive loop?” *J. Pers. Soc. Psychol.*, 36(1), 1–12.
- [138]. Izard, C. E. (2010). The many meanings/aspects of emotion: Definitions, functions, activation, and regulation. *Emotion Review*, 2(4), 363-370.
- [139]. Jeanne, M., Gross, J. J., Persons, J. B., & Hahn, J. (1998). Mood matters: Negative mood induction activates dysfunctional attitudes in women vulnerable to depression. *Cognitive Therapy and Research*, 22(4), 363-376.
- [140]. Jensen, R., & Biegelski, C. (1989). Cockpit resource management. In R. Jensen (Ed.), *Aviation psychology* (pp. 176-209). Aldershot, England: Gower Technical.
- [141]. Joëls, M., Pu, Z., Wiegert, O., Oitzl, M. S., & Krugers, H. J. (2006). Learning under stress: how does it work?. *Trends in cognitive sciences*, 10(4), 152-158.
- [142]. Johnson, E. J., & Tversky, A. (1983). Affect, generalization, and the perception of risk. *Journal of personality and social psychology*, 45(1), 20.
- [143]. Judd, C. M., McClelland, G. H., & Ryan, C. S. (2017). *Data analysis: a model comparison approach to regression, ANOVA, and beyond*. Routledge.
- [144]. Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, 263-291.
- [145]. Kahneman, D., Wakker, P. P., & Sarin, R. (1997). Back to Bentham? Explorations of experienced utility. *The quarterly journal of economics*, 112(2), 375-406.
- [146]. Kane, F., Coulombe, D., & Miliaressis, E. (1991). Amygdaloid self-stimulation: A movable electrode mapping study. *Behavioral neuroscience*, 105(6), 926.
- [147]. Klein, G. A. (2017). *Sources of power: How people make decisions*. MIT press.

- [148]. Keane, T. M., Zimering, R. T., & Caddell, J. M. (1985). A behavioral formulation of posttraumatic stress disorder in Vietnam veterans. *Behavior Therapist*, 8(1), 9-12.
- [149]. Kline, P. (2014). *An easy guide to factor analysis*. Routledge.
- [150]. Koelsch, S. (2010). Towards a neural basis of music-evoked emotions. *Trends in cognitive sciences*, 14(3), 131-137.
- [151]. Konradt, U., Filip, R., & Hoffmann, S. (2003). Flow experience and positive affect during hypermedia learning. *British journal of educational technology*, 34(3), 309-327.
- [152]. Kazis, R., Callahan, A., Davidson, C., McLeod, A., Bosworth, B., Choitz, V., & Hoops, J. (2007). Adult learners in higher education: Barriers to success and strategies to improve results. Employment and Training Division Occasional Paper, 3.
- [153]. Keller, C., Siegrist, M., and Gutscher, H. 2006. The role of the affect and availability heuristics in risk communication. *Risk Analysis*, 26(3), 631-639
- [154]. Keltner, D., Ellsworth, P. C., and Edwards, K. (1993). Beyond simple pessimism: effects of sadness and anger on social perception. *Journal of personality and social psychology*, 64(5), 740.
- [155]. Kensinger, E. A. (2009). Remembering the details: Effects of emotion. *Emotion review*, 1(2), 99-113.
- [156]. Kensinger, E. A., & Schacter, D. L. (2008). Neural processes supporting young and older adults' emotional memories. *Journal of cognitive neuroscience*, 20(7), 1161-1173.
- [157]. Kerka, S. (2002). *Teaching Adults: Is It Different? Myths and Realities*.
- [158]. Ketelaar, T. (2004). Ancestral emotions, current decisions: Using evolutionary game theory to explore the role of emotions in decision-making. *Evolutionary psychology, public policy and personal decisions*, 145-168.
- [159]. Knowles, M. (1980). *The modern practice of adult education: From pedagogy to andragogy* (Rev. and Updated. ed.). Wilton, Conn.: Association Press.
- [160]. Knowles, M. (1984). *The Adult Learner: A Neglected Species*. Houston: Gulf Pub. Kobasa, SC (1982). The Hardy Personality: Toward a Social Psychology of Stress and Health. In GS Sanders and J. Suls (Eds.), *Social Psychology of Health and Illness*, 3-32.

- [161]. Knowles, M. S., Holton III, E. F., & Swanson, R. A. (2014). *The adult learner: The definitive classic in adult education and human resource development*. Routledge.
- [162]. Krapp, A. (2000). Interest and human development during adolescence: An educational-psychological approach. In J. Heckhausen (Ed.), *Motivational psychology of human development* (pp. 109–128). London: Elsevier.
- [163]. Krapp, A., & Fink, B. (1992). The development and function of interests during the critical transition from home to preschool. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 397–429). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- [164]. Krapp, A., Hidi, S., & Renninger, K. A. (1992). Interest, learning, and development. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 3–25). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- [165]. Krueger, N., & Dickson, P. R. (1994). How believing in ourselves increases risk taking: Perceived self-efficacy and opportunity recognition. *Decision Sciences*, 25(3), 385-400.
- [166]. Kunar, B. M., & Bhattacharjee, A. (2006). Study of Some Occupational and Individual Factors in Coal Miners Injuries. *Journal of Mines Metals and Fuels*, 54(12), 356-361.
- [167]. LaBar, K. S., & Phelps, E. A. (1998). Arousal-mediated memory consolidation: Role of the medial temporal lobe in humans. *Psychological Science*, 9(6), 490-493.
- [168]. Lall, U., & Sharma, A. (1996). A nearest neighbor bootstrap for resampling hydrologic time series. *Water Resources Research*, 32(3), 679-693.
- [169]. Lang, A. (2006). Using the limited capacity model of motivated mediated message processing to design effective cancer communication messages. *Journal of communication*, 56(s1), S57-S80.
- [170]. Lawton, M. P., Kleban, M. H., Rajagopal, D., & Dean, J. (1992). Dimensions of affective experience in three age groups. *Psychology and aging*, 7(2), 171.
- [171]. Lazarus, R. S. (1991). *Emotion and adaptation*. Oxford University Press on Demand.

- [172]. LeBlanc, V. R., McConnell, M. M., & Monteiro, S. D. (2015). Predictable chaos: a review of the effects of emotions on attention, memory and decision making. *Advances in Health Sciences Education, 20*(1), 265-282.
- [173]. LeDoux, J. E. (1993). Emotional memory systems in the brain. *Behavioural brain research, 58*(1-2), 69-79.
- [174]. LeDoux, J. (1998). *The emotional brain: The mysterious underpinnings of emotional life*. Simon and Schuster.
- [175]. LeDoux, J. E., and Phelps, E. A. (1993). Emotional networks in the brain. *Handbook of emotions*, 109-118.
- [176]. Lerner, J. S., & Keltner, D. (2000). Beyond valence: Toward a model of emotion-specific influences on judgement and choice. *Cognition & emotion, 14*(4), 473-493.
- [177]. Lerner, J. S., & Keltner, D. (2001). Fear, anger, and risk. *Journal of personality and social psychology, 81*(1), 146.
- [178]. LePatner, B. B. (2008). *Broken buildings, busted budgets: How to fix America's trillion-dollar construction industry*. University of Chicago Press.
- [179]. Liao, S. G., Lin, Y., Kang, D. D., Chandra, D., Bon, J., Kaminski, N., ... & Tseng, G. C. (2014). Missing value imputation in high-dimensional phenomic data: imputable or not, and how?. *BMC bioinformatics, 15*(1), 346.
- [180]. Liaw, Y.-L., Lin, K.-Y., Li, M., and Chi, N.-W. (2012). "Learning assessment strategies for an educational construction safety video game." *Proc., of the 2012 Construction Research Congress, ASCE, VA, 2091–2100*.
- [181]. Lin, K. Y., Son, J.W., and Rojas, E. M. (2011). "A pilot study of a 3D game environment for construction safety education." *Electron. J. Inf. Technol. Constr., 16*, 69–84.
- [182]. Lindeman, E. C., Gessner, R., and Otto, M. (1956). *The simulationcratic man: Selected writings of Eduard C. Lindeman*, Boston.

- [183]. Linnenbrink-Garcia, L., Durik, A. M., Conley, A. M., Barron, K. E., Tauer, J. M., Karabenick, S. A., & Harackiewicz, J. M. (2010). Measuring situational interest in academic domains. *Educational and Psychological Measurement*.
- [184]. Litwak, E., Messeri, P., Wolfe, S., Gorman, S., Silverstein, M., & Guilarte, M. (1989). Organizational theory, social supports, and mortality rates: A theoretical convergence. *American Sociological Review*, 49-66.
- [185]. Loewenstein, G., and Lerner, J. (2002). The role of emotion in decision making. In Davidson, R. J., Goldsmith, H. H., and Scherer, K. R. (eds.), *Handbook of Affective Science*, Oxford University Press, Oxford, pp. 619–642.
- [186]. Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological bulletin*, 127(2), 267.
- [187]. Longmore, M., Wilkinson, I., Baldwin, A., and Wallin, E. (2014). *Oxford handbook of clinical medicine*. Oxford University Press.
- [188]. Lundberg, C. A. (2003). The influence of time-limitations, faculty, and peer relationships on adult student learning: A causal model. *Journal of Higher Education*, 665-688.
- [189]. Maindonald, J. & Braun, J. (2007) *Data Analysis and Graphics Using R – An Example-Based Approach*, 2nd edn. Cambridge University Press, Cambridge.
- [190]. McHugo, G. J., Smith, C. A., & Lanzetta, J. T. (1982). The structure of self-reports of emotional responses to film segments. *Motivation and Emotion*, 6(4), 365-385.
- [191]. MacLeod, A. K., & Byrne, A. (1996). Anxiety, depression, and the anticipation of future positive and negative experiences. *Journal of abnormal psychology*, 105(2), 286.
- [192]. MacNaughton, G., & Clyde, M. (1990). *Staffing the Practicum: Towards a New Set of Basics through Clarifying Roles*.
- [193]. Markus, H. R., & Kitayama, S. (2001). The cultural construction of self and emotion: Implications for social behavior. *Emotions in social psychology: Essential reading*, 119-137.

- [194]. Mather, M. (2007). Emotional arousal and memory binding: An object-based framework. *Perspectives on Psychological Science*, 2(1), 33-52.
- [195]. Matsumoto, D., Yoo, S. H., & Nakagawa, S. (2008). Culture, emotion regulation, and adjustment. *Journal of personality and social psychology*, 94(6), 925.
- [196]. Mayer, R. E. (1997). Multimedia learning: Are we asking the right question?. *Educational psychologist*, 32(1), 1-19.
- [197]. Mayer, R. E. (2009). *Multimedia Learning*, 2nd edition, Cambridge; New York: Cambridge University Press.
- [198]. McCarney, R., Warner, J., Iliffe, S., Van Haselen, R., Griffin, M., & Fisher, P. (2007). The Hawthorne Effect: a randomised, controlled trial. *BMC medical research methodology*, 7(1), 30.
- [199]. McClernon, C. K., McCauley, M. E., O'Connor, P. E., & Warm, J. S. (2011). Stress training improves performance during a stressful flight. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 53(3), 207-218.
- [200]. McCloskey, M., Wible, C. G., & Cohen, N. J. (1988). Is there a special flashbulb-memory mechanism?. *Journal of Experimental Psychology: General*, 117(2), 171.
- [201]. McDonald, J.H. 2014. *Handbook of Biological Statistics*. 3rd ed., Sparky House Publishing, Baltimore, Maryland, USA. This web page contains the content of pages 180-185 in the printed version.
- [202]. McGaugh, J. L. (2004). The amygdala modulates the consolidation of memories of emotionally arousing experiences. *Annu. Rev. Neurosci.*, 27, 1-28.
- [203]. McKenna, F. P., Horswill, M. S., & Alexander, J. L. (2006). Does anticipation training affect drivers' risk taking?. *Journal of Experimental Psychology: Applied*, 12(1), 1.
- [204]. Medin, D. L., & Ortony, A. (1989). Psychological essentialism. *Similarity and analogical reasoning*, 179, 195.
- [205]. Mellers, B. A., and McGraw, A. P. (2001). Anticipated emotions as guides to choice. *Current Directions in Psychological Science*, 10(6), 210-214.

- [206]. Merriam, S. (2004). The changing landscape of adult learning theory. In J. Comings, B. Garner, and C. Smith (Eds.), *Review of adult learning and literacy: Connecting research, policy, and practice* (pp. 199- 220). Mahwah, NJ: Lawrence Erlbaum Associates.
- [207]. Mesquita B. (2003). Emotions as dynamic cultural phenomena. In: Goldsmith H, Davidson R, Scherer K, editors. *Handbook of the Affective Sciences*. Oxford; New York: 2003. pp. 871–890.
- [208]. Meyer, D. K., & Turner, J. C. (2002). Discovering emotion in classroom motivation research. *Educational psychologist*, 37(2), 107-114.
- [209]. Mitchell, M. (1993). Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of educational psychology*, 85(3), 424.
- [210]. Moorthy, K., Munz, Y., Adams, S., Pandey, V., & Darzi, A. (2005). A human factors analysis of technical and team skills among surgical trainees during procedural simulations in a simulated operating theatre. *Annals of surgery*, 242(5), 631-639.
- [211]. Morrow, L. M., Sharkey, E., & Firestone, W. A. (1993). *Promoting independent reading and writing through self-directed literacy activities in a collaborative setting*. National Reading Research Center.
- [212]. Mroczek, D. K., & Kolarz, C. M. (1998). The effect of age on positive and negative affect: a developmental perspective on happiness. *Journal of personality and social psychology*, 75(5), 1333.
- [213]. Nadeau, R., Cloutier, E., & Guay, J. H. (1993). New evidence about the existence of a bandwagon effect in the opinion formation process. *International Political Science Review*, 14(2), 203-213.
- [214]. National Safety Council, “National Safety Council Injury Facts 2016 Edition,” National Safety Council, Itasca, IL, 2016.
- [215]. Neiss, M. B., Leigland, L. A., Carlson, N. E., & Janowsky, J. S. (2009). Age differences in perception and awareness of emotion. *Neurobiology of aging*, 30(8), 1305-1313.
- [216]. Nesse, R. M., & Klaas, R. (1994). Risk perception by patients with anxiety disorders. *Journal of Nervous and Mental Disease*, 182(8), 465-470.
- [217]. Nichols, A. L., & Maner, J. K. (2008). The good-subject effect: Investigating participant demand characteristics. *The Journal of general psychology*, 135(2), 151-166.

