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Personality Factors and Nuclear Power Plant Operators: Initial License Success

Cynthia Catherine DeVita-Cochrane
Walden University

Walden University

College of Social and Behavioral Sciences

This is to certify that the doctoral dissertation by

Cynthia DeVita-Cochrane

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Review Committee
Dr. James Herndon, Committee Chairperson, Psychology Faculty
Dr. Lori LaCivita, Committee Member, Psychology Faculty
Dr. Richard Thomlinson, University Reviewer, Psychology Faculty

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Eric Riedel, Ph.D.

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Abstract

Commercial nuclear power utilities are under pressure to effectively recruit and retain licensed reactor operators in light of poor candidate training completion rates and recent candidate failures on the Nuclear Regulatory Commission (NRC) license exam. One candidate failure can cost a utility over $400,000, making the successful licensing of new operators a critical path to operational excellence. This study was designed to discover if the NEO-PI-3, a 5-factor measure of personality, could improve selection in nuclear utilities by identifying personality factors that predict license candidate success. Two large U.S. commercial nuclear power corporations provided potential participant contact information and candidate results on the 2014 NRC exam from their nuclear power units nation-wide. License candidates who participated (n = 75) completed the NEO-PI-3 personality test and results were compared to 3 outcomes on the NRC exam: written exam, simulated operating exam, and overall exam result. Significant correlations were found between several personality factors and both written and operating exam outcomes on the NRC exam. Further, a regression analysis indicated that personality factors, particularly Conscientiousness, predicted simulated operating exam scores. The results of this study may be used to support the use of the NEO-PI-3 to improve operator selection as an addition to the current selection protocol. Positive social change implications from this study include support for the use of a personality measure by utilities to improve their return-on-investment in candidates and by individual candidates to avoid career failures. The results of this study may also positively impact the public by supporting the safe and reliable operation of commercial nuclear power utilities in the United States.

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Dedication

This work is dedicated to my late maternal grandmother, Catherine Beatty Helms, the first and most significant scholar in my life.

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It is overwhelming to consider all the sacrifices made by others so that I could complete this process. I will never be able to express my gratitude fully to the people who have been there every step of the way, but here is my feeble attempt. Thank you first and foremost to my amazing husband Nathan, who said yes to this whole thing from the beginning and kept saying yes, even when it meant late night coffee runs, and single parenting, and juggling all the household chores on top of his own career, and cheerleading me back to writing when I thought I had nothing to say. Nathan, I love you fiercely and forever. Thank you to my four sons who have put up with my absences and pitched right in on household work and did a whole lot more than their peers, who didn't have a mom who was still in college. Josh, Caleb, Levi and Thayne, you have been my best teachers. Thank you for going on this journey with me. To my parents, Pete and Terry DeVita, thank you for the support, encouragement, babysitting, and well, you know, I owe you for everything I am. A big huge thank you to my amazing dissertation chair, Dr. James Herndon, who was tough on me when I needed it and stuck with me though this took much longer than either of us planned. Dr. Herndon, I admire your strength and your discipline and want to be just like you when I grow up. Thank you to my methodologist, Dr. Lori LaCivita for wisdom and insight, and for the example she is to all women of how to navigate a phenomenal career with intelligence and grace. Thank you to my university research reviewer Dr. Paul Thomlinson for his critical insight into my study design and analysis. Finally, and most importantly, thank you Jesus for saving my life and redeeming me. May I always be useful to you, and may you get all the glory.

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Chapter 1: Introduction to the Study

Introduction

The pupose of this study was to ascertain the predictive capacity of a personality measure to identify nuclear operator candidates who are able to successfully complete the 18-month to two-year licensing process and achieve a Nuclear Regulatory Commission (NRC) license to operate a commercial nuclear power plant. This research meets a current need in the nuclear power industry by addressing a potential source of the industry-wide problem of the low throughput of initial candidates for NRC licenses. "Low throughput of candidates in license classes" refers to the low ratio of individuals who are selected for licensing compared to those that complete the process and achieve a license. Poor throughput has resulted in millions of dollars of losses across the industry and has been a poor return on investment in personnel (Nuclear Energy Institute [NEI], 2011). A number of needs may have diminished the effectiveness of the industry's current selection processes: a shifting and more diverse talent stream, a tremendous uptick in demand, and a subsequent increase in competition for top talent (Krell, 2008). The addition of a valid and reliable personality measure to the current selection criteria for new license candidates may improve throughput by improving selection.

Nuclear power is something of an enigma. What began in the United States as an industry with the great potential to be a reliable and stable source of energy, became a source of controversy after the accident at Three Mile Island in 1979 (NRC, 2013a). Subsequently, the growth of nuclear power stalled, construction halted on new plants (WNO, 2013; Cook, 1985), and nuclear power became somewhat ignored as a career path

in the 80s and 90s (Kenley, et. al, 2009). However, recently nuclear power is exhibiting something of a renaissance. There are currently 102 licensed nuclear power reactors in the United States which produce 20% of its domestic power, but that number will increase by as many as 24 in the next ten years (NRC, 2013). This renaissance has brought with it unique challenges in an industry unaccustomed to rapid growth, given past events.

The partial meltdown at the Three Mile Island nuclear power plant in the spring of 1979 brought tremendous change to the oversight of nuclear plants and effectively halted the growth of nuclear power in the United States (Cook, 1985; Kenley, et. al, 2009; NRC, 2013a). As a result, in the last several decades, the need to recruit and train new nuclear operators diminished significantly. Nuclear power educational programs at universities and technical colleges all but disappeared in the 1980s (Krell, 2008; NEI, 2009). According to the training manager at Nine Mile Point, a dual unit nuclear power plant in New York, at some sites, including his, initial license classes for new nuclear operators were not conducted for as many as fifteen years, resulting in a very stable, even stagnant, workforce (R. Brown, personal communication, August 20, 2010). Meanwhile, the U.S. Navy, a reliable source of talent for the industry in the past, continued to shrink (Jean, 2010). Added to these challenges is the large number of anticipated retirements of current operators in the near future (Wells, 2007). Taken together, the factors converging during the current renaissance of nuclear power require that nuclear sites compete for scarce talent either emerging from the U.S. Navy, or from the many new and resurrected

university and technical college nuclear power training programs nationwide (Krell, 2008; NEI, 2009).

As measured by throughput, the ratio of initially selected individuals to those who actually complete nuclear power plant operator training and pass the NRC operating license exam, the industry is not succeeding at attaining optimal staffing for the future. Currently the industry-wide average throughput for initial license classes is 60% (NEI, 2011). In some plants it is much lower. This represents a tremendous financial loss to nuclear power utilities in terms of return on investment,because the cost of training a new nuclear operator exceeds four hundred thousand dollars (NEI, 2011). Moreover, in a highly regulated industry, this type of failure affects more than just the bottom line of the organization. It becomes a matter of public safety. Regulatory requirements will not allow a nuclear power plant to operate understaffed, or staffed by poorly qualified individuals (10 CFR part 55.54; NRC, 2013c). Therefore, the industry must improve their throughput numbers.

There are a number of factors that may affect the throughput of initial license candidates. However, the scope of my study was limited to examining one potential aspect of this issue: candidate selection. Candidate selection in nuclear power warrants study, as it is the initial point at which the utility has the opportunity to acquire top talent and maximize their potential for success. By improving selection, it may be possible to improve throughput. One consideration regarding the issue of selection is that nuclear utilities' talent pools have shifted significantly since the initial wave of staffing occurred. It is likely, given the static workforce in nuclear power, that the processes used to select

license class candidates have not significantly changed over the past few decades, and as such, may not be sufficient to differentiate top candidates. Indeed, a recent report suggested that the industry conduct completely new job analyses (NEI, 2011). This suggestion was likely in response to the 2009 Institute for Nuclear Power Operations (INPO) "Call to Action," which addressed the poor industry-wide throughput numbers. As the internal governing body of commercial nuclear power, INPO tracks trends and identifies potential industry issues. In this case, INPO indicated the selection of initial license candidates as the second-most common reason for poor throughput in initial license classes, and identified this as an industry-wide weakness (NEI, 2011). Operations training organizations within nuclear power utilities were tasked with improving throughput based on this INPO report (NEI, 2011). However, the problem of poor throughput in the industry reaches back at least as far as 2004 according to a report from the National Academy of Nuclear Training (NANT), the training arm of INPO that supports member training organizations (NANT, 2009). This report also indicated operator selection criteria as part of the root cause for poor throughput for initial operator licensing industry-wide.

Following the Three Mile Island accident, the nuclear power industry made great strides improving the training of operators on cognitive requirements. This was done in response to increased oversight from the NRC and in-line with a revised Code of Federal Regulations Part 10, which governs the operator licensing process (10 CFR 55). The Kemeny Commission Report (Kemeny, 1979) produced by the President's commission to investigate the root cause of the TMI accident was the vehicle that initiated the increased

oversight and also resulted in the formation and acceptance of INPO as a self-governing body for commercial nuclear power (U.S. Government Accountability Office, 1991). Subsequently, by applying the systematic approach to training (SAT), the industry developed an extensive knowledge and abilities catalogue which clarified the cognitive requirements of the operator role (NRC, 2000). By using the SAT five-step ADDIE process (analyze, design, develop, implement, and evaluate), training and operations departments in commercial nuclear power had a clear process to identify the knowledge and abilities required of licensed operators, which in turn informed the selection process (INPO, 2010; NRC, 2000). However, no direct guidance was given regarding the personality or other personal qualities required in the selection process because the aim was to improve training and elevate the level of knowledge required for license examinations (NRC, 2000). The NRC remained the regulator and established a standard for licensing, but allowed the industry, through INPO, to establish the hurdles for hiring. Subsequently, a standardized, industry-developed cognitive test called the plant operator selection system (POSS) was developed, which became the main hurdle for new operator candidates (Edison Electric Institute, n.d.).

In short, selection processes became very focused on answering the question of whether a candidate *could do* the required work. However, the question of whether an individual *would do* what was required, by aligning personality profiles with behavioral work requirements, was not clearly identified by this approach (Baird & Hammond, 1982; Barrick & Mount, 2005; Cellar, Nelson,York, & Bauer, 2001). It is interesting to note that even in early reports of the throughput problem, certain personality factors are

identified as root cause items, but no guidance on how to measure such items is given. For example, the NANT (2009) report noted that candidates did not display "personal commitment necessary to obtain a license" (p. 4), but gave no guidance on how to measure such "commitment." It appears that the industry is aware of personality factors that could influence success during initial licensing, but it is unclear whether they measure them effectively. This may be due to the fact that a measure of normal, or non-clinical, personality was not routinely included in the selection process.

In regard to non-cognitive requirements for selection of operators, the NRC has only required the use of personality tests to screen-out potential problem employees (Baird & Hammond, 1982; Frank, Cohen, & Lindley, 1981). In such a highly regulated industry, adherence to the regulatory guidance takes precedence. Therefore, as the NRC directed, personality testing is viewed by the industry as an obstacle used to prevent emotionally unstable individuals from serving in sensitive positions (10 CFR part 50.50; 10 CFR part 50.54; ANSI/ANS 3.1-1993). These regulations couch personality testing as part of the fitness-for-duty requirements for operators. The industry almost exclusively chose to use the Minnesota Multiphasic Personality Inventory (MMPI) to screen for psychopathology, and has combined the test with a physical exam, thus categorizing personality testing as medical in nature (Lavin, et.al, 1987). Local norms for nuclear power were developed in the mid-to-late 1980s which further served to bolster the particular use of the MMPI as the measure of choice to screen-out individuals for psychopathology (Lavin, 1984; Lavin, et.al, 1987). The prevalent view of personality

testing as a medical hurdle for operators may have served as an obstacle to the use of personality to predict desirable behaviors.

