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Walden University

College of Social and Behavioral Sciences

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Joseph Bonnell

has been found to be complete and satisfactory in all respects,
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Walden University
2018

Abstract

Measuring Skill Decay in Fire Ground Commanders

by

Joseph Bonnell

MS, Northeastern University, 1993

BS, Northeastern University, 1991

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Public Policy and Administration

Walden University

November 2018

Abstract

Despite improved technology and equipment and a steady decline of structure fires, firefighter line-of-duty deaths and injury rates have increased over the past 10 years. Independent reports indicated poor decision-making by fire ground incident commanders (FGCs) as the primary cause of deaths and injuries. FGCs are vulnerable to skill decay given the expertise needed to manage an incident and limited opportunities to remain proficient. Guided by skill decay theory, the purpose of this quantitative study was to examine the relationship between skill decay among FGCs and experience, drilling, and training opportunities (overlearning), years of experience, and time since initial training. A web-based survey was used to collect data from a convenience sample of 376 certified fire department officers. Findings from multiple linear regression analysis indicated that time since initial training in a fire command training program was significantly related to skill retention among FGCs (p = .008). Experience, drilling, and training opportunities (overlearning), and years of experience in the fire service were not significantly related to skill retention. Findings may be used to strengthen fire service policies and reduce loss of life and property damage in the fire service and communities.

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Dedication

This dissertation is dedicated to my children, James, Joshua, Joseph, and Jordyn Rae. I hope by witnessing this endeavor that you learned that most admirable goals can be achieved through perseverance, courage, and hard work. “The dictionary is the only place that success comes before work. Work is the key to success, and hard work can help you accomplish anything.” ― Vince Lombardi

Acknowledgments

Foremost, I would like to give special thanks to Dr. Karen Shafer, my dissertation chair and methodologist, who showed an interest in my study and offered credible suggestions when I became stuck and frustrated; thank you for rescuing me. Equally important, I would like to convey my sincere gratitude to Dr. David Milen, my committee subject matter expert. We have both experienced the positive and negative aspects of the culture of the fire service and recognize the significance it has as an impediment to effective leadership in public service; thank you for your support and guidance.

I would like to thank my family of six: my sons, Joshua and Joseph, for your sense of humor and the countless times you joined me at the library and Starbucks for support and companionship. My wife, Johanna, for your unwavering love and care. My daughter, Jordyn, for your drawings and notes of encouragement that decorated my desk with love. Finally, to my son with autism, James: We have a special connection that I cannot put into words. You fill my heart with joy and purpose. You transform me as a person, and I am grateful to be your dad. Remember how much you are loved. I am so proud of you! I would also like to thank my dad, Jim, and brother, Tim. You both have been there for me through the end. Thank you for teaching me the virtue of resilience and empowering me to move through hardship and become stronger.

Finally, the Brunacini family. You took me in like a lost son and inspired me to keep going. My only regret is that I did not finish before Bruno passed away, but I am sure that he is proud as he looks down and sees what we accomplished together.

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Chapter 1: Introduction to the Study

Although considerable emphasis has been placed on research to increase firefighter safety and effectiveness (Madrzykowski, 2016), firefighter line-of-duty deaths (LODDs) and injury rates have been unaffected over the last 10 years (United States Fire Administration [USFA], 2014). Multiple independent investigative reports by the National Institute for Occupational Safety and Health (NIOSH), the National Fire Fighter Near-Miss Reporting System, and the USFA indicated inadequate training and insufficient experience for fire ground commanders (FGCs) as primary causes (Kunadharaju, Smith, & DeJoy, 2011; Standridge, 2012). What constitutes adequate training and sufficient experience as it relates to fire ground safety has not been explored.

Training within the fire service begins at the recruit academy where probationary firefighters learn core competencies in firefighting operations. Recruits then harness their skills in a more natural environment such as live-fire-training until they graduate from their academy. From there, skills are maintained through practical experience and infrequent training (Perry, Wiggins, Childs, & Fogarty, 2012; Standridge, 2012). Firefighters experience extended periods of nonuse, making them susceptible to skill decay. Researchers suggested that skill decay may appear when trained or acquired skills are needed after long periods of nonuse (Arthur, Bennett, Stanush, & McNelly, 1998; Kluge & Frank, 2014; Wang, Day, Kowollik, Schuelke, & Hughes, 2013). FGCs are vulnerable to skill decay given the lack of opportunities to acquire fire-command experience and perform trained skills (Arthur et al., 1998).

The application of skill decay theory (Arthur et al., 1998) helped me examine the relationship between practical experience and the degree of skill decay among FGCs after completion of a curriculum-based training program. Findings contributed to current literature involving fire ground training, natural decision-making, and the impact of practical experience on skill decay. Findings may be used to strengthen fire service policies, improve decision-making on the fire ground, and reduce loss of life and destruction of property in the fire service and communities.

In this chapter, I provide background for the study and present the problem statement, purpose statement, research questions, and hypotheses. I also include the theoretical framework, nature of the study, definition of terms, assumptions, limitations, and delimitations. I conclude with a summary and transition to Chapter 2.

Background

Over 30,000 fire departments and 1,160,450 firefighters serve and protect local communities throughout the United States (Hamins, Bryner, Jones, & Koepke, 2015). Fire departments provide a broad range of services for medical emergencies, car crashes, structure fires, hazardous materials, technical rescue operations, and wildland fires. These types of services place firefighters in dangerous environments.

When joining the fire service, individuals take a solemn oath that they will risk their lives to protect others and property. In return, leadership is expected to create organizational policies to minimize risks and promote best practices. Standard operating procedures (SOPs) are commonly used in fire departments. Department SOPs prescribe effective actions for incident conditions, are used to drive training programs, and are used to develop officers while refining the organization; however, there are no national standards for SOPs (Brunacini & Brunacini, 2004). Although there are specific standards referencing training, staffing, equipment standards, and fire codes such as those recommended by the National Fire Protection Association (NFPA), standard procedures for local incident management differ among fire departments. Consequently, SOPs become subjective based on personal observations, opinions, limited data, and jurisdictional agreements (Hamins et al., 2015). At a multicompany or multiagency incident, the response strategy may be based on limited or unreliable information, creating a dangerous situation.

Firefighting remains a highly dangerous profession. In 2015, firefighters responded to 501,500 structure fires in the United States causing 29,130 firefighter injuries (Haynes, 2015) and 24 line-of-duty deaths (Fahy, LeBlanc, & Molis, 2016). Roughly 100 firefighters are killed in the line of duty every year (USFA, 2014). Multiple independent investigative reports indicated poor command decision-making due to inadequate training and awareness (Hamins et al., 2012; Klein, Calderwood, & Clinton-Cirocco, 2010; Kunadharaju et al., 2011). FGCs acquire their skills early in their careers as firefighters and then gradually gain the experience needed to make safe decisions. Entry-level firefighters receive considerable training as recruits. From there, knowledge retention and skill development depend on the opportunities to practice their abilities at fire incidents. Over time, firefighters acquire practical experience and move into leadership roles as senior firefighters, company officers, or command officers. Regardless of rank, firefighters rely on training and hands-on experience to acquire and retain the skills needed to operate safely on the fire ground (Lamb, Davies, Bowley, & Williams, 2014; Wener et al., 2015).

The fire ground is where firefighters work from under the leadership of the incident commander. Leaders manage hazard zone operations and assign resources in immediately dangerous to life or health (IDLH) conditions. Klein et al. (2010) examined experienced FGCs and the decisions they make on the fire ground and found that many do not make decisions at all, but instead apply prototypical scenarios from experience. Klein et al. created a recognition-primed decision (RPD) model for decision-making in these fast-paced, uncontrolled environments like a structure fire; however, RPD concerns for less experienced firefighters and command officers lack depth. In response, simulation-based training programs offer a safe alternative to expose firefighters to realistic settings so they can acquire the necessary skills to make safe decisions (Williams-Bell, Kapralos, Hogue, Murphy, & Weckman, 2015). However, little is known about how successful the training efforts of local departments are (Sinclair, Doyle, Johnston, & Paton, 2012). Examining fire department training programs may illuminate deficiencies and minimize fire losses.

Skill decay is a concern when knowledge and expertise are not applied for extended periods of time (Arthur et al., 1998; Farr, 1987; Wang et al., 2013). Because firefighters, company officers, and command officers in the fire service may experience extended periods of time without having the opportunity to perform their skills at a structure fire, skill decay may occur. Skill decay is a significant threat to the fire service because most firefighters receive little if any ongoing training.

With time and the absence of opportunity to perform or restore developed skills, and the ability to recall knowledge deteriorates (Bourne & Healy, 2012). Skill decay refers to a decrease in accuracy or an increase in response time (Ebbinghaus, 1913). Ebbinghaus (as cited in Gronlund & Kimball, 2013) showed a relationship between forgetting and time, and created the forgetting curve. Arthur et al. (1998) advanced Ebbinghaus's research and created a more contemporary model of forgetting that defined skill decay as an observed reduction in performance on taught or developed skills after a given period of nonuse. Arthur et al. described a positive relationship between the nonuse period and skill decay, where the rate of decline slowed over time.

Several organizational and task-related factors impact skill decay, including drilling and practice opportunities (overlearning), cognitive tasks, and conditions of retrieval (Arthur et al., 1998). Kluge and Frank (2014) found that cognitively complex decision-making skills were particularly vulnerable to skill decay, as were skills that rely on SOPs. Although extensively researched in the field of process automation (Kim, Ritter, & Koubek, 2013; Kluge & Frank, 2014; Kluge, Frank, Maafi, & Kuzmanovska, 2015), skill decay in firefighters has not been studied. The current study was conducted to examine skill decay among firefighters and provide valuable information to the fire service and public officials. Findings may be used to improve training policies and operational efficiency to minimize fire losses.

Problem Statement

Advances in fire protection systems, fire codes, and safety legislation have produced a significant reduction in fires reported nationally (USFA, 2014). Over the previous 15 years, there has been a 21% reduction in reported fires and civilian deaths (Haynes, 2015). Folz and Shults (2014), Haynes (2015), and the USFA (2014) contributed this to advancements in fire protection systems, fire codes, and safety legislation. However, these results have produced unintended consequences.

Research by the NFPA (as cited in Haynes, 2015) and the USFA (2014) indicated that each year roughly 100 firefighters perish in the line of duty and 80,000 are injured. These rates are higher than any other industrialized country in the world (USFA, 2014). Of those annual firefighter LODDs, approximately 37 firefighters are killed during fire ground operations, while 27 perish at the scene of a structure fire (USFA, 2014). Although there have been concerted efforts to improve fire ground safety, trends in overall rates and disparities between reported fires, civilian deaths, and firefighter LODDs merit further examination of fire ground operations.

Managing a fire incident requires an incident commander to make safe and efficient decisions in time-pressured and dangerous conditions. As fire ground conditions become more complex and dynamic, the capacity to create safe and efficient choices becomes more challenging (Bayouth, Keren, Franke, & Godby, 2013). This ability consists of a particular set of skills, knowledge, and experience to perform the necessary functions of command. These abilities include assessing the event to recognize life-threatening factors, incorporating those factors in a sensible risk management plan, developing a strategy based on those factors, and creating an incident action plan that addresses the tactical priorities within the chosen strategy (Brunacini, 2002).

To perform these objectives, incident commanders must maintain their skills to make the right decisions, especially when lives depend on it. However, when individuals operate under highly complex procedural environments, they are highly susceptible to skill decay (Farr, 1987). Additionally, FGCs are vulnerable to skill decay because most receive little if any skill development other than their first fire training academy (Arthur, Day, Bennett, & Portrey, 2013). Contributing to this dilemma is the gradual reduction of fire incidents and the opportunity to expose commanders' experiential learning opportunities created by fire incidents (Lamb et al., 2014). Research by Anderson (2010) indicated that in the lack of repetition, memory strength deteriorates as a power function of preservation. Knowledge and skill attainment are only useful in providing a safe fire ground if the opportunity exists for applying and retaining those qualities and making safe and effective decisions on the fire ground.

Despite the critical role of firefighters and the complex decision-making skills they use when managing a structure fire, literature provided limited information regarding skill retention or decay, and the impact of experiential learning opportunities. Much of the research on talent retention and decline has been qualitative (Jenkins, Wills, Pick, & Al-Kutubi, 2015; Johnson, 2016) and has involved unique and straightforward skills in highly automated industries. These include military (Johnston et al., 2015), medical (Amaral & Troncon, 2013; Yang et al., 2012), oil refineries (Nazir & Manca, 2015), nuclear power plants (Oglesby et al., 2014), and chemical plants (Kluge et al., 2015). These skills range from simple motor skills such as typing and speech (Kim et al.,

2013) to more robust functions like surgical procedures (Spruit, Band, Hamming, & Ridderinkhof, 2014).

Simple skills and sophisticated skills are different, and the rate and amount of degradation may vary (Villado et al., 2013). Villado et al. (2013) observed a considerable degree of decline for simple tasks and a moderate level for complex tasks. However, there were significant levels of decay on sophisticated skills during particular nonuse intervals (Villado et al., 2013). These results indicated that the patterns of retention and decline for complex skills are unclear.

In addition to task-related factors affecting conservation and decay, there are methodological matters to consider, such as distributed practice effects (i.e., spacing between tests, training sessions, or experiential learning opportunities). Although studies showed a positive association between the length of spacing and skill decay, this relationship involved short nonuse intervals (Arthur et al., 1998; Kluge et al., 2015). In an analysis of the effects of retention intervals, Cepeda, Pashler, Vul, Wixted, and Rohrer (2006) stated that seven out of 254 studies involved intervals longer than 7 days. Few studies have addressed the decay of complex cognitive skills over an extended period (Kluge & Frank, 2014; Lawani, Hare, & Cameron, 2014). Moreover, researchers have not examined how safety-related actions or skills decline over long nonuse intervals (Burke & Signal 2010). When FGCs have less opportunity to develop and retain their abilities at fire incidents, they begin to lose their ability to make safe and effective decisions on the fire ground (Klein et al., 2010). Limited research suggested that the decay of complex skills used by incident commanders while managing a hazardous incident warranted further investigation.

Purpose of the Study

The purpose of this quantitative study was to study the degradation of decision-making skills among local incident commanders while managing a structure fire. The intent was to understand how much of the variation in the dependent variable (skill decay) was explained by multiple independent variables. In this study, the primary independent variable was the number of incidents (working fires) an incident commander experienced after completing training. Secondary independent variables included (a) drilling and training opportunities (overlearning), (b) overall years of experience, and (c) time since initial training. This study also included the following control variables: (a) education obtained, (b) training motivation, (c) self-efficacy, (d) department size, (e) current rank including time served in the position, (f) sex, and (g) age.

Drawing from Farr’s (1987) and Arthur et al.’s (1998) research on the long-term retention of knowledge and skills, I examined skill decay due to diminished incident exposure. Empirical studies suggested multiple organizational and task-related factors influence the degradation of trained or acquired skills (Arthur et al., 1998; Cepeda et al. 2006; Wang et al., 2013). This study addressed gaps in the skill decay literature regarding the influence of organizational and task-related factors on the decline of decision-making skills used by FGCs.

Research Question and Hypotheses

The research question studied in this analysis was as follows: After incident commanders complete a curriculum-based simulation training program on fire ground command, what factors contribute to skill decay?

The following hypotheses were used to address the research question:

$H_0 1_a$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and experience as an incident commander.

$H_1 1_a$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and experience as an incident commander.

$H_0 1_b$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and the amount of drilling and training opportunities (overlearning).

$H_1 1_b$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and the amount of drilling and training opportunities (overlearning).

$H_0 1_c$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and the number of overall years of experience in the fire service.

$H_1 1_c$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and the number of overall years of experience in the fire service.

$H_0 1_d$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and the amount of time since initial training.

$H_1 1_d$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and the amount of time since initial training.

Theoretical Framework

Skill decay theory provided a basis for this study that addressed the magnitude of cognitive skill decline among FGCs. Skill decay theory originated in 1885 and was developed by Ebbinghaus (1913) in research on speech retention. Ebbinghaus examined the recollection of nonsense syllables and found that a relationship exists between forgetting and time, commonly referred to as the forgetting curve (Gronlund & Kimball, 2013). Recent studies on skill decay have focused on high-reliability organizations (HROs) where retention of talent is critical, such as the military, nuclear power plants, oil refineries, and aviation (Kluge & Frank, 2014). Firefighters operate in HROs that involve IDLH environments. There is little room for error in these conditions. Skill decay is a concern for firefighters, but no empirical studies have addressed skill decay in the fire service.

There is general agreement among skill decay theorists that an observed reduction in acquired skills occurs after a time of nonuse (Arthur et al., 1998; Farr, 1987). The construct of decay as a description of what happens to memory over time is elusive because the mechanism by which memory deteriorates is not well understood (Gronlund & Kimball, 2013). There is, however, empirical evidence suggesting that in addition to time, several organizational and task-related factors affect the degradation of skills, including (a) the duration of the retaining interlude, (b) the extent of drilling and practice opportunities (overlearning), (c) nature of the task, (d) testing methods such as recognition or recall tests, (e) surroundings of recovery, (f) instruction methods, and (g) discrete abilities (Arthur et al., 1998).

Retention interval is the period between the evaluation and the most current training opportunity (Arthur et al., 1998; Ebbinghaus, 1885). Skill degradation is positively related to the duration of retention intervals (Wang et al., 2013). However, Wang et al. (2013) detected a moderate outcome where a significant degree of erosion occurred soon after the evaluation but diminished as the retaining intermission increased.

Researchers evaluating task complexity, including cognitive and physical demands, found mixed results. Moderate to highly complex cognitive tasks with minimal physical requirements showed significant skill decay (Cepeda et al., 2006). Less cognitively complex tasks paired with more significant physical elements deteriorated less (Wang et al., 2013). These discoveries suggested that deterioration is influenced by the difficulty of the task.

Grounded by Arthur et al.'s (1998) meta-analysis on the degradation of knowledge and skills, I chose skill decay theory as they theoretical framework to guide this quantitative study. According to previous quantitative studies on cognitive skill decay (Arthur et al., 1998; Villado et al., 2013), decay is an outcome rather than a process that represents a decrease in performance on trained or acquired knowledge and expertise after a given period of nonuse. This definition was used to measure the effect of experiential learning factors (related to actual field experience as an incident commander) that influence knowledge and skill decay after training. Skill decay theory helped me explain decline of competencies among FGCs through an examination of organizational and task-related factors.

The application of skill decay theory is most relevant in organizations where trained or acquired skills must be preserved during extended periods of nonuse (Arthur et al., 1998; Kluge & Frank, 2014; Wang et al., 2013). Depending on locations, fire officers could work for years without having a structure fire in their first due area. Skill decay theory is also applicable when training is delivered in one long course rather than numerous short courses (Arthur et al., 1998). Fire officers receive little skill development besides their recruit training. Lastly, skill decay theory is suitable when examining complex decision-making skills that depend on SOPs. Kluge and Frank (2014) concluded that forgetting was significant in procedural tasks like SOPs. SOPs are commonly used by the fire departments to minimize risks and promote best practices (Kunadharaju et al., 2011). Given these applications, skill decay theory was appropriate in examining the decline of fire ground decision-making skills among incident commanders.

Nature of the Study

The nature of this study was quantitative with a nonexperimental survey design. Quantitative research is consistent with testing scientific theories by assessing the functional association among variables (Creswell, 2013). The hypothesis of skill decay was tested to determine whether the decline was a function of experience after completing a training program. A survey was created to measure the dependent variableof skill decay among FGCs after completing a training program. The study also included independent variables, such as experience, drilling and practice opportunities (overlearning), overall years of experience, and time since initial training. The control variables included sex, age, education, training motivation, self-efficacy, department size, and current rank including time served in the position.

The survey-based quantitative design addressed gaps in the literature by measuring cognitively complex decision-making skills of fire ground incident commanders (Arthur et al., 2013; Wang et al., 2013; Yang et al., 2012). The quantitative study involved distributing an online survey to fire department officers who were certified as local incident commanders. Completed survey responses were collected by Google Forms, and the data were organized and exported to SPSS 23 (IBM Corp., 2015) for statistical analysis. Multiple linear regression analysis was used to determine whether and to what degree independent variables predicted the dependent variable.

Definitions

Command: The person, function, and location of command, which provides a standard identifier for the incident commander (Brunacini, 2002). Command is also the first component of the Incident Command System (International Fire Service Training Association [IFSTA], 2016).

Company officer or captain: The person responsible for managing a fire company and coordinating task-related, tactical, and strategic activities of that group (IFSTA, 2016).

Conditions of retrieval: The resemblance between the environment where the learning took place and the context of the recovery test (Arthur et al., 1998).

Distributed practice: The frequency of numerous short practice sessions over a lengthy period (Arthur et al., 2013; Cepeda et al., 2006).

Engine company: Firefighters assigned to a fire apparatus who are accountable for obtaining a water supply (fire hydrant), operating hose lines, and leading search and rescue actions (IFSTA, 2016).

Hazard zone: Any area that necessitates the use of an self-contained breathing apparatus (SCBA) to function (Brunacini, 2002).

Horizontal ventilation: A method of ventilating a structure through doors and windows so that toxic gases, smoke, and heat can escape (IFSTA, 2016).

Immediately dangerous to life or health (IDLH): A dangerous atmosphere that contains toxic, corrosive, or asphyxiating substances that directly threaten life (Centers for Disease Control and Prevention [CDC], 2014).

Incident commander: The person leading the incident who is accountable for all outcomes involving the supervision of the scene (IFSTA, 2016).

Ladder or truck company: Firefighters assigned to a fire apparatus who specialize in vertical and horizontal ventilation, roof operations, forcible entry, extrication, and ladder functions (IFSTA, 2016).

Massed practice: Exercising that involves continuous training sessions with limited breaks (Arthur et al., 2013).

Mayday: A code used when a firefighter cannot safely leave an IDLH hazard zone (Brunacini, 2004).

Nonuse or *retention interval*: The period of time between performance assessments (immediate posttest and delayed posttest); also described as the time between the end of training and immediate posttest (Arthur et al., 1998).

On-deck: A temporary holding assignment beyond the hazard zone placed near the entryway of a tactical location (Brunacini & Brunacini, 2004).

Overlearning: Training-related factors that go beyond initial proficiency, such as drilling and practice opportunities (Arthur et al., 1998).