- [218]. Oatley, K., Keltner, D., & Jenkins, J. M. (2006). *Understanding emotions*. Blackwell publishing.
- [219]. Occupational Safety and Health Administration. "Commonly Used Statistics." U.S. Department of Labor. Retrieved July 12, 2018, from <https://www.osha.gov/oshstats/commonstats.html>.
- [220]. O'hara, R. B., & Kotze, D. J. (2010). Do not log-transform count data. *Methods in Ecology and Evolution*, 1(2), 118-122.
- [221]. Öhman, A., and Mineka, S. 2001. Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. *Psychological review*, 108(3), 483.
- [222]. Oliver, R. L. (1980). A cognitive model of the antecedents and consequences of satisfaction decisions. *Journal of marketing research*, 460-469.
- [223]. Orne, M. T. (1962). On the social psychology of the psychological experiment: With particular reference to demand characteristics and their implications. *American psychologist*, 17(11), 776.
- [224]. Palomba, D., Sarlo, M., Angrilli, A., Mini, A., & Stegagno, L. (2000). Cardiac responses associated with affective processing of unpleasant film stimuli. *International Journal of Psychophysiology*, 36(1), 45-57.
- [225]. Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational psychology review*, 18(4), 315-341.
- [226]. Pekrun, R., Elliot, A. J., & Maier, M. A. (2009). Achievement goals and achievement emotions: Testing a model of their joint relations with academic performance. *Journal of educational Psychology*, 101(1), 115.
- [227]. Pekrun, R., Frenzel, A. C., Goetz, T., & Perry, R. P. (2007). The control-value theory of achievement emotions: An integrative approach to emotions in education. In P. A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 13–36). San Diego: Elsevier
- [228]. Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational psychologist*, 37(2), 91-105.

- [229]. Pekrun, R., & Linnenbrink-Garcia, L. (2012). Academic emotions and student engagement. In *Handbook of research on student engagement* (pp. 259-282). Springer, Boston, MA.
- [230]. Peters, E. (2006). The functions of affect in the construction of preferences. *The construction of preference*, 454-463.
- [231]. Peters, E., Slovic, P., & Gregory, R. (2003). The role of affect in the WTA/WTP disparity. *Journal of Behavioral Decision Making*, 16, 309-330.
- [232]. Peters, E., & Slovic, P. (1996). The Role of Affect and Worldviews as Orienting Dispositions in the Perception and Acceptance of Nuclear Power 1. *Journal of applied social psychology*, 26(16), 1427-1453.
- [233]. Perlman, A., Sacks, R., & Barak, R. (2014). Hazard recognition and risk perception in construction. *Safety science*, 64, 22-31.
- [234]. Peterson, C., & Bell, M. (1996). Children's memory for traumatic injury. *Child development*, 67(6), 3045-3070.
- [235]. Peterson, C., & Whalen, N. (2001). Five years later: Children's memory for medical emergencies. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, 15(7), S7-S24.
- [236]. Pillemer, D. B. (1984). Flashbulb memories of the assassination attempt on President Reagan. *Cognition*, 16(1), 63-80.
- [237]. Pintrich, P. R., & Zusho, A. (2002). The development of academic self-regulation: The role of cognitive and motivational factors. In A. Wigfield & J. S. Eccles (Eds.), *Development of achievement motivation* (pp. 249–284). New York: Academic.
- [238]. Pratt, D. D. (1993). Andragogy after twenty-five years. *New directions for adult and continuing education*, 1993(57), 15-23
- [239]. Rachman, S. (2004). Fear of contamination. *Behaviour research and therapy*, 42(11), 1227-1255.
- [240]. Rathunde, K. (1998). Undivided and abiding interest: Comparisons across studies of talented adolescents and creative adults. In L. Hoffman, A. Krapp, K. A. Renninger, & J. Baumert (Eds.),

- Interest and learning: Proceedings of the Seon conference on interest and gender (pp. 367–376). Kiel, Germany: IPN.
- [241]. Reio, T. G., & Wiswell, A. (2000). Field investigation of the relationship among adult curiosity, workplace learning, and job performance. *Human Resource Development Quarterly*, 11(1), 5-30.
- [242]. Reisberg, D., & Heuer, F. (2004). Memory for emotional events. In D. Reisberg & P. Hertel (Eds.), *Memory and Emotion* (pp. 3–41). New York: Oxford University Press.
- [243]. Renninger, K. A. (2000). Individual interest and its implications for understanding intrinsic motivation. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 375–407). New York: Academic.
- [244]. Renninger KA, Hidi S, Krapp A, editors. *The role of interest in learning and development*. Hillsdale, NJ: Erlbaum; 1992.
- [245]. Reyna, V. F., & Ellis, S. C. (1994). Fuzzy-trace theory and framing effects in children's risky decision making. *Psychological Science*, 5(5), 275-279.
- [246]. Reyna, V. F., & Farley, F. (2006). Risk and rationality in adolescent decision making: Implications for theory, practice, and public policy. *Psychological science in the public interest*, 7(1), 1-44.
- [247]. Riva, G., Mantovani, F., Capideville, C. S., Preziosa, A., Morganti, F., Villani, D., Gaggioli, A., Botella, C., & Alcañiz, M. (2007). Affective interactions using virtual reality: the link between presence and emotions. *CyberPsychology & Behavior*, 10(1), 45-56.
- [248]. Roberts, N. A., Levenson, R. W., & Gross, J. J. (2008). Cardiovascular costs of emotion suppression cross ethnic lines. *International Journal of Psychophysiology*, 70(1), 82-87.
- [249]. Robinson, M. D., Boyd, R. L., & Liu, T. (2013). Understanding personality and predicting outcomes: The utility of cognitive-behavioral probes of approach and avoidance motivation. *Emotion Review*, 5(3), 303-307.
- [250]. Robinson, M. D., & Clore, G. L. (2002). Episodic and semantic knowledge in emotional self-report: evidence for two judgment processes. *Journal of personality and social psychology*, 83(1), 198.

- [251]. Rook, K. S., Thuras, P. D., & Lewis, M. A. (1990). Social control, health risk taking, and psychological distress among the elderly. *Psychology and Aging, 5*(3), 327.
- [252]. Rotgans, J. I., & Schmidt, H. G. (2017). Interest development: Arousing situational interest affects the growth trajectory of individual interest. *Contemporary Educational Psychology, 49*, 175-184.
- [253]. Rottenberg, J., Ray, R. R., & Gross, J. J. (2007). Emotion elicitation using films. In J. A. Coan & J. J.B. Allen (Eds.), *The handbook of emotion elicitation and assessment* (pp. 9_28). New York: Oxford University Press.
- [254]. Rottenstreich, Y., & Hsee, C. K. (2001). Money, kisses, and electric shocks: On the affective psychology of risk. *Psychological science, 12*(3), 185-190.
- [255]. Russell, J. A. (1980). A circumplex model of affect. *Journal of personality and social psychology, 39*(6), 1161.
- [256]. Russell, S. S. (2006). An overview of adult-learning processes. *Urologic Nursing, 26*(5), 349.
- [257]. Safety and Health Council of NC. (n.d.). HAND SAFETY in the WORKPLACE. Retrieved April 21, 2017, from <http://www.safetync.org/>. Retrieved from <<http://www.nsc.org/Membership%20Site%20Document%20Library/Recorded-Webinars/Safety%20at%20Hand.pdf>>
- [258]. Sansone, C., & Smith, J. L. (2000). Interest and self-regulation: The relation between having to and wanting to. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 341–372). New York: Academic.
- [259]. Schaffer, B. S., & Riordan, C. M. (2003). A review of cross-cultural methodologies for organizational research: A best-practices approach. *Organizational research methods, 6*(2), 169-215.
- [260]. Schiefele, U. (1999). Interest and learning from text. *Scientific Studies of Reading, 3*, 257–280.
- [261]. Schiefele, U. (1996). Topic interest, text representation, and quality of experience. *Contemporary Educational Psychology, 21*, 3–18.
- [262]. Schiefele, U. (1991). Interest, learning, and motivation. *Educational psychologist, 26*(3-4), 299-323.

- [263]. Schwarz, N., & Clore, G. L. (2003). Mood as information: 20 years later. *Psychological Inquiry*, 14(3-4), 296-303.
- [264]. Sileshi, G., Hailu, G. & Nyadzi, G.I. (2009) Traditional occupancy-abundance models are inadequate for zero-inflated ecological count data. *Ecological Modelling*, 220, 1764–1775.
- [265]. Silvia, P. J. (2001). Interest and interests: The psychology of constructive capriciousness. *Review of General Psychology*, 5, 270–290.
- [266]. Sissel, P. A., Hansman, C. A., & Kasworm, C. E. (2001). The politics of neglect: Adult learners in higher education. *New Directions for Adult and Continuing Education*, 2001(91), 17-28.
- [267]. Slovic, P. (1987). Perception of risk. *Science*, 236(4799), 280-285.
- [268]. Slovic, P., Finucane, M., Peters, E., & MacGregor, D. G. (2002). Rational actors or rational fools: Implications of the affect heuristic for behavioral economics. *The Journal of Socio-Economics*, 31(4), 329-342.
- [269]. Slovic, P., Monahan, J., & MacGregor, D. G. (2000). Violence risk assessment and risk communication: The effects of using actual cases, providing instruction, and employing probability versus frequency formats. *Law and human behavior*, 24(3), 271-296.
- [270]. Slovic, P., & Peters, E. (2006). Risk perception and affect. *Current directions in psychological science*, 15(6), 322-325.
- [271]. Slovic, P., Peters, E., Finucane, M. L., & MacGregor, D. G. (2005). Affect, risk, and decision making. *Health psychology*, 24(4S), S35.
- [272]. Specht, L. B., & Sandlin, P. K. (1991). The differential effects of experiential learning activities and traditional lecture classes in accounting. *Simulation & Gaming*, 22(2), 196-210.
- [273]. Steadman, R. H., Coates, W. C., Huang, Y. M., Matevosian, R., Larmon, B. R., McCullough, L., & Ariel, D. (2006). Simulation-based training is superior to problem-based learning for the acquisition of critical assessment and management skills*. *Critical care medicine*, 34(1), 151-157.
- [274]. Stewart, T. R., Roebber, P. J., & Bosart, L. F. (1997). The importance of the task in analyzing expert judgment. *Organizational Behavior and Human Decision Processes*, 69(3), 205-219.

- [275]. Stone, T. W. (1981). Theophylline does not affect morphine inhibition of the isolated vas deferens. *British journal of pharmacology*, 73(3), 787-789.
- [276]. Tabachnick, B. G., and Fidell, L. S. (2007). *Using multivariate statistics*, 5th Ed., Pearson Allyn and Bacon, Upper Saddle River, NJ.
- [277]. Taylor, S. E., & Brown, J. D. (1988). Illusion and well-being: a social psychological perspective on mental health. *Psychological bulletin*, 103(2), 193.
- [278]. Thiel, C. E., Connelly, S., Harkrider, L., Devenport, L. D., Bagdasarov, Z., Johnson, J. F., & Mumford, M. D. (2013). Case-based knowledge and ethics education: Improving learning and transfer through emotionally rich cases. *Science and engineering ethics*, 19(1), 265-286.
- [279]. Tsai, J. L. (2007). Ideal affect: Cultural causes and behavioral consequences. *Perspectives on Psychological Science*, 2(3), 242-259.
- [280]. U.S. Bureau of Economic Analysis (2018). Gross-Domestic-Product-(GDP)-by-Industry Data. U.S. Department of Commerce. < https://www.bea.gov/industry/gdpbyind_data.htm>
- [281]. U.S. Bureau of Labor Statistics, “2017 Labor Force Statistics from the Current Population Survey” U.S. Department of Labor, Washington, DC, Jan. 2018.
- [282]. U.S. Bureau of Labor Statistics, “2016 Survey of occupational injuries and illnesses Charts Package,” U.S. Department of Labor, Washington, DC, Nov. 2017.
- [283]. U.S. Department of Education, National Center for Education Statistics. (2013). Digest of Education Statistics, 2012 (NCES 2014-015), Retrieved from: <http://nces.ed.gov/programs/digest/d12/>.
- [284]. US Department of Energy, “Buildings Energy Data Book,” Building Energy Data Book, Mar-2012. [Online]. Available: <http://buildingsdatabook.eren.doe.gov/ChapterIntro1.aspx>. [Accessed: 25-May-2016].
- [285]. Verduyn, P., Delvaux, E., Van Coillie, H., Tuerlinckx, F., and Van Mechelen, I. (2009). Predicting the duration of emotional experience: two experience sampling studies. *Emotion*, 9(1), 83.
- [286]. Verduyn, P., Van Mechelen, I., and Tuerlinckx, F. (2011). The relation between event processing and the duration of emotional experience. *Emotion*, 11(1), 20.