Concurrent with the addition of personality to the selection process as a screen-out measure in nuclear power, the scholarly debate on personality in the literature in the 1970s and 1980s reflected the sentiments of Mischel (1968; 2009) and others who rejected personality measures as predictive of work behaviors. It is likely that this prevailing perspective informed the NRC and prevented consideration of personality as a predictive tool. With the publishing of meta-analyses such as Barrick and Mount (1991), scholarly literature began to shift away from this perspective. However, it appears the influence of this shift was not influential in nuclear power, likely because the process in place was effective and the need to select new operators, as mentioned previously, had tapered significantly. Thus, it appears that the selection processes in the utilities remained the same (Daly, 2009; NEI, 2011). It was not until much later that the industry began to experience poor throughput, and the selection process was highlighted as a potential root cause (NEI, 2011).

The nuclear power industry apparently has a well-developed process to identify the cognitive skills and abilities, the "can do" aspects, which are required for the licensed operator role. The knowledge and abilities catalog for nuclear power utilities enumerates some 5,500 items necessary for the licensed operator role (NRC, 2000). The industry-developed POSS test is designed to identify candidates who possess or can acquire those skills. The question then, is whether that hurdle--the POSS test--along with a clinical personality measure to screen out psychopathology, is sufficient to select a new

generation of nuclear operators. Perhaps this approach is insufficient given the current industry-wide struggle with throughput. It may be that the addition of a measure of normal personality to identify the "will do" aspects of the operator role is warranted. This study was designed to explore and identify the key personality factors of currently successful initial license candidates, and to querry the extent to which those factors may provide a template, or benchmark, to guide future selection.

This introductory chapter provides a background and setting for this research study and a summary of current literature on the subject of personality and selection in high reliability organizations (HRO) like nuclear power utilities. This chapter then previews the literature gap that I have identified and outlines how my study addressed that gap. Following that is a discussion of the problem my research addressed, an explanation of the purpose of the study including its research questions and hypotheses, and a description of the overall nature of the study. I conclude this chapter by presenting the study's definitions, assumptions, scope and delimitations, limitations, potential significance, and social change implications.

Background

Literature Review Summary

In preparation for the study, I conducted an exhaustive literature review over a period of two years using the literature search methodology that I extensively address in Chapter 2. Because of the paucity of recent literature on the subject of personality and selection in nuclear power utilities, I included sources beyond peer-reviewed journals such as utility publications, government documents, and unclassified reports. Several

salient points emerged, including the following. First, as in other HROs where technical proficiency is paramount, personality facets are not generally relied upon in personnel selection in the nuclear power industry (Flin, 2001). Rather, resumes, interviews by supervisors (and sometimes by subject matter experts), and the POSS test, are the preferred selection tools (R. Brown, personal communication, August, 2011). Second, nuclear utilites exclusively use the Minnesota Multiphasic Personality Inventory (MMPI) to identify potential psychopathology and to subsequently select out undesirable candidates (Frank, et. al, 1981; Lavin, Chardos, Ford, & McGee,1987). Third, it may be that objections to the use of non-clinical personality as a select-in measure may have been rooted in long-standing debates about the validity of personality in selection (Barrick & Mount, 1991; Frank, et. al, 1981; Guion & Gottier, 1965; Mischel, 1968, 2009). It is clear that the bulk of scholarly literature supporting the reliability and validity of personality to predict work behaviors was published after the guidance given by the NRC by a number of years (Barrick, Mount, & Judge, 2001; Costa, 1996; Cellar et.al, 2001; Digman, 1990; Hogan & Holland, 2003) and therefore may have not been considered for inclusion in such guidance. However, there may have been other objections to the use of personality to predict performance in such a highly technical field.

Questions regarding the validity of personality tests are centered on four main topics: their self-report nature (Morgeson, et.al, 2007), the potential for faking on personality tests (Converse, Peterson, & Griffith, 2009), the influence of situational factors (Mischel, 1968, 2009; Mischel & Shoda, 1995), and the perception that personality tests are clinical or medical in nature and therefore not useful for prediction in

a work setting (Lavin, 1984). These objections, which I address in more detail in Chapter 2, along with the timing of the literature development supporting non-clinical uses of personality measures, may have led both to the use of the MMPI as an exclusively screen-out measure and to some resistance to the addition of a personality measure as a predictive tool. It is unlikely that individuals working in the nuclear power industry are aware of the differences between personality measures (clinical vs. non-clinical), or the incremental validity provided by personality over cognitive measures (Barrick & Mount, 2005; Schmidt & Hunter, 1998), because according to a corporate training director at one of the largest nuclear power companies in the U.S., there are very few industrial-organizational psychologists employed within the industry (G. Ludlum, personal communication, June, 2010). In addition, decision-making on selection and training issues has historically been the function of the operations division of a utility, rather than the human resources organization (McCullough, 2004). Nuclear power operation is a highly specialized role, requires years of advanced training, and for SROs a technical degree is also required (Weick & Sutcliffe, 2007). Given that their technical specialty is in nuclear power, it is unlikely that typical operations personnel are also experts on personality, and thus they may not even be aware of the usefulness of a non-clinical approach to personality measurement in selection such as the five-factor model (FFM). The FFM has been shown to be a valid and effective tool for selection and talent development purposes across a wide range of industries including HROs (Barrick & Mount, 2005; Flin, 2001), but has not been well studied in the nuclear power setting, likely because of the difficultly with gaining access to nuclear plant personnel (Flin,

2001; Lavin, 1987). Evidence may exist that personality is important to nuclear operator success, but may have to be inferred from other published documents such as job descriptions, regulations, and competency models. Reviews of additional literature from related fields such as team dynamics, shared mental model studies, and human factors/error prevention research also provide clues to salient personality facets required for nuclear operators, however they are not all consistent. I develop this line of inquiry in Chapter 2.

Literature Gap

My exhaustive review of peer-reviewed journals, utility publications, government regulations and documents, and unclassified reports revealed that, to date, no domestic peer-reviewed publication has examined the ability of an empirical measure of personality to predict the success of initial license nuclear operator candidates.

Study Need

If there is a current, well-designed study on the predictive capacity of normal personality facets indicating success for initial nuclear operator license candidates, it has not been published. There is certainly no record of a domestic study of the topic in a peer-reviewed journal. Therefore, it is likely that empirical information on whether personality facets play a role in initial license operator success is not widely available to nuclear utilities. In a variety of other settings, including other HROs, personality facets have been shown to be valuable predictors of success as defined by measures such as job performance (Barrick & Mount, 2001; Rothstein & Goffin, 2006), positive life outcomes (Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007), and organizational citizenship

(Bourdage, Lee, Lee, & Shin, 2012). Within HROs, there is some evidence that personality has been used to provide incremental validity for selection in roles similar to nuclear operators, such as air traffic controllers and pilots (Barr, Brady, Koleszar, New, & Pounds, 2011; King, 2014; Luuk, Luuk, & Aluoja, 2009) and medical providers (Webster, 2005; Wedertz, 2012). It follows that this study, by addressing a gap in the literature, may assist the nuclear utility industry in selecting and developing a new generation of nuclear operators more effectively. On a broader scale, my study contributes to the literature on personality as predictive of job success in HROs.

Problem Statement

Nuclear power utilities are experiencing poor throughput of their initial nuclear operator license candidates (NEI, 2011). The impact on the utilities of poor ILC throughput results in a misuse of human capital and losses in the millions of dollars (NEI, 2011). The selection process for individuals hired to pursue licenses as reactor operators (ROs) and senior reactor operators (SROs) are similar, and may both be improved by the addition of a select-in personality measure that is predictive of initial license candidate (ILC) success.

Relevant Cultural Issues

The issue of inadequate selection of new nuclear operators for licensing classes is exacerbated by current circumstances including an increased need to recruit because of impending new builds, the trend of license renewals for existing plants, and the anticipated large wave of retiring licensed operators in the next 10-plus years (Wells, 2007). In addition, the generally insular nature of the nuclear power industry may have

prevented its selection process from changing significantly in the past two or more decades. One of the principal characteristics of the nuclear utility culture encouraged by INPO is that nuclear power is "special and unique" (2004, p. 6), and as such, is very inwardly focused on their unique "safety culture" (p. 6). The highly technical culture of nuclear power values technical expertise and experience, and relies upon benchmarking within the industry for continual improvement (INPO, 2009). This insular orientation is supported by a cultural norm of "deference to expertise" with the most senior and expert individuals on a nuclear site being the most experienced licensed operators (Weick & Sutcliffe, 2007, p.73). The tendency toward insularity in nuclear power culture is recognized by the industry and has even been indicated as a root cause in major accidents, such as the most recent event at Fukushima (Acton & Hibbs, 2012; National Diet of Japan, 2012). Indeed, the same INPO *Principles of Safety Culture* document states that in a nuclear culture "The line organization…is the primary source of information, and the only source of direction" (2009, p. 2). There is some evidence that the expert operators who make hiring decisions at commercial power plants are just recently becoming aware of more current approaches to personnel selection (G. Ludlum, personal communication, August, 2010). In addition, the selection process guided by government regulation from the NRC and through INPO via self-assessments, benchmarking, and sharing of best practices in the industry may not always be followed. According to the NANT report in 2009, one of the root causes of poor throughput was that "Candidates were placed in class when they did not meet selection criteria" (p. 4), indicating that the line organization could and did ignore their own selection process

governance. The selection process developed as a result of the Three Mile Island accident was apparently effective for many years, but may no longer be sufficient because of scarce talent, a shifted talent pool, increasing demand, and an insular culture which allows deviation from selection process guidance.

Relevance to Current Literature

The issue of the use of personality measures to improve selection is relevant to the current dialogue on personality in the literature. For example, my study contributes to discussions regarding the incremental validity of personality measures plus cognitive measures over the use of cognitive measures alone. My study is also relevant to current discussions regarding the use of personality measures to select-in as aligned to specific job expectations, rather than merely as a screen-out barrier for those ill-suited for certain roles due to identifiable psychopathology. In spite of its relatively small sample size, my study represents a significant contribution to the literature, as it extends the sparse domestic dialogue on the usefulness of personality measures in HROs in general, and nuclear power organizations in particular. This study also builds on previously published international research on the personality facets common in successful operators (Xiang, Xuhong, & Bingquan, 2008). In addition, related research, which I address further in Chapter 2, on human performance, team performance, and training may be impacted by the results of this study. Finally, this study directly addresses a gap in the literature on personality as predictive of the success of initial license candidates in the nuclear power industry.

Purpose of the Study

Purpose Statement

I designed this study to address the issue of throughput in nuclear operator initial license classes by investigating the predictive capacity of personality for selection into ILC. Using a quantitative, correlative study design, I sought to identify whether personality domains based on a five-factor model correlated with the successful nuclear operator initial license candidates. I also designed the study to determine which domain-level personality factors are most predictive of success on the written and simulator portions of the NRC operator-licensing exam as well as the overall candidates' results of pass or fail on the exam.

Type and Intent of Study

The correlational design of my study utilized descriptive statistics, differential analysis, product-moment and bi-serial correlation, and logistic regression as well as multiple regression to identify whether personality factors correlate with the success of initial license nuclear operator candidates, and whether any five-factor model domains are predictive of success on the NRC operator-licensing exam. Identification of correlational and predictive factors support the social change goal of this study by providing information on personality that may aid in future initial nuclear operator license candidate selection. I offer a more detailed description of the study design and intent in Chapter 3.

Study Variables

The independent, or predictor, variables for the research question described below are the five domains of the NEO-PI-3 personality assessment instrument. The dependent, or outcome, variables in this study are the candidates' scores on the written exam, the simulator portion, and their composite scores, pass or fail, on the NRC licensing exam.

Research Questions and Hypotheses

The following questions (RQs) guided my research:

RQ1: Do successful initial operator license candidates (ILC), as differentiated from unsuccessful candidates, have certain personality factors (as measured by the domains of the NEO-PI-3) in common?

RQ2: Which, if any, of the common factors of successful ILCs correlate with successful completion of the licensing process, including the written portion, the simulator portion (pass/fail), and the final score (pass/fail) of the NRC licensing exam?

RQ3: Which personality factors are most predictive of the success of ILCs on the written test, the simulator portion (pass/fail), and the final score (pass/fail) of the NRC licensing exam?