Primary all-clear: A rapid search and clearing of all involved zones of the building for victims (Brunacini, 2002; IFSTA, 2016).

Secondary all-clear: A more detailed, exhaustive examination of the structure after obtaining control of the fire and smoke-removal operations (Brunacini, 2002).

Self-contained breathing apparatus (SCBA): Protective breathing equipment for firefighters (IFSTA, 2016).

Skill decay: A decrease in performance on trained or acquired knowledge and expertise after a given period (Arthur et al., 1998).

Spacing of Practice: Learning techniques including massed or distributed practicing (Arthur et al., 2013); education is said to be spaced when a measurable period separates training events for a given item (Cepeda et al., 2006).

Testing methods: Testing procedures used to assess learning and retention (Arthur et al., 1998).

Ventilation: Actions taken to replace toxic smoke, heat, and gases inside a structure fire with clean air (IFSTA, 2016).

Vertical ventilation: The process of cutting holes in the roof by using saws, axes, and other tools so that heat, smoke, and toxic gases can escape the building (IFSTA, 2016).

Working fire: A structure fire that will necessitate the commitment of all responding fire companies in tactical operations for a prolonged interval (Brunacini, 2002).

Assumptions

This study included several assumptions. I assumed that skills eroding over periods of disuse is recognized doctrine (see Villado et al., 2013). This assumption is based on simple skills and short nonuse intervals (Arthur et al., 1998; Villado et al., 2013; Kluge et al., 2015). Arthur et al. (1998) examined complex cognitive abilities over prolonged periods of nonuse and identified a variety of factors that influence the decay or retention of acquired abilities over time. I assumed that the variables named by the theory were valid. I also assumed that some level of decay would occur. However, because there was no clear relationship between FGC expertise and skill decay, I did not presume the degree to which the variables may or may not have had for this study.

Also, I made assumptions about the participants. I assumed that the list of certified incident commanders that was provided by leadership was current and accurate. Participants were required to be company officer rank or higher and have successfully obtained their training certification. I assumed that participants responded to the survey accurately and truthfully. The survey included a limited number of open-ended questions that allowed the participants to provide accurate estimates, such as the number of structure fires they experienced as commanding officer. I assumed that these estimates were accurate. Finally, I assumed that simulation-based training reflects an individual's operational performance ability.

Scope and Delimitations

The study addressed gaps in the literature by focusing on skill decay in the fire service. More accurately, I examined the degradation of decision-making skills used by fire officers and commanders. At the time of the study, no study has addressed the association between FGC expertise and skill decay over prolonged periods of nonuse. Previous studies focused on progressive deterioration of acquired knowledge and skills in other domains where processes were decidedly automatic, including aeronautics, nuclear power plants, and oil factories (Casner, Geven, & Williams, 2013; Kluge & Frank, 2014). The current study was provided knowledge on critical issues related to skill decay and the fire service.

The scope of the study was limited to fire officers who function as incident commanders who oversee and direct fire ground procedures for local National Incident Management System (NIMS) Type 4 and Type 5 incidents. I specifically examined fire department officers who completed a curriculum-based training program and were certified commanders. I did not measure skill decay among the general fire service population. Results from the study are generalizable only to the specific population under review.

The goal of this study was to determine whether there is a significant association between skill decay and experience as an incident commander after completion of a simulation-based training program. Skill decay was defined as decrease of performance on trained or acquired knowledge and expertise after a given period (Arthur et al., 1998). This study did not address the process of forgetting. Instead, this study focused on factors influencing skill decay after training.

Another characteristic that narrowed the purpose and scope of the study pertained to the dissimilarities between research and program evaluation. Although the targeted population under study included certified fire department officers who had completed a particular training program, I conducted scientific research, not program evaluation. Levin-Rozalis (2003) described the difference between assessment and study: “the purpose of research is to enlarge the body of scientific knowledge; the purpose of the evaluation is to provide useful feedback to program managers and entrepreneurs” (para. 1). Research is conducted to expand a body of knowledge that can be applied to numerous settings. In contrast, evaluation is used to assign a value to a particular project and provide feedback for the evaluated project (Levin-Rozalis, 2003).

I employed quantitative measurements to assess the functional relationship between incident command experience (IV) and skill decay (DV) while considering the effect of drilling and practice opportunities (overlearning) (IV), overall years of experience (IV), and time since initial training (IV). This focus was appropriate for several reasons. First, the scope of the theory was appropriate. Skill decay theorists argued that individual organizations are susceptible to skill decay under the following conditions: (a) when members receive massed forms of training, as opposed to distributed or spaced training; (b) when members use cognitively complex decision-making skills and reference SOPs for guidance; and (c) when members are exposed to limited opportunities to sustain their abilities to remain competent (Arthur et al., 1998; Kluge et al., 2015; Lamb et al., 2014). Because these parameters were consistent with the targeted population of FGCs, this theory was appropriate. Also, skill decay theory consists of a set of measurable concepts explaining a phenomenon. Therefore, its scope was not restricted to one particular variable. The use of multiple variables grounded in theory and empirical evidence provided a framework for analysis.

Limitations

Some limitations influenced the study outcome. The sampling frame was limited to the e-mail list provided by a nationally recognized incident command certification program. This list included those who are company officer rank or higher and have successfully obtained their first training certification within the last 3 months. Therefore, the sampling was limited to e-mail addresses and to those who qualified. Second, I employed an online survey instrument to gather data. The availability of Internet use was presumed because the targeted population first acquired training through a web-based program. However, a potential bias in socioeconomic status existed. Third, the survey design was based on different sets of questions with the ability to answer a restricted number of responses, thereby limiting the accuracy of the data. Finally, study participants were asked to provide information about previous experiences, such as the number of incidents in which they were the incident commander. Participants may have reported an estimate rather than a precise value. Survey questions were designed to cover a limited range of time and situations to improve the accuracy of estimates (Sue & Ritter, 2011).

A significant limitation of this design related to the method of examining the performance of FGCs. Commanders employ decision-making methods that involve life-threatening conditions with little time to assess the situation at hand. Klein et al. (2010) discovered that FGCs use perceptual recreation to determine a plan of action. However, examining the skills of FGCs in situ was impractical and dangerous. Therefore, the method of evaluating command skills was limited to simulations to recreate realistic environments while managing a fire ground.

There were concerns about the validity and reliability of assessing skills required to manage a structure fire given thee subjectivity of assessment, including grader bias. A potential bias that might have influenced the outcome of the study was that I am fire captain employed in the fire service industry with 20 years of experience. I had acquired a predisposed disposition regarding fire command. To address this bias, I constructed the survey instrument from curriculum-based nationally recognized standards extrapolated from fire command (Brunacini, 2002) and command safety (Brunacini & Brunacini, 2004), not personal observations or opinions. By using standardized benchmarks used to train certified FGCs, I mitigated grader bias. Furthermore, to enhance the validity and reliability of the survey, I asked a committee of experts to evaluate the survey. The committee included company and command officers in the fire service with over 20 years of experience in establishing command of a structure fire.

Also, the web-based method for administering the survey minimized interactions between me and the participants. Scientists using face to face contact may unintentionally express their expectations concerning the member's performance (Frankfort-Nachmias & Nachmias, 2015). Lastly, the data analysis plan used to generate descriptive and inferential conclusions included standard statistical procedures in analyzing the data. Descriptive analysis included tests for normality, kurtosis, and skewness. Multiple linear regression analysis was used to assess the impact of experience on skill decay while at the same time assessing the impact of overlearning, overall years of experience, and time since initial training. Objective data analysis using quantitative methods further mitigated researcher bias.

Significance

Training is a crucial yet costly endeavor in the fire service. Based on a 2012 report by the National Institute of Standards and Technology, an estimated $40 billion was spent on formal training among U.S. career fire departments (Hamins et al., 2012). Although the commitment to ensure the safety and welfare of firefighters is necessary and righteous, little is known about the effectiveness of training (Sinclair et al., 2012). Much of the research on skill development has been qualitative involving simple skills and short nonuse intervals (Arthur et al., 1998; Kluge et al., 2015). FGCs use complex problem-solving skills that must be maintained over extended periods of nonuse. Few studies have addressed the decline of cognitive skills over extended periods (Kluge & Frank, 2014; Lawani et al., 2014). Moreover, no studies addressed the decay of complex skills used by incident commanders while managing a hazardous incident. I attempted to address these gaps by examining the degradation of skills acquired by FGCs after completing a training program. Findings may advance scholarship by filling existing gaps regarding fire command skill decay.

Firefighting in the United States is dangerous. Several investigative agencies including NIOSH, USFA, and the National Fire Fighter Near-Miss Reporting System concluded that the primary cause of fire ground fatalities is poor command training and insufficient experience among FGCs (Kunadharaju et al., 2011; Standridge, 2012). Nearly 100 firefighters perish in the line of duty every year, and over 80,000 injuries are sustained on the fire ground (USFA, 2014). These figures do not account for the pain and suffering endured by families, organizations, and communities. Leadership from local, state, and federal fire agencies can ill afford continuous fire losses (Paveglio, Abrams, & Ellison, 2016).

Results from this study may be used to predict the amount of knowledge and skill decay for various periods of nonuse. Models and equations generated as a result of this study may be used to direct the timing and sequencing of refresher training. Results may be used to minimize the loss of complex skills employed by ICs during emergent events and to maintain a level of competency during periods of nonuse. Findings may also be used to reduce firefighter deaths, injuries, and property loss because of improved firefighter training policies.

The focus of this study was the decay of FGC skills over an extended period of nonuse. Although some degree of decline over time may be assumed, Wang et al. (2013) did not find a clear relationship between sophisticated expertise and decay over prolonged periods of nonuse. Given the absence of empirical evidence regarding complex skill retention over extended periods of nonuse and the degree of skill decay related to complex tasks, this study provided an original contribution to skill decay research.

Summary

Skill decay is a commonly known concept studied since the early 1900s (Ebbinghaus, 1913). Skill decay continues to be a major issue when proficient or developed skills are needed after long stages of nonuse (Arthur et al., 1998). Skill degredation is critical for FGCs because most receive little if any skill development other than their first fire training academy.

Many factors affect skill decay, including organizational factors in the form of drilling and practice opportunities (overlearning), the spacing of practice, conditions of retrieval, and the structure of the training. Task-related factors affecting decay refer to the complexity at hand (Arthur et al., 1998). Despite these factors, little is known about how complex cognitive skills employed by FGCs decay after training. I observed gaps in the literature regarding the relationship between practical experience, decision-making, and skill decay. This study was conducted to address these gaps by surveying FGCs’ skills after completing a simulation-based training program.

In Chapter 2, I present significant themes in the reviewed literature, including substantial organizational and task-related factors that impact skill degradation and retainment, operational systems used in the fire service, environmental factors in which FGCs operate, firefighter LODDs, and incident commander training. I also review studies that addressed factors affecting decay, including the duration of the retention interval, degrees of overlearning, testing methods, conditions of retrieval, experiential learning, and the spacing of practice.

Chapter 2: Literature Review

Firefighting is a hazardous profession. There are ways to improve fire safety by providing training to acquire and maintain skills that are necessary to make safe and efficient decisions. When individuals operate under hazardous environments, they are highly susceptible to skill decay (Arthur et al., 1998; Farr, 1987). Fire ground commanders (FGCs) are vulnerable to skill decay given the lack of opportunities to acquire fire command experience and perform trained skills (Arthur et al., 1998). This study addressed the relationship between skill decay and factors such as experience among FGCs.

Findings may be used to enhance training programs to impede knowledge and skill decay after a prolonged period of nonuse. Applying the findings to future training procedures may improve the effectiveness and efficiency of FGCs in their mission to prevent harm by keeping firefighters and communities safe. Current professional, government, and scholarly literature indicated the need for data regarding the degradation of complex cognitive skills used by FGCs.

At the time of the study, no empirical evidence had indicated the degree of skill decay for FGCs over extended periods of nonuse. Although some level of decline over time may be assumed, researchers had not examined FGC expertise over prolonged periods of nonuse (Wang et al., 2013). Arthur et al.'s (1998) skill decay theory was used to examine decay as a measurable decrease in performance in trained or acquired knowledge and expertise after a period of nonuse. Researchers have shown that a marked reduction in prepared or learned cognitive skills occurs after a time of nonuse (Arthur et al., 1998; Farr, 1987; Wang et al., 2013). The purpose of this study was to determine whether there was a statistically significant relationship between skill decay and experience of an incident commander after completion of a simulation-based training program.

The literature on skill decay involving complex tasks offered contradicting findings. Wang et al.’s (2013) conclusions regarding retention were consistent with the outcomes of Arthur et al.’s (1998) study that indicated the more extended the period of nonuse, the more significant the extent of decay on complex tasks. Wang et al. found that the rate of decline of complex functions may be more resistant to degradation than formerly thought. Wang et al. evaluated the relationship between retention intervals, skill decay, and content demands and found that performance declined after a period of nonuse. However, the decrease was smaller than that found by Arthur et al. Arthur et al. also showed inconsistent results. For example, for tasks involving moderate cognitive and low physical elements, a significant decline occurred. However, a smaller decline occurred for functions combining weak cognitive and high physical elements. Also, more deterioration was found in less cognitively complex tasks. These finding suggested that decay is a joint function of the complexity of cognitive and physical elements (Arthur et al., 1998). These discrepancies suggest skills vary as to which approach best aids the lasting remembrance of that understanding.

The absence of scholarly literature on the degradation of cognitive skills among FGCs supported the need for this study. No research had addressed the retention of FGCs’ problem-solving skills over extended periods of time. The available literature on complex cognitive skill decay focused on highly automated industries, such as the military and emergency medical domains (Jastrzembski, Gluck, & Gunzelmann, 2006; Kluge & Frank, 2014; Risavi, Terrell, Lee, & Holsten, 2013). Research from these areas was used to make assumptions about the design of the current study. Scholarly evidence on the degradation of FGC's skills may be used to create a more efficient and effective training system to ensure preparedness and response among FGCs. Chapter 2 contains an examination of the literature on command systems used in the fire service, naturalistic decision-making, and simulation-based training as it relates to FGC skill decay. I also describe the literature search strategy and explain the theoretical foundation.

Literature Search Strategy

The purpose of this review was to survey, assess, and synthesize the literature addressing skill decay and FGC decision-making. For all searches, I privileged scholarly and peer-reviewed literature published in the past decade with particular emphasis on literature published within 5 years. The literature review included U.S. government-published valuations, journals, books, and policy declarations and peer-reviewed articles, books, dissertations, and theses. To find appropriate literature, I used Walden University's online library as a primary resource. Specific databases included ProQuest, Academic Search Premier, Sage Online Journals, EBSCO Databases, and Homeland Security Digital Library. I also used the Advanced Google Scholar search engine. Other sources included the National Fire Protection Association, the U.S. Fire Administration, the National Institute for Occupational Safety and Health, the International Society of Fire Service Instructors, the Fire Department Safety Officers Association, and the

Congressional Fire Services Institute websites. Furthermore, I reviewed fire service journals, trade publications, books, and curriculum related to fire command, command training, and decision-making skills.

Specific key words used to search the databases included *knowledge/skill decay*, *knowledge/skill degradation*, *knowledge/skill retention*, *knowledge/skill deterioration*, *knowledge/skill maintenance*, *spaced learning*, *spacing effect*, *massed/distributed training*, *incident command*, *incident command training*, *simulation-based training*, *training effectiveness*, *training evaluation*, *naturalistic decision-making*, *experiential learning*, and *firefighter injuries/fatalities*.

Theoretical Foundation

I employed skill decay theory to examine the cognitive skill decline among FGCs. FGCs are susceptible to skill decay given the extended period between training and opportunities to exercise and maintain acquired skills (Villado et al., 2013). FGCs are expected to perform in high-risk, low-frequency environments. Therefore, examining the factor associated with skill decay among FGCs was necessary. A better understanding of the factors related to skill decline among FGCs may be used to modify the frequency of training programs to enhance skill and knowledge retention.

The theory of skill decay dates to Ebbinghaus's (1913) study on nonsense syllable forgetting. Ebbinghaus examined the conservation of individual skills and discovered a relationship between forgetting and time that became known as the "forgetting curve" (Gronlund & Kimball, 2013, p. 26). Despite limitations to his study, Ebbinghaus (as cited in Murdock, 1985) showed that a relationship exists between time and decay.

Although Ebbinghaus developed the concept of decay, skill decay theory is rooted in Arthur et al.'s (1998) study describing decline as an observed decrease in performance on trained or acquired knowledge and expertise following a given period of nonuse. Results from Arthur et al.'s skill decay and retention meta-analysis showed a substantial positive correlation between the duration of the retaining interval and power loss. This finding indicated that the greater the time of nonuse, the more significant the quantity or extent of deterioration. However, the rate of forgetting slowed over time, showing a functional relationship between forgetting and time. Additional results of this study showed that several organizational and task-related factors impacted the relationship between the duration of nonuse and the amount of skill degradation (Arthur et al., 1998). These factors included drilling and practice opportunities (overlearning), testing familiarity, and task complexity. Moreover, results suggested that testing familiarity had the most considerable influence on skill decay (Arthur et al., 1998). Conclusions from this study indicated that the length of nonuse and testing familiarity significantly impacted the degradation of attained skills. Consistent with Arthur et al.'s study, I used skill decay as an observed outcome in the current study.

Skill decay theorists noted that a marked reduction in performance occurs on trained or acquired skills after a period of nonuse (Arthur et al., 1998; Farr, 1987). Multiple studies have addressed the degradation of individual ability over time using a variety of variables including verbal, motor, and procedural tasks (Gronlund & Kimball, 2013; Jenkins et al., 2015; Johnson, 2016). Findings have been consistent in recognizing the core set of factors that induce the loss or retention of acquired skills over time. These factors include (a) the duration of the retention interval, (b) the extent of overlearning, (c) the nature of the task, (d) testing methods such as recognition or recall tests, (e) circumstances of retrieval, (f) training procedures, and (g) discrete abilities (Arthur et al., 1998).

Retention Interval

The duration of the retention interval has a significant influence on skill decay (Arthur et al., 1998; Chavaillaz, Wastell, & Sauer, 2016; Farr, 1987; Gerbier & Toppino, 2015). Arthur et al. (1998) described the retention interval as the time between immediate and delayed posttest. To formalize the retention interval, Arthur et al. (1998) and Wang et al. (2013) assessed retention over time involving the same measurements taken immediately after training and at a later time. The intermission of the retention interval had to be higher than the pause between the end of practice and immediate posttest (Arthur et al., 1998; Wang et al., 2013). Arthur et al. (1998) established a positive association between the duration of the retention interval and the amount of decay but also observed a moderating effect of task-related factors and other organizational factors. This finding indicated that the relationship between retention intervals and decline is not always direct.

Like Arthur et al.'s (1998) analysis, Wang et al. (2013) evaluated the relationship between retention intervals, skill decay, and content demands, and found mixed results. For example, for tasks involving moderate cognitive with low physical features, a significant degree of the decline occurred. Whereas as a smaller amount of corrosion occurred for functions combining weak cognitive and high physical elements. However, in comparison with high cognition versus low cognition, more deterioration was found in less cognitively complex tasks. This finding aligned with Cepeda et al. (2006), suggesting that decay is a joint function of the complexity of cognitive and physical features.

Degree of Overlearning

In addition to retention intervals, Arthur et al. (1998) examined other organizational factors, such as levels of overlearning. Overlearning goes beyond initial proficiency by providing additional training. Consequently, the relationship between the stimulus and the response strengthens, thereby reducing the possibility that the reaction will be forgotten (Arthur et al., 1998). For example, Sharif, Abdullah, and Mardi (2014) found that training-related features (overlearning) describe 58.5% of the change replicated in the transmission of knowledge. The general conclusions showed that overlearning has a significant part in the transfer of knowledge. These findings parallel the findings derived from previous research in the overlearning literature (Driskell, Willis, & Copper, 1992; Farr, 1987; Rohrer, Taylor, Pashler, Wixted & Cepeda, 2005) that overlearning produced a significant effect on retention. These consistent results confirmed the relevance of overlearning on skill decay.

Nature of the Task

Along with organizational factors, Arthur et al. (1998) also examined task-related factors after periods of disuse which too have shown to influence the loss of skill. Unlike Farr (1987), who classified task varieties into broad categories, Arthur et al. (1998) investigated functions separately and hypothesized that the rate of decline for each skill would be different, depending upon the underlying requirement for that task. Task content was treated as a categorical variable depending if it was either physical or cognitive. Arthur et al. (1998) found that the characteristics and patterns of decay for cognitive tasks was more excellent than physical tasks. Also, they discovered that open-looped assignments declined more than close-looped tasks. This finding showed that decay was less for physical functions than for cognitive functions, and more decline for closed-looped tasks than for open-looped tasks. These results exemplified Farr's (1987) study on long-term retention of skill; that decay is less for sophisticated skills, where tasks are more planned, have more meaning, as compared to more simplified functions.

Testing Methods

Arthur et al.'s (1998) meta-analytic study also examined different procedures of examining for first knowledge and retainment. Research indicated that different testing procedures could generate varying levels of conservation (Arthur et al., 1998; Farr, 1987). There are two primary methods of accessing retention: recognition and recall (Anderson & Bower, 1972; Farr, 1987; Haist, Shimamura, & Squire, 1992). Recognition and recall memory was represented by strength theory and generate-recognize theory (Haist et al., 1992). That is, recognition involves an unconscious single-step process that requires familiarity of an event or object (Haist et al., 1992). Unlike recall, a two-stage process in which retrieval of previously encoded memory is replayed to generate a response, followed by a familiarity decision (Haist et al., 1992). Thus, recognition tests frequently produce higher retention scores than recall trials (Arthur et al., 1998; Farr, 1987; Haist et al., 1992). Therefore, it was essential to examine testing methods and the potential regulating effects it has on retention.

Conditions of Retrieval

Conditions of retrieval refer to the resemblance between the environment where the first learning took place and the context of the recovery test. Arthur et al. (1998) observed that retention was higher when the conditions at the recovery test were similar to those of first learning. In fact, the resemblance regarding retrieval and early learning was shown to have the most effect on retention. This finding suggested that skills are more readily reserved when the initial learning environments closely match post-testing settings (Haist et al., 1992; Tulving & Thompson, 1973; Tulving, 1985). Therefore, the effects of retrieval conditions on decay warranted meaningful interpretation.