- [287]. Wagenaar, W. A., & Keren, G. B. (1986). Does the expert know? The reliability of predictions and confidence ratings of experts. In *Intelligent decision support in process environments* (pp. 87-103). Springer, Berlin, Heidelberg.
- [288]. Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of personality and social psychology*, 54(6), 1063.
- [289]. Weinberger, D. A. (1990). The construct validity of the repressive coping style. *Repression and dissociation: Implications for personality theory, psychopathology, and health*, 337-386.
- [290]. Wierzbicka, A. (1999). *Emotions across languages and cultures: Diversity and universals*. Cambridge University Press.
- [291]. Wilkins, J. R. (2011). Construction workers' perceptions of health and safety training programmes. *Construction Management and Economics*, 29(10), 1017-1026.
- [292]. Wolf, O. T. (2008). The influence of stress hormones on emotional memory: Relevance for psychopathology. *Acta psychologica*, 127(3), 513-531.
- [293]. Wright, W. F., & Bower, G. H. (1992). Mood effects on subjective probability assessment. *Organizational behavior and human decision processes*, 52(2), 276-291.
- [294]. Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics*. Allyn & Bacon/Pearson Education.
- [295]. Taylor, S. E., & Brown, J. D. (1988). Illusion and well-being: a social psychological perspective on mental health. *Psychological bulletin*, 103(2), 193.
- [296]. Tixier, A. J. P., Hallowell, M. R., Albert, A., van Boven, L., & Kleiner, B. M. (2014). Psychological antecedents of risk-taking behavior in construction. *Journal of Construction Engineering and Management*, 140(11), 04014052.
- [297]. Tobias, S. (1995). Interest and metacognitive word knowledge. *Journal of educational psychology*, 87(3), 399.

- [298]. Tough, A. (1979). *The Adult's Learning Projects. A Fresh Approach to Theory and Practice in Adult Learning.*
- [299]. Tomkins, S. S. (1984). Affect theory. *Approaches to emotion*, 163(163–195).
- [300]. Troyanskaya, O., Cantor, M., Sherlock, G., Brown, P., Hastie, T., Tibshirani, R., Botstein, D. & Altman, R. B. (2001). Missing value estimation methods for DNA microarrays. *Bioinformatics*, 17(6), 520-525.
- [301]. Turner, C., & McClure, R. (2003). Age and gender differences in risk-taking behaviour as an explanation for high incidence of motor vehicle crashes as a driver in young males. *Injury control and safety promotion*, 10(3), 123-130.
- [302]. Umberson, D. (1987). Family status and health behaviors: Social control as a dimension of social integration. *Journal of health and social behavior*, 306-319.
- [303]. Van de Vijver, F., & Leung, K. (1997). *Methods and data analysis of comparative research.* Allyn & Bacon.
- [304]. Venter, K. (2003). Coping with isolation: The role of culture in adult distance learners' use of surrogates. *Open Learning*, 18(3), 271-287.
- [305]. Verduyn, P., Delvaux, E., Van Coillie, H., Tuerlinckx, F., and Van Mechelen, I. (2009). Predicting the duration of emotional experience: two experience sampling studies. *Emotion*, 9(1), 83.
- [306]. Verduyn, P., Van Mechelen, I., and Tuerlinckx, F. (2011). The relation between event processing and the duration of emotional experience. *Emotion*, 11(1), 20.
- [307]. Wagner, V., Klein, J., Hanich, J., Shah, M., Menninghaus, W., & Jacobsen, T. (2016). Anger framed: A field study on emotion, pleasure, and art. *Psychology of Aesthetics, Creativity, and the Arts*, 10(2), 134.
- [308]. Watson, D., & Tellegen, A. (1985). Toward a consensual structure of mood. *Psychological bulletin*, 98(2), 219.
- [309]. X. S. Dong, J. A. Largay, & X. Wang, "New trends in fatalities among construction workers," *Cent. Prot. Work. Rights CPWR Data Brief*, vol. 3, no. 2, Jun. 2014.

- [310]. Yuen, K. S., & Lee, T. M. (2003). Could mood state affect risk-taking decisions?. *Journal of affective disorders*, 75(1), 11-18.
- [311]. Zhang, S. (2012). Nearest neighbor selection for iteratively kNN imputation. *Journal of Systems and Software*, 85(11), 2541-2552.

APPENDIX A: International Construction Specialty Conference, Vancouver, British Columbia, 2015

NEW MULTIMEDIA SAFETY EDUCATION PROGRAM: IMPACTS ON EMOTIONs, RISK PERCEPTIONs, AND LEARNING

Abstract: Safety training is a vital component of any construction organization's safety program. Training offers an opportunity for the transfer of explicit and tacit knowledge of safe work practices. Often, safety training focuses on core issues faced by the specific organization and links to desired worker behaviour. Unfortunately, the typical delivery modes involve PowerPoint presentations, written safety protocols, and classroom-style settings. Such teaching modes do not facilitate active, inductive, context-based learning that is essential for effective andragogy (i.e., adult learning) and, therefore, often fail to achieve their desired objectives. This study tests the hypotheses that a new method of risk-free safety training, Live Safety Demos, increases engagement through emotional response to training activities. The technique involves demonstrating the cause and effect of actual injuries to human hands, which are the most commonly injured body part in construction. The delivery of the demos include the following key components: (1) biologically-realistic replicas of human hands that include flesh, bones, and blood networks; (2) in-person demonstrations of common injuries to worker's hands (e.g., pinch-points between sections of pipe); (3) videos showing injuries to the replicas recorded at over 2100 frames per second to show detail; and (4) worker-led activities to design work practices that would prevent each injury type. The research was achieved with a team that included one faculty member, three students, a senior manager from the owner organization, four safety managers, and an English-to-Spanish translator. To test the aforementioned hypothesis, the research team used field-validated methods from experimental psychology to measure emotional response to the training program. Using a longitudinal A+B experiment, the demos were tested over the course of a one-week period with approximately 1,200 workers who belonged to approximately 100 crews. The results indicate a very strong emotional response to the Live Safety Demos with statistically

significant changes in almost every emotion category. There was a significant increase in negative emotions, which is known to increase risk perception and decrease risk tolerance. Increase in induced activating emotions lead to a more engaged learning commitment during safety training, which increases the ability of workers to recognize more hazards. Thus, this research shows that live safety demos, although resource-intensive, has the potential to transform safety training in the construction industry. Future research is suggested to broaden the sample population and to test additional elements such as retention levels, duration of these induced emotions, communication networks, and ability to respond ad hoc to new safety environments.

1. Introduction

Carter and Smith (2006) and the Center for Disease Control and Prevention (CDC 2012) suggest that construction workers lack the necessary skill set to correctly identify potential hazards at the job-site. This is a valid claim because, despite constantly improving industry standards and years of extensive research to reduce injuries, there were 4,405 fatal work-related injuries during 2013 (Bureau of Labor Statistics 2013). Furthermore, although there was a modest decline in injury rates between 2011 and 2013, there was an overall increase in fatality rates and a dramatic 7% increase in injuries and fatalities to Hispanic workers (Bureau of Labor Statistics 2013). These trends imply that the industry could benefit from more engaging safety-training that heightens awareness of potential hazards and addresses andragogical principles of learning (Wilkins 2011).

There has been extensive research conducted to understand how people learn in occupational contexts. For example, Baddeley (1992) suggested that the working memory uses both verbal and visual channels to process and retain information. Hence, in contrast to generic presentation-based training programs, multimedia styles of learning are theoretically more effective as they engage both visual and verbal channels. Moreover, adults seek engaging learning approaches with significance to everyday life as

a motivation for learning (Lindeman 1956). This study involved the development and empirical testing of Live Safety Demos, an experiential learning program built upon the principles of Generative Theory of Multimedia Learning (Mayer 1997). As Mayer (1997, p.4) suggests, “multimedia instruction affects the degree to which learners engage in the cognitive processes required for meaningful learning within the visual and verbal information processing systems.” The Live Safety Demos were designed within this theoretical context.

The Live Safety Demos included realistic simulations of commonly occurring injuries and a concurrent explanation of the cause and effect of those injuries. To enhance andragogy, the demos involved biologically accurate replications of human hands, realistic simulation of injuries on the artificial hands, a high-speed video of the injury to illustrate detail, and in-depth conversations with the workforce. To test the effectiveness of this new form of safety training, the research team aimed to measure the extent to which the participant’s emotions change as a result of the training program. There has been substantial research that suggests that emotions play a major role in a person’s decision-making process and, thus, affect an individual’s risk perception and tolerance (Clare et. al. 1994; Keller et. al. 2006). This is the first investigation to measure emotional response to an experiential safety program despite the empirical connections between emotional response, learning, and safe work behaviour.

2. Live Safety Demonstration Creation and Delivery

Researchers have found that the only major factor that affects an individual’s risk tolerance is previous personal injury history (Hallowell 2010). That is, a past injury or witnessing a severe injury to a close co-worker is the only factor that has been shown to decrease risk tolerance. Unfortunately, the implication of this finding is that someone must be injured in order for risk tolerances to change. A major objective of this research was to create a hyper-realistic demonstration of an injury that gives participants the experience of an injury without the negative consequences. In this study, we gauge change in emotional

response to measure the change in the risk perception/tolerance. Drevets and Raichle (1998) showed that blood supply to brain decreased near the risk-based decision-making sections during acute induced emotional moments and Loewenstein et. al.'s (2001) research found that specific emotions sway human response in adverse situations. Previous studies have shown that people with positive emotional state have more affinity for risk (Isen and Patrick 1983). This implies that if the demonstrations induce a negative emotional state, it should lower the participant's affinity towards risk.

An important component of the Live Safety Demos was the creation of a hyper-realistic demonstration of an injury. To achieve the goals artificial hands were created that look, feel, and respond like actual human hands (Figure 1). The hands were built using life-casting techniques primarily found in dentistry and prosthetics and include flesh with the exact properties of a human hand, an internal blood bladder and blood network, and bones. To illustrate the level of realism achieved in the creation of the hands, Table 1 provides a complete comparison between the fabricated hand and the average adult human hand according to the Oxford Handbook of Clinical Medicine (Longmore et al. 2014). As one can see from Table 1 and Figure 1, the hands were sufficiently accurate to serve as a realistic proxy for a worker in dangerous situations.



Figure 1: Artificial hands for Live Safety Demonstration

Table 14: Comparison between Real and Demo Hand

Properties	Fabricated Hand	Actual Human Hand
Specific Gravity	1.07 g/cc	1.067 g/cc
Hardness	10 A	10 A
Tensile Strength	475 psi	421 psi
Elongation at Tear	364%	245%
Die B Tear Strength	102 pli	100 pli
Shrinkage	<0.001 in/in	<0.001 in/in
Bone Shear Strength	70 Mpa	52 Mpa
Bone Breaking Force	280 lbs	267 lbs

To accompany the fabricated hand in a training demonstration, a video was created where the hand was injured in two modes: a falling concrete chisel and a pinch point between two sections of three-inch steel pipe. A brief description of the two demonstrations is provided below.

Falling Concrete Chisel: This demonstration aimed to replicate an actual disabling injury where a carpenter dropped a one-kilogram concrete chisel when stripping concrete formwork. The falling chisel

struck another worker who was working below the formwork and punctured his hand. Ultimately, there were three broken phalanges and nerve damage, which resulted in limited use of the hand. The first part of the demonstration involved educating the workers of the speed that the chisel was falling at time of impact (approximately 43 kilometers per hour), the impact area of the chisel (0.30 cm²), and the overall pressure on the hand (48 MPa). To achieve a memorable mnemonic, a discussion related to speed, sharpness, and weight was held among the workers as prompted by the instructors. Following this discussion, the resilience of the human hand was described. Specifically, the human hand can withstand approximately 1 MPa without significant damage. Given the load on and resistance of the hand, the workers were asked to predict what would happen to a gloved and ungloved hand. Once this discussion was complete, a high-speed video was shown with both a gloved and ungloved hand, illustrating dramatic differences in outcome. The first demonstration session concluded with a discussion of the safe work practices for the type of work demonstrated.

Pinch Points between Two 3-Inch Steel Pipes: The second demonstration focused on an injury where a worker was in the process of connecting a 3-inch steel pipe to a pipe couple when the pipe sling shifted and the worker's hand was pinched between the pipe and the couple. The result of the injury was a deep flesh wound and nerve damage. Similar to the falling chisel demo, the first step of the demonstration was to present the physics behind the injury. This included the momentum of the moving pipe, the contact area of the pipe, and the overall pressure on the hand. Once the resistance of the hand to pressure (1 MPa), the workers predicted the outcome for a gloved and ungloved hand and the associated videos were shown that depicted both scenarios. Also, a discussion was held regarding the potential outcomes of a heavier, sharper, or faster moving pipe. The session also concluded with a discussion of safe work practices for installing steel pipe.



Figure 2 – Screen capture of a gloved hand being struck by a falling concrete chisel.

3. Research Methods

As previously indicated, our research goal for this study was to measure emotional response to the active, experience-based demonstrations that incorporated theory of andragogy. In order to achieve this goal, we delivered the demos to 1,200 construction workers in a one-week period in Kenedy, Texas through sixteen different sessions (average of 75 workers per session). The same delivery technique and the same instructors were used in each session to ensure consistency. Additionally, a set script was followed to enhance reliability and replicability of the study and all instructors followed a set script.

In order to measure emotional response, we implemented a before and after (AB) experimental design where Rottenberg et al.'s (2007) emotional polarity questionnaire was used to survey workers before and after the Live Demos. On this questionnaire, the participants were asked to rate their emotions on 8-point scale. In addition to Rottenberg et al.'s (2007) questionnaire, we considered various alternative methods to gauge the emotional response such as the Balloon Analogue Risk Task (BART), which is a laboratory based computerized self-reporting risk assessment tool (Lejuez, C. W., et al. 2002). We decided

to pursue the paper form of the Rottenberg et al. (2007) questionnaire because of our sample size and time and resource constraints in the field. The emotion questionnaire was quantitative with one optional qualitative question, which requested comments or other emotions.