For my study, I tested the hypotheses (H) below to answer the research questions outlined above. They are outlined in both the null and alternative forms. For RQ1:

$H1_0$: There is no difference in the means of successful candidates and unsuccessful candidates on any of the five NEO-PI-3 personality domains. So, for each domain, $H1_0$: $\mu_s = \mu_u$.

$H1_a$: There is a difference in the means of successful candidates and unsuccessful candidates on any of the five NEO-PI-3 personality domains. So for at least one domain, $H2_a$: $\mu_s \neq \mu_u$.

For RQ2:

$H2a_0$: There is no significant correlation between any personality factor and ILCs' final NRC written exam scores, H_0: $r = 0$.

$H2a_a$: A significant correlation exists between any personality factor and ILCs' final NRC written exam scores, H_a: $r \neq 0$.

$H2b_0$: There is no correlation between any personality factor and ILCs' final NRC simulator portion exam scores, $H2b_0$: $r = 0$.

$H2b_a$: There is a significant correlation between at least one personality factor and ILCs' final NRC simulator portion exam scores, $H2b_a$: $r \neq 0$.

$H2c_0$: There is no significant correlation between any personality factor and ILCs' final NRC exam scores (pass/fail), $H2c_0$: $r = 0$.

$H2c_a$: There is a significant correlation between at least one personality factor and ILCs' final NRC exam scores (pass/fail), $H2c_a$: $r \neq 0$.

For RQ3:

$H3a_0$: There is no significant linear relationship between any personality factor and ILCs' final NRC written exam scores, $H3a_0$: $B = 0$.

$H3a_a$: A significant linear relationship exists between at least one personality factor and ILCs' final NRC written exam scores, $H3a_a$: $B \neq 0$.

$H3b_0$: There is no significant linear relationship between any personality factor and ILCs' final NRC simulator exam scores, $H3b_0$: $B = 0$.

$H3b_a$: A significant linear relationship exists between at least one personality factor and ILCs' final NRC simulator exam scores, $H3b_a$: $B \neq 0$.

$H3c_0$: There is no significant linear relationship between any personality factor and ILCs' final NRC exam scores (pass/fail), $H3c_0$: $B = 0$.

$H3c_a$: A significant linear relationship exists between at least one personality factor and ILCs' final NRC exam scores (pass/fail), $H3c_a$: $B \neq 0$.

Theoretical Framework

I used the five factor theory as the principal source theory to provide structure and underpinning to this study. It is derived from the lexical approach to personality and supported by empirical evidence from five factor model research (Poropat, 2009). However, several other major hypotheses undergirded the aim of this study as well, including research on the predictive capacity of personality assessments in job settings and the incremental validity provided by personality assessments over cognitive measures alone. I examine the theoretical basis for this study in Chapter 2.

Nature of the Study

The purpose of this study was to attempt to identify whether the addition of a measure of normal personality to nuclear operator selection may improve the accuracy of predicting the success of an ILC in the nuclear power industry. I accomplished this goal by assessing the personality of license class candidates and conducting a regression

analysis to compare the personality scores to data on candidate scores on the NRC exam in order to determine the personality factors that are most predictive of ILC success.

The Design. This quantitative correlational research design is appropriate for several reasons. As noted previously, nuclear power is a highly technical industry. A survey by the International Atomic Energy Agency (IAEA) indicates that most individuals in management positions at nuclear utilities have university degrees in technical fields, many with master's degrees in such fields as nuclear physics or engineering (IAEA, 2002). The positive social change design of this study -- to improve selection through the use of a measure of normal personality, potentially saving the industry millions of dollars, preventing individual career derailment, and contributing to the safe and reliable operation of nuclear power in the U.S. -- was therefore achieved through a quantitative design. Given the technical orientation of the majority of decision makers in the nuclear power industry, I reasoned that the results from a study that provided concrete, quantitative data might prove more persuasive than a qualitative approach. In addition, I designed this correlational study, which can also be described as non-experimental due to the inability to perform actual random selection from the population, the lack of random assignment to experimental groups, and the lack of an intervention or variable manipulation, to be representative of all four of the NRC regions of nuclear plants. This approach, a balanced regional representation of the population of United States nuclear operator candidates, was intended to improving the overall generalizability of results. The correlational design of the study was appropriate for identifying and evaluating whether personality characteristics are predictive of operator

licensing success. The characteristics I identified in this study and report in the results section of this dissertation may help improve ILC selection in the nuclear power industry. I found several statistically significant relationships between personality factors and the established success criteria (NRC exam results) in my analysis of the collected data, which confirm that the choice of study design was appropriate. Finally, my use of the NEO-PI-3 was appropriate because it provides clear, concise language based on common descriptors of personality, which may improve the applicability and accessibility of the results of this study to an industry that may be less familiar with personality theory and constructs.

The Variables. The independent, or predictor, variables in this study were the five domains of the NEO-PI-3. The dependent, or outcome variables for the research question are the candidates' results on the Nuclear Regulatory Commission licensing exam: The written portion score, which is a continuous variable, the simulator portion score, and final NRC exam result which are both dichotomous variables – either pass or fail. I include a more detailed description of the variables and methods for their measure in Chapter 3.

The Sample. I designed this study to be conducted with approximately 100 nuclear operator license candidates, in cooperation with 10-12 U.S. nuclear power-plant training facilities and including at least two facilities in each of the four NRC regions to ensure geographic diversity. I contacted training facility managers to request participation from candidates who were in a license class any time during 2014. Candidates were fully informed of the purpose of the study via an email, which I describe further in Chapter 3. I

asked candidates to voluntarily participate by taking the NEO-PI-3 via secure email link. In addition, I asked candidates who chose to participate for their consent to allow the training facility to provide me final NRC exam results for final analysis. I analyzed data via IBM's Statistical Package for the Social Sciences (SPSS), and provided participant sites aggregated summary data at no charge as an incentive to participate. I provided participants access to their personality assessment results directly when requested.

Definitions

The definitions of terms relevant to this study are provided below:

Five-factor model: a model of personality based on everyday language, sometimes referred to as the lexical hypothesis, which has been distilled over many decades by a number of different researchers from various disciplines and perspectives. These personality descriptors have been collected into five basic categories, which are purported to encompass the majority of the variation in how personality is described (Digman, 1990).

HRO: High Reliability Organizations are defined by the literature as being technically complex organizations that operate to reliably lower their great risk potential (La Porte, 1996). They are defined in the HRO literature as limited to the following categories: aviation (pilots and air traffic controllers), medicine (surgeons or emergency physicians), aeronautics (pilots and space engineers), and nuclear power (engineers and operators).

Initial license class: the initial license class for SROs and ROs is typically eighteen months to two years long. The candidates are hired by the utility to attend class

with the expectation that they subsequently pass the NRC exam. ROs and SROs go to the same classes, which include such topics such as nuclear physics, plant systems, and operating procedures (INPO, 2010).

INPO: The Institute of Nuclear Power Operations is a non-governmental organization owned by its members – commercial nuclear power utilities. It was formed in response to the investigation following the Three Mile Island accident. The president's commission recommended that the utilities establish a self-governing body, which would develop and share expertise across the industry (Kemeny, 1979). In addition, INPO accredits nuclear training programs, conducts industry self-assessments, tracks trends and makes recommendations to the NRC in order to support its supervision of commercial nuclear power (INPO, n.d).

NEO PI-3: The latest revision of the NEO personality inventory, based on the five-factor model. The NEO PI-3 consists of five domain level descriptors of personality: neuroticism, extraversion, openness, agreeableness, and conscientiousness. Underlying each of these five domains are six facet level descriptors, making 30 facet level descriptors in all (Costa & McCrae, 1995, 1996, 2005).

Nuclear fleet: a group of nuclear power plants that are owned by local or regional power companies. Typically fleets have similar procedures and corporate governance in common. In contrast, single-site plants are not members of a fleet and operated independently.

Nuclear Regulatory Commission (NRC): The NRC was formed in 1975 to replace the Atomic Energy Commission. Its directive was to protect the health and safety of the

U.S. population through supervising commercial nuclear power plants and regulating the use of nuclear materials (NRC, 2013d)

NRC exam: One of the main roles of the NRC is to license individuals as reactor operators and senior reactor operators. License candidates who meet all the criteria enter class. Their first hurdle is to complete the generic fundamentals exam (GFE) early in their training. If they successfully pass the GFE they complete the balance of their training, which is site specific (NRC, 2013e). This includes an extensive exam over two days, which includes a written examination, made up of 75 multiple choice questions, followed by a practical exam conducted in a simulator. Individuals applying for an SRO license must take an additional 25-question exam and are graded on additional items during simulations. The candidate must pass both the written and simulated portions of the exam in order to achieve a license (NRC, 2004).

RO: Reactor Operators (RO) are licensed to operate a nuclear power plant. They are the individuals who bear direct responsibility for reactivity control as well as the control of the additional systems operating on the plant site. From the control room, they coordinate the plant operators who actually manipulate systems out in the plant (NRC, 2004).

SRO: A Senior Reactor Operator (SRO) is the senior licensed operator at a site. The NRC licenses them as supervisors as well as reactor operators. They bear the overall responsibility for all decisions made in regards to the operation of the nuclear power plant while they are on shift. Typically there are at least two SROs on a plant site at any given

time, and at least one in the control room of the power plant at all times supervising the reactor operators (NRC, 2004).

Screen-out: The process of using a measure such as a personality test as a means of de-selecting undesirable applicants.

Select-in: The process of using a measure such as a personality test, to choose applicants that are well suited for a given role.

Throughput: This is a term coined by the nuclear power industry to describe the ratio of individuals who are selected to enter a license class as ROs or SROs compared to those who actually complete the licensing process and pass the NRC exam (NEI, 2011).

Training organizations: Within the nuclear power industry, training organizations play a key role in maintaining licensed and trained personnel. The training organization supervises and trains initial license candidates. In addition, licensed operators--SROs and ROs--are required to attend requalification training every five weeks for a solid week. At the end of this requalification week, they must pass an exam to be able to remain on shift. The training organization also conducts ongoing training of other non-licensed site personnel. Nuclear training organizations undergo their own periodic accreditation process and must meet INPO standards in order to support the operations of the power plant. The operational success of a nuclear power plant is closely tied to the quality of its training organization (INPO, 2010).

Assumptions

There are several assumptions upon which this study design rested. First, that passing the NRC exam with its academic and practical components is a good measure of

success. To guide the use of the term "success" in my study, I slightly modified and paraphrased the definition of success provided by Judge, Higgins, Thoresen, & Barrick (1999). For the purposes of this study, success is defined as the attainment of occupational prestige and financial reward. When examined in this light, the attainment of an operator license equals success, as it brings with it both prestige and monetary reward. Licensed operators are among the highest paid careers that do not require a college degree (Bureau of Labor and Statistics, 2014). In addition, SROs earn six figures according to average job description listings compiled by Indeed.com (Senior Reactor Operator Salary, 2014). Qualifying for and passing the NRC exam is the singular hurdle to obtaining this prestigious and financially rewarding role. This study has relied on the expertise of the industry in regard to whether those who gain a license will also be successful in the operator role. The NRC examination of nuclear operators appears to be an objective measure that is intended to select those who will perform optimally in that role. However, confirming that each licensed operator also performs ideally in other job performance measures is outside the scope of my study. It is necessary, for the purposes of this study, to assume that the NRC exam measure is a valid and reliable tool for selecting optimal operators.

A second assumption relates to the timing of the personality assessments of candidates. This study rested on the assumption that assessing candidates who participated in license classes during a one-year span (2014) was an ideal timeframe for data capture. I assumed that most academic removals had happened by this point--the last 12 months of the licensing process. I also assumed that most operators who make it

through to the second half of the licensing process will possess the cognitive ability necessary to pass the exam, therefore making any differences between those who pass and those who fail more likely the result of non-cognitive factors such as personality. Ideally, this study would be a longitudinal design that followed the candidates for two years, from selection to NRC exam. However, given the time constraints of this study, that was not possible.