Training Methods: The Spacing of Practice

The training plan is another organizational factor that can be modified in the design process to facilitate the retention of acquired knowledge and reduce decay. Training methods refer to instructional techniques to deliver knowledge and skills in a controlled environment and then conveyed later in a more natural work setting (Arthur et al., 1998). The spacing of practice is a training method that has shown to have a significant influence on ability retention (Arthur et al., 2010; Cepeda, 2006; Mulligan & Peterson, 2014; Schmidt & Bjork, 1992). Research on spaced learning typically examines massed or distributed practice settings. Education is said to be spread when a measurable period separates training events for a given item (Cepeda et al., 2006). Distributed practice integrates numerous short practice sessions over an extended period. In contrast, the massed method involves continuous training sessions with limited breaks. Researchers in the learning and performance literature viewed that massed practice is inferior to distributed practice are widely accepted (Arthur et al., 2013). The frequency of training was an essential consideration in measuring skill decay because it has been shown to influence retention.

Individual Differences

The role of individual differences was recognized as a significant issue in the skill retainment literature (Arthur et al., 1998). Individual difference variables typically include cognitive ability, personality, and motivational differences (Arthur et al., 1998; Farr, 1987). Multiple studies have demonstrated that individuals with higher cognitive skills obtain greater abilities in similar time periods than people with less cognitive abilities (Arthur et al., 1998; Farr, 1987; Schendel, Shields, & Katz, 1978). However, while cognitive skills may predict first learning, studies indicated that the rate of decay is similar across individuals, despite talents (Vineberg, 1975). This finding aligned with Schendel et al. (1978), Farr (1987), and Arthur et al. (1998).

Another critical point is cognitive abilities demonstrated a strong association between training and productivity (Ree, Earles, & Teachout, 1994). For example, people with greater amounts of cognitive ability acquire further senior levels of knowledge, and this higher knowledge acquisition leads to increased performance (Day, Arthur, & Gettman, 2001). In addition to cognitive abilities affecting skill retention, numerous studies have shown that attitudinal dispositions such as self-efficacy and motivation are positively correlated with performance-based outcomes (Bell & Kozlowski, 2008; Colquitt, Lepine, & Noe, 2000). Given these points, the analysis of distinct changes contained by the framework of skill degradation was relevant.

In summary, the examination of skill decay did not show a simple linear relationship between forgetting and how great individuals go without performing a task. While one would expect to forget over time, the lack of a clear trend between decay and the length of nonuse suggests that factors other than the period of nonuse are essential to consider; features such as the complexity of the job, and the combination of perceptive and physical demands that are employed.

Previous Studies of Skill Decay

The progressive deterioration of acquired knowledge and expertise is a severe problem in particular industries where skills unused over extended periods of time. For instance, skill decay is recognized in the field of process automation (Kim et al., 2013; Sauer, Hockey, & Wastell 2000) where operations are highly automated (Kluge & Frank, 2014). These so-called “High-Reliability Organizations” operate under high-risk environments with complex hazardous technologies where poor decisions can produce harsh costs for people and the surroundings (Kluge, Sauer, Burkolter, & Ritzmann, 2010, p. 1). Some of these industries include aviation, nuclear facilities, and oil factories (Casner et al., 2013; Kluge & Frank, 2014). For example, the Air Force Research Laboratory’s Warfighter Readiness Research Division examines individual and team skill acquisition, retention, and transfer after extended periods of nonuse for improving military readiness (Jastrzembski et al., 2006). Arthur et al. (2007) evaluated skill decay about the relative success of massed versus distributed practice schedules using Jane’s Fleet Command, a simulation-based naval warfare training program. Arthur et al. (2007) found that massed training exhibited a significantly higher amount of decay versus distributed practice schedules. Notably, performance increased when training opportunities were spaced further apart sequentially (Arthur et al., 2007). This finding aligned with Arthur et al. (2003) and Lawani et al. (2014).

Similarly, the fire service belongs in the category of HROs. FGCs function on an elevated level of belief because lives are affected by the decisions they make. Under those circumstances, skill loss is a concern on cognitively complex decision-making abilities employed by FGCs. Given the fatal significances related with inferior execution in managing fire operations, further examination was required concerning the degree to which FGC skills are not as vulnerable to decay over extended periods of nonuse.

The wind energy industry also examines skill decay (Lawani et al., 2014). The Global Wind Organisation (GWO) regulates operational wind farms to have an emergency response plan for personnel involved in accidents (Lawani et al., 2014). Accordingly, wind technicians train in the evacuation, escape, and rescue operations. However, there are no required training ideals that precisely pertain to rescue operations within the wind industry (Lawani et al., 2014). In a study exploring skill decline of wind turbine specialists in the use of rescue procedures, Lawani et al. (2014) observed a decline in the performance of trainees over a duration of 28 and 90 days. Thus, the proposal and support of refresher training help sustain acquired skills.

Chemical plants and oil refineries are more examples of HRO's where skill decay is pertinent. For example, disasters over the past few years, including the BP Texas City refinery event in 2005, or the Deepwater Horizon Oil catastrophe from 2010, has brought attention to the interplay of organizational factors contributing to these incidents (Kluge

& Frank, 2014). Some of these factors included training effectiveness regarding measuring skill retention (Kluge & Frank, 2014). Investigative reports for both events indicated small safety-related training programs such that many of the safety procedures were forgotten (MacKenzie, Holmstrom, & Kaszniak, 2007; Naderpour, Lu, & Zhang, 2014). Researchers suggested refresher or recurrent training in the form of distributed practice to counterbalance skill decay (MacKenzie et al., 2007).

Skill decay is also applicable to first responders such as emergency management personnel, police officers, firefighters, and disaster response teams alike. To analyze knowledge transfer and retention, Wener et al. (2015) deployed a internet-based collaborative training tool (ALIVE) that imitates the critical decision-making features of rescue operations. Skill retention measures the performance tests from the pre-training, post-training, and a delayed posttest (retention) two weeks after the simulation modules, Analyses of the results showed a decline in performance from post-training to preservation (Wener et al., 2015). However, the pre-training scores were lower than the retention scores, indicating significant retainment. These results suggested that given the decay of firefighter skills during nonuse, the distribution of practice was a significant factor in the design of firefighter training programs.

In addition to firefighting, skill decay is problematic in other emergent domains. For instance, training for incidents concerning scores of patients (mass-casualty events) requires complex interactions of cognitive and psychomotor skills (Risavi et al., 2013). Pre-hospital providers, such as EMTs, paramedics, and disaster response teams, experience prolonged periods of nonuse and deficient retraining. However, they are nonetheless required to perform a high standard of care when called. In a study on mass-casualty triage skill decay, Risavi et al. (2013) measured the attenuation of skills employed by emergency medical service providers with two performance intervals; an immediate posttest and a delayed post-test six months later. Findings indicated significant skill decay during long-term retainment intervals ($P<.05$) over time (Risavi et al., 2013). The calculations of this study recommend that there is a substantial declining effect caused by the sequence of training intervals.

In this study, I examined the degree of skill decay among fire ground commanders after completing a training program. Also, this study included an investigation of organizational and task-related factors that influence knowledge and skill decay in fire command officers, and how skill decay can be mitigated. My rationale for selecting skill decay theory was to help evaluate the relationship of these factors and how they affect skill decay among commanders.

Arthur et al. (1998) specifically provided several rationales for selecting skill decay theory to this study. First, skill decay is particularly salient when accomplished, or learned skills are needed after long stages of disuse (Arthur et al., 1998; Kluge & Frank, 2014; Wang et al., 2013). Command and company officers in the fire service may work for years without having the opportunity to perform their skills in managing a structure fire. Second, skill decay theory is applicable in situations where individuals and teams receive initial training in a massed format, yet they may not be required or provided the opportunity to integrate numerous short training sessions over lengthy time frames (Arthur et al., 1998). Command and company officers in the fire service are particularly vulnerable to skill decay because a majority receive little if any skill development other than their first fire training academy.

Finally, skill decay theory was appropriate in understanding and measuring the attenuation of cognitively complex decision-making skills; skills that FGC's demonstrate while managing a structure fire (Arthur et al., 1998; Klein et al., 2010). Empirical investigations suggested that these types of skills are particularly vulnerable to decay due to the organizational and task-related synergistic effects (Arthur et al., 1998; Arthur et al., 2007; Meador & Hill, 2011). For these reasons, skill decay theory was most applicable to my investigation of the magnitude of decline of fire ground IC decision-making skills.

Given that Arthur et al.'s (1998) is nearly 20 years old, a renewed analysis appeared applicable. Furthermore, this study expanded on Arthur et al.'s (1998) skill decay theory by examining the influence of organizational and task-related factors on the degradation of competencies formerly never tested in the fire service. To date, no studies examine the deterioration of complex cognitive skills used by FGCs.

Literature Review Related to Fireground Commanders

In this section of Chapter 2, I start with an analysis of the literature on command systems, focusing on operating systems utilized in the fire service. I then discuss the role of FGCs within those systems, followed by an analysis of firefighter line of duty death's (LODD's). Further in Chapter 2, I examine environments that FGCs work in, focusing on Naturalistic Decision-Making and Recognition-Primed Decision models. Finally, this section discusses simulation-based training and the essential functions of FGCs.

Different Types of Command Systems Used in the Fire Service

Regardless of size, all disasters and emergency incidents start locally. First responders from local police and fire departments are –in most cases the first to arrive on the scene and establish order at most often a highly dynamic, chaotic scene. To mold chaos into a manageable incident, a standardized response, will, in turn, produce standard outcomes (Brunacini, 2002). Standards assist in the communications by establishing pre-determined response capabilities, it also provides efficient resource allocation, response times diminish, and the preservation of life. These standards are communicated and mandated from the local, state, and federal levels, such as Incident Command System (ICS), National Incident Management System (NIMS), and the National Response Framework.

The command system represents an organizational agreement between the incident commander, who serves as the overall site manager of the event, and all responders on the scene, who agree to play their assigned roles and support the incident commander's plan. There are three basic types of command systems employed in the American fire service today. They are Incident Command System (ICS), National Incident Management System (NIMS), and the Incident Management System (IMS). In this first segment of the Literature Review, I examined each of these systems, and what they are designed to manage and the differences between them.

Incident Command System. The Incident Command System (ICS) originated in 1970 in the aftermath of a devastating wildfire in Laguna, California (Stambler & Barbera, 2011). In as limited as 13 days, a fire devastated 700 buildings, over one-half million acres scorched, and 16 people perished (Jamieson, 2005). Soon afterward, local, state and federal authorities developed a command system known as FIRESCOPE (Firefighting Resources of California Organized for Potential Emergencies). This system was later used to manage other large-scale disasters, including forest fires, floods, and earthquakes. It is also used to control the massive amount of resources required to mitigate these types of significant events. These incidents encompass vast geographical areas that incorporate several jurisdictions. They can last from weeks to months, need thousands of incident responders and include the use of federal and statewide resources.

National Incident Management (NIMS). The terrorist attacks on 9/11 was a catastrophic disaster that required a federally coordinated response with state and local agencies on a much larger scale than ever before. Thus, new government agencies, responsibilities, and policies followed. Congress passed the Homeland Security Act in the fall of 2002 resulting in an innovative federal agency, the Department of Homeland Security (DHS). DHS holds a cabinet position in the United States federal government led by a Secretary with 22 consolidated agencies and 40 distinct governmental entities (Sylves, 2014). Soon after 9/11, an independent bi-partisan commission (9/11 Commission) completed a comprehensive report describing the conditions surrounding the attacks, including preparedness and response analyses (Sylves, 2014).

The 9/11 Commission indicated the need for a national incident management system. In response, President Bush issued Homeland Security Presidential Directive-5 (HSPD-5). Under this directive, the secretary of homeland security is responsible for developing a National Response Plan (NRP) and a National Incident Management

System (NIMS) (Sylves, 2014). This plan combines all levels of government with emergency management functions and uses one universal command structure to manage domestic emergencies (Sylves, 2014). NIMS is like ICS, but with built-in expandability that can handle more massive catastrophic disasters like 9/11 or Hurricane Katrina. This single, combined approach to domestic incident management coordinates valuable resources that prepare, respond, and recover from terrorist attacks, large-scale disasters, and other emergencies (Sylves, 2014).

The National Response Plan has since been updated and is now called the National Response Framework (NRF) that incorporates the all-hazards approach. This improvement allows the Secretary of DHS the power to use "pre-declaration authorities" to move resources to the affected area (Sylves, 2014, p. 73). All Federal departments and agencies must now use the NIMS in their domestic incident management and emergency management functions. State and local agencies are mandated to adopt NIMS to qualify for federal grants that provide emergency management funding and other lucrative contracts (Sylves, 2014). The Secretary for DHS developed standards and guidelines for determining whether a State or local department has implemented NIMS (Sylves, 2014).

NIMS uses five event types: Type 1 activity involves large-scale operations that typically last weeks, if not months. At this level, a Type 1 overhead team manages the functions of command. Type 2 incidents are still considered large-scale federal events but entail a smaller management presence, fewer supplies and less time to bring them under control. Type 1 and two operations are supported and managed by federal resources. A state or federal agency requests Type 1 and Type 2 Incident management teams, which respond within 24 to 48 hours. These teams consist of members located across the country who are trained and certified as Type 1 or 2 overhead managers. Being approved in a role or position on Type 1 or 2 command staff or section requires years of training, evaluation for several different areas within the division, and being an active member of a team that has attended several deployments. Type 3 incidents are designed to manage resources on a statewide level. Based on local incident operations, Type 4 and five operations represent fire department incident activity (FEMA, n.d.).

As described in Table 1, local incidents pose distinct characteristics from those commonly associated with large-scale NIMS events (Brunacini, 2002). Regardless of size, jurisdiction, or classification, safety is everybody's responsibility. This responsibility includes ICs and their ability to recognize current, relevant, and accurate information to determine the most efficient strategy, create an incident action plan (IAP) that match event conditions and take control of an often-chaotic scene. This essential skill must be acquired and maintained by FGCs to manage safe and efficient hazard zone operations.

Incident Management System. The Incident Management System (IMS), also recognized as "*fire command*," was developed by Phoenix Fire Chief Alan Brunacini (Brunacini, 2002; Perry, 2003; Lindell, Perry, & Prater, 2005). IMS is a considerably scaled-down form of ICS, and it was created to manage NIMS Type 4 & 5 events—that everyday fast-moving, high-hazard incidents that constitute 99 % of all American Fire Service responses (Brunacini, 2002; Lindell et al., 2005; Perry, 2003). These include house, apartment and warehouse fires, hazmat incidents and motor vehicle accidents.

This system manages the local fire department resources needed to control and mitigate local events.

Table 1

Distinction Between NIMS Event Types by Brunacini (2002)

Major incidents: NIMS type 1, 2, and 3	Local incidents: fire command operations NIMS type 4 and 5
Compare with complex major military campaigns	Parallel small, yet violent street fights
Prolonged events lasting days to weeks with emphasis on planning and schedules	Compressed, simultaneous, decentralized incidents
Typically involve large geographic areas	Include relatively small and very hazardous geographic areas
Operations are more calculated, highly dependent on logistical support, and contingent on weather conditions	Involve IDLH environments requiring hazard-zone accountability responsibilities such as: • Staying together as a company • Always maintaining the capability to exit the hazard zone • Not working past any crew member’s expected air supply • No Freelancing
Direct bureaucratic involvement in the incident organization with shared responsibilities for the event	Involve rapid, decentralized, and sequential phases within the jurisdiction of one or two agencies where a primary focus is on establishing command and keep those working in the hazard zone (IDLH) safe

Typically, the operational period for NIMS Type 4 and five events ranges from 10 minutes to a couple of days. The primary goals of an IMS are to maintain initial and ongoing firefighter safety and to coordinate all command and operational actions used to control the incident hazards. In short, an IMS exists to solve the customer's problem while ensuring all responders' safety. Regardless of IC systems, firefighters continually die while operating on the fire ground. This continuation suggested that the training policies themselves warranted further review.

The Incident Management System (IMS) and the role of the Incident Commander. When firefighters reached the scene of a fire, someone must assume command of the incident (IC), quickly assess the situation using standard event factors, and implement a plan to mitigate the hazards involved. Depending upon the department's Standard Operating Procedures, this individual is typically the first arriving unit and fire captain. It is essential for the IC to demonstrate knowledge and skills to conduct a rapid size-up and interpret critical factors into a communicated plan that provides command and control (Brunacini, 2002). This policy must reflect the overall strategy for managing the incident that allows for effective decision-making and a safer event scene (Brunacini & Brunacini, 2004). This responsibility can be extremely challenging when the amount of initial information is limited; resources are scarce, and time is of the essence because lives are in danger.

Fire ground commanders are considered local ICs that face unique challenges, unlike large-scale NIMS operatives. FGC's manage hazard zone operations in smaller fast-paced environments and control the deployment of assigned resources in IDLH conditions. IDLH is a denomination used by the National Institute for Occupational Safety and Health (NIOSH) as criteria for a dangerous atmosphere that contains concentrations of toxic, corrosive or asphyxiate substance that immediately threatens life (Centers for Disease Control and Prevention [CDC], 2014). An IDLH environment also produces permanent or delayed ill side-effects or restricts an individual's capacity to flee from a harmful situation (CDC, 2014).

Firefighters assigned to the interior, roof operations, or just outside a structure fire are in an IDLH atmosphere and are operating in the hazard zone. While working in a hazard zone, firefighters are required to use a self-contained breathing apparatus (SCBA) with a complete facepiece providing positive pressure air supply (CDC, 2014). SCBAs reduces their exposure to a variety of toxins that are quite dangerous. When FGCs assign companies to critical operating positions, it is imperative to consider the time it takes to get them into place and allocate the right amount of resources in the work area.

In a recent study by Underwriters Laboratories (UL) Firefighter Safety Research Institute (FSRI), scientists sampled a variety of chemical compounds from within a structure fire (Horn, Kerber, Fent, Fernhall, & Smith, 2016). Results disclosed hydrogen cyanide readings seven times the IDLH exposure limits and benzene levels 15 times higher (Horn et al., 2016). Based on these results, the dangers associated are clear. The supply of air firefighters take into the hazard zone on their backs dictates how FGCs manage and deploy these units in the hazard zone (Brunacini, 2002). FGCs must base their operations on realistic working times, which typically lasts an average of 16 minutes and 30 seconds when breathing air through an SCBA (Brunacini, 2002). Thus, an average firefighter work cycle is 10 to 12 minutes, keeping in mind that a crew needs a 25 % air reserve to exit the structure (Brunacini, 2002) safely. It is the FGCs duty to assign enough resources to critical tactical locations in a timely manner to avoid companies from exhausting their safe air reserves.

When confronted with decision-making in these dangerous conditions, FGCs must rely on previously acquired knowledge and experiences for safe decisions. However, due to enhanced fire-safety features like fire alarms and sprinklers, there has been a consistent nationwide decrease in structure fires (USFA, 2014). Thus, FGCs gradually obtain less practical experience, and therefore lack of intuitive knowledge and skills (Fiedler, 1994). FGCs typically experience extended nonuse periods following the initial training, further provoking the vulnerability of FGCs and the dangers that lie. Fire agencies need to incorporate a far-reaching approach to FGC training to sustain the skills that are necessary to remain proficient. What remained unexplored was what constitutes an effective incident command training program. Regardless of which IC system is used and the types of training that are currently provided, firefighters continually die while operating on the fire ground. This outcome suggested that the training policies themselves warranted further review.

Firefighter Line of Duty Deaths (LODDs)

Regardless of improved technology, equipment, and a continual decline of structure fires over the past ten years, nearly 100 firefighters are killed in the line of duty every year (USFA, 2014). Also, over 80,000 fire ground injuries occur in the United States. This total is greater than any other industrialized country (Kunadharaju et al., 2011; USFA, 2014). Concerted efforts to reduce firefighter LODD is admirable, but the results have not significantly improved.

Each year the National Fire Protection Agency (NFPA) obtains data from the United States Fire Administration (USFA) and conducts a report on firefighter deaths in the United States; the 2013 annual report is the latest publishing. This report is broken down into a multitude of variations including the broad term of a firefighter. There are career and volunteer firefighters, full-time public safety officers as firefighters, law enforcement, state, territory, and federal government fire service members, plus wildland and privately funded firefighters. For this study, the term firefighter refers to career firefighters as those working full-time for public municipalities rather than for private, State, or federal government positions. What constitutes as an on-duty death comprises of any harm or illness endured while on duty that proves fatal (USFA, 2014). The type of function performed when the firefighter dies also categorized including fire ground operations, kind of fire ground activity, fixed property used for structural firefighting deaths, responding/returning, training, non-fire emergencies, and after the incident categories (USFA, 2014).

In 2013, 106 firefighters perished while on duty, an increase of 24 firefighters from 2012 (USFA, 2014). Of those 106 LODDs, 55 firefighters were killed during fire ground operations, while 27 perished at the scene of a structure fire (USFA, 2014). The report goes even further and displays the types of fire ground actions in which firefighters were involved at the time of death. The leading cause of fatal injury was sudden myocardial infarction, commonly known as a heart attack (USFA, 2014). However, the numbers and categories can be misleading.

Under the construct of heart attacks, of those 106 firefighters that died while on duty, 36 firefighters died from heart attacks (USFA, 2014). The phrase “cause of injury” denotes the action, lack of action, or circumstances that directly resulted in the fatal wound (USFA, 2014, p.12). The phrase “nature of injury” denotes the medical cause of the fatal injury or illness, which relates to the physiological cause of death (USFA, 2014, p.12). For example, the “cause” may be a lost or disoriented firefighter inside a burning building, but the “nature of injury” results in a heart attack, even though the death did occur at the scene of the structure fire. As an aggregate, sudden cardiac death accounts for the most significant share of the on-duty deaths (36 deaths, or 56 %) (Fahy et al., 2016).

Another program that collects and shares firefighter data is the National Fire Fighter Near-Miss Reporting System, a reporting system created by the International Association of Fire Chiefs (IAFC). A near miss event defines an unintentional, unsafe occurrence that could have resulted in an injury, fatality or property damage (National Fire Fighter Near-Miss Reporting System [Near-Miss], 2008). Based on 590 reports received in 2008, the most significant contributing factors were situational awareness (285) or decision-making (246) (Near-Miss, 2008). Understanding the decision-making process firefighters make designing a training program to improve those decisions may eradicate the fatal and costly mistakes that cause injury, death, and unnecessary fire losses in the local response area.