Out of the 1200 workers, 489 (40%) participated in the surveys as participation was voluntary and uncompensated. The surveys were administered in paper form and all the participants were provided sufficient time and resources to complete the surveys both times. Surveys were provided to the participants immediately before and immediately after the Live Demonstrations and no more than a 3-minute time lag was allowed as suggested by Verduyn et. al. (2009 & 2011).

The following protocol was implemented when delivering the live safety demos and collecting data:

- [1]. Introduction to the topic and welcome
- [2]. Emotions survey with demographics
- [3]. Delivery of dropped object demo or pinch point demo
- [4]. Delivery of the second demo (one not delivered in step 3)
- [5]. Emotions survey and open-ended qualitative question
- [6]. Closing remarks

As previously indicated, all demos were delivered to workers in Kenedy, Texas. Subjects involved had no knowledge of the demos prior to the session. Some work crews in this region were Spanish-only-speaking while others were English-only-speaking. We delivered the demonstrations in both English and Spanish, as members of the research team were bilingual. The participants were allowed to choose between the English or Spanish session. Seventy-five percent of the participants attended English sessions and 25% attended Spanish sessions.

To ensure anonymity, the participants were not required to enter their names or any direct identification. Instead, workers used a personal password that was not linked to their name, trade, or employer. For demographic questions, we also offered participants the opportunity to decline to answer a question if they felt uncomfortable providing the information. In our sample, 69% were married, 50% had witnessed a severe injury first-hand, 23% had been injured (recordable injury), 6% have a bachelor's degree or more, 32% have some college education, 57% completed high school, 4% have no education, 70% were Hispanic, and 30% were Caucasian. The average age of the participants was 38 years and, interestingly, less than 5% of the workers were female. Figure 3 illustrates the overall research process including development, data collection, statistical comparisons, and conclusions.

4. Results

In order to study the emotional responses, the data were analyzed using paired t-tests. Paired t-tests were used because we have two nominal variables and one measurement variable (McDonald, J.H. 2014). One nominal variable represents the participant and other is the “pre” and “post” emotional state recorded via their responses. Table 2 shows the results of the emotional change for the entire sample. We considered the change to be significant at 95% confidence ($p < 0.05$). Based on the results shown in Table 2, there was a large and statistically significant change in the following emotions: confusion, disgust, guilt, fear, happiness, joy, love, pride, sadness, surprise, and unhappiness. The greatest change occurred in fear and surprise. We can also say here that the ‘negative’ emotions or those associated with being serious, sombre, and vulnerable increased significantly.

Table 3 shows the emotional response of Caucasians and Hispanic workers separately. It also shows that Caucasians showed a significant change in confusion, fear, happiness, joy, love, pride, sadness, shame, and surprise whereas Hispanic workers had a significant change in anger, confusion, fear, guilt, happiness,

joy, love, pride, sadness, surprise, and unhappiness. This is further discussed in the next section in the context of this paper.

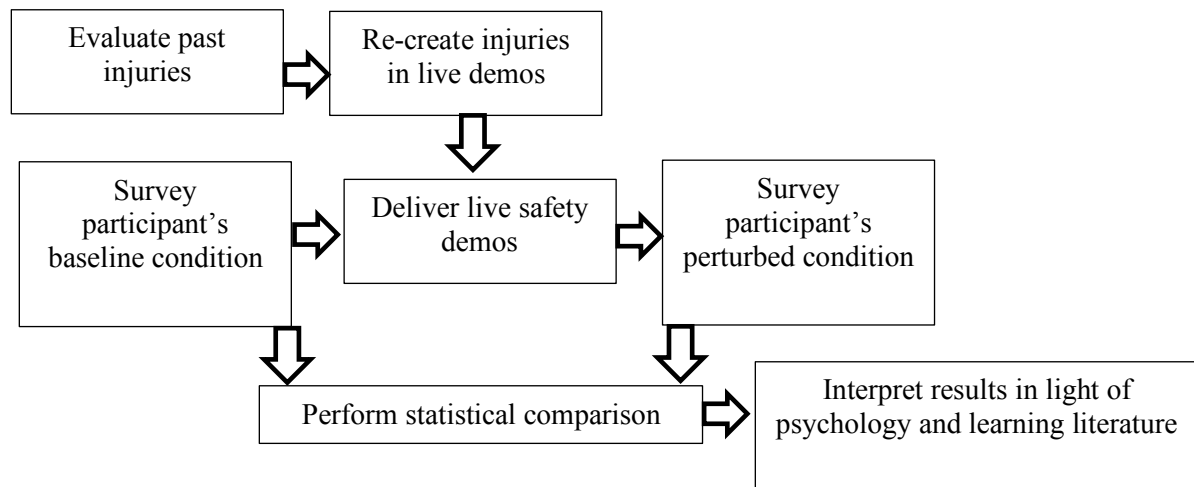


Figure 3 – Overview of research process

Table 2 – Changes in Emotional State due to Live Safety Demo

Emotion	Average Before	Average After	Difference	P-value
Amusement	4.06	4.16	2%	0.319
Anger	1.65	1.53	-7%	0.154
Anxiety	1.82	1.94	7%	0.092
Confusion	1.68	1.45	-14%	<0.01
Disgust	1.44	1.62	12%	0.044
Embarrassment	1.52	1.45	-4%	0.401
Fear	1.45	2.13	47%	<0.01
Guilt	1.36	1.54	13%	0.013
Happiness	5.68	4.05	-29%	<0.01
Interest	6.11	6.00	-2%	0.322
Joy	5.43	4.07	-25%	<0.01
Love	5.29	3.73	-29%	<0.01
Pride	5.61	4.33	-23%	<0.01
Sadness	1.51	2.15	43%	<0.01
Shame	1.57	1.69	7%	0.277
Surprise	2.66	3.91	47%	<0.01
Unhappiness	1.47	1.74	18%	0.007

Note: The plus and minus sign represent the increase and decrease of that particular emotion.

Table 3: Results from English and Spanish Surveys

Emotions	Average Before (Caucasian)	Average After (Caucasian)	Difference (%)	P- value	Average Before (Hispanic)	Average After (Hispanic)	Difference (%)	P- value
Amusement	3.97	3.79	-5%	0.80	4.10	4.29	5%	0.20
Anger	1.64	1.59	-3%	0.91	1.63	1.45	-11%	0.04
Anxiety	1.85	2.01	9%	0.13	1.78	1.64	4%	0.40
Confusion	1.65	1.38	-16%	<0.01	1.44	2.20	-12%	0.01
Disgust	1.50	1.71	14%	0.17	1.38	1.53	11%	0.15
Embarrassment	1.36	1.28	-6%	0.42	1.57	1.46	-7%	0.36
Fear	1.31	2.25	72%	<0.01	1.49	2.04	36%	<0.01
Guilt	1.26	1.39	10%	0.12	1.37	1.57	14%	0.04
Happiness	5.52	3.85	-30%	<0.01	5.78	4.23	-27%	<0.01
Interest	6.00	5.96	-1%	0.77	6.19	6.05	-2%	0.31
Joy	4.90	3.58	-27%	<0.01	5.66	4.40	-22%	<0.01
Love	5.00	3.31	-34%	<0.01	5.41	3.95	-27%	<0.01
Pride	6.12	4.80	-22%	<0.01	5.40	4.15	-23%	<0.01
Sadness	1.52	2.11	39%	<0.01	1.48	2.08	40%	<0.01
Shame	1.30	1.68	30%	<0.01	1.66	1.66	0%	0.62
Surprise	2.28	3.89	71%	<0.01	2.76	3.97	44%	<0.01
Unhappiness	1.54	1.69	10%	0.28	1.40	1.67	20%	0.01

5. Discussion and Conclusions

Key takeaways from the data are that emotions such as anger, anxiety, confusion, disgust, embarrassment, fear, guilt, happiness, joy, pride, sadness, love, surprise, and unhappiness showed a fluctuation in the same direction. Both Hispanic and Caucasian workers registered an aggregate decrease in their positive emotions such as happiness (-29%), joy (-25%), love (-29%), and pride (-23%) and an increase in negative emotions unhappiness (18%), fear (47%), surprise (47%), and sadness (43%). When viewed separately, Caucasian surveys showed statistically significant change in 'fear' and Hispanic surveys showed statistically significant change in 'anger' and 'fear' (activating).

The implications of the observed emotional changes on learning are significant. Pekrun (2006) explains that negative emotions increase extrinsic motivation to learn and avoid failure. Specifically, Pekrun et. al. (2002, p.97) claims that "Emotions may trigger, sustain, or reduce academic motivation and related volitional processes." They also suggest that changes in positive emotions (happiness, joy) and negative emotions (anxiety, anger) can be activating and may facilitate learning. Bless et. al. (1996) further proposed that negative emotions lead to more detail-oriented and cautious approach towards solving problems, which could be preferable to construction safety. Thus, it can be concluded that Live Safety Demos is an improvement over the current training style for the construction crews because workers will be more detail-oriented and cautious as they troubleshoot safety problems and plan for safe work.

In addition to enhanced learning, the changes in emotions are linked to decreased risk taking. As mentioned in the introduction, it is overwhelmingly accepted that negative emotions lead to a less affinity towards taking risk (Öhman and Mineka 2001; Clore et. al. 1994; Keller et. al. 2006). Taylor and Brown (1988) claimed that "false optimism" leads to a fake sense of security towards any situation thus, making them less cautious and oblivious to hidden risks. Additionally, it should be noted that negative emotional states are strongly associated with an increase in risk perception (i.e., workers perceive greater risk in their environment) and reductions in risk-taking behaviour (Gruber et. al. 2011). Results in table 3 and table 4

also show that there is a significant decrease in joy and interest emotions, which leads a decrease in safety valuations of situations (Izard 1977). Based on these established theories, we believe that the Live Safety Demos makes construction workers perceive more risk, which should decrease sense of false optimism and risk-taking behavior.

There were some interesting differences in the emotional reactions between Hispanic and Caucasian workers. Firstly, Caucasian workers experienced greater increases in anxiety, fear, surprise, shame, and disgust than their Hispanic counterparts. Hispanic workers, on the other hand, experienced greater relative changes (increase) in amusement unhappiness, and guilt. Hispanic workers were less angry and less happy while Caucasian workers were much more fearful and surprised. Matsumoto et. al. 1988 showed that there are cultural differences in self-reporting of any emotional experience, which include intensity, control, and duration of emotion. However, these induced emotions though varying in intensity, need to correlate positively with cognition among these workers. Since the changes in emotions are all in the same direction, there is no indication that the differences in emotional response would have any serious implications for risk taking or safety learning. Figure 4 outlines some of the major changes due to Live Safety Demos on the participants and the implications of those changes.

The findings mentioned above come with limitations. As discussed briefly in research methods section, the survey responses are never quite accurate for various reasons. First, there was an inherent discomfort observed among the participants even if surveys are anonymous that they could be traced back to them. Second, there was also some conversations among the participants as they filled the surveys out which might have also affected their answers. Third, and most importantly, it has been documented that people are sometimes incapable of understanding our own emotions. Finally, there is a clear male bias in the sample.

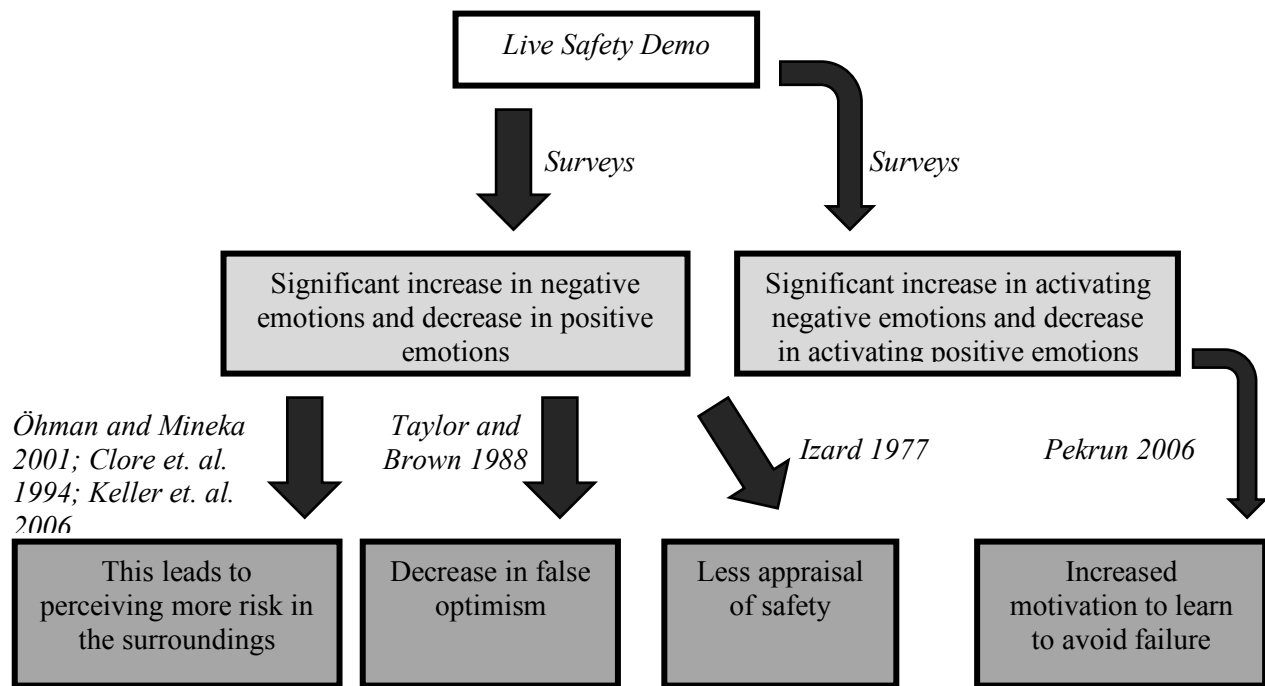


Figure 4 – Major Implications of the Results from Live Safety Demos

Other studies can further these results by analyze how long did the induced emotions last among the participants after the demos and what is the level of emotional intelligence among construction workers. It will be interesting to also research if ethnicity impacts. More importantly, emotional intelligence examination might allow us to judge whether self-reporting questionnaire form is a good choice or not among construction workers. In conclusion, this paper shows that current safety training programs are inefficient and monotonous. Live Safety Demos is an effective multi-media safety-training program, which embraces the andragogical principles and increases risk perception by inducing a sombre and cautious emotional response among construction workers. These demos will by-pass the need to introduce new and more stringent rules by improving participants' hazard recognition and the risks associated with it.