An additional assumption was that domain level factors are the ideal unit of study. I based this assumption on discussions of the predictive capacity of personality in the research literature. There is some argument in the literature that domain factors are less reliable for predicting job behaviors than facet level factors (Costa & McRae, 1996, 1998; Hough & Oswald, 2008). However, a number of meta-analyses have established the usefulness of domain level factors for predicting job related outcomes (Barrick & Mount, 2003). Therefore, for the purposes of this study I assumed that the analysis of personality at the domain level was adequate.

Scope and Delimitations

My study addressed the problem of low initial license candidate throughput by investigating to what extent personality may impact initial license candidate success, and by assessing whether the addition of an FFM-based measure of normal personality may improve the selection of individuals to attend license classes. The scope of this study was limited to U.S. nuclear plants. Global nuclear power is certainly growing (NEI, 2002; Kenley, et.al, 2009), a fact that may necessitate similar studies conducted from an international perspective. However, my study was not designed to address global nuclear

power and caution must be used if one wishes to extrapolate the results of this study to the global stage. In addition, the source of the sample used for this study was exclusively from fleet sites. Groups of U.S. nuclear plants are often owned in full or in part by larger organizations, and are referred to as members of a fleet as I note in the definitions section. Fleet sites have central governance, which made it more time and cost-effective for me to gain access to multiple sites by approaching fleets rather than single-sites. Therefore, caution should be exercised in generalizing results from this study to non-fleet sites, as none are included in the sample.

Limitations

This study was designed to address the issue of low ILC throughput by examining whether successful candidates share certain personality factors that may be predictive of their success. This narrow focus may have overlooked other factors that contribute to operator licensing success such as cognitive ability, education level, or training program quality, which may be considered a limitation of this study. In addition, I was limited in my ability to consider other contextual factors that may have an impact on ILC success. For example, in certain plants, the workforce is unionized. As a part of the collective-bargaining agreement in a number of nuclear plants, candidates may be chosen for license class based on their seniority as much as their ability. This policy, as described to me by a fleet training supervisor with a major utility, is known internally as "forced progression," (C. Millard, personnel communication, August 2010). Forced progression policies are likely to have some impact on both the culture and the individuals chosen as candidates.

The lack of consideration regarding the impacts of such contextual factors may be considered a limitation of this study.

Operator demographics may further limit the interpretation of the results of this study. Operator demographics are currently not representative of the general U.S. population (NRC, 2009) and, as expected, women and individuals of color were underrepresented in the sample used in this study.

Finally, though each nuclear facility is unique in many ways--plant culture, training programs, personnel--the candidates were not viewed as specific to each site. Rather, they were seen as individuals all undergoing the same process for the purposes of this study. The aggregation of data on these individuals may have caused some loss of important site-specific information--in fact data aggregation is a topic of controversy in social science research in general (Bartram, 2008)--and may have limited the interpretation of results for specific sites. However, at this time and for the purpose of this study, aggregation was the most reliable method of addressing the proposed research questions. It must therefore be noted as a limitation of the study because the data gathered has certainly lost site specificity.

Significance

As I have previously noted, the issue of throughput for initial license candidates in nuclear power is significant and industry-wide. The failure of a license candidate on the NRC exam after nearly two years of employment as a full-time student represents a tremendous financial loss to the utility and to the candidate. By demonstrating that candidates with certain personality factors are generally more successful in license

classes, this study contributes information that could result in significant savings for the industry. In addition, this study established the usefulness of a personality measure as a select-in tool for license class candidate selection in the nuclear power industry, which may prevent the improper selection of ill-suited individuals and the subsequent negative career impact of a license class failure. The results of this study also highlight the need for further research on this issue, thereby extending both the science of personality at work in general, and the study of personality specifically in HROs. I designed this study to significantly contribute to social change by uncovering the potential benefits of adding a normal measure of personality to the selection process in nuclear power, in order to improve throughput in initial license classes. Potential positive social changes that may result from this research could have an impact on the licensed workforce by avoiding improper selection, impact the utilities by improving the return on investment in their license classes, and positively impacting the U.S. population by contributing to the safe and reliable operation of domestic nuclear power plants.

Summary

The correlational design of this study was intended to identify whether successful initial nuclear power license candidates possess common personality factors that may predict their success. This study addressed an established, industry-wide need to improve ILC throughput by investigating whether the current ILC selection process may be improved by the addition of a measure of normal personality. Prior to a detailed description of the design of my study, in Chapter 2 I offer a summary of the exhaustive literature review I conducted prior to commencing my study.

Chapter 2: Literature Review

Introduction

In order to discover whether personality factors have been considered as predictive characteristics of successful initial license candidates, I conducted a comprehensive search of published, peer reviewed, and private literature over the course of two years. The results of this search indicated that the use of a non-clinical, five-factor personality measure for selection purposes has not been well studied in commercial nuclear power. In the following literature review, I describe the methodology and results of the search, provide an overview of the literature regarding the major theories informing this study, and review key concepts and variables and their application in HROs. I conclude this chapter by summarizing the literature gap that I identified by this exhaustive review.

Literature Review Results

The literature review strategy included a search of periodical databases, government collections, government agency records, and documents from private utility corporations. I conducted the database search using EBSCO and included PsycArticles, PsycInfo, Government Collections, Business Source, and Academic Premier, but occasionally expanded the search to include all EBSCO databases. I paired the Boolean search terms, *nuclear power plant*, *nuclear plant operator*, *senior reactor operator*, *nuclear reactor operator*, and *nuclear utilities* in every permutation with the terms *personnel selection*, *personality*, *personality test*, *selection test*, *requirements*, and *criteria*. There were no date limits placed on the search. I considered international

studies. However, the focus of my research was domestic (U.S.) nuclear power, so while I discovered two international studies relating personality facets to successful nuclear operators (Juhász & Soós, 2011; Xiang, et. al, 2008), I did not use the results to inform my hypotheses because of the potential for introducing confounding variables resultant from cultural differences. I did include both of these in the discussion as structurally relevant.

My search uncovered a paucity of literature on the use of personality assessments on nuclear reactor operators, so I expanded it to relevant government agencies including the Nuclear Regulatory Commission (NRC), the Department of Energy (Nuclear Power Division), the National Nuclear Laboratories (Idaho, Sandia, Argonne and Oak Ridge), and the United States Navy (Nuclear Power School). In addition, I conducted a search of documents available from privately funded organizations that support nuclear power including the Institute for Nuclear Power Operations (INPO), the American Nuclear Society (ANS), the Nuclear Energy Institute (NEI), and the Electric Power Research Institute (EPRI). Both the government agencies and the private organizations noted above appear to give great attention to cognitive and experiential factors required of nuclear power plant operators. However, personality facets are not addressed directly in any of the documents discovered in this literature search. Some indirect indications of desirable personality facets required by nuclear operators can be extrapolated from these source documents, which I discuss later in this section. Further, in an attempt to discover any indirect references to personality factors required by successful nuclear operators, I

reviewed competency lists, training literature, human factors research, and studies of teamwork among nuclear power plant operators.

Finally, I made direct appeals to nuclear power plant utility owners such as Constellation Energy, Duke Energy, Exelon, Entergy, Pennsylvania Power and Light, and South Carolina Electric and Gas, for documents that addressed the topic. This last effort resulted in productive and enlightening discussions, but few usable documents beyond general procedural guidance on operator selection. It appears that other than the long-standing use of the Minnesota Multiphasic Personality Inventory (MMPI) to screen-out new operator license candidates with undesirable scores (Baird & Hammond, 1982; NRC, 2000), utilities typically focus on cognitive and experiential requirements to select new operators.

The comprehensive literature review described above resulted in no domestically published peer-reviewed studies that addressed the topic of personality factors as predictive of new operator license candidate success. Further, no studies reflected the use of personality assessments for selection of new operator license candidates, with the exception of the MMPI, as mentioned.

The literature review did reveal the historically heavy reliance of utilities on experiential and cognitive predictors of success for new operator license candidates (Baird & Hammond, 1982; Shumacher, Kleinmann, & Melchers, 2010), which may indicate a lack of confidence in personality measures as a selection tool. This discovery led to a general review of the use of personality measures in selection, particularly in similar high reliability organizations (HROs) such as aviation/air traffic control and

medicine. However, before discussing the literarure on the use of personality in HROs, I review applicable personality theories and key concepts so as to contextualize the topic of the predictive validity of personality measures in work settings itself.

Theoretical Foundation

Theories

Theories of personality abound and are too numerous to be fully reviewed in this dissertation. However, personality theories can be categorized into two larger groups: theories of personality from an identity perspective; and theories of personality from a reputation, or observed behavioral perspective (Hogan, 2005). This reputation-observation orientation is driven by a stream of research aimed at uncovering individual differences in personality, a concept that is highly germane to the discussion of predicting individual behavior. As my study was concerned with the impact of personality on work behaviors, I focused on the reputation-based personality theoretical orientation.

Origin/Source

The American Psychological Association (APA) has published a *Dictionary of Psychology* in which the term *theory* is defined as "A principle or body of interrelated principles that purports to explain or predict a number of interrelated phenomenon [sic]" (APA, 2012). This definition highlights the crux of a long-standing debate in personality psychology over the nature and structure of human personality and how best to measure it. The definition above notes that theoretical approaches are intended to "explain or predict" phenomena. However, much of the discussion captured in the literature on personality has centered on attempts to discover a theoretical construct for personality

that would both explain *and* predict behavior (McCrae, 2010). The foundational construct of personality has been a topic of much debate and myriad theories have arisen to address it (Hogan, 2005). However, over the last fifty years, the literature regarding prediction of behavior based on personality, which is the focus of this dissertation effort, has yielded a widely used and well-supported model of personality called the five-factor model (FFM; Rothstein & Goffin, 2006).

Major Theoretical Propositions/Assumptions

The FFM, also referred to as the Big Five, is a source of contention for some scholars due to the nature of its development (Mischel, 1968; Pervin, 1994). It is an empirical model based on factor analyses of the results from lexical surveys of the English language (Poropat, 2009). The lexical approach has been employed by a number of researchers to distill essential personality descriptors from everyday language (Cattell, 1943; Allport & Odbert, 1937; Tupes & Cristal, 1961; Norman, 1963; Saucier & Goldberg, 1996). These adjectives were then subjected to statistical factor analysis to discover common underlying "factors" which would allow them to be grouped together with other related descriptors. These adjectives describing personality are frequently also referred to as personality traits and are the reason this type of research is often considered under the heading Trait Theory.

Trait Theory. While the FFM development is more recent, it is based in large part on the lexical approach to personality traits first used by Sir Frances Galton as early as 1884. Galton uncovered the foundation of modern personality traits when he searched for "that definite and durable 'something'" which he believed shaped character. He

turned to a thesaurus with the objective of discovering "landmarks in character to serve as basis for a survey" (Galton, 1949, p. 179-181). Galton noted over a thousand terms that described personality in the English language. A similar approach used by Allport and Odbert (1937) resulted in a list of nearly eighteen thousand personality trait names from a dictionary, which they then classified into four categories. However it is interesting to note that Allport and Odbert also reference the work of one of their contemporaries, L. Thurstone, in the midst of their monograph. A statistician and psychologist, Thurstone acknowledged the large number of trait names, but identified a much smaller list of actual traits (Thurstone, L., as cited in Allport & Odbert, 1937). Further, Thurstone utilized factor analysis to identify five underlying concepts, which could be utilized to group related traits. He also projected that this would be an area of extensive research. He was correct in this assertion as subsequent research confirmed the existence of five factors (Fiske, 1949; Norman, 1963; Smith, 1967). In addition, Norman (1963) added a level of theoretical understanding to the empirical approach by noting that the most meaningful phenotypes, or surface descriptions of personality, would logically be those most utilized by the layman. Therefore, to the extent that an adjective was useful and meaningful, it became embedded in everyday language (Norman, 1963; Saucier & Goldberg, 1996). Norman envisioned that "the eventual development of psychometrically adequate methods and devices for the assessment of personality characteristics [would be] markedly aided by the availability of a comprehensive and clearly articulated taxonomy of trait descriptive terms" (1963; p. 1). The goal of achieving a comprehensive taxonomy

of personality factors and their underlying traits became the topic of extensive subsequent research (Poropat, 2009).