Further studies from Firefighter LODDs show that fire officers do not receive suitable training and they also did not have the understanding needed to recognize dangerous fire ground hazards (Standridge, 2012). The greatest recurrently cited references in multiple independent investigative reports by the National Institute for Occupational Safety and Health (NIOSH), the National Fire Fighter Near-Miss Reporting System, and the USFA pertains to poor incident command decisions (Kunadharaju et al., 2011). The trouble is that ICs make critical assessments on the fire ground because of inadequate training and knowledge (Hamins et al., 2012; Klein et al., 2010). What is not known is how often training should be provided to reduce the magnitude of skill decay.

There will continually be an inherent risk in firefighting. It is a dangerous occupation that requires a high level of individual strength, agility, and cardiovascular endurance as well as having to make critical decisions under extreme time pressure. Supporting a high level of physical fitness keeps firefighters safe. Preserving a prominent level of cognitive skills once they are acquired can also keep firefighters safe. One way to improve firefighter survivability is not only to learn safe and practical skills but to maintain those skills and make correct decisions. Firefighter survivability can be accomplished by creating efficient as well as robust training systems; an operational training system that is designed first to instruct and then certify FGCs hazard zone operations. However, learning needs to be enduring such that FGC's remain proficient in their skills, particularly during extended periods of nonuse.

Naturalistic Decision-Making

The term naturalistic decision-making, or NDM, first appeared in 1989 when a group of scholars began to research how qualified people make decisions in their natural environments or in simulations that mirror their physical surroundings (Zsambok & Klein, 2014). Traditional models of decision-making are laboratory-based and contrast with NDM approaches along various measurements. These dimensions include time pressure, expertise, and the severity of consequences when poor decisions are made (Klein et al., 2010).

The study has demonstrated that established models of decision-making do not consider many severe characteristics of natural settings that are faced by fire ground commanders (Klein et al., 2010). Instead, Klein et al. (2010) discovered that FGCs make decisions by matching prototypical scenarios from experience. After a sequence of reports examining fire ground commanders, Klein et al. (2010) formed a recognition-primed decision (RPD) model of naturalistic decision-making that demonstrates how people can use the experience to circumvent some of the restrictions of methodical plans. Klein et al. (2010) asserted that in real-world situations, people could make choices short of having to compare options by weighing the circumstances to create a plan of action and then practices perceptual reformation to determine what course of action (Klein et al., 2010). For example, most career firefighters that work for some vast metropolis encounter hundreds if not thousands of house fires throughout their career.

When responding to a fire, firefighters perform a quick scene size-up and identify essential fire ground factors, such as the size the building, the fire itself, and the smoke conditions, like black, brown, and white colored smoke, and pressure of the smoke pushing out of the building. Experienced firefighters characteristically encounter these types of conditions and categorize them as “typical.” So, when firefighters complete a scene size-up, the IC matches the perception as a prototype with an incident action plan or some course of action. However, the ability to recognize event types through a process of socialization may be a challenge for new ICs.

The problem today is the young or inexperienced are unexposed to enough standard conditions to build and reinforce the foundation for that connection (Perry et al., 2012; Standridge, 2012). The dilemma becomes even more substantial when the IC makes poor decisions because the operating procedures are antiquated and purely based on personal observation and opinions (Groenendaal & Helsloot, 2016; Rake & Njå, 2009). Without this ability, FGCs are in no position to take command, even less maintain, firefighter safety. Being qualified to take command is a lot different than being highly capable of managing a fire ground. Nevertheless, recognition decision-making is more likely when people with added experience make conclusions and work under natural conditions (Klein et al., 2010). The challenge then is to design training programs so that FGCs can acquire and retain the necessary skills to manage the fire ground safely. To date, there are no empirical studies measuring performance degradation utilized by FGCs.

The necessity for more inquiry in this area becomes most striking as the United States fire service fights to supply leadership ranks emptied by a growing amount of retiring Baby Boomers (Standridge, 2012). The deficit of leadership creates a void in knowledge and experience that is essential for cautious and competent operations

(Standridge, 2012). In a career where valid and reliable decisions are developed primarily through acquired knowledge and practice, this gap becomes challenging in these high-risk settings that are often met by firefighters (Klein et al., 2010; Standridge, 2012). It is unavoidable upon today's fire service leaders to provide training that not only safeguards a high standard of safety for fire department members, but also safe, effective, and fiscally responsible. An ideal training program may include a combined approach that contains cognitive, knowledge, and evidence-based curriculum with manipulative skill enhancement capabilities through simulation exercises (Sinclair et al., 2012; Williams-Bell et al., 2015). Current studies show that it is undetermined how successful the training efforts of local government organizations are (Sinclair et al., 2012). Understanding the decision-making process firefighters make and designing a training program that includes advancements in science may eliminate the fatal and costly mistakes that cause injury, death, and unnecessary fire losses in the local response area.

Simulation-Based Training

The most conventional incident command development approach is through practical experience and formal training (Standridge, 2012). However, preparation requires a significant investment of resources and time. Based on a 2014 report by the Association for Talent Development, organizations continued to show their commitment to employee learning, making sound investments in education programs. On average, U.S. organizations spent $1,299 per employee on training; an increase of 1.7 % from 2013 (Miller, 2014). The usual number of training hours used per employee also rose from 31.5 hours in 2013 to 32.4 hours in 2014 (Miller, 2014). A prioritized investment in training is of particular importance in high-risk domains such as the fire service, where company and command officers work and manage in IDLH hazard zones. Everything on the fire ground takes place simultaneously, and the management process is enormously unforgiving (Brunacini, 2002). Simulation-based training can prepare FGCs to meet the needs of its members and its organization.

Former routines and lessons acquired are vital assets and suggest a useful way to assess where the hazard is now and forecast where it is heading. If ICs have seen the actual circumstances in the former and set up a strategy to counter those situations, they can predict the result of those activities if they were to use them another time. An accomplished IC will equate former repetitions to current conditions to evaluate where the danger is and predicted to lead the event (Brunacini, 2002.). Per Klein's naturalistic decision-making model, decision methods should be observed "in situ," but this is unrealistic for new events that are erratic and challenging (Alison et al., 2013, p. 256). Because training encompasses the growth of individuals' practices, expertise, and skill sets under protected surroundings, simulation-based training (SBT) offers a secure and adequate substitute for individuals to learn (Alison et al., 2013). In substitution for dangerous environments, SBT practices are employed to instruct individuals and expose them to accurate surroundings while managing multifaceted choices (Alison et al., 2013). SBT findings have found to offer team skills, ability, efficacy, and performance for firefighters, police officers, and the military (Sotomayor, 2010; Vickers & Lewinski, 2012; Vogel-Walcutt, Gebrim, & Nicholoson, 2010; Williams-Bell et al., 2015).

With current influential environmental factors such as the economic characteristics associated with fiscal restraints, budgetary reductions, and political pressures to reduce spending, training programs need to be durable and efficient (Thatcher, 1998). However, firefighter training can be costly and dangerous, exclusively when joined with live-fire drills. With more stresses on financial accountability and the interest in fire ground safety, there is a restored awareness in the significance of computer-based IC simulation instruction (Sinclair et al., 2012). Computer-based replications offer a protected, more cost-efficient substitute than live burns (Bayouth et al., 2013). When considering influential factors on skill decay, experiential learning and the spacing of education has shown to have a positive effect (Cepeda et al., 2006; Klein et al., 2010; Kolb, 1984).

Experiential Learning

An important consideration when examining skill decay among FGCs is to understand the learning process and how firefighters typically acquire knowledge and expertise within the fire service domain. Traditionally, learning within the American fire service has revolved around on-the-job experience, lecture-based classroom instruction, and a variety of hands-on training programs such as live-fire training evolutions (Wener et al., 2015). Entry-level firefighters assigned to a training academy learn basic firefighting methods, emergency medical services, building construction, salvage operations, physical fitness and associated wellness topics to prepare for employment as a firefighter. This process typically lasts 5-6 months and includes some form of traditional classroom activity, while much of their time they spend on hands-on training; a characteristic of the experiential learning process (Kolb, 1984).

The science of experience-based learning is rooted in Kolb's (1984) experiential learning theory (ELT), who described it as a progression of producing understanding during the conversion of experience. This process includes the combination of "grasping experience-Concrete Experience (CE) and Abstract Conceptualization (AC)-and transformational experience-Reflective Observation (RO) and Active Experimentation (AE)" (Kolb & Kolb, 2005, p. 194). That is, if learners are to be effective, they must be able to engage in new experiences, reflect and explain that experience, then finally, apply what was learned to solve problems and make decisions (Kolb, 1984). Regarding the fire service, problem-solving and decision-making describes what firefighters do.

Experiential learning theory supports the naturalistic decision-making environment in which ICs operate. Naturalistic decision-making environments are fast-paced and unforgiving, where ICs make 80 % of their decisions in less than one minute (Klein et al., 2010). Consequently, ICs make decisions based on recognized patterns from previous firefighting experiences known as the recognition-primed decision-making theory (Klein et al., 2010). For example, when an IC takes command, they simultaneously perform a size-up and identify the incident's essential factors, declare the incident strategy, then apply and execute an incident action plan that attends to those factors (Brunacini, 2002).

Recognition-primed decision-making theory is grounded in empirical research into fire ground operations to describe decision-making among FGCs (Klein et al., 2010).

Recognition-primed decision-making generally referred to as intuition centers on the ability to recognize and respond to situational cues and choose an approach that worked satisfactorily in the past (Groenendaal & Helsloot, 2016). Although RPD is a useful decision-making approach, this strategy can become problematic for those who are inexperienced or have less depth on which to draw. Recognition-primed decision-making thus underscores the magnitude of developing a high degree of experiential learning through practical experience.

While hands-on experience is a primary source of learning and development in the fire service, it comes with costly, dangerous, and sometimes fatal repercussions. For example, researchers at the National Institute of Standards and Technology (NIST) report that the annual cost of sustaining U.S career fire departments is approximately $40 billion (Hamins et al., 2012). Researchers also reported a 10-year study on firefighter fatalities and injuries, showing 108 firefighters perished while involved in training during that time, of which 13 firefighters (12%) died during live fire training (Fahy, 2012). While practical experience as an IC offers the opportunity to expose commanders experiential learning opportunities created at fire incidents, leaders in the fire service must find safer, more cost-effective alternatives to promote experiential learning and negate skill degradation.

Spacing of Practice

Another critical variable for the research study is the spacing of practice. Research on learning and the effects of spacing date back to over a century ago when Ebbinghaus (1885) discovered greater performance in long-term memory when training sessions were spaced apart in comparison to massed practicing without spacing. This form of spacing is known as distributed practice and has been widely researched for many years (Arthur et al., 1998; Arthur et al., 2007; Carpenter, Cepeda, Rohrer, Kang, Pashler, 2012; Cepeda et al., 2006; Cepeda et al., 2008; Cepeda et al., 2009; Delaney, Verkoeijen, & Spirgel, 2010; Donovan & Radosevich, 1999; Karpicke, & Bauernschmidt, 2011; Kluge & Frank, 2014; Kluge et al., 2015). The spacing of practice is a critical factor when examining skill degradation because it has shown to affect learning (Arthur et al., 2010; Bjork, Dunlosky, & Kornell, 2013). The spacing of practice refers to the relative time between training intervals in the form of massed or distributed practice conditions (Cepeda et al., 2008).

When a measurable time interval exists between training sessions, learning is spaced or distributed (Cepeda et al., 2006). In contrast, education is massed when the topic under study is not subjected to intervening items or intervening time periods (Cepeda et al., 2006). For example, when teaching FGC's eight primary functions of command, each function can be broken into separate training modules demonstrating distributed practice or the eight functions can be delivered all at once, thereby representing massed practice.

In general, research shows that massed practice is less effective than spaced or distributed method in enhanced memory (Arthur et al., 2010; Cepeda et al., 2006; Kluge et al., 2015; Kluge & Frank, 2014). However, stipulations to this effect include task complexity and cognitive demands (Arthur et al., 2010). For instance, Cepeda et al.'s (2006) retention study examined spacing effects for simple tasks that involved memorizing short word lists using a 10-day and six-month RI. For the 10-day RI, Cepeda et al. (2006) found that performance improved on the final recall test as the ISI increased from 15 minutes to one day, but then decayed when the ISI was higher than one day. The six-month RI showed an increase of performance up to a one-month ISI before diminishing (Cepeda et al., 2006). Similarly, Donovan and Rodosevich (1999) demonstrated that longer ISI's for simple tasks declined as the complexity of the tasks increased. Results from these studies suggested that skills for simple tasks reduced less under massed practice conditions, while spaced or distributed effects produced greater decay for simple tasks. They also demonstrated that spaced learning is a shared function of the ISI and the RI.

The spacing effect has also been established using sophisticated skills; skills that FGCs demonstrate while operating on the fire ground. Skills that are complex require greater cognitive demands that involve information processing, problem-solving, sense-making, and decision-making (Arthur et al., 1998; 2010; Kluge & Frank, 2014; Kluge et al., 2015). Farr (1987) discovered that the degree of task complexity, whether it is forced or intrinsic by the learner, appeared to have the most significant effect on the acquisition and long-term retention. Still, little is known about how complex cognitive skills employed by FGCs decay after training. This study tried to address this gap by examining FGC's skills after completing an SBT program.

Nonetheless, there are voids in the literature to clarify the association concerning IC simulation instruction, decision-making, and skill decay (Young, Gibson, Partington, & Wetherell, 2013). There is an innate absence of clarity about the associations between computer-based IC instruction standards, the degradation of those skills once obtained, and firefighter safety (Bayouth et al., 2013; Kunadharaju et al., 2011. To address this gap, I used the research question to guide my study: After Incident Commanders complete a curriculum-based simulation training program on fire ground command, what factors contribute to skill decay?

Summary and Conclusions

I presented significant themes in the reviewed literature in Chapter 2 which included substantial organizational and task-related features that impact skill decline and preservation, operational systems utilized in the fire service, environmental factors from which FGCs operate in, Firefighter LODDs, and IC training. Studies have shown several factors affect skill decay to include the duration of the retention interval, degrees of overlearning, testing methods, conditions of retrieval, experiential learning, and the spacing of practice (Arthur et al., 1998; Cepeda et al., 2008; Farr, 1987; Haist et al.,1992; Mulligan & Peterson, 2014; Sharif et al., 2014). However, the relationship between organizational factors and the decay of complex cognitive skills correctly used by FGCs was unknown. This study helps fill this gap in the research by examining the variation in the number of actual incidents as FGCs and the impact of those experiences on their ability to complete a skill assessment.

The early studies regarding skill retention and forgetting served as a foundation from which to investigate the degradation of complex cognitive skills employed by FGCs. Studies in the field of human factors and naturalistic decision-making have recently begun to examine the attenuation of cognitively complex decision-making skills in emergent domains (Risavi et al., 2013; Wener et al., 2015). The frequency and duration of IC training are unknown in the growth of people's understandings, comprehension, and skill sets. Proficiently designed simulation-based training programs can develop less-experienced Incident Commanders while sustaining the skills acquired by experienced ICs through refresher interventions. Determining if a relationship exists between organizational factors and the reduction of FGC skills fills the void that currently exists in the literature on skill decay.

In Chapter 3, I present the study design for the current analysis and the rationale for choosing a quantitative approach. I will further expand on how the theory of skill decay will bridge the gap between the retention of complex cognitive skills, FGC performance, and training analyses. The methodology for this study is comprehensive to include the target population, the rationale, and procedures for sampling, development of the instrument to gather the data, ethical considerations, as well as operational definitions of all variables.

Chapter 3: Research Method

This study was designed to measure skill decay among fire ground commanders (FGCs) based on the number of incidents after completing training. FGCs are vulnerable to skill decay for several reasons. First, FGCs receive little if any skill development other than their first fire training academy (Arthur et al., 2013). Second, FGCs use complex decision-making skills when managing a structure fire. Researchers have shown that a significant reduction in performance occurs on prepared or learned cognitive skills after a period of nonuse (Arthur et al., 1998; Farr, 1987; Wang et al., 2013). Finally, FGCs are susceptible to skill decay given the reduction of fire incidents and the lack of opportunity to retain the skills necessary to remain competent (Lamb et al., 2014).

The current study filled gaps in the literature regarding FGCs experience and skill decay. Deficiencies needing further examination given the limited amount of research on the decline of cognitively complex skills used by incident managers when managing a hazardous incident. I addressed this gap by implementing a quantitative, nonexperimental survey design and multiple linear regression analysis of data from nationally certified fire department company and command officers.

In Chapter 3, I present the research question and hypotheses, research design and rationale, data collection methods, population and sampling techniques, and procedures for recruitment and participation. Additionally, I discuss the instrumentation, threats to validity, and ethical considerations.

Research Question and Hypotheses

The research question studied in this analysis was as follows: After incident commanders complete a curriculum-based simulation training program on fire ground command, what factors contribute to skill decay?

The following hypotheses were used to address the research question:

$H_0 1_a$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and experience as an incident commander.

$H_1 1_a$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and experience as an incident commander.

$H_0 1_b$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and the amount of drilling and training opportunities (overlearning).

$H_1 1_b$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and the amount of drilling and training opportunities (overlearning).

$H_0 1_c$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and the number of overall years of experience in the fire service.

$H_1 1_c$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and the number of overall years of experience in the fire service.

$H_0 1_d$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and the amount of time since initial training.

$H_1 1_d$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and the amount of time since initial training.

Research Design and Rationale

Adopting a postpositive worldview, I used a cross-sectional survey design to examine the degree of skill decay among FGCs. The primary independent variable was experience, which was defined as the number of incidents (working fires) after completing training. Secondary independent variables included (a) drilling and training opportunities, (b) overall years of experience, and (c) time since initial training. The dependent variable was skill decay for FGCs, which represented a decrease in performance on trained or acquired knowledge and expertise after a given period. Sex, age, attention/motivation, relevance, and education were included as control variables that affected the participant’s performance separately from the independent variables.

A quantitative methodology was appropriate given the nature of the research question, gaps in the literature, and the need to define factors that influence an outcome. The nature of my research question was quantitative because I was investigating the relationship between variables: primarily field experience and skill decay. A quantitative approach was needed to address a void in the literature by measuring complex decision-making skills of FGCs (Arthur et al., 2013; Wang et al., 2013; Young et al., 2013). A quantitative approach is appropriate when researchers examine influential factors and relationships among variables and outcomes (Creswell, 2013). A cross-sectional survey design involving inferential statistical analysis is the appropriate mode of data collection and analysis to test whether a familiar pattern grounded by evidence is discernable in the data (Frankfort-Nachmias & Nachmias, 2015).

By employing a holistic approach in designing this quantitative study, I considered multiple aspects of creating a system for collecting and analyzing data. In doing so, I selected an online survey design that addressed the study's purpose and research question while evaluating time and cost restraints (see Sue & Ritter, 2011). The advantages of using an e-mail survey design for this study included efficiency, economy, convenience, and simplicity (see Sue & Ritter, 2011).

The target population for this study included approximately 16,000 certified fire department officers who function as incident commanders supervising and managing fire ground operations for local NIMS Type 4 and Type 5 events. An e-mail distribution list was provided by administrators of the training program so I could send the survey to hundreds of participants (see Sue & Ritter, 2011). Replies were received swiftly through Google Forms, and data were downloaded for further examination (see Creswell, 2013). Efficiency, or the speed with which members of the target population are sampled, provides the researcher with a good rationale for choosing an e-mail survey design (see Sue & Ritter, 2011).

Compared with traditional data collection methods such as paper questionnaires, telephone calls, and postal mail, e-mail surveys are relatively inexpensive to carry out (Sue & Ritter, 2011). The costs of printing and postage, not to mention the clerical time for processing, can be substantial. Online surveys are less expensive to create and require less time and effort to produce (Fowler, 2013). Also, survey software like Google Forms converts all form data into Excel spreadsheets and analytical graphs.

An e-mail survey was convenient because it allowed me to create a familiar-looking measurement tool. The targeted respondents were certified fire department officers who completed an online training program. This program incorporated simulation videos and multiple-choice questions to evaluate incident commander skills for fire ground operations. The measurement tool for this study included streaming video and multiple-choice questions to measure skill performance.

The use of simulations offers interactive features that enhance the critical fire ground factors (Sue & Ritter, 2011) and expose incident commanders to realistic environments while making difficult decisions (Alison et al., 2013). Additionally, e-mail surveys are desirable when the sample size is substantial and broadly dispersed geographically (Sue & Ritter, 2011). E-mail surveys can include video content to accurately measure a large group of incident commanders and their skills in realistic fire ground environments.

The survey instrument used in this study was Google Forms, an online software that is user-friendly and includes tutorials and step-by-step instructions. A link to an electronic survey using Google Forms software was sent out to the targeted participants. Data were then collected and tabulated using this software.

Although e-mail survey designs can be useful, researchers must also recognize limitations when choosing this data collection technique (Sue & Ritter, 2011). A significant limitation of the study was the technological knowledge or skills necessary to create a digital survey that incorporates structure fire simulations with multiple choice questions. A private consultant with fire command and simulation design expertise assisted me in creating the survey link. Also, administrators of the Incident Command Certification Program own the e-mail list of certified incident commanders. Permission to access the file of certified incident commanders was limited. Therefore, I depended on leadership in the training program to assist in the creation and distribution of the digital survey.

Other resource constraints in the design included additional investments in time and money necessary for different survey designs. A longitudinal study addressing the effect of simulation-based training and field experience using a long-term retention interval would have required grant funding to offset the cost. Several studies, such as Villado et al. (2013) and Healy et al. (2013), addressed skill decay among paid participants and required financial support through grants such as the Navy Personnel, Studies, and Technology (NPRST) or the Army Research Institute. These support mechanisms were not available for the current study; therefore, a more cost-effective means was identified.

I employed a quantitative, cross-sectional survey design with a multiple regression analysis. Cross-sectional designs are widely used in social science research, including survey research (Frankfort-Nachmias & Nachmias, 2015). A cross-sectional design was suitable because the participants were measured at a particular moment in time (see Osborne, 2008). From an existing list of certified incident commanders, a one-shot measure was conducted to examine the relationship between skill decay and field experience (see Kumar, 2014).