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7. References

- [1]. Bless, H., Clore, G. L., Schwarz, N., Golisano, V., Rabe, C., and Wölk, M. 1996. Mood and the use of scripts: Does a happy mood really lead to mindlessness? *Journal of personality and social psychology*, 71(4), 665-679.
- [2]. Baddeley, A. 1992. Working memory: The interface between memory and cognition. *Journal of cognitive neuroscience*, 4(3), 281-288.
- [3]. United States of America. United States Department of Labor. Bureau of Labor Statistics. *Census of Fatal Occupational Injuries Summary, 2013*. N.p., 11 Sept. 2014. Web. 6 Jan. 2015. <<http://www.bls.gov/news.release/cfoi.nr0.htm>>.
- [4]. Carter, G., and Smith, S. D. 2006. Safety hazard identification on construction projects. *Journal of Construction Engineering and Management*, 132(2), 197-205.
- [5]. Clore, G. L., Schwarz, N., and Conway, M. 1994. Affective causes and consequences of social information processing. *Handbook of social cognition*, 1, 323-417.
- [6]. Drevets, W. C., and Raichle, M. E. 1999. Reciprocal suppression of regional cerebral blood flow during emotional versus higher cognitive processes: Implications for interactions between emotion and cognition. *Cognition and emotion*, 12(3), 353-385.
- [7]. Gruber, J., Mauss, I. B., and Tamir, M. 2011. A dark side of happiness? How, when, and why happiness is not always good. *Perspectives on Psychological Science*, 6(3), 222-233.
- [8]. Hallowell, M. 2010. Safety risk perception in construction companies in the Pacific Northwest of the USA. *Construction management and economics*, 28(4), 403-413.
- [9]. Izard, C. E. (1977). *Human emotions* (Vol. 17). C. E. Izard (Ed.). New York: Plenum Press.
- [10]. Isen, A. M., and Patrick, R. 1983. The effect of positive feelings on risk taking: When the chips are down. *Organizational Behavior and Human Performance*, 31(2), 194-202.
- [11]. Keller, C., Siegrist, M., and Gutscher, H. 2006. The role of the affect and availability heuristics in risk communication. *Risk Analysis*, 26(3), 631-639.

- [12]. Lejuez, C. W. Read, J. P. Kahler, C. W. Richards, J. B. Ramsey, S. E. Stuart, G. L. Strong, D. R. and Brown, R. A. 2002. Evaluation of a behavioral measure of risk taking: the Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied*, 8(2), 75.
- [13]. Lindeman, E. C., Gessner, R., and Otto, M. (1956). The democratic man: The selected writings of Eduard C. Lindeman (R. Gessner, Ed.). Boston: Beacon, USA.
- [14]. Loewenstein, G. F., Weber, E. U., Hsee, C. K., and Welch, N. 2001. Risk as feelings. *Psychological bulletin*, 127(2), 267-286.
- [15]. Longmore, M., Wilkinson, I., Baldwin, A., & Wallin, E. (2014). *Oxford handbook of clinical medicine*. Oxford University Press.
- [16]. Mayer, R. E. 1997. Multimedia learning: Are we asking the right questions? *Educational psychologist*, 32(1), 1-19.
- [17]. Matsumoto, D., Kudoh, T., Scherer, K., and Wallbott, H. 1988. Antecedents of and reactions to emotions in the United States and Japan. *Journal of Cross-Cultural Psychology*, 19(3), 267-286.
- [18]. McDonald, J.H. 2014. Handbook of Biological Statistics. 3rd ed., Sparky House Publishing, Baltimore, Maryland, USA. This web page contains the content of pages 180-185 in the printed version.
- [19]. Öhman, A., and Mineka, S. 2001. Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. *Psychological review*, 108(3), 483.
- [20]. Pekrun, R. 2006. The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, 18(4), 315-341.
- [21]. Pekrun, R., Goetz, T., Titz, W., and Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational psychologist*, 37(2), 91-105.
- [22]. Rottenberg, J., Ray, R. D., & Gross, J. J. (2007). Emotion elicitation using films. *The handbook of emotion elicitation and assessment*; London: Oxford University Press, 9.

- [24]. Taylor, S. E., and Brown, J. D. 1988. Illusion and well-being: a social psychological perspective on mental health. *Psychological bulletin*, 103(2), 193-210.
- [25]. Wilkins, J. R. 2011. Construction workers' perceptions of health and safety training programmes. *Construction Management and Economics*, 29(10), 1017-1026.
- [26]. Verduyn, P., Van Mechelen, I., and Tuerlinckx, F. 2011. The relation between event processing and the duration of emotional experience. *Emotion*, 11(1), 20-28.
- [27]. Verduyn, P., Van Mechelen, I., Tuerlinckx, F., Meers, K., and Van Coillie, H. 2009. Intensity profiles of emotional experience over time. *Cognition and Emotion*, 23(7), 1427-1443.

APPENDIX B: Construction Research Congress, Puerto Rico, 2016

EMOTIONAL STATES AND THEIR IMPACT ON HAZARD IDENTIFICATION SKILLS

ABSTRACT

Every safety meeting and training program is built upon the assumption that construction workers can identify hazards. However, recent research has shown that may not be true because construction workers and managers lack basic hazard recognition skills. Currently, there is relatively little understanding of the factors impacting hazard recognition skill. Based upon the recent discovery that emotional state impacts risk perception, this study examines, the connection between emotion and hazard recognition. Using a longitudinal A+B experiment, this study measured the extent to which variability in emotional state predicts variability in hazard recognition skill and subsequent safety decisions. Autobiographical recall was used to induce and measure emotional state in 45 subjects. Subjects were asked to complete hazard identification and risk perception test before and after the induction. The emotional induction produced significant changes in desired emotions and the results showed that subjects induced with positive emotions showed a statistically significant decrease in hazard identification skills.

INTRODUCTION

Carter et al. (2006) and the Center for Disease Control and Prevention (CDC 2012) found workers lack the skills to identify hazards because of the dynamic and fragmented nature of the industry. Furthermore, Albert et al. (2013a) found that before any intervention was introduced, construction workers are able to identify only 38% of hazards on site. Similarly, Hansen (2015) found that designers could identify only 33.5% of hazards prior to any intervention.

All safety programs require strong hazard recognition skills (Albert et al 2014a). Pre-job safety meetings, for example, require workers to describe their work tasks, identify all hazards expected for their tasks, and create a plan to control hazard and work safely. The fact that hazard recognition skills are vital but poor highlights the importance of research into this domain.

Inspired by recent research that shows a connection between emotions and risk perception (Clore et al. 1994 and Keller et al. 2006), the present study tests the hypothesis that variability in emotional state predicts variability in hazard recognition skill. That is, that emotion and hazard recognition are intrinsically linked. This hypothesis is built upon the fact that emotions are known to strongly influence our decision-making abilities (Elster 1998; Higgins 1997). Lowenstein et al. (2001)'s '*risk-as-feelings*' hypothesis also suggests that emotions such as fear, dread, worry, and anxiety influences individual's responses in threatening/dangerous situations. If true, understanding the connection between emotional state and hazard recognition could have a profound effect on how the industry understands the fundamental drivers of worker behavior in complex situations.

METHODS

The primary goal of this study was to test the hypothesis that *does a particular emotional state predicts variability in hazard recognition skill*. Intrinsically, this hypothesis assumes that hazard recognition, like risk perception, is a psychological construct and not simply a basic skill. If the hypothesis tests false, the implication would suggest that hazard recognition is, indeed, a skill. Either outcome provides important learning.

To test the hypothesis, data were collected using a longitudinal before/after (i.e., A+B) experiment. All the participants were asked to complete an initial survey to gauge their baseline emotional state, hazard identification skills, risk perception, and decision-making tolerance. Subjects were then randomly induced into specific emotional states using autobiographical recall. Following that, subjects were asked to complete

a hazard recognition test using photographs of actual construction scenarios and hazard recognition, risk perception, and decision-making tolerances were measured once again. The high-level process is illustrated in Figure 1 and the details of this experiment are described below.

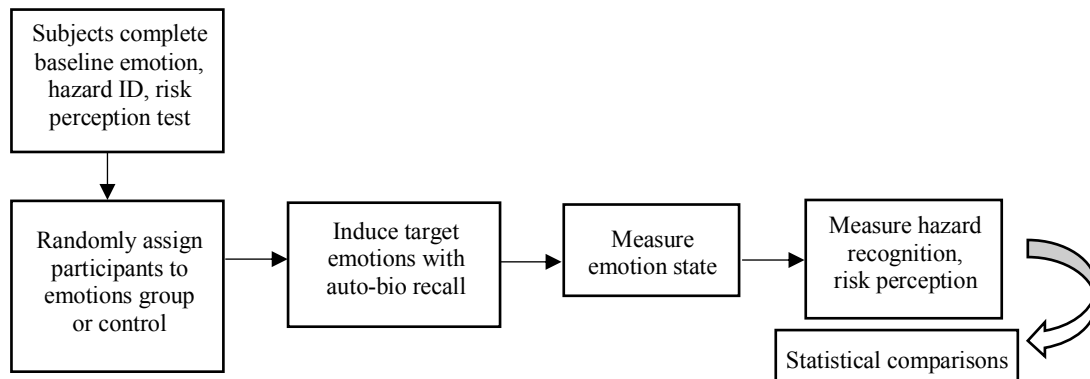


Figure 1 – Overview of research process

Participant recruitment and test environment

Forty-five subjects were recruited as a convenience sample, coming predominantly from the student population at the authors' university. Participation was voluntary and no compensation was provided. The subjects were mainly male graduate engineering students. Specifically, the sample consisted of: 76% males and 24% females; 93% engineering and 7% arts and sciences majors; 64% graduate and 36% undergraduate. Since, the authors were attempting to measure a basic psychological construct student participants were preferred over construction workers because they tend to lack experiential bias (Tixier et al. 2014).

The experiment was performed in a neutral environment in an engineering computing laboratory/study-rooms. Great care was taken to control the environment with comfortable chairs, adequate space between each participant, temperature control, moderate lighting, and an absence of adjacent

Joy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Love	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pride	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sadness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shame	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Surprise	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Unhappiness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 2 – Emotional State Measurement Instrument

Measuring emotional state

To measure the emotional state, the authors used Rottenberg et al.'s (2007) questionnaire in both the baseline and post-induction surveys, which has been validated in countless studies across disciplines. The questionnaire (as shown in Figure 2) requires participants to self-report and rate the intensity of basic emotions (e.g., happiness, anger, sadness) and complex emotions (e.g., guilt, embarrassment). Emotional states were measured before and after the induction.

Emotions can dissipate as quickly as they can be instigated (Verduyn 2011). Thus, the participants were asked to begin the post induction survey immediately after completing the autobiographical recall. Verduyn (2011) suggests that emotional episodes dissipate after the first 30 min. Therefore, post survey data were captured within 20 minutes of the recall activity.

Measuring hazard recognition and risk perception

The hazard recognition component of the survey consisted of photographs of construction workers performing discernable tasks with identifiable hazards. When creating the survey, a team of researchers identified all the hazards in each photograph that were used. When completing the hazard recognition skill test, participants were asked to record and identify the location of all the hazards they could identify in each photograph. Subjects reviewed five randomly assigned photographs before emotional induction and five after emotional induction.

Hazard recognition skill was measured as the proportion of hazards identified (i.e., the number of hazards identified divided by the total number of hazards in the photograph). In the case when a participant identified a hazard that the research team did not identify prior to the survey, these hazards were reviewed and, if confirmed, were added during analysis for completeness.

Once hazards were identified and recorded, participants were asked to rate their perception of the magnitude of risk posed by the situation. Using guidance from Baradan and Usmen (2006) and following the same protocol used by Hallowell (2010) and Tixier et al. (2013), participants were asked to rate the frequency with which an injury may occur at various levels of severity (e.g., how often first-aid injury would be expected in this environment). This rating was provided for each picture. A sample of the survey is shown below as Figure 3.

Following convention, risk perception was quantified for each severity level by finding the product of the frequency and the severity (see equation 1). The frequency levels were designed to correspond to tangible work periods as shown in Figure 3 and the severity scale introduced by Hallowell and Gambatese (2008) was used to quantify the respective levels of severity. The overall risk perception for a particular participant and a particular photograph was measured by taking the average across all severity levels.

$$Safety\ Risk\ \left(\frac{S}{time}\right) = Frequency\ \left(\frac{Incidents}{time}\right) * severity\ \left(\frac{Severity}{incident}\right) \quad (1)$$

Injuries	Once Every Week (40 w-h)	Once Every Month (167 w-h)	Once Every Year (2000 w-h)	Once Every 10 years 20,000 w-h)
First Aid				
Medical Case				
Lost Work Time				

Permanent Disablement or Fatality				
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Figure 3 – Risk Perception Measurement Instrument (w-h = worker-hours)

Measuring action and decision making

After identifying hazards and recording risk perceptions, the participants were asked to answer the following questions for each photograph on a 9-point Likert scale where 1 represented ‘no/definitely not’ and 9 represented ‘yes/definitely yes’:

1. If you are the supervisor on site when this task is being performed, would you ‘stop work’ based on how this task was being performed?
2. Assume you are working on this site; would you report how this work is being performed to your immediate supervisor?
3. Would you be willing to perform this task as it is being performed right now?
4. Would you be willing to perform this task in the exact environment?