The five factors. Tupes and Christal (1961) were the first to uncover five strong and recurrent factors underlying personality descriptors in their comprehensive studies, which included both U.S. Air Force recruits and undergraduate students, and included peer and self-reports over multiple survey administrations. Their work built on earlier research by Cattell (1947) who analyzed 25 trait names and argued for twelve factors, Fiske (1949) who analyzed 22 trait names and found five strong factors across peer and self-ratings, and Eysenck (1951) who identified three major traits, with seven facets grouped under each. However, Tupes and Christal continued to develop their taxonomy throughout the early 1960s, resulting in five factor categories that closely resemble the current FFM (Goldberg, 1992).

Over the next fifty years, the literature has continually supported the FFM as a useful personality construct (Barrick & Mount, 1991, 2001; Bartram, 2004; Digman, 1990; Costa, 1986; Costa & McRae, 1998; Hogan, 2005, Hough & Oswald, 2008; Judge, Rodell, Klinger, Simon, & Crawford, 2013; Poropat, 2009; Rothstein & Goffin, 2006). Despite critiques from scholars who find the FFM lacking due to its empirical, or a-theoretical, nature (Mischel & Shoda, 1994; Pervin, 1994), the FFM continued to gain momentum and evidence across a myriad of settings. Even those researchers who set out to disprove the FFM often became convinced by the data (Digman & Inouye, 1986). However, arguably the most important development in the practical application of the FFM was the creation of a well-designed five-factor assessment tool.

Costa and McCrae, two gerontology researchers who initially intended to study age differences in personality, discovered three "clusters" of traits, which they subsequently named Neuroticism (initially dichotomously named anxiety-adjustment), Extraversion (initially introversion-extraversion), and Openness to Experience (Costa & McCrae, 1985). Through their prolific research Costa and McCrae developed and honed a scale to measure these three domains: the NEO personality inventory (NEO-PI). Within ten years, however Costa and McCrae also found consistent evidence for five factors rather than three, and subsequently expanded their inventory to include two additional factors: Agreeableness and Conscientiousness (McCrae & Costa, 1985). The resulting NEO-PI and its subsequent revisions is arguably the most well-researched and widely used assessment of personality based on the FFM (Ones, Viswesvaran, & Dilchert, 2005; Saucier & Goldberg, 2001). In support of this model, and perhaps to address critics that belittled the FFM due to its lack of theoretical underpinnings, McCrae and Costa (1999) took steps to clearly articulate the Five Factor Theory.

In its current form, based on the wealth of literature examining the FFM, the five-factor theory (FFT) includes the following assumptions:

a.) Personality is both inherited and context specific. There is still considerable disagreement on this issue in the literature. McCrae and Costa along with others have insisted the heritability of personality traits explains 30%-51% or more of their expression, whereas shared environment explains very little (Bergeman, et. al, 1993; McCrae, Costa & Ostendorf, et al., 2000). However a number of well-designed studies have challenged this assertion, and the

literature has not provided robust support for the absolute genetic transmission of personality traits (McCrae & Costa, 2003; McCrae, Scally, Terracciano, Abecasis, & Costa, 2010). For the purpose of this study, a "both-and" approach has been adopted, which recognizes that personality traits are generally inherited; yet their behavioral expression may be contextually influenced.

b.) The structure of personality can be legitimately described and measured lexically regardless of setting. This is essentially the legacy of the trait theorists described above, and is fairly well embraced in some form by most who acknowledge the taxonomy of the FFM (Judge, et. al, 2013; McCrae & Costa, 1997).

c.) Personality is fairly stable over time and quite stable after age 30. The Five Factor Theory as espoused by Costa and McCrae states that "Traits develop through childhood and reach mature form in adulthood; thereafter they are stable in cognitively intact individuals" (2003, p. 148). This postulate is supported from a number of meta-analyses, as well as from the extensive longitudinal studies on aging conducted by Costa, McCrae and their colleagues (McCrae, et. al, 2000; Terracciano, McCrae, Brant, & Costa, 2005)

d.) There is high agreement between self-and-other reports on FFM scales. This is one of the strongest supporting arguments for the legitimacy of the FFM (Chang, Connelly & Geeza, 2012; Hogan, 2005; McCrae & Costa, 1987).

e.) Domain and facet-level traits are not completely orthogonal. Initially FFM researchers insisted domain level traits were orthogonal, and that when newer statistical methods that showed otherwise, they were merely pointing out the expected inverse factor loadings on facets associated negatively with their opposites (McCrae, Zonderman & Costa, et al., 1996; Costa & McCrae, 1998). However, some more recent research points to variations in the degree of orthogonality at the facet level, which point to overlap. That some facets appear oblique may be dependent on the source of the ratings (Biesanz & West, 2004; Chang, Connelly & Geeza, 2012; Ones, Viswesvaran & Dilchert, 2005), and whether orthogonality is determined through varimax rotation or confirmatory factor analysis (McCrae, Zonderman & Costa, 1996). This debate is currently quite active in the literature (see Judge, et. al, 2013), and its resolution is beyond the scope of this dissertation. So, the stance that will prevail in this discussion is the assumption of generally orthogonal domains and facets, without a complete reliance on that fact in order to draw conclusions.

f.) Personality factors, on a domain level, are predictive of behavior in specific contexts. The pivotal meta-analysis by Barrick and Mount (1991) illustrated the usefulness of the FFM to predict job performance in a number of settings. This finding has been confirmed across a myriad of settings and cultures (Barrick & Mount, 2005). In a recent meta-analysis, Judge, Rodell, Klinger, Simon, and Crawford (2013) suggest that higher order domains and lower

order facets be used in tandem to gain the best prediction outcomes in work settings. In line with the trend toward more specific alignment of personality measures to job criteria in selection processes (McCrae, 2010), the developers of the NEO-PI have encouraged practioners to utilize a "bottom-up" approach (Costa, 1996, p. 227), which aligns job criteria to personality traits at the lowest level.

Analysis of theory applied in similar studies

I designed my study to uncover the personality factors that provide valid prediction of nuclear operator candidates' success in the Nuclear Regulatory Commission initial licensing process. Use of personality measures is an atypical approach to the selection of new license candidates, and has not been well studied, as is discussed below. However, certain principles can be drawn from the established literature and applied to the current study. The use of the FFM of personality to provide incremental validity over cognitive measures in selection processes is well established (Barrick & Mount 1991, 2005; DeCorte, Lievens & Sackett, 2007; Dudley, Orvis, Lebiecki, & Cortina, 2006; Rothstein & Goffin, 2006). The literature on personality assessments in Nuclear Power is sparse and typically limited to a screen-out tool (Lavin, 1987), as I have previously noted, the use of personality measures is common in other HROs to predict safe operations (Cellar et. al, 2001; Clarke & Robertson, 2008) to predict employee achievement (Flin, 2001), and to predict both professional success (Kennedy & Zilmer, 2006) and success in training settings (Dean & Conte, 2006), all of which are germane to the current study.

Rationale for theory choice

The FFM--and its supporting theory--was a logical choice to provide guidance and direction for my study for several reasons. First it is a current and well-researched taxonomical structure of normal personality, as I noted above. In their extensive meta-analysis, Judge, et. al stated, "Few theoretical frameworks can compete with the impact of the five factor model (FFM) on psychological science" (2013, p.875). In addition, its most well known measure, the NEO-PI, has been well studied as a selection tool in work settings (Barrick & Mount, 1991; Barrick & Zimmerman, 2009; Judge, et. al, 2013; Rothstein & Goffin, 2006). In contrast to the MMPI, the FFM, on which the NEO-PI is based, did not arise from a clinical theoretical orientation; rather it was developed based on the lexical hypotheses of Galton and Cattell and many others, as I mentioned earlier, as a means to understand personality in terms of reputation and behavior rather than identity or mental processes (Hogan, 2005). This provided a unique opportunity to encourage participation of candidates in my study by couching the NEO-PI as a measure of normal personality rather than a diagnostic tool.

FFT Relevance and Extension in this Study

The FFT is relevant to this study for one main reason: The FFT provides a theoretical underpinning for the assessment instrument I chose for this study, the NEO-PI-3, the latest revision of the NEO Personality Inventory. I used the NEO-PI-3 to extend the FFT in several ways. The research questions I asked in this study built on and extended the FFT by applying it to a study of with the nuclear power industry, which is a novel setting. My study furthered the understanding of FFT domain-level personality

factors as success predictors, particularly of success in a technical field. Also, my study adds to the sparse literature on the use of personality measures based on the FFT for selection in HRO environments (Flin, 2001).

Literature Review of Key Variables and Concepts

Concept: Personality and Selection

Historically, personality factors have been viewed as second to cognitive factors as predictive of employee performance (Barrick & Mount, 1991). The notable objections to the use of personality as a selection criterion are that personality measures are medical or clinical measures, they are most often self-reports, that the answers are subject to faking, and results are influenced by situational factors. In order to discuss personality measures as helpful indicators of success for the nuclear operator role, these objections must first be addressed.

It is argued that personality measures based on psychodynamic theory, which have long been used for clinical diagnosis, are less ideal for use in work settings (Aamodt, 2004; Finerty, 2005) and in the case of my study, may not provide the nuclear power industry with meaningful results for selection (Kelley, Jacobs & Farr, 1994). In contrast, the empirically derived Five Factor Model (FFM) of personality has been used extensively in work settings. Current literature supports the FFM as a valid and reliable basis for predicting job performance, particularly providing incremental validity over cognitive measures (Biesanz & West, 2004; Ones, Dilchert, Viswesvaran, & Judge, 2007). The NEO personality inventory, in its various verions, is arguably the most well researched instrument for assessing FFM personality facets (Barrick & Mount, 1991;

Biesanz & West, 2004; McCrae, Costa & Martin, 2005). For this reason, the most recent version of this measure, the NEO PI-3, was the personality assessment I used for my study. I discuss the development of this empirical model in more detail below.

Another argument opposing the use of personality measures in personnel selection is that personality assessments are typically self-reports that reflect the individual's self-perception, or identity. As such, the accuracy of the assessment is dependent on the level of each individual's self-awareness and may not accurately capture the self as revealed in social contexts, also known as the individual's reputation. Socio-analytic theory addresses this concern by positing an understanding of personality from both of these perspectives, identity and reputation (Hogan & Holland, 2003). The empirically-based FFM uses a taxonomy of trait words to capture personality in terms of reputation, but from the perspective of the individual. The NEO PI-3, which was the personality measure I used in my study, is an empirically based measure derived from the FFM. The literature supports the use of reputation based personality measures, like the NEO, through studies of self-other agreement, with fairly robustly positive results in same-context self-other agreement (Connolly & Ones, 2010; Malloy, Albright & Kenny, Agatstein, & Winquist, 1997; Watson, Hubbard, & Wiese, 2000).

Concerns of faking on personality tests have presented an additional obstacle to their use in selection contexts (Berry & Sackett, 2009; Goffin & Christiansen, 2003). The debate regarding faking on personality measures centers on the variable responses to the magnitude of the faking. For instance, it appears to matter whether or not the behavior is a deliberate attempt to mislead, in which case integrity is a concern, or whether the

individual is engaging in mild impression management, a behavior that is frequently seen in a high-stakes selection environment (Converse, et. al, 2009; Hogan, Barrett & Hogan, 2007). The literature on this issue has not definitively addressed the extent to which the validity of the personality measure is actually compromised by faking behavior. In a meta-analysis, Ones, Viswesvaran and Reiss (1996) analyzed over 1,400 correlations between social desirability and criteria such as personality traits, cognitive abilities and education level for over 400,000 individuals and found virtually no support for the concept that faking good improves results on any real criterion. A number of researchers agree that impression management does not diminish criterion prediction significantly in a real world setting, and should not inhibit the use of personality as a predictor of job success (Hogan, Barrett, & Hogan, 2007; Schmitt & Oswald, 2006; Smith & Ellingson, 2002). Moreover, the general thrust of those studies that utilize empirical measures of personality, such as those based on the Five Factor Model, demonstrate the continual usefulness of personality measures for selection purposes, in spite of faking behaviors (Converse, et. al, 2009; Goffin & Boyd, 2009). An additional line of research supports the use of diverse and varied selection criteria in conjunction with personality measures, such as cognitive assessments or bio-data, to inhibit poor hiring decisions (Peterson, Griffith, & Converse, 2009).