This design was also appropriate due to the functional nature of the variables investigated (Frankfort-Nachmias & Nachmias, 2015). For example, I examined skill decay as a function of actual field experience as an independent variable. Linear regression analysis applies to functional relationship variables (Schroeder, Sjoquist, & Stephan, 2016). Thus, I used a multiple linear regression analysis as a control mechanism to determine the functional association between various variables.

The use of multiple regression analysis was prevalent for this research due to the statistical advantages when examining skill decay. Skill decay literature indicated numerous organizational and task-related factors influence skill decay after training (Arthur et al., 1998; Kluge & Frank, 2014; Villado et al., 2013; Wang et al., 2013). Multiple linear-regression can measure the connection among numerous variables while controlling the effect of others (Frankfort-Nachmias & Nachmias, 2015). For example, Wang et al. (2013) conducted a multiple regression analysis to examine the particular effect of each moderator variable on decay. The study indicated that deterioration was primarily associated with the extent of disuse or neglect and cognitive demand (Wang et al., 2013). A multiple linear regression analysis conducted by Cooke, Gorman, Duran, Myers, and Andrews (2013) showed an association between team performance decay and team coordination rather than individual task performance. Thus, a quantitative, cross-sectional design with a multiple-regression analysis was consistent with previous models established by researchers.

The objective of this study was to advance knowledge on critical issues related to skill decay and the fire service. The usefulness of quantitative modeling was established for this research because it allowed the researcher to measure skill decay in association with some other form of a variable. The design choice afforded me the opportunity to advance scholarly knowledge by testing skill decay theory in different settings and with diverse populations.

Methodology

The methodology of the analysis was founded on the research question, resource constraints, sample size, and access to the targeted population under review. Frankfort-Nachmias and Nachmias (2015) define population as a complete set of relevant units of analysis. In simpler terms, population represents a group that researchers want to conclude (Babbie, 2002). The target population for this study included 16,000 certified fire department officers. This particular training program is an internationally recognized certification program for fire officers who serve in the role of Incident Commanders that supervise and manage fire ground operations for local NIMS Type 4 and Type 5 events. I intentionally selected this system because it is the only third-party accredited command training and certification program.

The American fire service has no regulation or governing body that evaluates firefighting methods and practices as they apply to structural firefighting. Each fire department's approach to structural firefighting is unique. Moreover, within each fire department, every battalion and shift do it their way. This philosophy does not exist in the air transportation, auto, or EMS industries. For instance, the credentials for certified paramedics are based on science, are accredited, and have reciprocity capabilities nation-wide. However, there are no nationally recognized standards for fire ground commanders, and therefore, do not have reciprocity skills. As a result, every fire department manages a fire ground differently. This training program is the first to standardize and certify fire department officers who operate in the position of Incident Commander that supervise and manage emergency and hazard zone operations for every day, local NIMS Type 4 and Type 5 events (bshifter, 2015). Moreover, this training program is a comprehensive operational system based on empirical evidence over the past 130 years as to what effective incident operations look like (bshifter, 2015).

Sampling and Sampling Procedures

The sampling strategy was based on a convenience sample of fire department officers that are certified fire department officers. Convenience samples are "nonprobability" samples without the use of random choice measures (Sue & Ritter, 2011, p. 43). Unlike probability sampling, social scientists often use nonprobability or convenience sampling when reliance characteristics exist (Babbie, 2002). The design of this study relies upon leadership within the training program to offer an e-mail list of the population members. This list provided a sampling frame to draw my sample (Sue & Ritter, 2011).

Convenience sampling is also proper when potential respondents can self-select into the sample (Sue & Ritter, 2011). In this case, respondents under study freely took part in the survey. Furthermore, the sampling frame from which to draw from restricts those who are Company Officer rank or higher and have successfully obtained their first training certification within the last three months. Because these parameters disqualified individual members in the targeted population, the population of the nonprobability sample was qualified or restricted (Frankfort-Nachmias & Nachmias, 2015). Therefore, a nonprobability convenience sample was best suited for this study.

In social science, the margin of error and the level of confidence decides how precise a sample represents a population (Sue & Ritter, 2011). When using nonprobability sampling, no statistical formulas exist since it is impossible to calculate the probability of any specified participant selected for the sample (Sue & Ritter, 2011). However, if a researcher uses nonprobability sampling, methodologists recommend "rules of thumb" or ad-hoc, non-statistical methods (Daniel, 2011, p. 243). Typical sample estimates are 95% for confidence levels and a 5% margin of error (Fowler, 2013).

To date, the training program has certified 16,000 fire department officers who serve in the role of Incident Commander that supervise and manage fire ground operations for local NIMS Type 4 and Type 5 events. Per Raosoft (2004), the sample size calculator indicated ensuring a confidence level of 95% with a 5% acceptable margin of error, 376 surveys from the population of 16,000 certified officers needed to participate. A reasonable rate of response at 30% (Taylor-Powell, 1998) was calculated to ensure at least 376 surveys were returned. In this manner, I began with a sample of 1,253 surveys to safeguard for nonrespondents. Of those 16,000 certified officers, a randomized list of 1,253 officers was generated through Excel where each participant was then assigned a distinct number.

A time-based sampling frame was utilized to recruit the certified incident commanders in this study. The anticipated period was three weeks or until 376 surveys were collected. Follow-up correspondence was transmitted to the randomly assigned participants after two weeks to thank each member for their participation and to remind those who had not taken part to complete the survey. If an increase of the involvement was necessary at the end of three weeks, I generated a new list of randomly selected participants until 376 surveys were collected. Participants from the second list were crosschecked to prevent repeated participation.

Recruitment of Participants

Arrangements were made with training program leadership for access to certified ICs using a list of e-mail addresses secured from within the program. The e-mail included the consent form and the survey link. The survey was administered directly to fire company officers and commanders through a web-based survey host Google Forms. Each participant was provided an implied consent form located in Appendix D by e-mail.

The survey took about 30 minutes to finish, and the data was assembled by Google Forms survey software. Completed survey responses went directly to Google

Forms, and the data was automatically organized into a CSV format to export to SPSS 23 (IBM Corp., 2015) for statistical analysis. Participants exited the study by clicking the SEND button located at the top of the surveys. A follow-up e-mail was forwarded to the population after five days from the original date that I sent out the survey to thank each participant and to remind those who had not participated in completing the study.

Pilot Study Protocol

To test the validity, reliability, and internal consistency of the researcher-generated surveys, I employed a pilot study before the primary research. Extant literature suggested that a pilot study sample should be 10% of the sample size used for the primary research (Connelly, 2008). However, for internet survey research, Hill (1998) proposed a range of 10 to 30 participants as a proper sample for a pilot study. Nevertheless, Julious (2005) suggested a minimum of 12 participants in deciding a confidence interval. Accordingly, I included a convenience sample of 12 company and command officers employed in the fire service to take part in the pilot study. First, I approached each potential participant in person to ask if they would take part in the study. Officers that voluntarily agreed received an e-mail that included a consent form with clear explanations describing the purpose, importance, and potential risks involved. I then directed a linkage to the online study through Google Forms to those contributors that voluntarily chose to participate.

The pilot study also established sufficiency by verifying the performance of the survey. The pilot study confirmed if the survey link reached the intended participants and not filtered into junk e-mail files. After the pilot study was complete, I asked for feedback from the participants to verify ease of use and to hear if the instructions and questions were clear and concise.

Instrumentation

I designed the survey instrument into three segments: an operational performance section, a section about operational factors affecting decay, and demographics. The operational performance section employed a computer-based simulation of a typical structure fire in conjunction with a multiple-choice questionnaire. This part of the survey measured skill decay as a performance outcome of participants as FGCs while managing the simulated incident. I developed the operational performance section with the help of an experienced webmaster (see Appendix A). The basis for developing an original survey instrument was the lack of previous research regarding the decay of cognitively complex skills used by FGCs while managing a multifaceted hazardous incident. Moreover, creating the instrument was necessary because no other tool currently existed that measures the dependent and independent variables as described.

Segment 2 consisted of questions that focus on organizational factors affecting decay including (a) experience; (b) drilling and practice opportunities; (c) overall years of experience; (d) time since initial training (IT); and (e) time since last department training. These factors are consistent with previous studies in recognizing the core set of factors that affect skill decay (Arthur et al., 1998; Farr, 1987; Kluge & Frank, 2014; Kolb, 1984; Wang et al., 2013). The third segment questionnaire consisted of demographic or person-related variables.

Social scientists evaluate instruments by its degree of reliability and validity. Reliability refers to the consistency of a measuring device, that is, the ability to measure variables at several places and times and observe the same results (Frankfort-Nachmias & Nachmias, 2015). However, variables in the social sciences are indirect and therefore, will produce variable errors to some degree (Frankfort-Nachmias & Nachmias, 2015). Statistical tests, such as regression equations, is a helpful statistic that facilitates the validity of a study. Both the pilot study and multiple linear regression models offered evidence for the reliability of the survey.

The validity of an instrument was the degree to which the device was measuring whatever it was intended to measure (Field, 2013). I offered evidence of two types of validity, content validity and construct validity for this study.

Content validity is recognized when all the characteristics of the concept that is being measured are covered (Frankfort-Nachmias & Nachmias, 2015). The performance survey measured the skills of Incident Commanders while managing a structure fire. Curriculum-based nationally recognized standards formed the basis of the performance instrument to assist in establishing the validity of the survey. Two such textbooks exist fire command (Brunacini, 2002) and command safety (Brunacini & Brunacini, 2004). These definitive works on local incident command define and describe the job and responsibilities of the FGC; most commonly referred to as the eight functions of command (Brunacini, 2002; Brunacini & Brunacini, 2004). The eight basic command functions are

1. deployment management;

2. assume, confirm and position command;

3. situation evaluation (size up);

4. strategy development/incident action planning;

5. incident communications;

6. incident organization;

7. review and revision; and

8. continuation, support, and termination of command (Brunacini, 2002).

The International Fire Service Accreditation Congress (IFSAC) is an internationally recognized governing system designed to establish and maintain standards-based accrediting services for fire-related degree programs and fire service certification programs (International Fire Service Accreditation Congress, 2016). IFSAC adopted the eight essential command functions in fire command and recognized as the Hazard Zone Incident Command Standard (bshifter, 2015).

The Hazard Zone Incident Command Standard is endorsed by the International Association of Fire Chiefs, International Association of Fire Chiefs Safety, Health, and Survival Section, Center for Public Safety Excellence, International Society of Fire Service Instructors, and the Fire Department Safety Officers Association (bshifter, 2015). The performance survey is a direct reflection of the benchmarks established in fire command (2002), which are nationally recognized standards in the fire service.

These curriculum-based nationally accepted standards helped to ascertain the validity of the survey. In addition to curriculum-based measures, a method of regression in which the statistical significance in the relationship among select variables increased the validity of the study. These variables were thoroughly researched and grounded in literature to validate the analysis.

Construct validity is the way a measuring instrument reflects the concepts of the theory tested (Frankfort-Nachmias & Nachmias, 2015). Variables under study, including problem-solving skills, practical experience, and time, empirically tied into the theoretical assumptions of skill decay theory (Arthur et al., 1998; Kluge & Frank, 2014; Wang et al., 2013). Empirical investigations suggested that cognitively complex decision-making skills, skills that FGC's demonstrate while managing a structure fire (Klein et al., 2010), are particularly vulnerable to decay (Arthur et al., 1998; Arthur et al., 2007; Meador & Hill, 2011). Further empirical research indicated that previous experience plays a central role in making effective decisions when faced with complex situations (Klein et al., 2010). For example, after a sequence of observations studying fire ground commanders, Klein et al. (2010) formed a recognition-primed decision (RPD) representation of naturalistic decision-making. These empirically based findings helped establish the validity of the study.

Operationalization of Variables

Dependent Variable

The outcome variable in this study is the degree of skill decay of fire ground commanders. For this study, skill decay was a ratio-level measurement that represents a decrease in performance outcome on trained or acquired knowledge and expertise after a given period. The first segment, or operational performance survey, was used to calculate skill decay. The performance survey incorporated a computer-based simulation of a typical structure fire in conjunction with a multiple-choice questionnaire. Participants had 21 items to answer with five possible answers for each question. Skill decay was measured by the performance outcome which equals the summated number of correct answers (scoring 0-21 points). The higher the performance outcome score, the lower amount of skill decay (see Appendix A).

The questions for the skill decay section of the survey were developed using curriculum-based nationally recognized standards on local incident management. Questions are based on the actual incident conditions (or critical factors) that are designed to evaluate the participant's ability to manage hazard zone operations safely and more efficiently. The simulation progressed as a natural structure fire that firefighters typically encounter. All multiple-choice questions for this section required tactical action that is based on the actual incident conditions (or critical factors) and is grounded in the fire command curriculum. Skill decay was therefore operationalized regarding the performance outcome, which equals the sum of correct answers scored. Appendix A describes which questions on the survey are being used to address the independent variable.

Independent Variables

In the present study, the effects of four types of independent variables were investigated: (a) experience; (b) drilling and practice opportunities (overlearning); (c) overall years of experience; and (d) time since initial training (IT). Questions about independent variables were in the second segment of the survey that consisted of items that focused on organizational factors affecting decay.

Experience. Practical experience, the primary independent variable, is a ratio-level measurement and was defined as the actual number of working structure fires the participant was involved with as an incident commander. The term “working fire” was a common designation indicating a structure fire that at least required the commitment of all responding fire companies, was involved in tactical operations and was held at the scene for a prolonged period (Brunacini, 2002). A negative coefficient was expected on this variable because skill decay decreases as experience increases (Klein et al., 2010) (see Appendix A). Participants were asked to type in the appropriate answer to this open-ended question.

Drilling and practice opportunities. Drilling and practice opportunities are ratio-level variables that describe a form of overlearning through purposeful learning and exercises going beyond initial proficiency after initial mastery (Arthur et al., 1998; Ebbinghaus, 1913). Studies showed that overlearning strengthens the relationship between the stimulus and response, thereby increasing the probability that the answer will be remembered (Arthur et al., 1998; Schendel & Hagman, 1982). Overlearning such as drilling and practicing are training-related factors that have shown to have a significant impact on the transfer of knowledge (Sharif et al., 2014). A negative coefficient was expected on this variable because those FGCs who drill and practice more often should reduce their amount of skill decay by strengthening their memory (see Appendix A). Participants were asked to type in the appropriate answer to this open-ended question.

Overall years of experience. Total years of experience remained a ratio measurement that represents time served in the fire service. Years of experience is related to experiential learning theory (ELT), whereby knowledge creates the transformation of experiences (Kolb, 1984). It was assumed that years of experience was related to the creation of learning opportunities. A negative coefficient was expected on this variable because of chances of creating knowledge through experiences increases as skill decay decreases. Overall years of experience measured by years based on the date of employment (see Appendix A). Participants were asked to type in the appropriate answer to this open-ended question.

Time since initial training. Time since initial training was a ratio measurement that represented the retention interval or time between immediate and delayed posttest (Arthur et al., 1998). For this study, the retention interval was the time between the initial IC training certification and the date of the survey. A positive coefficient was expected on this variable because the amount of skill decay increases as the duration of the retention interval increases (Arthur et al., 1998; Wang et al., 2013). Participants were asked to type in the appropriate answer for this open-ended question (see Appendix A).

Control Variables

Control variables were chosen to ensure that essential characteristics were not affecting the participant's performance independently from the independent variables named. Key features include sex, age, education, training motivation, self-efficacy, department size, and current rank including time served in this position (see Appendix A).

Training motivation. Following Colquitt et al. (2000), training motivation refers to the individual's persistence and intensity of behavior within a training environment.

Training motivation was an ordinal variable using a Likert scale from 1, “I strongly disagree,” to 5 “I strongly agree.” The higher the training motivation score, the more favorable the responses; hence the more motivated the participants scored. Participants were asked to click on the appropriate answer to this multiple-choice question.

Self-efficacy. Self-efficacy represents an individual’s belief that they can successfully achieve specific objectives or goals (Arthur et al., 2013). Self-efficacy was an ordinal measurement using a Likert scale from 1, “strongly disagree,” to 5 “strongly agree.” The higher the self-efficacy score, the more favorable the responses. Participants were asked to click on the appropriate answer to this multiple-choice question.

Age. Regarding age effects on skill decay, many studies offer empirical evidence of a negative association between learning and age (McCausland et al., 2015; Phipps, Prieto, & Ndinguri, 2013). Age as a control variable measured at the ratio level in the number of years since birth. Participants were asked to type in the appropriate answer to this open-ended question.

Education. The level of education achieved by each participant measured at the ordinal level. In this case, education increased from the lowest level of education, less than a high school diploma, to the maximum level of education, a doctoral degree. Participants were asked to click on the appropriate answer to this multiple-choice question.

Sex. Sex was measured at the nominal level as a mutually exclusive variable. Sex was coded as 0 = male, 1 = female, 2 = other. Participants were asked to click on the appropriate answer to this multiple-choice question.

Department size. The size of the member's department represented the number of firefighters or sworn members currently employed and was measured at the interval level. Participants were asked to type in the appropriate answer to this open-ended question.

Rank. Rank was the participant's current position or title and was measured at the interval level.

Rank tenure. Rank tenure was the amount of time served in the current position and was measured at the interval level. Appendix A shows which question on the survey was being used to address each control variable.

Data Analysis Plan

Once the survey period closed, I uploaded and organized the data into a CSV format to export to SPSS. IBM SPSS® Statistics version 23 was used to generate both descriptive and inferential analysis of the collected data. The study included data preparation such as proofreading the data for incomplete questions, missing data, and logical uniformity in the coding descriptions (Frankfort-Nachmias & Nachmias, 2015). Surveys with incomplete data were purged before describing the data. Next, I checked to ensure that answers were entered correctly, and the values fell within the range (Pallant, 2013). Once the data file was clean, the descriptive phase of my data analysis proceeded.

The descriptive statistical analysis helped describe the characteristics of my sample and check for any violation of assumptions underlying the multiple linear regression (MLR) statistical techniques (Pallant, 2013). Descriptive analysis was also be used to test for normality, kurtosis, and skewness. Tests of normality comparing the sample distribution from the normal distribution were utilized using the Shapiro-Wilk test to indicate if the distributions were significantly different. A finding of $p < .05$ demonstrates that the sample distribution is substantially different from the normal distribution (Hinton, McMurray, & Brownlow, 2014).

Multiple linear regression analysis was used to assess the effect of experience on skill decay while at the same time bearing in mind the impact of overlearning, overall years of experience, and time since initial training. Regression analysis was made up of predicted parameters that were estimated from the data (Field, 2013). These parameters, designated as b_0 *and* b_1, were regression coefficients that were used to quantify the strength of the independent variable on the outcome variable. In this linear model, Skill Decay was the outcome variable, and each independent variable had a regression coefficient β attached with it. If the probability value was less than .05, the null hypothesis was rejected (Hinton et al., 2014).

Threats to Validity

In general, the validity of a survey design study is the extent to which the questions measure the fundamental concepts being considered (Sue & Ritter, 2011). In other words, valid surveys estimate what they are intended to measure. A well-prepared researcher must consider all likely factors that could potentially invalidate their study.

Internal Threats to Validity

There are two types of threats that may potentially invalidate a study: (a) internal threats and (b) external threats (Creswell, 2014). Internal threats pertain to the researcher’s ability to control factors that are not under investigation that may be responsible for changes in the outcome variable (Frankfort-Nachmias & Nachmias, 2015). For example, the primary question under review was constructed to examine the association among two variables: experience and skill decay among fire ground commanders. However, skill decay literature indicated several other variables, such as organizational and task-related factors, influence the decline of naturalistic decision-making skills used by fire ground commanders (Klein et al., 2010). To mitigate this potential threat, I used a multiple linear regression analysis as a control mechanism to determine the functional relationship between various variables.

External Threats to Validity

External validity refers to the ability to make generalizations- that is, how well a sample represents a population (Frankfort-Nachmias & Nachmias, 2015). The margin of error and the level of confidence commonly measure this degree of representation. However, this study examined skill decay among fire ground commanders using a nonprobability convenience sample. Therefore, the generalizability of this study was limited to those commanders who have completed this particular type of training and may not be transferable to other training programs.

In addition to internal and external threats to the validity of a study, there are other risks in particular for survey designs that warrant further discussion. There are two categories of threats to validity for survey research: (a) respondent-centered threats and (b) question format and wording risks (Sue & Ritter, 2011).

Participant-Centered Threats to Validity

Participant-centered threats to validity include inaccurate information provided by the respondents. There are several reasons for this. First, participants may report misinformation for social desirability reasons; to conform, fit in, and be viewed in a favorable light (Sue & Ritter, 2011). However, since this study used an e-mail questionnaire, participants were more inclined to give honest answers when using a computer as opposed to facing an interviewer (Sue & Ritter, 2011). To reduce social desirability bias, I repeated the agreement that all participants remained anonymous and the data collected was strictly confidential.

Another reason participants may offer wrong information is when they are asked to provide an estimate rather than a precise value (Sue & Ritter, 2011). This threat was a valid concern particularly for the questions that pertain to the independent variables. For example, for experience, overlearning, years of experience, and time since initial training questions, the participants were asked to give information about past performance or events. Participants may not remember behaviors or activities that are no longer relevant. The accuracy of estimates improved by providing questions that asked for specific action within a recently defined period (Sue & Ritter, 2011).

Question Format and Wording Threats to Validity

Validity can also be threatened by the format and wording of the questions (Sue & Ritter, 2011). The two main types of survey questions are open-ended and closed-ended questions. Open-ended questions do not provide response options, while closed-ended questions do. Open-ended questions permit the contributor to use their own words and can be useful when exploring new topics (Sue & Ritter, 2011). However, open questions create more work for the respondents by recalling information. The benefit of open questions is that the answers are more valid than closed-ended questions because participants are not forced to pick one of the options available (Sue & Ritter, 2011). As a result, open-ended questions should be used cautiously.

Likewise, there are benefits and risks involved with closed-ended questions. Closed-ended questions are accessible for online surveys because they are easy to answer and provide reliable measurement (Sue & Ritter, 2011). However, the list of options generated by the researcher must be comprehensive so that all possible response options are covered (Sue & Ritter, 2011). Also, response options should be mutually exclusive in that participants should not be able to pick more than one answer per question ((Sue & Ritter, 2011).

To establish credibility in quantitative research, one must be able to draw significant and valuable inferences from data on the instruments (Creswell, 2014). To do so, researchers must create valid and reliable tools for scientific research. Many participant-centered factors may contribute to the threats of validity, including social desirability. I reviewed some methods that helped minimize these risks. I also pointed out some potential drawbacks and benefits associated with the design of the survey.