These questions were posed to determine the action that a participant would take for each scenario. Because hazard recognition, risk perception, and risk tolerance/decision making are distinct components of situational interest (Tixier et al. 2014), they were considered independently. These data also allowed the team to make statistical comparisons of final decisions for the emotional groups.

RESULTS AND ANALYSIS

The experiment resulted in a rich dataset with pre- and post-induction measures of: emotional state, hazard recognition, risk perception, and action decisions. This dataset was well suited for both standard t-tests and paired t-tests, which can be used to measure differences between groups and changes within single units of analysis, respectively.

A paired t-test was employed to measure changes in the emotional state following the autobiographical recall. Since participants were randomly assigned to either the positive or negative emotions group, they were analyzed as two separate samples. The authors considered the change to be significant at 95% confidence ($p < 0.05$). Table 2 shows that the autobiographical recall was successful in achieving the desired results within both groups. Participants who were given positive emotions had a statistically significant increase in happiness, joy, love and a significant decrease in confusion. Alternatively, participants who were given negative emotion recall task showed statistically significant increase in anger, disgust, embarrassment, fear, guilt, sadness, shame, unhappiness and a significant decrease in amusement, happiness, interest, joy, and love. As expected, there was no statistically significant difference in any emotional state between the groups before induction. There was no statistically significant difference between the change in emotions of participants given positive emotion recall test showed and the change in emotions of the participants given negative emotions.

Once the target emotions were confirmed, tests were performed to measure changes in hazard recognition skill and risk perception and to compare the positive and negative emotions groups. To measure the influence of these induced emotions on hazard recognition skills two comparisons were made. First, the hazard recognition skill scores before emotion induction were compared to the skills after induction. Second, the hazard recognition skills scores of the positive and negative emotions groups were compared. The same comparisons were made for risk perception and decision-making.

Hazard Identification Skills

Of the 45 participants, 23 received positive emotional induction. The participants belonging to this group showed an overall decrease in their hazard identification skills by -18.1% after the induction ($p < 0.01$). There was a clear decline in their hazard identification skills after the emotion induction exercise. However, participants who received negative emotional induction revealed no statistically significant

change ($p=0.24$). In Table 1, participant's pre-survey average is compared against the post survey hazard identification average. The two groups (i.e. positive and negative group) did not have a statistically significant difference in their baseline hazard identification skills.

Table 1 – Hazard Identification Results for both Groups

Positive Emotions Group				Negative Emotions Group			
Participant ID	Before	After	Change	Participant ID	Before	After	Change
1A	0.21	0.11	-48%	1B	0.15	0.11	-27%
2A	0.33	0.30	-9%	2B	0.49	0.50	2%
3A	0.06	0.02	-67%	3B	0.08	0.05	-38%
4A	0.16	0.11	-31%	4B	0.65	0.68	5%
5A	0.39	0.35	-10%	5B	0.14	0.18	29%
6A	0.15	0.08	-47%	6B	0.67	0.61	-9%
7A	0.06	0.06	0%	7B	0.09	0.09	0%
8A	0.22	0.16	-27%	8B	0.17	0.28	65%
9A	0.05	0.09	80%	9B	0.28	0.11	-61%
10A	0.43	0.33	-23%	10B	0.09	0.11	22%
11A	0.40	0.40	0%	11B	0.22	0.36	64%
12A	0.27	0.20	-26%	12B	0.17	0.11	-35%
13A	0.19	0.02	-89%	13B	0.38	0.29	-24%
14A	0.15	0.05	-67%	14B	0.11	0.11	0%
15A	0.13	0.11	-15%	15B	0.18	0.15	-17%
16A	0.02	0.04	100%	16B	0.18	0.22	22%
17A	0.05	0.05	0%	17B	0.14	0.07	-50%
18A	0.15	0.14	-7%	18B	0.15	0.13	-13%
19A	0.18	0.09	-50%	19B	0.21	0.12	-43%
20A	0.34	0.31	-9%	20B	0.05	0.00	-100%
21A	0.11	0.07	-36%	21B	0.11	0.16	45%
22A	0.32	0.24	-25%	22B	0.17	0.04	-76%
23A	0.70	0.58	-17%				
Average	0.22	0.17	-18%	Average	0.22	0.20	-11%

Risk Perception

Risk perception was analyzed using the same statistical tests used for the hazard recognition data. Participants induced with negative emotions showed a decrease in risk perception (-34%) but the change was not statistically significant. Participants induced with positive emotions decrease in risk perception (-56%) also and it had weak statistical significance. These very large effect sizes with low statistical significant suggest that the experiment should be conducted again with a larger sample size.

Decision-making

Again, paired t-tests were used to compare the decision-making questions. Participants induced with negative emotions showed no statistically significant change for any of the decision-making questions. However, participants induced with positive emotions showed a statistically significant change for 2 out of 4 questions. They recorded a 12% decrease in willingness to stop work ($p=0.04$), a 17% decrease in willingness to report on-going work ($p<0.01$), and a 16% increase in willingness to perform work shown exactly as shown in the photograph ($p=0.08$).

Table 2. Results from Emotional Induction

Emotions	Positive Emotion Group				Negative Emotion Group			
	Average Before	Average After	Change (%)	P-value	Average Before	Average After	Change (%)	P-value
Amusement	4.39	5.09	16%	0.12	3.95	2.39	-39%	<0.01
Anger	1.26	1.52	21%	0.21	2.32	3.52	52%	0.04
Anxiety	2.48	2.30	-7%	0.56	3.41	3.24	-5%	0.79
Confusion	2.61	1.52	-42%	<0.01	3.55	3.62	2%	1.00
Contempt	3.22	2.70	-16%	0.10	2.14	2.95	38%	0.08
Disgust	1.22	1.26	3%	0.71	1.32	2.71	105%	0.01
Embarrassment	1.26	1.57	25%	0.34	1.50	2.38	59%	0.02
Fear	2.09	1.35	-35%	0.06	1.68	2.62	56%	0.01
Guilt	1.48	1.43	-3%	0.82	1.45	3.14	117%	<0.01
Happiness	5.83	7.00	20%	<0.01	5.73	3.29	-43%	<0.01
Interest	6.22	6.52	5%	0.45	5.73	3.24	-43%	<0.01
Joy	5.57	6.35	14%	0.02	5.68	2.81	-51%	<0.01

Love	4.87	5.78	19%	0.03	4.95	3.33	-33%	0.03
Pride	4.13	5.09	23%	0.07	5.00	2.81	-44%	<0.01
Sadness	2.32	1.91	-18%	0.40	2.45	5.38	120%	<0.01
Shame	1.87	1.83	-2%	0.91	1.59	2.62	65%	0.05
Surprise	2.91	2.35	-19%	0.13	2.82	2.29	-19%	0.25
Unhappiness	2.04	1.61	-21%	0.18	2.05	5.71	179%	<0.01

DISCUSSION

The implications of the observed changes on hazard identification skills, risk perception, and risk tolerance are significant. Most importantly, results show that participants registered a decrease in hazard identification skills on being induced with positive emotions. *This suggests that hazard identification is not a pure skill and it can be psychologically influenced.* The findings presented here support what Taylor et al. (1988) coined as ‘false optimism,’ which leads to fake sense of security towards an environment when in a positive emotional state. Thus, there is increasing evidence that positive emotional state might be compromising overall situational awareness in occupational settings. Such a bold conclusion must be confirmed in repeated trials and across a larger, more diverse sample size.

In addition to changes in hazard recognition, the results revealed statistically significant changes in the decisions made with respect to the construction scenarios suggesting that risk-based decision-making is also a psychologically driven construct. Interestingly, these findings indicate that hazard recognition and decision-making are affected by emotion in the same direction and approximately the same magnitude found in past studies of risk perception (Izard 1977; Tixier et al. 2014; Öhman and Mineka 2001; Clore et al. 1994; Keller et al. 2006).

Given the magnitude of the problems associated with hazard recognition (e.g., skill less than 50% in the construction workforce found by Albert et al. 2014a), and the lack of correlation between hazard recognition training programs and hazard recognition skill (Perlman et al. 2014), practitioners must

overhaul current hazard recognition strategies. The present study suggests that the design of new strategies must incorporate an understanding of the role of emotion during actual work execution.

Practitioners may find the notion that they need to support a negative emotional state as a difficult practical and ethical task. However, one should note that emotions associated with vulnerability are known to be negative emotions (Rottenberg 2007). Thus, the authors suggest that fostering a sense of vulnerability and increasing the seriousness of the construction environment would be beneficial to the workforce. Jovial behavior, jokes, and light moods may be partially responsible for low hazard recognition performance, low perceptions of risk, and high tolerance of dangerous situations.

This study is not without limitations. For example, external validity was compromised with students as the units of analysis and the relatively small sample size, which also leads to some unstable effects. To address this limitation, the authors suggest a full-scale experiment with construction workers and a control group of students. Additionally, the experiment should be conducted with a more diverse sample. For example, a greater proportion of Hispanic and women subjects and greater distribution of age would increase generalizability. Also, future endeavors should incorporate more naturalistic environments. As Perlman et al. (2014) showed, subjects identify more hazards in virtual environments than in photographs. Finally, it should also be noted that nearly all the participants from both groups kept confusing acts of safety violations (i.e. no PPE) for hazards (i.e. objects at height, using electrical equipment, dust). Photographs with construction workers working with proper PPE were often classified as ‘safe’ and ‘no hazards observed’. This finding needs to be furthered examined with larger sample space from the target population to see if there is a gap in knowledge in distinguishing and identifying hazards leading to false assessment.

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REFERENCES

- [1]. Albert, A., Hallowell, M. R., & Kleiner, B. M. (2014). Experimental field testing of a real-time construction hazard identification and transmission technique. *Construction Management and Economics*, 32(10), 1000-1016.
- [2]. Albert, A., Hallowell, M. R., & Kleiner, B. M. (2013a). Enhancing construction hazard recognition and communication with energy-based cognitive mnemonics and safety meeting maturity model: Multiple baseline study. *Journal of Construction Engineering and Management*, 140(2), 04013042.
- [3]. Albert, A., & Hallowell, M. R. (2013b). Revamping occupational safety and health training: Integrating andragogical principles for the adult learner. *Construction Economics and Building*, 13(3), 128-140.
- [4]. Ayduk, O., Mischel, W., & Downey, G. (2002). Attentional mechanisms linking rejection to hostile reactivity: The role of “hot” versus “cool” focus. *Psychological Science*, 13(5), 443-448.
- [5]. Bahn, S. (2013). Workplace hazard identification and management: The case of an underground mining operation. *Safety science*, 57, 129-137.
- [6]. Baradan, S., & Usmen, M. A. (2006). Comparative injury and fatality risk analysis of building trades. *Journal of construction engineering and management*, 132(5), 533-539.
- [7]. Burke, M. J., Salvador, R. O., Smith-Crowe, K., Chan-Serafin, S., Smith, A., & Sonesh, S. (2011). The dread factor: how hazards and safety training influence learning and performance. *Journal of Applied Psychology*, 96(1), 46.
- [8]. Carter, G. , and Smith, S. D. (2006). “Safety hazard identification on construction projects.” *J. Constr. Eng. Manage.* , 10.1061/(ASCE)0733-9364(2006)132:2(197), 197–205

- [9]. Center for Disease Control, and Prevention. (2012). "Safety and health topics: Respiratory protection–hazard recognition." U.S. Dept. of Labor, Occupational Safety and Health Administration, Washington, DC, <
<http://www.cdc.gov/niosh/nas/rdrp/appendices/chapter6/a6-134.pdf>> (Dec. 18, 2012)
- [10]. Clore, G. L., Schwarz, N., & Conway, M. (1994). Affective causes and consequences of social information processing. *Handbook of social cognition*, 1, 323-417.
- [11]. Elster, J. (1998). Emotions and economic theory. *Journal of economic literature*, 47-74.
- [12]. Gruber, J., Harvey, A. G., & Johnson, S. L. (2009). Reflective and ruminative processing of positive emotional memories in bipolar disorder and healthy controls. *Behaviour research and therapy*, 47(8), 697-704.
- [13]. Gruber, J., & Kring, A. M. (2008). Narrating emotional events in schizophrenia. *Journal of Abnormal Psychology*, 117(3), 520.
- [14]. Hallowell, M. (2010). Safety risk perception in construction companies in the Pacific Northwest of the USA. *Construction management and economics*, 28(4), 403-413.
- [15]. Hallowell, M. R., & Gambatese, J. A. (2008, March). Quantification and communication of construction safety risk. In *2008 Working Commission on Safety and Health on Construction Sites Annual Conference, sponsored by the International Council for Research and Innovation in Building and Construction, Gainesville, FL*.
- [16]. Hansen, D. C. (2015). Measuring and improving designer hazard recognition skill (Doctoral dissertation, UNIVERSITY OF COLORADO AT BOULDER).
- [17]. Isen, A. M., & Patrick, R. (1983). The effect of positive feelings on risk taking: When the chips are down. *Organizational behavior and human performance*, 31(2), 194-202.