Finally, reluctance to rely on personality measures in the selection process is based on fairly low criterion-related validity for such measures in the literature (Barrick, et. al, 2001; Mischel, 2009). It is clear, from the scholarly dialogue captured by this research, that from a domain level perspective, a personality measure may not predict

every specific instance of behavior for an individual. However, domain level measures that aggregate responses over a large number of situations, are actually quite good predictors of the general tendency of an individual to behave according to certain principles (Heggestad & Gordon, 2008; Hough & Oswald, 2008). Roberts et. al (2007), supported this notion with their meta-analysis showing personality measures are as effective at predicting overall life outcomes as cognitive measures. In addition, the predictive capacity of personality measures improves further by the use of context-specificity (Heggestad & Gordon, 2008). So the valid use of personality measures in selection is predicated, to some extent, on the type of personality measure, and the method by which it is used. The frame of reference effect research by Lievens, De Corte, and Schollaert (2008) demonstrated that measures that are contextualized for a work setting are more predictive of work behaviors. Additional research on the frame of reference effect indicates that this contextualization can occur merely by providing pre-test instructions to the candidate. Specifically, candidates are instructed to respond to questions with a work setting in mind (Reddock, Biderman & Nguyen, 2011). Other research has shown that higher validity is achieved with item-specific contextualization, modifying or re-writing items to reflect the context for which they are administered (Bing, Whanger, Davison & VanHook, 2004).

The debate in the literature regarding the use of personality measures in a selection process will no doubt continue to refine the practice. However, the use of empirically based personality measures are supported in the literature as both valid and reliable when properly contextualized.

The Five-Factor Model Development and Differentiation

It is important to differentiate the use of personality measures for selection from a clinical purpose, as well as to establish the validity of personality measures for predicting criteria such as job performance. Recent case law indicates the use of clinical measures for selection or promotion may infringe on individual rights protected by the Americans With Disabilities Act of 1990 (Ford & Harrison, LLP, 2005; Tinwalla & Ciccone, 2006). Moreover, the use of measures intended to detect clinical psychopathology, such as the MMPI, for selection purposes may place the organization at risk for legal action based on discrimination (Finerty, 2005; Tinwalla & Ciccone, 2006). In addition, research on the reliability of the MMPI for repeated use, as would be common in a workplace setting, and is actually required in a nuclear power plant setting, reveals multiple administrations lower validity (Kelley, Jacobs & Farr, 1994).

In contrast to clinical measures, such as the MMPI, which are theory-driven and oriented to detect psychopathology (Costa, Zonderman & McCrae, 1985; Kelley, Jacobs & Farr, 1994), empirically derived personality measures are oriented to highlight personality as evidenced by observable behavior (Hogan, 2005). The empirically conceived FFM has gained wide acceptance amongst applied psychologists, supported by a myriad of research around its effective use in non-clinical settings (Barrick & Mount, 2005; Costa, 1996; Hogan & Holland, 2003; Poropat, 2009). The categories of the FFM are Emotional Stability (also referred to as Neuroticism or Emotional Control), Extraversion, Openness, Agreeableness and Conscientiousness.

FFM Use In Applied Settings

The results of research since the initial development of the FFM is compelling, leading some to reference the FFM as a universal personality model (Goldberg & Saucier, 1995; Hogan, 2005; McCrae & Costa, 1997). This perspective has played a key role in the increasing use of FFM-derived predictive measures in work settings. The use of personality to predict performance represents a historical shift in organizational practices away from the use of purely cognitive assessments, bolstered by research that demonstrates significant correlations of personality domains and facets with job performance criteria (Ones, Dilchert, Viswesvaran, & Judge, 2007; Schneider, 2007). Rather than suggesting that practitioners discard cognitive tests in favor of personality measures, the literature supports the addition of personality to a selection process as a practice that adds discriminant validity (Ones, Dilchert,Viswesvaran & Judge, 2007) as well as incremental validity (Bartram, 2004; Hough & Oswald, 2008). This is especially true when the personality measures have been properly aligned to the work criteria (Barrick, et. al, 2001; Bartram, 2004; Goffin & Boyd, 2009). A combination of cognitive and non-cognitive, or personality based measures, is recommended as well to reduce the potential for adverse impact on protected groups (DeCorte, Lievens & Sacket, 2007; Hough & Oswald, 2008), to decrease potential for turnover (Barrick & Zimmerman, 2009), and to mitigate the reliance of hiring managers on vague impressions and interview results (Highhouse, 2008). Providing alternatives to this practice is particularly important when the selection process is intended to predict job performance in high

reliability organizations (HRO), such as nuclear energy, aviation, or medicine, due to the heightened risk of accidents due to human error.

Use of Personality Measures in HROs

For the purposes of my study, high reliability organizations, or HROs, are defined as organizations of a highly technical orientation that depend upon the public trust to operate because the consequences for accidents or mistakes are quite severe. The term HRO was initially coined by researchers in the High Reliability Project at Berkley (La Porte, 1996), and was intended to describe a small sub-set of industries, which included aviation (pilots and air-traffic controllers), medicine (surgeons and surgical teams) and nuclear power plants (operators), (Bourrier, 2011; La Porte, 1996; Weick & Sutcliffe, 2001). HROs have similar challenges due to their technical complexity and their zero failure orientation, because, as I noted above, failures in HROs produce hazardous or disastrous outcomes. The HRO literature demonstrates the sharing of best practices and lessons learned among such organizations (Bourrier, 2011; La Porte, 1996; Webster, 2005; Weick & Sutcliffe, 2001). As I mentioned above, I found very little literature that was focused on personality and selection of nuclear power plant operators, and no published U.S. studies. As a result, I broadened my search of the literature to extend to organizations that were similar to nuclear power utilities, in this case other HROs. While there are certainly other high risk occupations for which selection is critical, such as law enforcement or other types of emergency responders, this discussion is limited to HROs because of their uniquely shared attributes, including the high level of technical proficiency required by key personnel (Weick & Sutcliffe, 2001). In particular, HROs

select employees in light of the need for "failure-free" operations (La Porte, p. 60) by their personnel, as they are interacting with highly complex technical systems. Indeed, comparisons across these specific specialty areas – medicine, aviation and nuclear power – are commonly found in the literature for HROs (Webster, 2005; Wedertz, 2012), to the exclusion of other high-risk occupations. So, I also considered the use of personality for selection in medicine and aviation to inform my literature review on nuclear power operations.

Medicine. Highly intelligent and capable individuals have long been drawn to the medical field and selected to attend medical school based on their cognitive capacity. However, non-cognitive individual differences have been identified also as key to physician success (Frey, Edwards & Altman, Spahr, & Gorman, 2003). The literature on the non-cognitive requirements for physicians has grown in the last decade. Researchers note that the motivation for this new research includes factors like reducing burnout, minimizing patient lawsuits, and improving overall patient-physician interaction and physician job satisfaction (Knights & Kennedy, 2006; McManus, Keeling, & Paice, 2004). Three of the six identified core competencies for 21st Century physicians as identified by the new standards of the Accreditation Council on Graduate Medical Education (ACGME) reflect personality-based components (Swing, 2007). The recent literature on selecting and training new doctors based on emotional intelligence, moral/ethical reasoning ability and personality reflects this shift (Chamberlin, 2010; Lumsden, Bore, Millar, Jack, & Powis, 2005). The development of new criteria for selection of medical students is in the final stages prior to the rollout of a new version of

the Medical College Admission Test (MCAT) that includes measures of personality (Koenig, Parrish, Terregino, Williams, & Vasilopoulos, 2010); confirming the shift in focus encompassing personality will be reflected in selection of the future individuals trained as doctors. One interesting and recent study, utilizing a Delphi survey methodology, captured opinions from a divergent field of medical practitioners regarding the core attributes of a good doctor, and cognitive ability was not even listed as part of the study (Lambe & Bristow, 2010). This is further proof that the medical profession has come to value personality factors highly.

Aviation: Air traffic control. Another HRO field, aviation, has consistently attracted individuals with high cognitive abilities, yet the literature from this area of expertise reflects a move to recognize the non-cognitive requirements of this role. The Federal Aviation Administration (FAA) continually evaluates the assessment protocol used to select air traffic control specialists (ATCS), and has long used one tool, with a small personality component, the Air Traffic Selection and Training Test (AT-SAT). This tool has recently been criticized for its lack of predictive ability (Barr, et. al, 2011). In 2006, the Army Research Institute conducted a thorough review of pilot selection, resulting in a report that encouraged the use of a measure of normal personality in addition to cognitive tests (King, Ratzlaff, Barto, Ree & Teachout, 2012). Most recently, the FAA has issued new guidance on the qualification and certification of pilots which included the suggested use of normal measures of personality to ascertain suitability for the role (King, 2014).

Similarly, a number of studies have recently been conducted in aviation that highlight the predictive power of personality assessments. King, et. al (2012), used the NEO-PI to assess military pilots prior to training and found pilots that failed to complete their training had significantly higher scores in the neuroticism domain than their peers that passed. In the pilot training process, King et. al, also found that those highest in conscientiousness and low in openness also had higher academic grades (2012). In an earlier study, those who voluntarily exited a pilot training program scored six times higher in neuroticism than their peers who remained (Anesgart & Callister, 2001)

In addition, recent FFM research shows how measures of personality provide incremental gains in the ability to predict air traffic control specialist success above the AT-SAT (King, Retzlaff, Detwiler, Schroeder, & Broach, 2003; Luuk, Luuk, & Aluoja, 2009). In the cognitively demanding roles of pilot and air traffic controllers, it appears that personality also plays an important function in predicting job success.

Commercial nuclear power. The current approach to selection of nuclear operators follows a process established by the industry in the years following the Three Mile Island accident in 1979 (INPO, n.d.). It consists of one or more interviews, an extensive security background check, as well as administration of the Plant Operator Selection System (POSS) test, an instrument designed to assess basic technically oriented cognitive skills (Edison Electric Institute [EEI], n.d.). However, the unofficial method of selection is perhaps more interesting, given the close-knit community of commercial nuclear power. In the past, according to an initial license training manager at a nuclear plant in New York State, a majority of the talent available for commercial nuclear power

operators were ex-Navy nuclear power operators, so it was not unusual for an operations manager in commercial power to connect with former military contacts for references on applicants (S.McCann, personal communication, July 2012). This type of personal reference is likely to have included some references to personality factors, if only casually. However, the practice is becoming less common, because, as I noted previously, the talent pool for the nuclear power industry has broadened, making the culture less insular and this first-person observation of work behaviors passed on by personal reference more rare. The.nuclear power industry retains a strong focus on cognitive skills for the selection of nuclear license candidates and does not appear to value objective measures of non-cognitive success indicators for ILCs. This raises a number of questions, especially regarding the level of information available to the industry on this topic. As I noted earlier, generally HRO literature demonstrates a trend towards recognizing non-cognitive success predictors for key personnel in other HROs. Currently, it appears that the nuclear power industry lacks objective supporting evidence based on the lack of studies targeted at this population. There are indirect references to desirable ILC personality factors in some documents I found, as I noted in the next section, that describe the nuclear operator role. However personality factors were not referenced in any job descriptions currently in use by nuclear utilities that I could find, or that were provided to me by the utilities that participated in my study.