Ethical Procedures

The role of the Institutional Review Board (IRB) is to assure that studies are conducted ethically to protect the participants involved in the study. The risks involved must be minimized, reasonable, and equitable for IRB approval (Walden University, 2017). All three objectives can be accomplished by carefully designing a study that addresses these issues. For instance, one ethical problem that I could have experienced before I collected the data was not to include informed consent procedures tailored to the study (Walden University, 2017). Informed consent included communicating verbally and in writing with all participants involved my intent, purpose, and method used before the study began (see Appendix D). Additionally, the consent form stated that participation was entirely voluntary and at any time the participant can withdraw from the research and that all information obtained would be kept confidential. No data, including that from the pilot study, was collected before IRB approval was given.

Security

Another ethical problem that I could have experienced involved the processing of data and securing it after collection. The data was password-protected through my Google account which was stored on Google's secure website. The researcher and committee members were the only individuals who had access to the codes that generated in the measurement instruments. All of the data was electronic and stored on a flash drive. After the study was complete, I downloaded all of the data onto a password-protected flash drive and stored the device in a secured box at home where it will stay for at least five years. A locked security box is used to store the thumb drive which contains all of the consent forms, instruments, coding, and data collected throughout the study. After five years pass, I will destroy the thumb drive.

Other Ethical Issues

The relational aspect of researcher and participant includes sharing everyday occupational experiences in the fire service and training programs. No participant in the study had any power or authority-type relationship with the researcher. Additionally, no participant, other than those selected for the pilot study, worked for the same fire department as the researcher.

Summary

The purpose of this quantitative analysis was to observe skill decay based on the number of actual incidents after completing training for fire ground commanders. The fundamental question that guided this research was: After completion of an SBT program on fire ground command, is skill decay a function of experience as an Incident Commander?

The objective of this analysis was to explore the functional association between Incident Command experience (IV) and skill decay (DV) while at the same time considering the effect of overlearning (IV), overall years of experience (IV), and time since initial training (IV). Adopting a postpositive worldview, I utilized a cross-sectional survey design to determine the degree of skill decay among fire ground commanders. The model included a convenience sampling of fire department officers that are certified fire department officers. To ensure that at least 376 surveys are returned, an initial sample size of 1,253 participants with an expected 30% rate of response, a confidence level of 95%, with a 5% acceptable margin of error was used.

Respondents in this study self-selected into the sample to participate in the web-based survey, and therefore, volunteered to participate. Additionally, information on the consent form included a statement that all data will be kept confidential and that those who wish to take part in the survey voluntarily are implying informed consent. Completed survey responses went directly to Google Forms, and the data was automatically organized into a CSV format to export to SPSS 23 (IBM Corp., 2015) for statistical analysis. Incomplete or missing data was purged from the data analysis for data cleaning and screening purposes.

Collected data was analyzed quantitatively using multiple linear regression analysis to determine the functional relationship between outcome and independent variables described. Additionally, plausible internal and external factors that could potentially invalidate this study were presented. Finally, ethical concerns related to recruitment processes and data collection procedures were considered. In Chapter 4, I will give a detailed evaluation of the statistical analysis, survey results, and hypotheses tested.

Chapter 4: Results

The purpose of this quantitative study was to examine the magnitude of cognitive skill decline among fire ground commanders (FGCs) and determine what organizational factors contribute to skill decay. I sought to identify the factors that impact the loss of cognitively complex skills employed by FGCs during periods of nonuse. Findings may be used to improve public policies and reduce firefighter deaths, injuries, and property loss.

The research question examined in this study was as follows: After incident commanders complete a curriculum-based simulation training program on fire ground command, what factors contribute to skill decay? The following hypotheses were used to address the research question:

$H_0 1_a$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and experience as an incident commander.

$H_1 1_a$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and experience as an incident commander.

$H_0 1_b$: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and the amount of drilling and training opportunities (overlearning).

$H_1 1_b$: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and the amount of drilling and training opportunities (overlearning).

H_01_c: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and the number of overall years of experience in the fire service.

H_11_c: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and the number of overall years of experience in the fire service.

H_01_d: After completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant relationship between skill decay and the amount of time since initial training.

H_11_d: After completion of a curriculum-based simulation training program on fire ground command, there is a statistically significant relationship between skill decay and the amount of time since initial training.

In this chapter, I present the findings from the data analysis. I begin with the pilot study and move to the data collection process, including recruitment and response rates, as well as cleaning and coding procedures. Baseline descriptive statistics and demographic data are then presented, followed by an evaluation of statistical assumptions and results from multiple linear regression analysis. I conclude by providing answers to the research question and a brief introduction to Chapter 5.

Pilot Study Results

After receiving approved from Walden University’s IRB (#12-06-17-0435811), I began the pilot study on December 7, 2017. First, I sent an initial contact e-mail to 12 company and command officers who are employed in the fire service. The intent, purpose, and method of the study were explained to pilot study participants before they completed the survey. All participants were advised of the nature of the study, and were provided with a statement of consent and contact information if they had any questions or concerns. The e-mail indicated that participants had 10 days to complete the survey. Next, I called each participant to inform them that I sent them an e-mail with a link to the study. Within 1 week, I received 10 completed surveys. On December 14, I sent an e-mail thanking participants and reminding those who had not taken part to complete the survey. By December 21, 2017, all 12 had participants had completed the survey.

The purpose of the pilot study was to test the validity, reliability, and internal consistency of the researcher-generated survey. I spoke with each participant individually and in-person for feedback. The questions were straightforward and understandable. There was some discussion regarding basement fires from the participants because they had not received incident commander training. All of the participants reported that the survey was informative and challenging. I reviewed the data and looked for any questions that participants frequently got wrong. I also recoded the education and rank variables so the lowest category was zero. Next, I transferred the data to Excel and then to SPSS for preliminary analysis. According to the results of the data and after speaking with the participants, the wording on the surveys was precise, and the results were as anticipated.

Data Collection

The data collection process started after I obtained approval from the Walden IRB in December 2017. After conducting the pilot study, I sent an invitation to participate to a randomized e-mail list of 1,253 certified incident commanders on January 8th, 2018.

Over 52 surveys were completed within the first 24 hours, and 150 were completed after 10 days, indicating a response rate of 12.5%. I sent a follow-up e-mail thanking participants for their participation and to remind those who had not taken part to complete the survey. By January 29th, 229 participants had completed the survey, representing a response rate of 18%. Because of lower than expected response rates, I generated a new list of 1,500 randomly selected participants every week until 376 surveys were completed. Participants from each list were cross-checked to prevent repeated participation. A total of 446 reviews were completed and downloaded for analysis on February 28th, 2018 after a total of 8,773 invitations were sent out over a 7-week period, representing over 54% of the population of certified incident commanders. The response rate of was roughly 5%. The data were then downloaded from Google Forms to Excel for screening and data cleaning.

Screening and Cleaning the Data

The next step in the data collection process involved screening the data for missing values. After making sure the data file contained only completed surveys, I validated the data by confirming that the answers to the survey questions were realistic by scanning for outliers that were very different from most other responses. Two independent variables (Training and Experience) contained most of the outliers. Training, defined as quarterly department drills involving multicompany units, requires several fire engines, ladder trucks, and personnel as well as the ability to remain out of service for several hours to complete the training. Expected numbers ranged from 0 to 5 or 6. Quarterly training of 20 or above was unrealistic, so those surveys were eliminated.

Experience was defined as the number of incidents (working fires) in which the person was the incident commander. Some participants answered with several hundred events in less than a year or two. Those outliers were very different from most others and were deleted. In total, 40 surveys contained missing data, and 30 surveys had bad data. The remaining 376 surveys contained complete and realistic data and were included in the analysis. The confidence interval of 95% with a 5% margin of error was met because 376 surveys were needed to meet that requirement.

After the data file was validated, I recoded the variables. The first section of the survey (Questions 1-21) was the operational performance section that measured skill decay. This part of the survey included a simulated house fire with multiple choice questions. These variables were recoded with new labels and assigned new values like 1 for the correct answer and 0 for “all other values.” I then added up new variables Q1 through Q21 to create a new variable “Total Score Dependent Variable Skill Decay” using the Transform and Compute Variable function for a total score value. Similarly, Questions 22 through 32 involved string variables using Likert scales and were recoded to numeric values and labeled.

Table 2 and Table 3 present descriptive statistics for the 376 survey participants. As shown in Table 2, the average age of the participant was 47, , the average certification time was 3.51 years, the average time in their current rank was 7.83 years, and the average number of sworn firefighters in their department was 191. The average performance outcome taken from the simulated structure fire exam was 11.73 or roughly 50%.

Table 2

Descriptive Statistics for Continuous Variables

Variable	*M (SD)*	*SE*	95% CI
Age	47.32 (7.468)	.385	[46.56, 48.08]
Skill decay	11.73 (2.394)	.123	[11.49, 11.98]
Department size	190.89 (358.787)	18.503	[154.50, 227.27]
Time in IC training	3.51 (2.115)	.11	[3.29, 3.71]
Rank time	7.83 (6.947)	.358	[7.13, 8.54]

Note. N = 376.

As noted in Table 3, company officers represented 47.1% of the sample, and battalion chiefs were 23.9%. Approximately 45% had been the commanding officer of five or fewer working fires, indicating an inexperienced group. Most participants were male (96%). Most participants (64%) had a college degree; 118 participants (31.4%) had a bachelor's degree, 29 (7.7%) had a master's degree, and 6 (1.6%) were doctors. The variable Department Training indicated that only 10.6% conducted training five or more times per quarter, whereas 89.4% trained four or fewer times per quarter. The sample represented 2.4% of the entire population of approximately 16,000 certified fire department officers who serve in the role of incident commander for local NIMS Type 4 and Type 5 incidents.

Table 3

Descriptive Statistics for Categorical Variables

Variable	Frequency	Percentage	Cumulative percentage
Sex			
Male	361	96%	96%
Female	14	3.7%	99.7%
Other	1	0.3%	100%
Education			
Less than a high school degree or GED certificate	1	0.3%	0.3%
High school degree, GED certificate, or trade school certificate	20	5.3%	5.6%
Vocational or technical school certificate or degree	31	8.2%	13.8%
Some college	86	22.9%	36.7%
Associates degree	85	22.6%	59.3%
Bachelor’s degree	118	31.4%	90.7%
Master’s degree	29	7.7%	98.4%
Doctoral degree	6	1.6%	100%
Total	376	100%	
Rank			
Firefighter	41	10.9%	10.9%
Company officer	177	47.1%	58%
Battalion chief	90	23.9%	81.9%
Deputy chief	24	6.4%	88.3%
Assistant chief	20	5.3%	93.6%
Fire chief	24	6.4%	100%
Total	376	100%	
Motivation			
Agree to strongly agree	239	63.6%	63.6%
All other values	137	36.4%	100%
Total	376	!00%	
Efficacy			
Agree to strongly agree	336	89.4%	89.4%
All other values	40	10.6%	100%
Total	376	100%	

(table continues)

Variable	Frequency	Percentage	Cumulative percentage
Working fires as IC			
5 or less	169	44.9%	44.9%
6-10	97	25.8%	70.7%
11 or greater	110	29.3%	100%
Total	376	100%	
Department training			
4 or less	336	89.4%	89.4%
5 or more	40	10.6%	100%
Total	376	100%	

Results

IBM SPSS ® Statistics version 23 was utilized to generate both descriptive and inferential analysis of the collected data. Before conducting the study, assumptions underlying the multiple linear regression models were tested. These included (Field, 2018; Green & Salkind, 2016):

- Assumption 1- Additivity and linearity: The Dependent Variable should be linearly correlated to the Independent Variables, and their collective influence is best explained by combining their effects as one.
- Assumption 2- Approximately normally distributed errors: Residuals were visually inspected using *P-P* plots and histograms.
- Assumption 3- Outliers: Extreme cases are identified, evaluated and removed to prevent a biased linear model.
- Assumption 4- Homoscedasticity: The residuals at each level of the Independent Variables have similar variances.
- Assumption 5- Little or no multicollinearity: The Independent Variables should not correlate to highly.

- Assumption 6- Variable Types: All Independent Variables must be quantitative or categorical, and the Dependent Variable must be quantitative.

Assumption Results

To examine if a linear relationship exists, I visually inspected scatterplots of the dependent variable plotted against the independent variables. The results determined that linearity reasonably existed between the dependent variable and independent variables. Likewise, the normality of residuals was supported by graphical examination (see Appendix C).

For the dependent variable skill data, the distribution was relatively normal. Furthermore, the residuals lie firmly along the diagonal in the *P-P* plot indicating a normal distribution. Notably, significance tests of skewness and kurtosis were not used since large sample sizes are likely to be significant when skew and kurtosis values are slightly abnormal (Field, 2018). The current study has 376 cases which surpass the necessary larger sample size. Although some malformations were apparent, the large sample size (higher than 30) exceeds the qualification to apply the central limit theorem and accept that the estimate came from a normal distribution in spite of what the statistical tests indicated or what the shape of the graphs revealed.

The next test of assumption was to check the residuals for evidence of bias. Any extreme values in the dataset will have a disproportionate influence on the results, especially when using linear regression models. I partially addressed this issue by excluding some surveys with outliers as the data was bad. Next, an assessment of *Casewise Diagnostics* was used to identify unusual cases that have standardized residual values above or below 3.0. In a normally distributed sample, only 1% of cases are expected to fall outside this range. In this sample, four cases (case numbers 31, 256, 357, and 364) had a residual value higher than 3.0 (Table 5).

Overall, I found 4 cases (1.1%) that are outside of the ± 3.0 parameters, which is what was expected. Therefore, these diagnostics showed that outliers fell within the normal range for this sample size and that there were no extreme values in the dataset that could produce a disproportionate influence on the results. In addition to examining Casewise Diagnostics, I inspected Cook's distance values for each case. No cases were exceeding .149, suggesting that there are no highly influential cases.

Homoscedasticity was tested to ensure that the change of the dependent variable is stable at all levels of the independent variable. Similar to linearity testing, homoscedasticity was examined by visually inspecting scatterplots. In this case, a plot of studentized residuals (**SRESD*) against the standardized predicted values of the dependent variable (**ZPRED*) based on the model (see Figure 3). Analysis of the scatterplot showed randomly scattered residuals, showing uncorrelated variables. This pattern suggests that the assumption of homoscedasticity was met for each variable.

Multicollinearity was evaluated next by assessing the correlation matrix for independent variables that correlate highly with values of r above 0.80 or 0.90 (Table 9). All of the correlation coefficients for the independent variables were well below the 0.80 level. The highest correlation was 0.485. Likewise, variance inflation factor (*VIF*) and the tolerance statistic was examined. All tolerance values surpassed the minimum 0.20 threshold with the lowest amount at 0.765. Lastly, *VIF* values stayed well below 10 with a narrow range of 1.029 to 1.31. Based on these results, multicollinearity assumptions were met.

The last assumption tested examined the type of variables measured. One hypothesis is that all independent variables must be quantitative or categorical (Field, 2018). The variables associated with skill decay as well as the control variables met this requirement, as they were continuous, categorical, or nominal. The other variable type assumption is that the dependent variable must be quantitative, continuous, and unbounded (Field, 2018). The dependent variable -skill decay was measured as a performance outcome by evaluating fire ground commanders managing a structure fire. A twenty-one-question test with multiple choice answers was given. This variable was measured as a scaled, continuous variable. Therefore, the variable type assumption was met.

In summary, statistical assumptions were evaluated using scatterplots, histograms, and diagnostic analysis. Tests for linearity indicated a reasonably correlated relationship. Further review showed normally distributed variables and randomly scattered residuals. Also, outliers were trimmed and reassessed, and correlation coefficients and *VIF* values evaluated for multicollinearity. Lastly, all independent variables were quantitative or categorical, and the dependent variable quantitative, thereby passing the variable type assumption test. Overall, assumption assessments were met showing that using MLR to test the hypotheses would be valid.

Statistical Results

A multiple linear regression statistical analysis was used to answer the research question and test the hypotheses. The method of entering predictors into the model was forced entry or enter so that all independent variables were forced into the model simultaneously; thus, no previously decided order in which the variables entered was determined, invoking a more rigorous method of theory testing (Fields, 2018). The summary of the model indicates that eleven independent variables in this study account for a statistically significant amount of influence on the dependent variable skill decay $R2 = .072$, F (11, 364) = 2.56, $p < .01$. The results of this analysis are found in Table 4 and Table 8.

Table 4

Regression Analysis Summary for Independent Variables

Variable	*B*	*SE B*	*β*	*t*	*p*
(Constant)	11.241	.908		12.378	.000
Experience	.258	.156	.091	1.650	.100
Training	-.030	.398	-.004	-.074	.941
Time in IC training	.164	.062	.145	2.665	.008
Rank time	-.030	.019	-.086	-1.518	.130
Motivation	-.049	.261	-.010	-.189	.850
Efficacy	-.762	.402	-.098	-1.894	.059
Age	-.007	.018	-.022	-.384	.702
Education	.131	.091	.075	1.443	.150
Sex	-1.159	.626	-.095	-1.852	.065
Department Size	.000	.000	.049	.955	.340
Rank	-.310	.199	-.090	-1.561	.119

Note. Dependent Variable Skill Decay.

The first research hypotheses: after completion of a curriculum-based simulation training program on fire ground command, there is no statistically significant association between skill decay and experience as an incident commander. This hypothesis tested the relationship between the number of incidents (working fires) as an incident commander after completing training (independent variable) and the degree of skill decay, measured as a performance outcome (dependent variable). A statistically significant association was not recognized. The statistical estimates for the association between the number of incidents and the degree of skill decay were not statistically significant: $B = .258$ [-.050, .566], $p = .100$. The null hypothesis cannot be rejected, and the alternative research hypothesis cannot be accepted.

The second hypothesis examined was there is no statistically substantial relationship between skill decay and the amount of drilling and training opportunities (overlearning) as an incident commander after completing a curriculum-based simulation training program on fire ground command. This hypothesis tested the relationship between training (independent variable), defined as quarterly department drills involves multicompany units, and the degree of skill decay, measured as a performance outcome (dependent variable). The results for training are not significant: $B = -.030$ [-.812, .752], $p = .941$. The null hypothesis cannot be rejected, and the alternative research hypothesis cannot be accepted.

The third hypothesis states there is no statistically significant relationship between skill decay and the number of overall years of experience in current rank in the fire service. The analysis revealed that total years of experience in a current position in the fire service did not statistically influence the degree of skill decay: *B* = -.030 [-.068, .009], $p = .130$. The null hypothesis cannot be rejected, and the alternative research hypothesis cannot be accepted.

The fourth hypothesis in this study examined was there is no statistically significant relationship between skill decay and the amount of time since initial training. A statistically significant association was identified. The statistical values for the relationship between the amount of time since initial training in incident command and the outcome performance of local incident commanders were substantial: *B* = .164 [.043, .285], $p = .008$. This null hypothesis was rejected as the amount of time trained in IC does have a statistically significant impact on the performance of incident commanders.

Analysis of the model summary describes the overall model fit (Table 6). The R^2 value of 0.072 indicates that 7.2% of the variability of the data can be explained by the model. The R^2 value also means that 92.8% of the variation in skill decay remains unexplored. This high percentage suggests there are many other variables influencing skill decay. This result is addressed in detail in Chapter 5.

The multiple correlation coefficients (*R*) shows a value of 0.268. Since there are several independent variables, this value is the correlation between skill decay and experience, training, time in the training program, motivation, efficacy, age, education, sex, department size, rank, and time served in class. A positive value of 0.268 suggests that as the values of the independent variables increase, the values of the dependent variable increases. Based on the magnitude of the correlation coefficient, the overall strength is marginally related to skill decay level in this sample.

Next, a correlational analysis was conducted to evaluate the relative importance of variables in predicting the outcome (Table 7). The column marked *Zero-order* indicates the bivariate correlation between each independent variable and the dependent variable-skill decay. In other words, the Zero-order value does not adjust for other variables. According to this analysis, the two most useful predictors (IV's) was Time in Training and Experience with a Zero-order value of .158 and .126 respectively. Time in Training and experience accounted for 4.1% of the variance of the dependent variable: skill decay, while the other variables contributed an additional 3.1%. The implication of this finding will be addressed further in Chapter 5.

Summary

In this Chapter, I reported the findings of the pilot analysis and presented the data collection and analysis processes. Additionally, I addressed the research question by testing several hypotheses. Four hypotheses were tested using multiple linear regression to determine the functional relationship between various variables. In three of the four hypotheses I was unable to reject the null.

The analysis of experience led to the acceptance of the null hypothesis which tested the relationship between the number of incidents (working fires) as an incident commander and the magnitude of skill decay. The experience variable did not have a significant association with the decision-making skills used by fire ground commanders while managing a structure fire. Following the experience analysis, I evaluated the amount of drilling and training opportunities (overlearning) and found no statistical relationship with skill decay. Therefore, the null hypothesis could not be rejected.

The third hypothesis assessed the number of overall years of experience in current rank in the fire service. The analyzed results indicated the absence of a statistically substantial association between the independent variable time in the current position and the significance attributed to skill decay. Consequently, the null hypothesis could not be rejected. Lastly, the analysis of time since initial training led to the rejection of the null hypothesis that compared the amount of time since initial training in incident command training and the outcome performance of local incident commanders. The statistical values for the relationship were significant.

Although the overall model indicated that a statistically significant association exists, a more rigorous look at the data showed that three of the four primary independent variables, including experience, drilling, and training opportunities (overlearning), and overall years of experience in current rank was statistically insignificant. As a result, three of the four hypotheses were rejected. In contrast, one of the four hypotheses, time trained in the program, was accepted.

In Chapter 5, I infer and elaborate on the findings regarding the statistical significance that each variable has on skill decay among fire ground commanders. I will also describe the limitations of the analysis, recommendations for future research, and implications for social change.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this quantitative study was to study the degradation of decision-making skills among local incident commanders while managing a structure fire. I measured and analyzed FGCs' performance on a skills test by creating a web-based survey that included a simulated structure fire. A multiple linear regression analysis was used to examine the relationship between skill decay and various contributing factors including experience, drilling and training opportunities, and time since initial training. Covariates were included to control for interceding effects including education, motivation, efficacy, rank, time in the fire service, department size, age, and sex.