- [18]. Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological bulletin*, 127(2), 267.
- [19]. Keller, C., Siegrist, M., & Gutscher, H. (2006). The role of the affect and availability heuristics in risk communication. *Risk analysis*, 26(3), 631-639.
- [20]. Öhman, A., and Mineka, S. 2001. Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. *Psychological review*, 108(3), 483.
- [21]. Perlman, A., Sacks, R., & Barak, R. (2014). Hazard recognition and risk perception in construction. *Safety science*, 64, 22-31.
- [22]. Rottenberg, J., Ray, R. R., & Gross, J. J. (2007). Emotion elicitation using films. In J. A. Coan & 952 J. J.B. Allen (Eds.), *The handbook of emotion elicitation and assessment* (pp. 9_28). New York: 953 Oxford University Press.
- [23]. Tixier, A. J. P., Hallowell, M. R., Albert, A., van Boven, L., & Kleiner, B. M. (2014). Psychological antecedents of risk-taking behavior in construction. *Journal of Construction Engineering and Management*.
- [24]. Verduyn, P., Van Mechelen, I., & Tuerlinckx, F. (2011). The relation between event processing and the duration of emotional experience. *Emotion*, 11(1), 20.
- [25]. Verduyn, P., Van Mechelen, I., Tuerlinckx, F., Meers, K., & Van Coillie, H. (2009). Intensity profiles of emotional experience over time. *Cognition and Emotion*, 23(7), 1427-1443.
- [26]. Yuen, K. S., & Lee, T. M. (2003). Could mood state affect risk-taking decisions?. *Journal of affective disorders*, 75(1), 11-18.

APPENDIX C: Construction Research Congress, New Orleans, Louisiana, 2018

USING AUGMENTED VIRTUALITY TO UNDERSTAND THE SITUATIONAL AWARENESS MODEL

ABSTRACT

Situational awareness concept has been long used in aviation and medical fields to understand and improve an individual's ability to interact and comprehend complex dynamic environments. This study attempts to empirically test situational awareness model proposed by Endsley within construction domain. Specifically, we will test how different levels of situational awareness interact with each other and how they interact with decisions. To achieve this goal, a controlled experiment was designed and conducted where the investigators (1) induced positive, negative, or neutral emotions in 72 subjects; (2) exposed participants to construction hazards within a high-fidelity virtual environment; and (3) measured participant's hazard recognition skills, their understanding of those hazards, severity assessment, and subsequent decisions. The results revealed there is moderate positive correlation among each level of situational awareness. A repeated measures ANOVA test revealed that there were differences in the degree and directionality of influence of each level of situational awareness on each other. Also, the analysis revealed that there were differences in the degree and directionality of influence from each level of situational awareness on the final decision.

INTRODUCTION

A new report by the Midwest Economic Policy Institute (MEPI) found that construction industry suffers an average of 868 annual fatalities (16 fatalities per week) that cost nearly \$5 billion per year in losses (MEPI, 2017). Moreover, fatality rates since 2011 have been on the rise (U.S. BLS 2016), which is

a tragic trend facing both academics and practitioners. One aspect of human factors research as it relates to safety that has begun to receive attention in the past decade is situational awareness (SA).

SA is popular concept of human factors engineering that is used in various fields (e.g., nursing, aviation, and military) that involve complex and dynamic environments. Perhaps the most pervasive definition of SA is, “*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*” (Endsley 1995, pg. 65). In other words, SA can be understood as a motivation for active and continuous extraction of information and assessment of that information that guides our decisions and subsequent actions.

SA is considered particularly critical in the aviation industry where poor SA was the critical causal factor identified in over 200 aircraft accidents (Hartel et al. 1991). Furthermore, individuals struggling to acquire and maintain SA might not detect and respond to problems with the system they are controlling or present in (Endsley and Kiris 1995).

Despite the fact that construction work is dynamic and complex role of SA with safety and decision-making has not been empirically explored in the industry. This is problematic because of the vulnerability of construction worker’s well-being to even small errors. In this study, we will aim to test the predictive nature of Endsley’s (1995) model. Specifically, we are aiming to test the relationships between each individual level of SA as it applies to construction safety and how each factor relates to an ultimate decision.

METHODS

Situational Awareness Model in Construction Context

SA is divided primarily into three levels: *perception*, *comprehension*, and *projection*. These levels will be the foci of this paper:

- [1]. The Level 1 of SA, *perception of the elements in environment*, refers to the ability to grasp relevant stimuli from environment along with their attributes and nature.
- [2]. The Level 2 of SA, *comprehension of the current situation*, refers to the ability of the individual to understand the stimuli perceived in Level 1.

[3]. Finally, Level 3 of SA, *projection of future status*, is the ability to take the information from Level 1 and Level 2 to make a prediction of the outcomes associated with the elements in the environment.

Endsley (1995) defines elements as the relevant stimuli in an environment that an individual must distinguish and value within a complex system. If we look at this from construction safety lens, then a hazard is an element. Thus, Level 1 refers to *identifying hazards in the environment*, Level 2 refers to *understanding the danger associated with those hazards*, and Level 3 refers to *assessing the severity associated with hazards*. There are many other key factors summarized in Endsley (1995; 2015) such as mental models, nature of information, and cognitive workload that influence the three levels. However, for brevity, the entire Endsley (1995) model cannot be discussed here.

There has been debate among researchers regarding the legitimacy and differing interpretation of the three-step model. Recently, Endsley (2015) rebutted the various alleged misconceptions and fallacies associated with the original SA model, claiming that the three levels of SA are not linear stages and, rather, represent ascending levels. Furthermore, Endsley also disagreed with the Salmon et al. (2012)'s suggestion that there needs to be in-depth exploration on the links and interactions between the levels of SA and Sorensen et al. (2010)'s assertion that each level of SA is highly separated. Endsley (2015) claims that this is an inaccurate understanding of the model because there is a natural progress to higher levels where the linkages are determined by mental models. Therefore, this study aims to explore the relationships between each level of SA while controlling for individual's emotional state and learn about the influences of each level on the subsequent decision under uncertainty.

Experimental Design

Our experiments were conducted in a controlled environment where each subject followed the trajectory shown in Figure 1. Overall experimental protocol was (1) induce three specific emotion states (positive, negative, or neutral) among young adult participants using standardized movie clips validated in previous studies, (2) allow participants to interact with construction hazards in high-fidelity augmented

virutality, (3) measure the three levels of SA, and (4) record their ultimate decision regarding safety. To measure each level of SA as it relates to construction hazards, we framed questions to participants based on each of the three levels. Specifically, we asked participants to: identify hazards (Level 1), rate the danger of each hazard (Level 2), and rate the risk associated with each hazard (Level 3). Participants continue this loop until they report there are no more hazards left. After participant report, there are no more hazards in the environment, they have to make a decision on whether or not to allow work being performed. They had option of choosing a decision on a scale of 1-5 where 1 represented *let work proceed as it is being performed*, 2 represented *let work proceed with high caution*, 3 represented *stop work and make minor changes*, 4 represented *stop work and make major changes*, and 5 represented *stop work and note as emergency condition*.

The experiment was carefully designed to ensure control over confounding factors and sources of variability. All subjects were given a private room that was closed to public and received the same laptops, headphones, comfort level, workspace, lighting, and air conditioning. Before starting the experiment, each participant was given a brief demonstration of how to navigate the AV system. Subjects were then randomly selected for the control group (i.e. neutral emotion) or randomly assigned an emotion eliciting video clip. Participants were told that the movie clip viewing was for another experiment to avoid response bias such as demand characteristics. Once the participants completed the emotion induction task, they entered the AV system that was pre-loaded on their computers. The participant's avatar was randomly placed in the environment and they were free to navigate anywhere on site. As they encounter a stimulus, they were told to click on the visual cues, which would unlock a detailed real-world image of construction task being performed. The participants responded to same embedded questionnaire for each unlocked image (Figure 1). When a participant completed the questions for the particular photograph, they were returned to the virtual site to find another stimulus. Each participant was given 30 minutes in the environment. There were 16 stimuli that a participant could encounter that were randomly distributed across the virtual site.

We recruited 72 subjects by sampling from upper-level undergraduate construction engineering courses taught at author's university. This is an obvious participant bias in our sample; however, we accept the bias since the objective was to understand the relationships among levels of SA and the impact of emotional state rather than the skill of the SA process. Furthermore, students offer less experiential bias given their relatively similar professional experiences (Tixier et al. 2014). It should be noted that each participant was given the same hazard recognition training one month prior to the experiment. This training was provided because Bhandari et al. (2016) noted that when asking participants to identify hazards (i.e., the sources of energy that could injure a person), most participants reported safety violations (e.g., not wearing proper protective equipment). This is a subtle but important limitation for most studies involving hazard recognition.

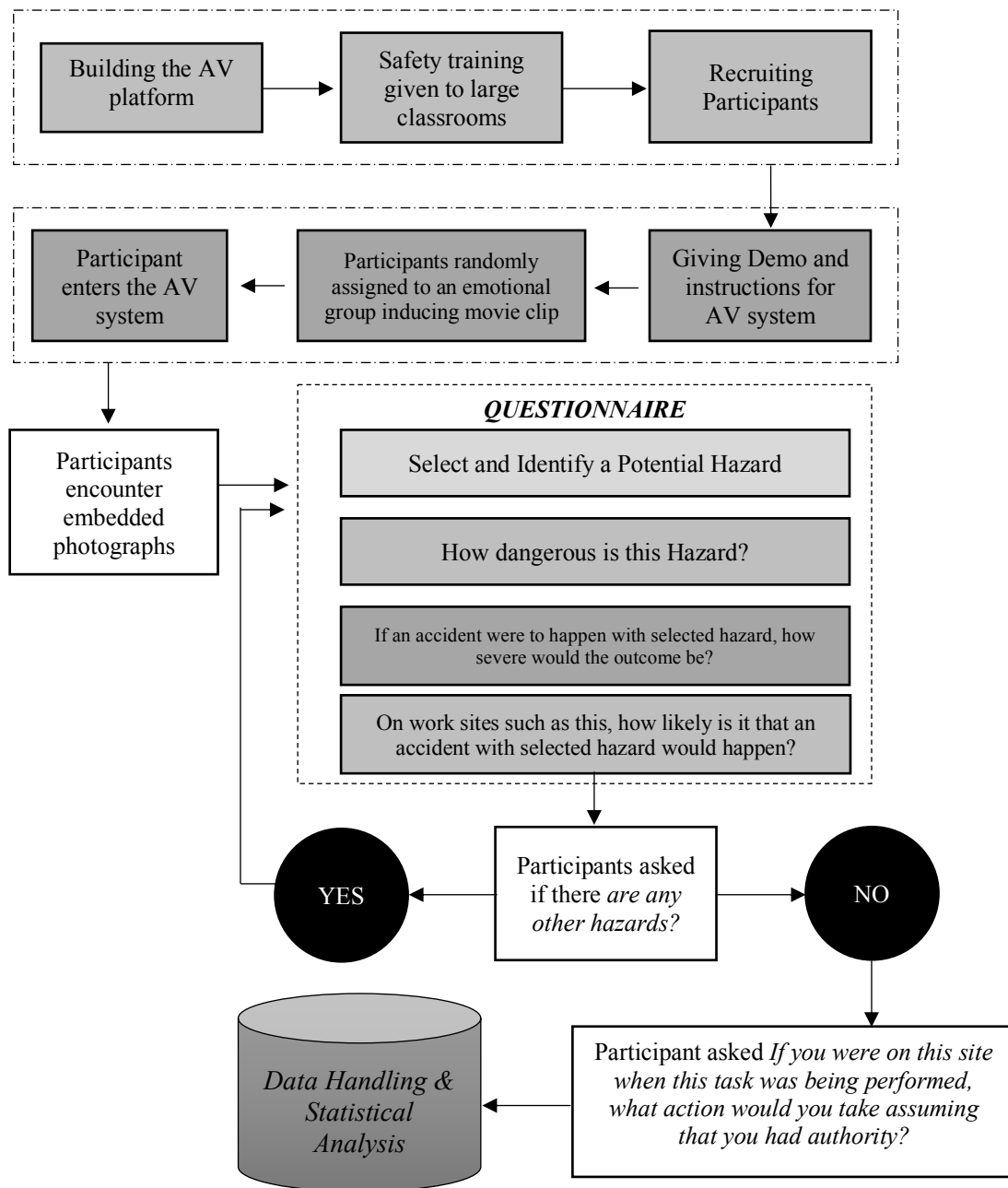


Figure 1. Overview of research process

Using High-Fidelity Virtual Construction Environment

The process of conducting experiments with safety on live construction sites is not possible when the experiment could place people in danger. Therefore, we elected to use a high-fidelity augmented virtual

environment as an experimental platform (see Figure 2). Such platforms have been used to conduct successful construction safety studies in the past, serving as a suitable alternative (Albert et al. 2013; Tixier et al. 2014). Although we lose some ecological validity by using an environment, the ability to control the experimental process allows for very strong internal and construct validity.

In our experiment, the platform we have developed can be classified as *augmented virutality* (AV) since it incorporates real-world images into the virtual environment. The images selected by the research team were high-definition images that captured different types of energies that could release and could cause injuries with varying degrees of severity. We included images that showed worker(s) exposed to high and low energy to enhance the sense of realism for the participants in the environment. These images and associated questionnaires were embedded in the AV system that measured different levels of SA discussed above.



Figure 2. Screenshots of AV platform.

The AV system was designed to maximize ecological validity through realism. For example, the system was designed with a non-repeating soundtrack capturing the typical noise of a site to give participants both visual and audible stimuli. Additionally, the system included embodied agents, which

were virtual workers controlled by an independent algorithm (Bailenson and Blascovich 2004). It was critical for us to have realistic virtual construction workers because studies have found that subjects in these environments interact with virtual humans like they would with real people (Donath 2007). By incorporating large equipment and material, moving virtual construction workers, and sounds of a construction site, we can support a true immersion in subjects that should engage their SA. This realism in the AV system also allows the subjects to look for hazards and dangerous simulations without putting them in actual line of fire.