Inferred Personality Requirements of Nuclear Operators

Competency models. As I have noted, the current literature does not directly address the topic of non-clinical personality in domestic commercial nuclear power plant

operator selection. However, a few relevant sources address personality and the role of a nuclear operator indirectly, the most comprehensive being the competency model developed via the O*NET database (O*NET, n.d.). The work styles section of this model lists the following preferred attributes for a nuclear power reactor operator: attention to detail, integrity, stress tolerance, analytical thinking, dependability, self-control, achievement/effort, persistence, cooperation, and adaptability/flexibility. Several of these items align to FFM facets, but not all. For instance, attention to detail, dependability, self-control, and persistence are synonymous with the facets underlying the conscientiousness domain in the FFM, whereas cooperation, adaptability/flexibility and integrity align to the agreeableness domain, and stress-tolerance is a function of emotional stability (Costa & McCrae, 1995).

In addition, recently the U.S. Department of Labor's Employment and Training Administration (ETA) has published an online catalogue of competency models, including a model for energy generation facilities. It is fairly generic, however the model includes a personal effectiveness segment (Tier 1) that lists qualities rooted in personality, such as integrity, dependability, and flexibility (ETA, 2012).

Finally,, the International Atomic Energy Association (IAEA) has published competencies for supervisors in nuclear power plants, though these are not strictly oriented to domestic nuclear power or specific to the operator role (Mazour, 1998). The publication is fifteen years old and refers to a number of "personal characteristics," (p.21) rather than personality traits. However many of those listed resemble FFM traits, such as

honesty, loyalty, ethics, self-control, creativity, empathy, flexibility, courage, perseverance and enthusiasm (Mazour, 1998, p. 21).

HRO performance and team shared mental model literature. The literature on nuclear power plant operation is heavily weighted towards the technical aspects of operation, and when operators themselves are the subjects of the study, it is typical for the research to focus on the cognitive aspects of their role (see Waller, Gupta & Giambatista, 2004). This is not surprising in a knowledge driven field where cognitive capacity has long been the primary basis of personnel selection. There are only two studies found in this literature search that directly addressed individual difference in personality factors, as they impact performance in nuclear power. One study found identified the nuclear power plant team member psychological characteristics that improved performance reviews and selection processes in Chinese nuclear plants (Xiang, et. al, 2008). Xiang, et al. found a "tight relationship" (p.1249) between psychological characteristics (gregariousness, venturesomeness [sic], self-regulation, emotional stability, risk taking and achievement motivation) and performance of operators. However, the study used the 16PF, a measure that is also empirically based, but does not completely agree with the FFM, making conclusions difficult to interpret and compare for the purposes of my study. The other was a Hungarian study (Juhász & Soós, 2011) of nuclear power plant teams that identified personality factors as key to performance. Juhász and Soós found significant positive relationships between crew performance and facets of the domains Extraversion and Openness, while a significant negative relationship was revealed between Agreeableness and performance, to the surprise of the

researchers. As noted in the introduction, both of these studies were outside the U.S., which makes them less than ideal for inclusion in this literature review considering cultural differences. However, both studies indicate the potential usefulness of personality as a predictive tool in this setting.

The domestic literature on HRO team dynamics, and particularly shared mental models (SMM) amongst team members was reviewed, as some literature occasionally, and indirectly, refers to personality factors. For instance, in a study by Mathieu, Goodwin, Heffner, Salas and Cannon-Bowers (2000) of shared mental models, one of the models discussed was the "team member model" (p.274) that included attitudes and preferences that sound very much like personality traits, as aspects of what team members needed to know about one another in order to anticipate behaviors. The results of the study demonstrated that team member models were nearly equally as important as task mental models to the overall team performance, highlighting the importance of considering personality factors on HRO teams. In a simulated HRO team dynamics study, Lepine (2003) found that certain personality facets predicted team adaptability during unforeseen changes, namely dependability, achievement, and openness, as measured by the NEO-PI-R, a FFM measure. In addition, a recent study focused on the sharing of tacit knowledge between operators in a nuclear power plant by Kuronen-Mattila (2010) identified "chemistry between operators," (p. 610) and individual attitudes as key components of the social aspect that mediated knowledge sharing behaviors. These studies indirectly recognize the influence of individual operator personality factors in successful nuclear power plant operation. Indirect references to the influence of

personality factors in successful outcomes in HROs are available from several other sources as well.

From aviation literature, we can see the potential for personality influence in descriptions of the five hazardous attitudes that predict negative outcomes for pilots: "They are: antiauthority (these rules don't apply to me); macho (I can do it!), impulsivity (I don't have time for this); invulnerability (this can't happen to me), and resignation (what's the use?)" (Stewart, 2008, p. 264). Personality factors are also evident in research on nuclear power from other perspectives such as human factors (Nuutinen, 2005), applied ergonomics (Carvalho, dos Santos, & Vidal, 2006), and safety/error research (Schumacher, Kleinmann, & Melchers, 2010). These alternative research perspectives give some slight clues as to which personality domains may prove to be predictive of success for a nuclear operator.

Key Personality Factors Derived from HRO Literature

Attitudes and preferences are generally seen as extensions of personality, mediated by situational and contextual factors (Bandura, 2001), and that while individuals may flex their behaviors according to their context, generally personality traits are stable beyond adolescence (Costa & McCrae, 1994; Hogan, 2005; McCrae & Costa, 1997; Terracciano, McCrae, Brant, & Costa Jr., 2005). The literature directly addressing personality traits of nuclear power plant operators is sparse, so it was necessary for me to draw upon related HRO literature to identify personality factors that may predict ILC success. My review of these studies demonstrated that certain

personality factors are common in successful key roles like air traffic controllers and surgeons, which are similar in many aspects to the role of a licensed nuclear operator.

It is generally acknowledged in personality literature that of the five domains in the FFM, Conscientiousness is the best overall predictor of job success regardless of context (Barrick & Mount, 2005; Chamorro-Premuzic, & Furnham, 2010; Heggestad & Gordon, 2008), as well as ethical behavior (Kalshoven, Den Hartog, & De Hoogh, 2011). Further, from my review of the HRO literature on this topic and the related descriptors of the nuclear operator role as noted above,I was able to identify personality descriptors that appear related to success. These descriptors include: attention to detail, integrity, stress tolerance, analytical thinking, dependability, self-control, achievement, persistence, cooperation, and adaptability/flexibility (O*NET, n.d.); honesty, loyalty, ethics, self-control, creativity, empathy, flexibility, courage, perseverance and enthusiasm (Mazour, 1998, p. 21); high levels of Extraversion and Openness (Juhász & Soós, 2011; Lepine, 2003); high levels of gregariousness, venturesomeness [sic], self-regulation, emotional stability, risk taking and achievement motivation, low levels of somatization, low obsessive-compulsiveness, low interpersonal sensitivity, low tendency to depression, low anxiety, low hostility, low phobic anxiety, low paranoid ideation and low psychoticism (Xiang, Xuhong & Bingquan, 2008); and finally respect for authority, low machismo, low impulsivity, a sense of vulnerability and high resilience rather than resignation (Stewart, 2008). This is a large and rather confusing list, which further highlighted the need for my study to bring some clarity to the question of what personality factors are necessary in a successful nuclear power plant operator.

Literature Gap Summary

The exhaustive literature review I conducted produced no domestic, peer-reviewed, published studies that used an FFM-based measure of personality factors to predict nuclear power plant operator license success. In addition, no peer-reviewed published studies were found validating the use of a FFM based personality measure for selection of new nuclear power plant operator license candidates. As I have previously noted, Five Factor measures have been used extensively to predict work success, and are well recognized for their utility in doing so. Further, I have shown that in settings similar to nuclear power, such as other HROs and internationally, personality is being used to predict success in similar roles. In light of the apparent scarcity of information on this topic specific to nuclear power, I designed my study to address the literature gap revealed by my research. Following is a description of the methodology and results of the study that I used to identify personality factors that are predictive of initial nuclear operator license candidate success..

Chapter 3: Research Method

Study Introduction

The purpose of this study was to attempt to identify personality facets that predict which individuals will be successful in the initial licensing process to become nuclear power plant operators. To provide some insight into the potential of personality to predict initial license candidate success, the following chapter details the research questions, hypotheses, research design, and study methodology that I used.

Study Purpose

My aim in this study was to pose several research questions in an attempt to identify correlations between personality facets and nuclear operator license success, and to address the question of which personality facets most predict the candidates that will be successful in the initial licensing process to become nuclear power plant operators. The following research questions (RQs) guided my study:

RQ1: Do successful initial operator license candidates, as differentiated from unsuccessful candidates, have certain personality factors (as measured by the NEO-PI-3) in common?

RQ2: Which, if any, personality factors of successful operator license candidates correlate with successful completion of the three parts of the licensing process, (a) the written portion, (b) the simulator portion, and (c) the final score (pass/fail) of the NRC licensing exam?

RQ3: Which personality factors are most predictive of the success of initial license candidates on (a) the written test, (b) the simulator portion of the NRC licensing exam, and (c) the final exam results?

Research Design

This quantitative study was designed to accomplish the above purpose in a multi-step process, which I initiated by contacting the fleet managers of nuclear power utilities to gain access to training department supervisors. I contacted training supervisors to meet the following goals:

1. To gain permission in writing via email contact to conduct the research with the candidates at that site (See Appendix A).
2. To explain the study design, explain the methodology, explain the steps that would be taken to assure anonymity of participants, and explain that the organization would be provided study results free of charge.
3. To gain permission in writing to contact the candidates via email, and obtain contact information for candidates.
4. To request follow-up data on written exam, simulator exam, and overall pass/fail results for each candidate on the NRC exam (only overall results are matter of public record and are aggregated anonymously).
5. To schedule participation.
6. To ask for any relevant job description that they currently utilize that may inform the discussion of which personality factors predict performance.

The purpose of goal 6 was to align with methodology noted in the literature as well as directives from the developers of the FFM/FFT, which indicated that prediction was improved when personality factors are aligned with job criteria (Costa, 1996). In lieu of engaging in a formal job analysis process which may vary from site to site, I requested current job descriptions from training managers with the hope that this information from subject matter experts would facilitate the identification of potentially key factors of personality required in the role of licensed nuclear power plant operator. I also hoped that this would allow me to refine and improve the research hypotheses by indicating certain commonly held traits of successful operators. In addition, I thought that this may allow me to rule out factors that were irrelevant to the role and thus avoid a Type I error on RQ1. Assessing actual candidates using the NEO-PI-3 personality inventory and collecting candidate scores on the Nuclear Regulatory Commission (NRC) licensing exam followed. I had the following goals when contacting participants:

1. To introduce the study, explain purpose of the study, and invite participation via email. The email included a link to the personality assessment (see Appendix B).
2. To explain to participants that their participation is voluntary.
3. To explain to participants that they can request a copy of their assessment directly from me via email so that their personality results would not be provided by name to the facility where they work.
4. To explain to participants that by clicking on the assessment they also give permission for their data to be used for the research purposes, including their final

NRC exam results, and that those results would be aggregated by the researcher anonymously to protect their identity.

5. To explain to participants that their data would be coded with a number after receipt and would remain anonymous during subsequent data use.

6. To notify participants that they would be required to provide demographic data, including age and gender, though this data is described as optional in the PAR iConnect framework in which the personality test was administered.

I identified potential site participants through the NRC license exam calendar which is a public listing of all nuclear utilities that have current candidate classes and their NRC Exam dates. I promised to provide overall study results to the utility free of charge as an incentive to participate. Two major fleet utilities responded positively to the requests to participate in the study, Exelon Nuclear and Entergy Nuclear. Both organizations provided individuals in their corporate structure that would serve as single points of contact for each fleet. I received participant names and emails from 9 Entergy plants and 14 Exelon plants. Together, these 23 sites represent 23% of the operating nuclear sites in the United States. In addition, these sites together are fairly geographically diverse, representing three of the four NRC regions.