Three of the four alternative hypotheses were rejected because findings did not support a statistically significant relationship between experience, drilling and training opportunities, and experience in rank and the skill performance of FGCs. A statistically significant relationship existed between the amount of time certified in training and the outcome performance of local incident commanders. Given previous studies, results from the current study were unexpected.

Interpretations of Findings

Former research on the degradation of trained or acquired skills focused on high-reliability organizations (HROs) where retention of talent is critical, such as the military, nuclear power plants, oil refineries, and aviation (Kluge & Frank, 2014). Little research had been conducted on the decay of complex skills used by FGCs while managing a hazardous incident. Results from this quantitative study contributed to this narrow field of scholarship by addressing the factors related to retention of skills employed by incident commanders at a structure fire. The variables used in this study were grounded by Arthur et al.'s (1998) skill decay theory that centers on organizational and task-related factors including experience, training-related factors (overlearning), and time since initial training.

Experience

Knowledge is created through the transformation of experience that involves the combination of concrete experiences, abstract conceptualization, reflective observation, and active experimentation (Kolb & Kolb, 2005). The primary independent variable in this study, experience, was operationalized as the number of working structure fires the participant experienced as an incident commander.

The null hypothesis asserted that there is no statistically significant relationship between skill decay and experience as an incident commander. Results indicated that expertise was not a statistically significant predictor of skill decay ($p > .05$). Therefore, an increase in experience in managing a structure fire was not a predictive factor affecting the performance of FGCs. This finding contrasts with previous research, beginning with Kolb's (1984) experiential learning study. Also, this finding did not support Klein et al.'s (2010) recognized prime decision (RPD) study that demonstrated pattern-matching techniques by FGCs as a form of experiential learning in natural decision-making environment like a structure fire. Klein et al. asserted that experienced FGCs could better forecast fire behavior and make safer decisions than less experienced commanders. According to other studies, experience led to quicker decision-making skills because the circumstances matched a typical environment previously addressed

(Bayouth et al., 2013; Kunadharaju et al., 2011). Klein et al. (2010) acknowledged that little is known about whether alternative decisions are made intuitively. Nevertheless, based on the results from the current study, the relationship between experience and skill retention was insignificant.

Drilling and Training Opportunities (Overlearning)

On-the-job training is standard in the fire service, both formally as a recruit in the academy or mandatory quarterly training, and informally at the fire station with the company officer. Research has shown that training provides additional learning beyond what was required for initial proficiency (Arthur et al., 1998; Ebbinghaus, 1913). Practice reinforces the relationship between the stimulus and response, thereby strengthening the memory (Arthur et al., 1998; Schendel & Hagman, 1982). The drilling and training (overlearning) variable was addressed in the study by asking how often the participant's department incorporates multicompany drills or practices on a quarterly basis. The null hypothesis asserted that there is no statistically significant relationship between skill decay and the amount of drilling and training opportunities (overlearning). Results indicated that drilling and training opportunities (overlearning) were not statistically significant in predicting skill decay ($p > .05$). Increased department quarterly training and drilling among certified commanders did not translate into higher performance in managing a hazardous incident. This result was not consistent with findings presented by Arthur (1998), Driskell et al. (1992), Farr (1987), and Rohrer et al. (2005). Therefore, it is not clear whether multicompany training and drilling is an effective strategy for skill retention.

Overall Years of Experience in the Fire Service

Total years of experience in the fire service relates to Kolb's (1984) experiential learning study maintaining that knowledge is created through the conversion of experiences. The null hypothesis asserted that there is no statistically significant relationship between skill decay and the number of overall years of experience in the fire service. I assumed that total years of experience equated to more learning opportunities. Regardless of model significance, results indicated that overall years of experience in the fire service was not a statistically significant predictor of performance of FGCs ($p > .05$). Increased years of experience did not predict greater skill retention in managing a hazardous incident. This findings contrasts with findings by Kolb (1984) and Kolb and Kolb (2005).

Time Since Initial Training

Time since initial training represents the retention interval or time between immediate and delayed posttest (Arthur et al., 1998). The retention interval also incorporates spacing of practice. For example, incident commander training leadership requires members to complete two 3-hour quarterly continuing education (CE) modules (from the date of online activation) to maintain certification status. The spacing of practice is a standard training method shown to have a significant effect on skill retention (Arthur et al., 2010; Cepeda, 2006; Mulligan & Peterson, 2014; Schmidt & Bjork, 1992). The required CE hours replicate a method of distributed practice whereby short practice sessions are spaced over time. For this study, the retention interval was the time between initial incident command training certification and the time the participant completed the survey. The null hypothesis asserted that there is no statistically significant relationship between skill decay and the amount of time since initial training. Results indicated that the amount of time in the training program was a statistically significant predictor of the performance among certified incident commanders in managing a hazardous event ($p < .05$). Therefore, the null hypothesis was rejected. The longer an incident commander is certified in the program, the higher his or her performance in managing a hazardous event. This finding was consistent with findings by Arthur et al. (1998), Arthur et al. (2010), Cepeda (2006), Mulligan and Peterson (2014), and Schmidt and Bjork (1992).

This finding provides an opportunity for further training enhancement. Leadership can now develop an assessment tool to evaluate the effect that credential maintenance activities, or continuing education (CE) hours, have on skill decay. By examining the number and frequency of achieved CE modules and the growth of skills necessary to maintain competency, leadership can construct effective training programs. Through refined timing and sequencing of refresher training, leadership can promote more cost-efficient and effective training models. The influence of time since initial training was supported by Kluge and Frank (2014) and Kluge, Burkolter, and Frank (2012), who showed that refresher training, as well as the retention interval, has a significant impact on the reestablishment of skills. Findings from the current study extended the previous research findings, mainly from other high-reliability organizations such as the military, nuclear power plants, oil refineries, and aviation, demonstrating the effectiveness of distributed practice and refresher training.

Theoretical Perspective

The theoretical framework used to examine factors that contribute to skill retention among local incident commanders was Arthur's (1998) skill decay theory. This theory was relevant because firefighters, company officers, and command officers in the fire service experience extended periods of time without having the chance to perform or refresh acquired skills. Performance deteriorates as a result of the inability to retain information (Bourne & Healy, 2012). From a theoretical perspective, the statistical significance of the overall model was consistent with previous findings (Arthur et al., 1998; Kluge et al., 2015; Lamb et al., 2014). However, of the four independent variables, the model only provided statistically significant results for time certified in the training program. The absence of a statistically significant relationship involving skill decay and experience might be explained regarding testing familiarity. Arthur et al.' (1998) suggested that testing awareness had the most significant influence on skill decay. Testing effect may not have occurred due to a weak association between experience in situ as a commanding officer of a real event as opposed to a simulated structure fire (Kluge & Frank, 2014). However, testing a commander's performance during unusual and challenging circumstances is unrealistic. Although the fundamental premise of the testing effect indicates that transfer processing of data leads to higher performance (Bjork et al., 2013), experience-based testing did not lead to superior performance in the current study. The results suggested that a skill that was acquired and needed to be recovered should be restored by using simulations (Kluge & Frank, 2014).

Another explanation for the lack of statistical significance between skill decay and accumulated experience regarding working fires is that this formulation does not take into consideration for forgetting, nor for the greater importance of more recent experiences. Research findings by Ebbinghaus (1913) established a forgetting curve that described a lawful relationship between forgetting and time. Arthur et al.'s (1998) more contemporary theory determined that faint experiences are less pertinent for today's performance. Therefore, these findings could be interpreted as indicating a deficiency in the interpretation of experience as defined for this study.

Although research by Arthur et al. (1998), Driskell, Willis, and Copper (1992), Farr, 1987; Rohrer, Taylor, Pashler, Wixted, Cepeda (2005), and Sharif et al. (2014) advocated that that overlearning yields a substantial result on retainment, calculations of the MLR analysis suggest drilling and training opportunities (overlearning) did not significantly contribute to the preservation of skills among local incident commanders. The negligible relationship could be explained by the participant's abilities and structure provided by the departments. For example, Kluge (2007) concluded that high-ability participants performed more excellent in a weakly structured training program where errors were encouraged. On the other hand, lower-ability participants performed greater in highly structured training programs. These results suggest that training frequency and structure design may produce greater skill retainment.

Hypothesis three of this study was that there is a statistically substantial association between skill decay and the amount of overall years of experience in the fire service. This hypothesis assumed that total years of experience equated to more learning opportunities. However, the results do not support Arthur et al.'s (1998) and Kolb's (1984) experiential learning theory. One explanation for this result is that more experienced commanders recognize greater consequences if a wrong decision is made, and therefore, may tend to seek more information during a simulation exercise where there is no time pressure (Bayouth et al., 2013). Whereas, less experienced command officers are less hesitant in their decisions because they are unaware of the hidden dangers. Thus, the results indicate that experienced commanders may take longer to make a decision.

Limitations

Anticipated limitations expressed in Chapter 1 were consistent with the constraints faced while carrying out the study. Limitations were due to the lack of previous research regarding the decay of cognitively complex skills used by FGCs while managing a multifaceted hazardous incident. For this reason, it was needed to create an original survey instrument since no other tool existed to measure the variables as described. As a result, the survey was not tested beyond the pilot, so there was not an opportunity to ensure the study was measuring the underlying concepts as accurately as possible.

This study took a unique firefighter approach to operationalize the cognitive abilities of FGCs. As a result, the transformation of variables into new, untested constructs, especially in a domain where there is little to draw from, produced unexplained model variations. For instance, a low *R2* value of 0.072 indicates that 7.2%

of the irregularity of the data can be explained. This statistic also means that 92.8% of the variation in skill decay remains unexplained.

The challenge of converting and measuring decision-making skills employed on the fire ground was recognized by Young et al. (2013) and Gonzalez, Meyer, Klein, Yates, and Roth (2013) who highlighted the limitations when studying naturalistic decision-making skills employed by FGCs. In highlighting the limitations of this approach, Arthur et al. (2010) and Kluge and Frank (2014), for example, describe the problems when operationalizing variables from one domain to another. Arthur et al. (2013) and Villado et al. (2013) acknowledged that researchers are left to assume that complex decision-making skills employed by first responders are similar to that of cognitively complex skills upon which the majority of skill decay research is founded. For example, the operational definition of command experience was limited to the number of working fires the participant was the commanding officer. However, command experience is a comprehensive term and can include a vast array of variables such as the number of fires the participant experienced as a firefighter before promoting to the position of company or command officer. There is also a significant distinction in what role the firefighter had at the time of the incident, in addition to when they arrived on scene. These distinct possibilities offer unique experiences that potentially impact the skills gained by future fire ground commanders.

The research method used to measure the performance of FGCs have some inherent limitations. Among these limitations lies in the ability to replicate a realistic environment that closely mimics a hazardous situation, while accurately measuring naturalistic-like decisions. Therefore, a sacrifice of realism was necessary to create a safe, controlled environment to tests their skills. One of the limitations related to the use of simulated-based training is the issue of ecological validity (Young et al., 2013). For instance, in real-world situations, incident commanders are exposed to a multifaceted mixture of stressors, such as acute time pressure, confusion, ambiguity, and the fear of injury or death of a fellow firefighter. While the high-fidelity simulated event contained within in the survey provided an interactive experience, participants were aware that no actual dangers are threatening themselves or their coworkers. Similarly, the multiple-choice questionnaire was not bound by time, thereby preceding any pressure induced decision-making.

Another limitation was that the participants were asked to provide information about previous experiences, such as the number of incidents' they were the commanding officer, or how often they're department performed multicompany drills on a quarterly basis. Therefore, members reported estimates rather than precise numbers. For example, several of the independent variables, experience, and training, in particular, included many 10s suggesting a rough estimate. As a result, the normality of the variables was inadequate. Changes were made in re-coding the data to categorical variables which improved the normality and linearity of the model.

Despite the identified limitations, this study involved a careful development of the survey including a pilot study to ensure the instrument was measuring what it was intended to measure. This process included the aid of an experienced webmaster to help design a simulated structure fire that was both realistic and challenging. From there, curriculum-based nationally recognized standards extrapolated from fire command (Brunacini, 2002) and command safety (Brunacini & Brunacini, 2004) were used to create multiple choice questions. To ensure the accuracy of the instrument, a committee that included company and command officers with over 20 years of experience each in the fire service studied the test. Also, questions were designed to cover a limited range of time and situations, thereby improving the accuracy of estimates (Sue & Ritter, 2011).

Lastly, concerns about grader bias were minimized by instituting curriculum-based nationally recognized standards extrapolated from fire command (Brunacini, 2002) and command safety (Brunacini & Brunacini, 2004). By using standardized benchmarks to gauge the performance of FGCs, personal observations and opinions were negated. This process safeguarded the internal validity of the research.

The generalizability of this study was limited to company and command officers employed in the fire service who are currently certified local incident commanders. The limited sampling frame was further restricted to those officers who successfully obtained their training certification at least three months past. These parameters disqualified firefighters below the rank of captain, those not currently employed in the fire service, and those with less than three months certification time. Furthermore, the generalizability of this study was limited to those who individually completed IC training. Findings from this study may not be transferable to other command training programs.

Recommendations

This study specifically focused on the functional relationship between incident command experience and skill decay while at the same time considering the influence of training and drilling opportunities (overlearning), overall years of experience, and time since initial training. Each of these variables was narrowly defined and measured. Consequently, variables involving different parameters remain unexplored. Future research striving to extend various levels of data regarding skill decay, command experience, and overlearning variations may uncover new insights than discovered in this study.

Additionally, the limitations imposed by the use of self-reported estimates, future research that can capture more precise data would be helpful. For instance, the department's ability to obtain data about the experience, such as the number of working fires and those involved, could generate precise data points to measure. Future researchers could collect more data, with higher accuracy and proficiency over extended periods of time.

I also recommend imposing stressors as part of the simulation-based assessment that would more accurately reflect fire ground operations. Available options could include acute time constraints when making critical decisions, muffled radio traffic further limiting chances to communicate relevant feedback, or any subsequent factor that creates a hazardous situation can be used to exemplify realistic elements commonly experienced on a fire ground.

This study found evidence that a statistically significant relationship existed between the amount of time certified in IC training and the outcome performance of local incident commanders. However, what remains unexplored is the effect that credential maintenance activities, or continuing education (CE) hours, has on skill decay. This analysis could take place in the form of archival data, such as the aggregate number of hours or the length of time between CE training and the performance measurement. This data can help determine the timing and sequencing of refresher training.

Further recommendations for future skill decay research include leading a longitudinal analysis of critical incidents to chronologically identify opportunities from which firefighters can acquire fire-command experience and perform trained skills. It would be beneficial to identify specific individual practice levels based on practical experience obtained in the field. However, from a practical perspective, there are substantial logistical costs associated with recruiting, retaining, testing, and retesting participants over extensive periods of time.

Last, future research in this area may consider a qualitative or mixed methodological approach by interviewing company and command officers regarding how they feel about skill decay. In-depth interviews may be helpful in discovering individual distinctions and training systems in the context of learning environments and task difficulty under which these occur. The findings of such a study can be used to recognize discrepancies in current training programs and to design suitable amendments.

Implications

The opportunity to affect positive social change was the most profound motivational factor in conducting this research. Findings from this study positively impact individuals, families, organizations, and society in general by providing data to essential constituents that are responsible for protecting firefighters from the many hazards they encounter every day. This responsibility centers on the ability of leadership within the fire service to provide adequate training programs designed to sustain their skills over their entire career. The problem is that firefighters are vulnerable to skill decay given the lack of skill development, the nature of expertise required to manage an incident, and the gradual reduction of fires to expose them the opportunity to sustain their abilities that are needed to remain proficient.

The study demonstrated that time invested in a particular IC training program, a comprehensive, standardized and empirically based operational system, was a predominant factor contributing to skill retention of FGCs. Findings also suggest that time trained in the program performed better than the statistically insignificant factors, such as experience as an IC, departmental training and time on the job. From an individual perspective, this data positively impacts firefighters by showing that time invested in the training program is an effective mediation in maintaining a skill level that was attained at the end of primary instruction. This data may also motivate trainees to keep their certification by completing the required continuing education (CE) hours.

Results from this study positively impact fire departments and training academies by providing them an opportunity to institute training measures used by this particular training program. Additionally, reviewing this data informs leadership to re-evaluate and strengthen fire service policies by examining the loss of expertise used by FGCs. By providing knowledge, this study improves awareness that firefighters are susceptible to skill decay and provides further understanding as to what factors contribute to retention. As a result, firefighter training policies will improve, thereby reducing firefighter deaths, injuries, and property loss.

Methodological, Theoretical, and Practical Implications

From a methodological and theoretical point of view, there are many distinctions from this study from previous studies, from which I built my theoretical framework. Skill decay theory has traditionally been qualitative (Jenkins et al., 2015, Johnson, 2016) involving highly automated industries (Kluge et al., 2015) and high-reliability organizations that work under dangerous environments (Kluge et al., 2010). This study is unique by extending knowledge related to skill decay and the fire service.

From a methodological viewpoint, it can be argued that the present study used a simulated-based controlled environment to evaluate the performance of FGCs. However, investigating the performance of FGCs in a real emergency is practically impossible while attesting to high internal validity (Kluge et al., 2015). It would also be logistically challenging to gather data from a large sample size in a department who is prepared to send many employees to test for several hours. Even so, the concept of applying skill decay theory in the fire service is reinforced through a literature review. I suggest further research should focus on evaluating the effects of high-fidelity versus low-fidelity simulations. Perhaps an induced stressful environment created by a more realistic environment may attribute to greater skill retention.

From a theoretical perspective, the underlying assumption is that skill decay refers to an outcome, and not a process, that is expressed as a performance result (Arthur et al., 2013). The construct of decay is practical as an informal description of what happens to skills over time. However, the means by which skills fade remains unsettled (Arthur et al., 2013). Nevertheless, researchers consistently recognize a core set of factors that induce the loss or retainment of acquired skills over time (Arthur et al., 1998; Arthur et al., 2010). Therefore, my underlying assumption is that skill decay among FGCs cannot be measured by time alone.

This study focused on organizational factors relevant to the fire service, including specific field experience, training and drilling (overlearning) opportunities, overall years of service, and time in training. By examining what factors contribute to the retention of FGC skills, this study broadened skill decay theory by finding the statistical support that organizational factors in the fire service contribute to preservation obtain by firefighters.

From a practical perspective, the study results show that time certified in IC training does have a statistically significant impact on the retainment of skills. Furthermore, this particular training program, or a training program similar to it, may be deemed as a valuable substitute for department training if the practice can be used using curriculum-based nationally recognized standards drawn from fire command (Brunacini, 2002) and command safety (Brunacini & Brunacini, 2004).

Conclusion

Despite concerted efforts, the current state of firefighting remains a highly dangerous profession. On average, roughly 100 firefighters are killed in the line of duty every year (USFA, 2014). Multiple independent investigative reports repeatedly cite poor command decision-making due to inadequate training and awareness (Hamins et al., 2012; Klein et al., 2010; Kunadharaju et al., 2011). Leadership must find a way to improve fire safety in general by providing training to acquire and maintain skills that are necessary to make safe, and efficient decisions.

In this quantitative study, I sought to comprehend what factors contributes to the retention of skills employed by fire ground commanders while managing a hazardous incident. A multiple linear regression analysis was conducted to examine the data and test the hypotheses. While the overall model showed that a statistically significant association exists, a closer look at the data indicated that three of the four primary independent variables, including experience, drilling, and training opportunities (overlearning), and overall years of experience in current rank was statistically insignificant. As a result, three of the four hypotheses were rejected. In contrast, one of the four hypotheses, time trained in this program, was accepted.

The most significant return for conducting this research was the ability to affect positive social change. By examining the degradation of expertise among FGCs, results from this study will strengthen fire service policies and decrease the loss of life and the damage of property in the fire service and communities.

This study established an original contribution in which skill decay was examined in a fire service domain. This study has also shown statistical support that time since initial training in this particular training program significantly impacts the retainment of skills employed by FGCs. As skill decay is expected to be a risk to safety due to inherent dangers in firefighting, findings from this study can improve decisions made on the fire ground.

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Appendix A: Incident Command Survey

Residential Fire Scenario Dispatch Information

Dispatched at 1200 hrs on a Wednesday as a 3 & 1 House fire at 5th & Main Street.

Assignment: E-1, E-2, E-3, L-1, BC-1, Ambo-1

You are the company officer on Engine 1. You arrive on scene first, less than 3 minutes after dispatch.

L-1 will arrive on scene (per SOPs) 1 minute after your arrival.

E-2 will stage 2 minutes after your arrival.

BC-1 will arrive on scene (per SOPs) 4 minutes after your arrival.

E-3 will stage 6 minutes after your arrival.