Inducing Target Emotions with Movie Clips

Emotions influence our behavioral, physiological, and experiential aspects of daily life by helping us interact and adapt with our surroundings (Oatley et al. 2006). Emotions consciously and sub-consciously influence our decision-making abilities and our decisions under uncertainty are made by valuing both the risk of a particular outcome and the emotional response to the outcome (Damasio et al. 1996). Various studies have shown that emotions influence our perception of risk and tolerance of risk (Clore et al. 1994; Tixier et al. 2014). These established findings elucidate the need to understand how emotional states influence both a person's progression through the three steps of SA and the final decision.

Table 1. Movie Clips for Emotion Induction

Target Emotion	Movie Clip (Duration)
Neutral (Control Group)	Denali National Park (3:40)
Negative (Treatment Group)	The Champ (3:21)
Positive (Treatment Group)	Whose Line is it Anyway? (2:13)

Inducing emotion through movie clips or videos is a well-established technique in the field of experimental psychology. This technique was selected to induce emotions because it has been successfully validated and used in various studies (Rottenberg et al. 2007; Gruber et al. 2008). This integrated well with our experimental design, allowing us to keep subjects engaged on their computer screens throughout the different phases of experiment. Such engagement reduces external influences that could interfere with the induced emotion. The clips selected are shown in Table 1 above.

ANALYSIS

As summarized in Figure 1, participants had to identify all the hazards and finish giving each of those hazards a danger, severity of possible injury, and likelihood of accident rating. After completing those questions, they were asked to decide what action if any, would they take regarding the work shown. Our data were collected as continuous variables. Participants were asked to rate the danger, severity, and likelihood on a sliding scale of 1-100 and the hazard recognition data were collected as percentage of hazards identified (i.e., number of hazards identified / total number of hazards identified by all participants for a photograph). Risk assessment value for each hazard was calculated by taking the product of the severity and likelihood scores provided by participants (Slovic et al. 1979). The average hazard recognition score was 30.3%, which is consistent with the average hazard recognition scores in industry (Albert et al. 2013).

Relationship Between Individual Levels of SA

There is marginal to strong correlation observed between the three levels as shown in Table 2 especially for Level 2 (Danger) and Level 3 (Severity) of SA.

Table 2. Correlation Matrix for 3 Levels of SA

	Hazard	Danger	Risk Assessment
Hazard	1.00	0.31	0.31
Danger		1.00	0.64
Severity			1.00

The emotion groups were orthogonally coded to test the two conditions: control vs. treatment (i.e. *neutral vs. positive and negative*) and *negative vs. positive* emotion groups. Response latencies were log-transformed and an analysis of variance (ANOVA) of the resulting latencies was then conducted, treating participant as within-subject factor and crossing photographs with the two emotion conditions. The analysis revealed:

Hazard perception was positively predicted by how dangerous they perceived the hazard to be [$b_0 = 0.13$, $F(1, XXX) = X.X$, $p < 0.01$] but hazard perception has an inverse relationship to risk assessment [$b_0 = -0.01$, $F(1, XXX) = X.X$, $p < 0.01$]. In other words, the relationship between Level 1 and Level 2 of SA is positive; however, there is a negative relationship between Level 1 and Level 3. There was no significant difference between the emotion groups.

Rating of danger had statistically significant relationship with hazard identification skill [$b_0 = 2.04$, $F(1, XXX) = X.X$, $p < 0.01$] and on risk assessment rating [$b_0 = 0.31$, $F(1, XXX) = X.X$, $p < 0.01$]. That is, both Level 1 and Level 3 positively predict Level 2 of SA. Again, there was no significant difference between the emotion groups.

Risk assessment was positively related to the rating of danger [$b_0 = 1.55$, $F(1, XXX) = X.X$, $p < 0.01$]; however, it is inversely related (marginal significance) to hazard identification skill [$b_0 = -0.63$, $F(1, XXX) = X.X$, $p < 0.07$]. This time there is a marginally significant effect showing positive emotion group

assessed more risk than negative emotion group [$b_0 = 10.59$, $p = 0.06$]. There was no difference between control (neutral) vs. treatment (positive and negative) emotion groups.

Relationship between levels of SA and decisions

Analysis of variance (ANOVA) tests were conducted again where participant was treated as a within-subject factor and the photographs were crossed with the two emotion conditions. The analysis showed that decision to take action regarding safety of work had a negative relationship with Level 1, positive relationship with Level 2, and no relationship with Level 3 of SA. In other words, decision regarding work being performed was significantly predicted by the hazards identified [$b_0 = -0.01$, $p < 0.01$] and danger rating [$b_0 = 0.005$, $p < 0.01$] that was assigned to each hazard by the participants. There was no statistically significant difference between control group (neutral emotion) v. experimental group (positive/negative emotion) nor was there any significant difference between positive or negative emotion induction groups.

DISCUSSION

The pilot study shows interesting preliminary results which are discussed below in the context of the existing body of knowledge.

Finding 1: hazard identification skills (Level 1 of SA) showed negative relationship and danger rating of the hazard (Level 2 of SA) showed positive relationship while risk assessment (Level 3 of SA) showed no relationship with the ultimate decision on stopping work to address safety concerns. Negative relationship between hazard identification and decision made under risk is counter-intuitive. However, March and Shapira (1990) found that individuals with higher perceived self-efficacy do not focus on failure or uncontrollable threats instead, they tend to frame risky choices as opportunities that they will be able to overcome and control through their skill. It is likely that subjects in our study assessed riskier actions showcased in AV environment from the perceived opportunities (for example:

higher productivity, potential overtime, wages) standpoint. Similarly, the lack of relationship between risk assessment and subsequent decision is curious however it is supported anecdotally by Bohm and Harris (2010) who found that construction dump truck drivers were taking risky actions despite perceiving associated high risk. The authors suggested that worker's assessment or perception of risk was not linked to likelihood of the accident rather the "perceived dread." Within the construction context, our results support the finding that risk assessment (measured as product of severity and likelihood) has a no influence on decisions.

These findings suggest that giving workers training on only improving their hazard identification and risk assessment skills does not influence their risk-taking behavior. It is important that the training given to workers pays significant emphasis on inducing dread associated with risks and organizing activities that challenge their biases and thrill-seeking nature. Dread based training can also be used to heighten engagement, risk perception, and learning among workers (Bhandari and Hallowell 2015). Results also show strong relationship between the amount of danger perceived in a scene and the ultimate decision that a person makes i.e. as a person perceives more danger for a hazard, they are more likely to make the decision to stop work. This may seem very obvious but safety training sessions rarely focus on developing understanding and context required to adequately assess the characteristics of a hazard rather emphasize more on regulations that should be followed (Albert and Hallowell 2013).

Finding 2: there is a negative relationship between hazard identification skills and risk assessment. It is likely that after perceiving hazards with high risk, participants tend to disregard the hazards with low risk because of contrast bias (Pepiton and DiNubile 1976). That is, individuals may have high SA but they may still disregard certain dangerous elements because projections of their risk are impacted by exposure to previous risks perceived in that environment.

Finding 3: there is no statistically significant impact of induced emotion on any level of SA.

This finding is contrary to existing risk and emotion studies, which have suggested that emotional state impacts risk perception (Clore et al. 2006). There are some possible explanations for why the results differ from previous studies: emotions were induced but not sustained for the duration of the experiment. Emotions are quite fickle and their typical residence time can range from minutes to hours (Verduyn et al. 2009). Also, the experience in the AV environment may have altered the induced emotional state because of the novelty of the technology (Riva et al. 2007). Finally, it is possible that we were unable to detect small or medium effects given our study was underpowered due to small sample. Although, we did see marginal significant difference between negative and positive emotion group where participants induced with positive emotions were seeing more risk in the environment. Negative emotions are usually associated with higher perception of risk, however Isen et al. (1988) proposed *mood maintenance hypothesis* that suggests individuals in positive mood are reluctant to take risks when perceived benefits or chance of success is low. This finding needs to be studied again with a different experimental design to ensure stronger intensity of induced emotions.

From a theoretical standpoint, the study revealed that the interactions and linkages among the levels of SA are not straightforward and unidirectional in nature. Although, it seems logical that individual identifies hazard, assess danger, quantifies risk and makes a decision however, such oversimplification can yield incorrect and potentially sub-optimal conclusions. The pilot study did not use the complete model (incorporating goals, memory structures, mental models, and attention of a person) as advocated by Endsley (2015) and future studies should scope this consideration in their experiment since the process appears to be much more complex and nuance than is typically recognized in the literature. From a practical standpoint, this study highlights what factors positively influence workers to make risk-averse decisions which can aid in designing better components of safety training to deliver more value to the workforce. In conclusion, this pilot study addresses the dearth of empirical research on testing a comprehensive SA model especially

within construction domain and examining the relationships among SA levels and mediating impact of emotions.

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REFERENCES:

- [1]. Albert, A., & Hallowell, M. R. (2013). Revamping occupational safety and health training: Integrating andragogical principles for the adult learner. *Construction Economics and Building*, 13(3), 128-140.
- [2]. Albert, A., Hallowell, M. R., & Kleiner, B. M. (2013). Enhancing construction hazard recognition and communication with energy-based cognitive mnemonics and safety meeting maturity model: Multiple baseline study. *Journal of Construction Engineering and Management*, 140(2), 04013042.
- [3]. Bailenson, J.N., & Blascovich, J. (2004). Avatars. In W.S. Bainbridge (Ed.), *Encyclopedia of human-computer interaction* (pp. 64–68). Great Barrington, MA: Berkshire.
- [4]. Bhandari, S., & Hallowell, M. (2015). New multimedia safety education program: impacts on emotions, risk perceptions, and learning.
- [5]. Bhandari, S., Hallowell, M. R., Van Boven, L., Gruber, J., & Welker, K. M. (2016). Emotional states and their impact on hazard identification skills. In *Construction Research Congress 2016* (pp. 2831-2840).
- [6]. Bohm, J., & Harris, D. (2010). Risk perception and risk-taking behavior of construction site dumper drivers. *International journal of occupational safety and ergonomics*, 16(1), 55-67.
- [7]. Cassell, J. (2000). Embodied conversational interface agents. *Communications of the ACM*, 43(4), 70–78.
- [8]. Clore, G. L., Schwarz, N., & Conway, M. 1994. Affective causes and consequences of social information processing. *Handbook of social cognition*, 1, 323-417.
- [9]. Construction Fatalities Cost the United States \$5 Billion Per Year. 2017, May 08. (Retrieved July 15, 2017, from <https://midwestepi.org/2017/05/08/construction-fatalities-cost-the-us-5-billion-per-year/>)

- [10]. Damasio, A. R., Everitt, B. J., & Bishop, D. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 351(1346), 1413-1420.
- [11]. Donath, J. (2007). Virtually trustworthy. *Science*, 317, 53–54.
- [12]. Endsley, M. R. (1995). Measurement of situation awareness in dynamic systems. *Human factors*, 37(1), 65-84.
- [13]. Endsley, M. R. (2015). Situation awareness misconceptions and misunderstandings. *Journal of Cognitive Engineering and Decision Making*, 9(1), 4-32.
- [14]. Endsley, M. R., & Kiris, E. O. (1995). The out-of-the-loop performance problem and level of control in automation. *Human factors*, 37(2), 381-394.
- [15]. Gruber, J., Johnson, S. L., Oveis, C., & Keltner, D. (2008). Risk for mania and positive emotional responding: too much of a good thing?. *Emotion*, 8(1), 23.
- [16]. Isen, A. M., Nygren, T. E., & Ashby, F. G. (1988). Influence of positive affect on the subjective utility of gains and losses: it is just not worth the risk. *Journal of personality and Social Psychology*, 55(5), 710.
- [17]. March, J. G., & Shapira, Z. (1990). *Variable risk preferences and the focus of attention*. Leonard N. Stern School of Business, New York University.
- [18]. Oatley, K., Keltner, D., & Jenkins, J. M. (2006). *Understanding emotions*. Blackwell publishing.
- [19]. Pepitone, A., & DiNubile, M. (1976). Contrast effects in judgments of crime severity and the punishment of criminal violators. *Journal of Personality and Social Psychology*, 33(4), 448.
- [20]. Riva, G., Mantovani, F., Capideville, C. S., Preziosa, A., Morganti, F., Villani, D., ... & Alcañiz, M. (2007). Affective interactions using virtual reality: the link between presence and emotions. *CyberPsychology & Behavior*, 10(1), 45-56.
- [21]. Rottenberg, J., Ray, R. R., & Gross, J. J. (2007). Emotion elicitation using films. In J. A. Coan & J. J.B. Allen (Eds.), *The handbook of emotion elicitation and assessment* (pp. 9_28). New York: Oxford University Press.

- [22]. Salmon, P. M., Stanton, N. A., & Young, K. L. (2012). Situation awareness on the road: review, theoretical and methodological issues, and future directions. *Theoretical Issues in Ergonomics Science*, 13(4), 472-492.
- [23]. Slovic, P., Fischhoff, B., & Lichtenstein, S. (1981). Rating the risks. In *Risk/benefit analysis in water resources planning and management* (pp. 193-217). Springer US.
- [24]. Sorensen, L. J., Stanton, N. A., & Banks, A. P. (2011). Back to SA school: contrasting three approaches to situation awareness in the cockpit. *Theoretical Issues in Ergonomics Science*, 12(6), 451-471.
- [25]. Tixier, A. J. P., Hallowell, M. R., Albert, A., van Boven, L., & Kleiner, B. M. (2014). Psychological antecedents of risk-taking behavior in construction. *Journal of Construction Engineering and Management*.
- [26]. U.S. Bureau of Labor Statistics, 2016. Census of Fatal Occupational Injuries (Accessed July 14, 2017 from: <http://www.bls.gov/data/#injuries>).
- [27]. Verduyn, P., Delvaux, E., Van Coillie, H., Tuerlinckx, F., & Van Mechelen, I. (2009). Predicting the duration of emotional experience: two experience sampling studies. *Emotion*, 9(1), 83.