Critical Fireground Factors

1. Which answer describes the four most significant critical factors for this scenario?

   - ☐ Time of day; roof construction; interior arrangement; heavy fire load
   - ☐ Fire's size extent and location; water supply; location and condition of any occupants; size of structure

- Size of structure; fire's extension into concealed spaces, possible attic fire; pressurized smoke
- Interior arrangement; size of structure; possible basement fire; dark, pressurized smoke
- Location and condition of any occupants; fire's extension into concealed spaces; fire's size extent and location; possible basement fire

Strategy

2. Based on the critical factors and the Risk Management Plan, choose the correct strategy
   - Marginal until a complete 360 is performed to confirm if a basement exists
   - Defensive
   - Offensive
   - Defensive until adequate resources arrive
   - Offensive until primary search is performed and then defensive

Hose-line Placement

3. Based on the chosen strategy, identify attack position No 1.
   - To the Charlie side first to confirm if a basement exists
   - Basement
   - Mobile command from the exterior
   - First floor, unless the 360 shows a basement fire
   - From the unburnt portion of the house

Second Attack Position

Based on the simulation, select the best answer below

4. Based on the chosen strategy, identify attack position No. 2.

- ☐ Basement
- ☐ Second Floor
- ☐ First Floor
- ☐ On-Deck
- ☐ Garage

Initial Support Work

5. Based on the chosen strategy, identify the necessary initial support work
    - ☐ Lay a supply line; pull an attack line to the seat of the fire; obtain fire control
    - ☐ Ventilate the roof; Positive Pressure Ventilation; secure utilities; open up concealed spaces
    - ☐ Put out the fire; check for fire extension; remove smoke, controlling the loss
    - ☐ Establish or support a water supply; secure utilities; obtain primary all-clear; ventilate the roof
    - ☐ Primary all-clear, fire control, loss stopped

Communications: Initial Radio Report

6. What are the size, height in stories, and occupancy type
    - ☐ Large, two story, single family residence
    - ☐ Small, two story, single family residence
    - ☐ Medium, single story, multiunit family residence
    - ☐ Medium, single story, single family residence
    - ☐ Large single story

Problem Description

7. Which best describes the smoke/fire conditions and the location/floor?
    - ☐ Smoke showing; coming from roof
    - ☐ Smoke showing; coming from basement
    - ☐ Working fire, coming from basement
    - ☐ Working fire, coming from the first floor
    - ☐ Defensive fire conditions, coming from roof

Initial Incident Action Plan

8. What is task #1 of the first arriving unit?
   - ☐ Assume command
   - ☐ Primary all-clear
   - ☐ Fire control
   - ☐ Establish a water supply
   - ☐ Obtain a 360
9. What is task #2 of the initial arriving unit?
   - ☐ Obtain a primary all-clear
   - ☐ Fire Control
   - ☐ Declare a strategy
   - ☐ Stretch an attack line
   - ☐ Establish a water supply
10. What is the location for Task #2?
    - ☐ Un-burned portion of the house
    - ☐ Second floor
    - ☐ First floor
    - ☐ On-deck
    - ☐ Charlie side

Resource Determination

11. What is your resource determination?
    - ☐ Hold original assignment
    - ☐ Cancel assignment
    - ☐ Balance the assignment to a full 1st Alarm/Box
    - ☐ Hold E1, Engine 2, Ladder 1. Balance can go available as they assemble
    - ☐ Hold E1, Engine 2, Engine 3, Ladder 1, Ambo 1. BC 1 can go available at their discretion

Communications: Follow-Up Report

12. What is the number of stories based on the results of the 360 (“Charlie” side)?

- ☐ Three-story
- ☐ Two-story
- ☐ One-story
- ☐ Four-story
- ☐ Two-story with a basement

13. What type of basement is this?

- ☐ Sub-basement
- ☐ Walk-out basement
- ☐ English Style
- ☐ Look-Out basement
- ☐ Deck basement

Post-360 Follow-Up Report

14. After completing a 360, what is your follow-up report?

- ☐ Working fire on the first floor to the Charlie side
- ☐ Working fire on the second floor extending into the attic
- ☐ Working fire in basement
- ☐ Defensive fire conditions
- ☐ Smoke showing from the Charlie side

Post-360 Follow Up Report Task #1

15. After completing a 360, what is the task, location, and objective #1?

- Pull an attack line to the first floor on Alpha side, use interior stairs, and obtain primary all-clear and fire control on the first floor
- Pull an attack line to the first floor on Alpha side, use interior stairs and make a quick hit on the basement before obtaining an all-clear and fire control on the first floor
- Redeploy handline to the Charlie side and enter the basement for primary all-clear and fire control
- Redeploy handline to the Charlie side, make a quick hit on the basement fire
- Obtain a quick search on the first and second floor and then go defensive

Engine Accountability Location

16. What is Engine 1's Accountability Location?
    - Charlie side
    - Alpha side
    - Bravo side
    - Delta side
    - North side

Assigning Ladder 1

17. How would you assign Ladder 1 (L-1)? Select One.
    - Spot your Ladder in a defensive position and set up an elevated master stream
    - Spot your ladder out of the way, go to the roof for vertical ventilation, secure utilities, and assign Ladder 1 Roof Sector
    - Spot on the Alpha side, stretch a handline off of E-1, obtain a primary search on the first floor and check for extension
    - Spot on the Bravo side, stretch a handline off of E-1, obtain a primary search on the first floor and check for extension
    - Spot on the Alpha side, stretch a handline off of E-1, quickly hit the basement on the Charlie side

Assigning Engine 2

Based on the simulation, select the best answer below

18. Assemble Your Radio Transmission for Engine 2 Assignment:
    - Pump E-1's supply line, stretch a handline off of E-1 to the Alpha side, back-up Ladder-1 to the first floor
    - Spot on E-1's hydrant, stretch a handline off of E-1 to the Alpha side, go on-deck
    - Lay a supply line to the Alpha-side, stretch a handline off your engine, obtain an all-clear to the second floor and check for extension
    - Lay a supply line to E-1 to Alpha side, stretch a handline off of E-1, check for extension to the second floor
    - Pump E-1's supply line, perform salvage and loss control

Communications: Command Transfer

You are now playing the role of BC-1

Please transfer command from the fast-attacking IC (the officer of E-1).

19. From the choices below, please select how you would organize the hazard zone for this scenario?
    - I would make E-1 Basement, Ladder 1 First Floor, E-2 On-Deck
    - I would make E-1 Charlie, make Ladder-1 First Floor, E-2 On Deck
    - I would leave E-1 as E1, leave Ladder 1 as Ladder 1, leave E-2 as E-2
    - I would leave E-1 as E1, leave Ladder 1 as Ladder 1, make E-2 On-Deck

- I would leave E-1 as Command, leave Ladder 1 as Ladder 1, leave E-2 as E-2

Conditions/Actions/Needs (CAN) Reports

Please listen to Sample Radio Transmission

"Engine 1 Command CAN report. Command from Engine 1 we got Fire Control, no extension to the joists in the basement and an All-Clear. We could use another Engine company down here to help mop up. Command copies Engine 1, fire control no extension to the floor joists in the basement, requesting another Engine company to help mop up. Ladder 1 Command CAN report. Command from Ladder 1, were All-Clear with no extension on the first floor requesting positive pressure ventilation. Command copies Ladder 1 you got an All-Clear with no extension on the first floor with no extension, requesting PPV. Engine 3 Level 1."

20. How would you deploy the On-Deck unit (E-2) and assign E-3 based on the CAN reports?
    - Have E-3 assist E-1 in the basement
    - Have E-2 deploy to the second floor to assist Ladder 1, assign E-3 to replace E-2 On-Deck
    - Have Ladder-1 re-deploy to the basement to assist E-1, assign E-2 to the first floor for PPV, assign E-3 On-Deck
    - Have E-2 deploy to the basement to assist E-1, assign E-3 to replace E-2 On-Deck
    - Have E-3 deploy to the basement to assist E-1, keep E-2 On-Deck

Wrap Up

Please listen to Sample Radio Transmission to hear E-2 and E-3's assignments

"Engine 2 Command. Engine 2. Engine 2 I need you to go to the basement and assist Engine 1 with mop-up. Engine 2 copies we'll make the basement and assist Engine 1 mop-up. Engine 3 Command. Engine 3. Engine 3 I need you to set up positive pressure on the Alpha side, I need you to go On-Deck Alpha side. Engine 3 copies we'll set up PPV and go On-Deck."

21. At this point in the Incident, what are your greatest priorities?
    - ☐ Evacuating the building for PARS
    - ☐ Salvage, Overhaul, and Loss Control
    - ☐ Return units back in service as quickly as possible
    - ☐ Re-Cycle Units, Re-hydrate, and Re-fill air bottles
    - ☐ Have a de-briefing with all assigned units with BC-1

Section 2: Operational Factors and Demographics
This Section pertains to operational factors and demographics that may impact situational awareness

22. After becoming a certified Incident Commander, how many working structure fires have you experienced as part of the incident management system on the scene? A "working fire" is a situation that at least required the commitment of all initial responding companies, engaged in tactical activities and held at the scene for an extended period. Please enter a numerical estimate.
23. How often does your Department incorporate multicompany drills or training on a quarterly basis? Please enter a numerical estimate.
24. How many overall years of experience do you have in the fire service? Please enter a numerical estimate.
25. How long have you been a certified IC? Please enter a numerical estimate in years than months. For example, 3 years, 5 months.
26. When performing the fire ground command survey, I tried hard to find the correct answers.
    - ☐ Strongly disagree
    - ☐ Disagree

- ☐ Neither disagree nor agree
- ☐ Agree
- ☐ Strongly agree

27. I believe I can accomplish many different tasks that are important to me.
    - ☐ Strongly disagree
    - ☐ Disagree
    - ☐ Neither disagree nor agree
    - ☐ Agree
    - ☐ Strongly agree
28. What is your age? Please enter a numerical estimate.
29. My highest level of education is:
    - ☐ Less than a high school degree or GED certificate
    - ☐ High school degree, GED certificate, or trade school certificate
    - ☐ Vocational or technical school certificate or degree
    - ☐ Some college
    - ☐ Associates degree
    - ☐ Bachelor’s degree
    - ☐ Master’s degree
    - ☐ Doctoral degree
30. I consider my sex to be:
    - ☐ Male
    - ☐ Female
    - ☐ Other
31. What is the size of your department? Please enter a numerical estimate.
32. What is your rank, position, or title?
    - ☐ Firefighter
    - ☐ Company Officer or Captain
    - ☐ Battalion Chief

- ☐ Deputy Chief
- ☐ Assistant Chief
- ☐ Fire Chief

33. How much time have you served at your current rank? Please enter a numerical estimate.

Appendix B: Tables

Table 5

Casewise Diagnostics

Case Number	Std. Residual	Dependent Variable Skill Decay	Predicted Value	Residual
31	-3. 022	6	13.07	-7.075
256	-3.436	3	11.04	-8.043
357	-3.745	1	9.77	-8.768
364	-3.697	1	9.65	-8.654

Note. Dependent Variable Skill Decay

Table 6

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.268	.072	.044	2.341

Note. Independent Variables: Experience, Training, Time Since Initial Training, Motivation, Efficacy, Age, Education, Sex, Department Size, Rank, Time in Rank.

Table 7

Correlation Coefficient

Model 1	Zero-order	Partial
(Constant)		
Experience	.126	.086
Training	.010	-.004
Time Since Initial Training	.158	.138
Time Rank	-.078	-.079
Motivation	-.027	-.010
Efficacy	-.088	-.099
Age	-.032	-.020
Education	.055	.075
Sex	-.108	-.097
Department Size	.067	.050
Rank	-.040	-.082

Note. Dependent Variable: Skill decay

Table 8

Analysis of Variance Showing Overall Fit of a Linear Model

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	154.678	11	14.062	2.566	.004
Residual	1994.726	364	5.48		
Total	2149.404	375			

Note. Dependent Variable: Skill.
Predictors: (Constant), Q32 Rank Time, Q29 Sex, Q23 IV Training Recat, Q26 IV Efficacy Dummy Variable, Q30 Department Size, Q22 IV Experience Working Fires, Q28 Education, Q25 IV Motivation Dummy Variable, Q27 Age, Q24 IV Time Since Initial Training, Q31 Rank Recatagorized

Table 9

Correlations

Pearson Correlation	Dependent Variable Skill Decay	IV Experience	IV Training	IV Since Initial Training
Dependent Variable Skill Decay	1.00	.126	.010	.158
IV Experience	.126	1.00	.094	.332
IV Training	.010	.094	1.00	.088
IV Time Since Initial Training	.158	.332	.088	1.00
IV Motivation	-.027	.029	-.010	.024
IV Efficacy	-.088	.033	.021	.030
IV Age	-.032	.098	-.041	.133
IV Education	.055	.067	.076	-.035
IV Sex	-.108	.006	.018	-.076
IV Department Size	.067	.036	-.060	-.018
IV Rank	-.040	.252	.056	.115
IV Rank Time	-.078	-.075	.035	.053

(table continues)

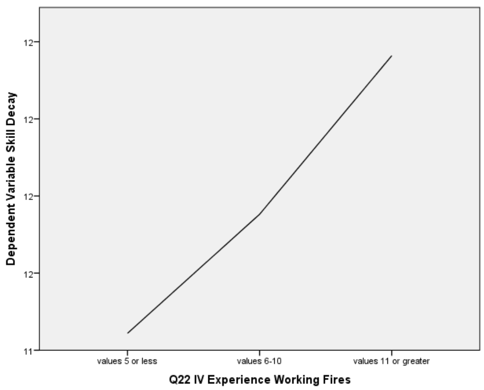
Pearson Correlation	IV Motivation	IV Efficacy	IV Age	IV Education
Dependent Variable Skill Decay	1.00	.126	.010	.158
IV Experience	.029	.003	.098	.067
IV Training	-.010	.021	-.041	.076
IV Time Since Initial Training	.024	.030	.113	-.035
IV Motivation	1.00	.187	.057	.006
IV Efficacy	.187	1.00	-.068	.050
IV Age	.133	.057	1.00	-.036
IV Education	.006	.050	-.036	1.00
IV Sex	-.041	.018	-.043	.087
IV Department Size	.008	-.048	.078	-.002
IV Rank	-.076	-.018	.268	.154
IV Rank Time	.176	-.056	.299	-.072

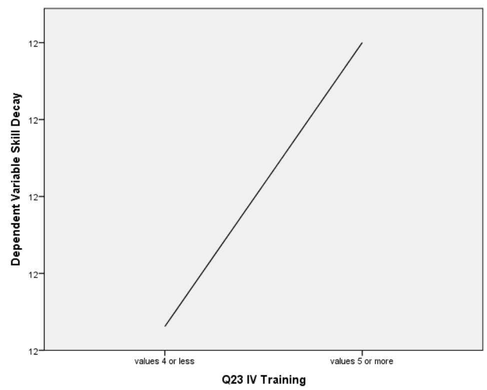
(table continues)

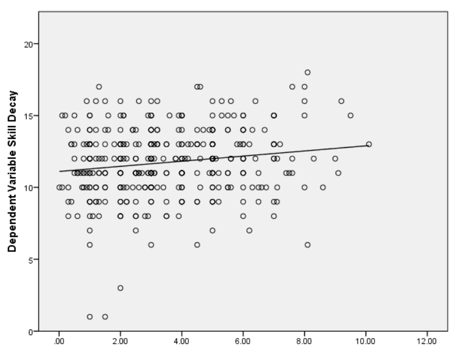
Correlations

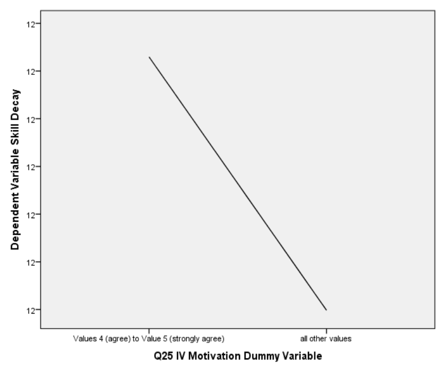
Pearson Correlation	IV Sex	IV Department Size	IV Rank	IV Rank Time
Dependent Variable Skill Decay	1.00	.126	.010	.158
IV Experience	.006	.036	.252	-.075
IV Training	.018	-.060	.056	.035
IV Time Since Initial Training	-.076	-.018	.115	.053
IV Motivation	-.041	.008	-.076	.176
IV Efficacy	.018	-.048	-.018	-.056
IV Age	-.043	.078	.268	.299
IV Education	.087	-.002	.154	-.072
IV Sex	1.00	-.025	.097	-.013
IV Department Size	-.025	1.00	-.087	-.043
IV Rank	.097	-.087	1.00	-.179
IV Rank Time	-.013	-.043	-.179	1.00

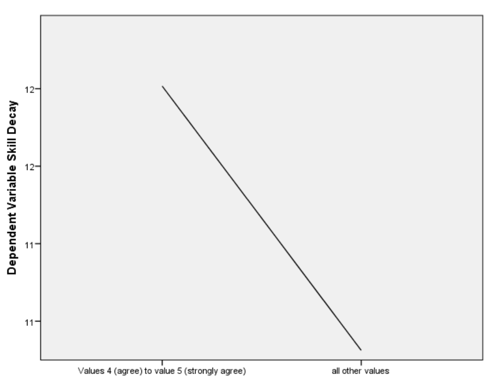
Appendix C: Figures

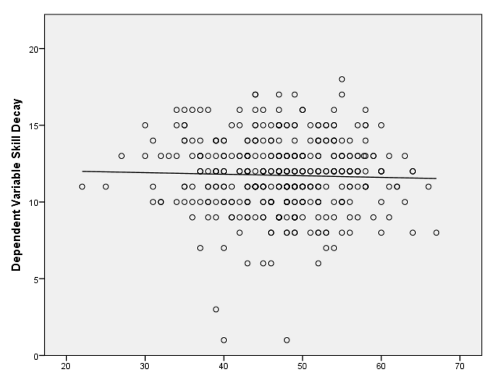












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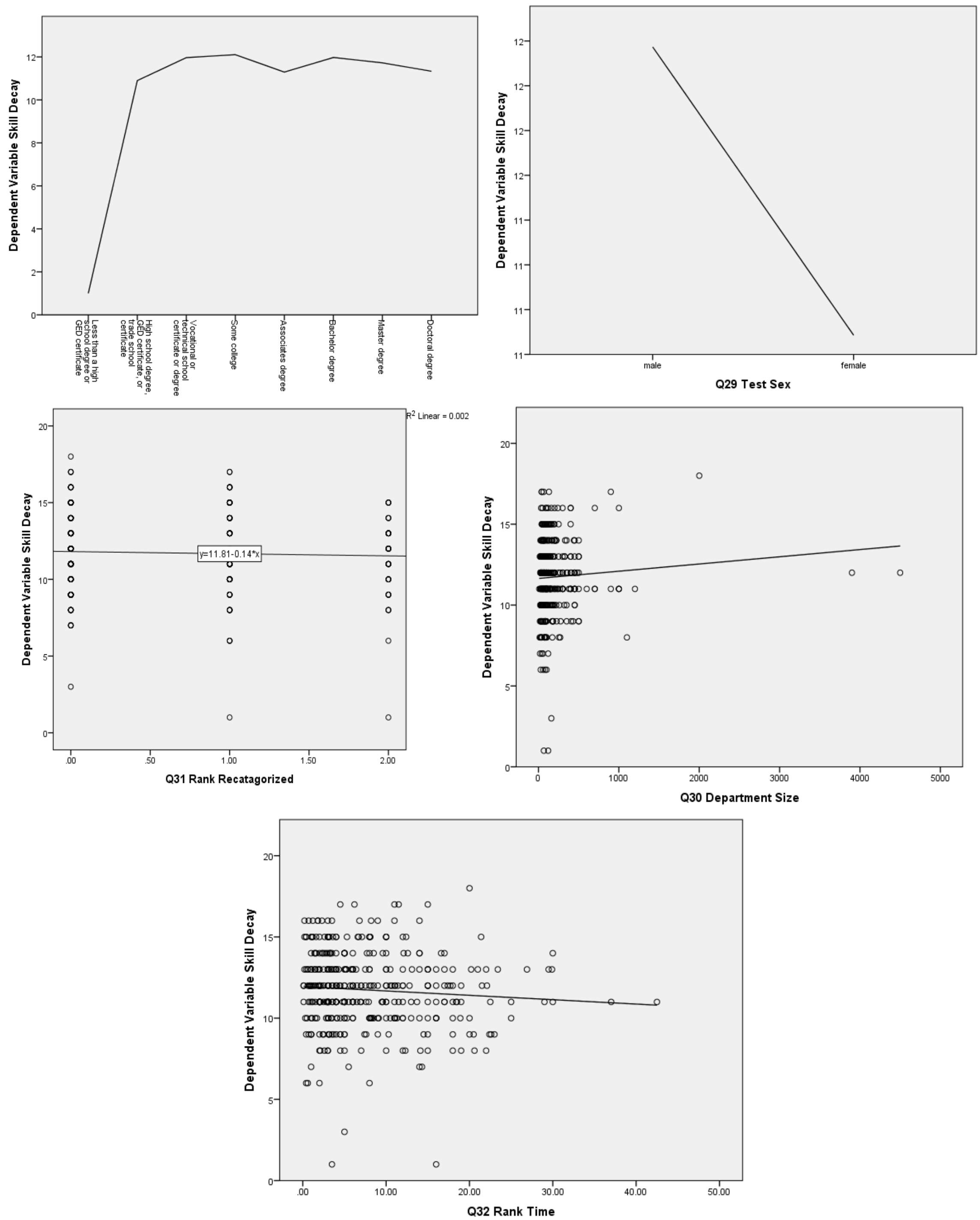

Figure 1. Scatterplots showing the relationship between the Dependent Variable and Independent Variables.

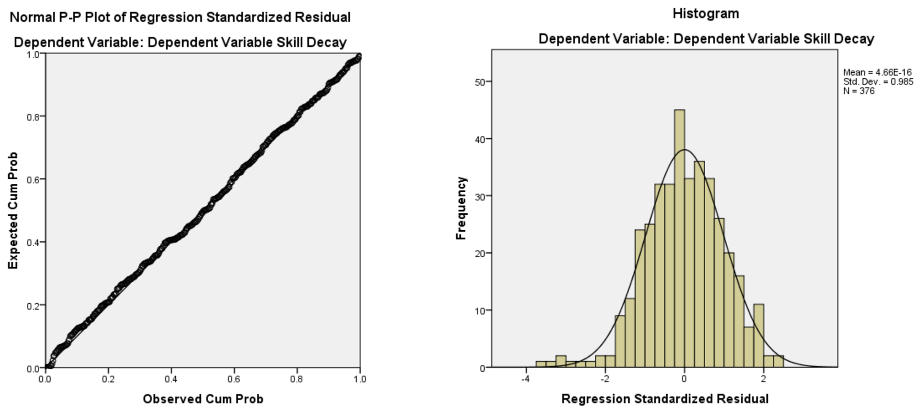

Figure 2. Histogram and normal P-P plot for the residuals from the model

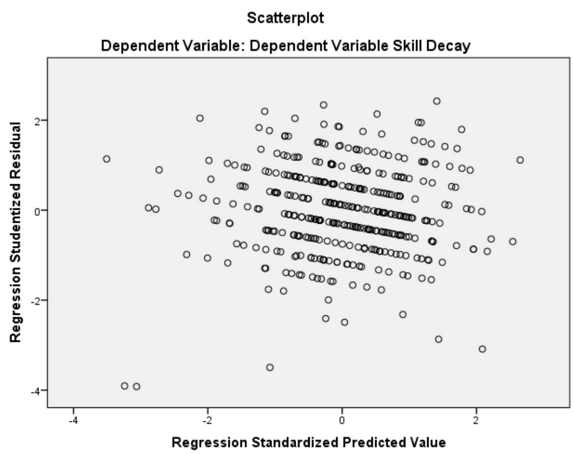

Figure 3. Scatterplot testing for homoscedasticity