I had initially planned to use descriminant analysis to address RQ1, but could not because of a lack of participation from candidates that did not pass the NRC exam. I discuss this further in Chapters 4 and 5 of this dissertation. I addressed RQ2a by conducting a Pearson product-moment correlation analysis on personality factors and candidate scores, and I used point-bi-serial correlation analysis to answer RQ2b. For

RQ2c, I could not complete the analysis because there were no participants from the "failure to pass the NRC exam" group. In addition, I used Spearman's Rho to analyze the data in support of the answer to RQ2. Using multiple regression to address RQ3a and RQ3b, I analyzed the candidates' scores on the NEO-PI-3 personality domains and their scores on the written exam. Finally, I intended to subject candidates' personality factors and their dichotomous scores on the overall NRC exam results (pass/fail) to regression analyses in order to answer RQ3c. However no scores were provided for the fail to pass group which precluded this analysis. Taken together, the results from the data were analyzed in order to answer the question of which personality factors were most predictive of initial license candidate success on two of the three outcome variables: written exam and simulator exam. Overall NRC exam result could not be used as an outcome variable because there was no comparison group. I also separated the data by license level--SRO or RO--in order to control for personality factors by role. I had planned to analyze the data by gender and age, but the female group ($N = 3$) was too small for comparison and no ages were provided by the utilities. Prior to analysis, I screened all data with appropriate measures to ensure that statistical assumptions of normality, linearity, reliability, and homoscedasticity were met, and that necessary statistical corrections were employed.

Variables

The independent, or predictor, variables in the RQs of this quantitative correlational study design were candidate scores on the five domains of the NEO-PI-3 personality inventory. The dependent, or outcome, variables were candidate success in

the licensing process as defined by candidates' final scores on the written portion (a numerical score), the simulator portion (pass/fail), and the final results (pass/fail) of the NRC licensing exam.

Methodology

Population

The current population of currently licensed nuclear power plant operators working in nuclear source electric power generation, transmission, and distribution plants in the U.S., according to the 2010 estimate from the U.S. Bureau of Labor and Statistics (USBLS), is 5,950 individuals (USBLS, 2013). According to a license supervisor at a nuclear facility in the Northeast United States, a typical breakdown in plant settings is that approximately one-third of the licensed operators are SROs and two-thirds are ROs (D. Britt, personal communication, January, 2013). I designed my study to address the research questions with this population in mind.

Sampling Procedures

A priori sample size analyses conducted in G*Power version 3.1 (Faul, Erdfelder, Buchner & Lang, 2009) for point bi-serial correlation with an anticipated medium effect size of $r^2 = .3$, $\alpha = .05$ and a 95% confidence interval indicated a requisite samples size of 111. An a priori analysis with the same software for linear multiple regression with an anticipated medium effect size of $r^2 = .3$, $\alpha = .05$ and a 95% confidence interval for the 5 predictors – domains of the NEO-PI-3 – revealed that the minimum number of participants in the sample should be 74 individuals. Based on these analyses and order to anticipate missing data or other unforeseen obstacles, the target sample size for this study

was 120 participants. This number also seemed reasonable in order to achieve generalization of results given the small total population of nuclear power plant operators.

Recruitment and Data Collection

Most nuclear power plants have current license classes with between 6 and 20 participants (D. Britt, personal communication, January, 2013), meaning that between 10-20 sites needed to be approached to participate in the study. There are 99 currently licensed nuclear power plant units in the U.S. (NRC, 2015), however many sites have more than one unit per site. I anticipated that that fewer site contacts would need to be made if dual unit sites were targeted for recruitment for the study. As I noted previously, I attempted to recruit at least two sites from each of the NRC's four regions in order to improve the generalizability of results. Once I received approval by Walden University Institutional Review Board to conduct research, I approached the plant sites through their training center management, which supervises candidates before they recieve their license. I request that I be allowed to contact the members of their training classes individually to invite each one to voluntarily participate in my study..A copy of the email that I sent to corporate contacts inviting their participation in the study is Appendix A to this dissertation. I defined an individual's participation as clicking on the link to take the NEO-PI-3 personality measure, and by so doing also granting permission for my use of their final NRC exam scores on the written, simulator, and overall results. In addition, I asked training managers to provide a current site job description, or criteria used to guide selection, which I expected would assist me as I attemped to identify potentially key

personality factors. In the invitation to participate, I gave the candidates specific instructions to contextualize the assessment in the work setting. My purpose in instructing them to visualize themselves in a work setting as they answered the questions on the NEO-PI-3 was to align my study with recommendations from the frame-of-reference literature that indicates accurately contextualizing personality assessments inmproves predictive validity (Heggestad & Gordon, 2009).

Participant Criteria and Protection

I placed no age or other demographic restrictions on participants, however I planned to collect of basic demographic data including, age and gender. My inclusion criteria was as follows: (a) those who were either SRO or RO candidates and were in a license class during 2014; *and* (b) those who either completed the NRC licensing exam, regardless of the outcome, pass or fail, or who were removed from the program prior to taking the NRC exam. Once I gained permission to approach the candidates from the utility training organization, I asked the training management to send emails to candidates via their onsite secure email describing the study and inviting voluntary participation. I followed-up those invitation with informed-consent emails to each candidate that included study instructions and information, including how the data would be used, and a request to obtain their final NRC exam scores for my research, as I have described previously. A copy of this informed consent email is included as Appendix B to this dissertation. The email I sent to the candidates contained an active link to the online testing web-portal for the NEO PI-3. Further, the email explained that by clicking on the link to the NEO-PI-3 they were consenting to participate in the study. The NEO-

PI-3 online delivery was provided via PAR iConnect (www.parinc.com) who is the test publisher and an authorized provider of online administration for the NEO-PI-3. I had previously established testing credentials with PAR to become an approved test administrator. I also gave participants instructions about how they could request a copy of their NEO-PI-3 results by replying directly to my email, and assured anonymity and confidentiality throughout the research study. I maintained participant anonymity and confidentiality by requesting the NRC exam result data from the corporate site coordinators for all candidates who were in class in 2014. The corporate site coordinators and training managers were not provided any information about which candidates agreed to take the NEO-PI-3. To prevent accidental exposure of participant data, I assigned each individual participant candidate a randomly generated alpha-numeric code designator, which I used rather than names in all subsequent analysis and data storage. I entered participant results into statistical software for analysis by code number only. I protected all participant files with passwords and was the only individual that could access or view participant data. The participants were made aware in my informed-consent email that their data could be made available to my dissertation committee members, if requested. I responded to participants who requested individual results, informing them that their results would be provided after the research study was complete. Nine individuals requested a NEO-PI-3 report. I provided individual NEO-PI-3 results via secure email as a password-protected Adobe portable document format (.PDF) file to the individual candidates that requested a copy. The password was sent to the candidate in a separate email. Results of all assessments and all data will be maintained on the researcher's

laptop in password-protected files. All hard copies of data will be retained in the researcher's personal locked file cabinets for five years, or as instructed by the Institutional Review Board of Walden University. At the end of the designated retention period, all hard-copy data will be shredded and disposed of.

Instrument Information

The NEO-PI-3, the instrument used for this study, is a 240-item self-report measure that assesses 30 separate personality facets, aggregated under five factors or domains: Neuroticism (N), Extraversion (E), Openness to experience (O), Agreeableness (A), and Conscientiousness (C). Each domain contains 6 associated facets, which are listed in Table 1. The facets are numbered with the first letter of the domain plus a number 1-6, under each domain. It is typical for facets to be referenced by their respective domain letter and number (e.g. N1=Anxiety) in personality research that involves the use of the NEO-PI-3. The publisher of the NEO-PI-3 has given permission for use of their instrument for research purposes in the purchase agreement.

The NEO-PI-3 is a more readable version of the well-established NEO-PI-R (McCrae, Cost & Martin, 2005). Costa and McCrae developed the NEO personality inventory originally in 1978 with three factors, Neuroticism, Extraversion and Openness. In 1985 the NEO-PI was published with five factors, adding Agreeableness and Conscientiousness. Once again the NEO was revised in 1992, bringing up the number of facets under each domain to 6, equaling thirty overall facets underlying five factors in the NEO-PI-R (Costa & McCrae, 2000). Internal consistency is high for the domains (coefficients alpha range from .86 to .95) and moderate to strong (.56 to .81) for the facet

scales. The NEO PI-R has evidenced strong temporal stability, with values ranging from .76 to .84 over a 15-year period (Costa & McCrae, 2000).

The NEO-PI-R has been used for the last 20 years in hundreds of studies with thousands of participants, as an excellent and reliable measure of personality traits in work settings (Barrick & Mount 1991, 2005). The predictive validity of FFM measures of personality have been established in meta-analyses methodologically relevant to this dissertation study such as in prediction of academic and training performance (Colquitt, LePine & Noe, 2000; Ackerman, Chamorro-Premuzic & Furnham, 2011), task performance (Dudley, et. al, 2006), even industrial accident prevention (Cellar et. al, 2001). The NEO-PI has been used in similar HRO settings as well, such as with pilots (Campbell, Castaneda & Pulos, 2009), in selecting air traffic controllers (King, Retzlaff & Detweiler, et al., 2003; Luuk, Luuk & Aluoja, 2009) and more recently in the medical field (Lumsden, et. al, 2005; Mustaffa, et. al, 2012).

Moreover, the validity of the NEO-PI personality measure has been extensively established in a myriad of other Industrial-Organizational Psychology uses (Costa, 1996; Hough & Oswald, 2008). The slight changes to the language that were made in order to clarify 37 items of the NEO-PI-R and making the NEO-PI-3 a more readable and accessible version regardless of educational level, have a negligible effect on practical validity. Due to the replication of the factorial structure of the NEO-PI-R, the validity of the original inventory is retained by the NEO-PI-3 (McCrae, Costa & Martin, 2005).

Table 1
Domains and Facets Measured by the NEO-PI-3

Domains	Facets
Neuroticism	(N1) Anxiety
	(N2) Angry Hostility
	(N3) Depression
	(N4) Self-Consciousness
	(N5) Impulsiveness
	(N6) Vulnerability
Extraversion	(E1) Warmth
	(E2) Gregariousness
	(E3) Assertiveness
	(E4) Activity
	(E5) Excitement-Seeking
	(E6) Positive Emotions
Openness	(O1) Fantasy
	(O2) Aesthetics
	(O3) Feelings
	(O4) Actions
	(O5) Ideas
	(O6) Values
Agreeableness	(A1) Trust
	(A2) Straightforwardness
	(A3) Altruism
	(A4) Compliance
	(A5) Modesty
	(A6) Tender-Mindedness
Conscientiousness	(C1) Competence
	(C2) Order
	(C3) Dutifulness
	(C4) Achievement Striving
	(C5) Self-Discipline
	(C6) Deliberation

Note. Adapted from McCrae, R. & Costa, P. (2010). The NEO Inventories Professional Manual. Lutz, Florida: PAR Inc.

Data Analysis

When I attained the minimum sample size goal for participation, the data from personality assessments, any demographics provided, and actual NRC exam scores were aggregated for statistical analysis after redacting candidate identifying information. I used the Statistical Package for the Social Sciences (SPSS) version 21 for Mac by IBM to analyze all data collected during the study process. I screened all data with appropriate measures to ensure statistical assumptions of normality, linearity, reliability and homoscedasticity were met, and employed all necessary statistical corrections. I analyzed the descriptive statistics and parametric statistics as described below to answer the research questions. I present and discuss the results of this statistical analysis in Chapters 4 and 5 in regards to the research questions, the potential social change implications, and the limitations of the study, followed by suggestions for future research.

Research Questions and Hypothesis Testing

As outlined earlier, the following RQs guided my study:

RQ1: Do successful initial operator license candidates (ILC), as differentiated from unsuccessful candidates, have certain personality factors in common as measured by the NEO-PI-3?

RQ2: Which, if any, of the common personality factors of successful ILCs correlate with successful completion of the licensing process, including a) the written portion, b) the simulator portion, and c) the final score (pass/fail) of the NRC licensing exam?

RQ3: Which personality factors are most predictive of the success of ILCs on a) the written test, b) the simulator portion, and c) the final score (pass/fail) of the NRC licensing exam?

For this study, I tested my hypotheses (H) below to answer the research questions outlined above. The hypotheses are outlined below in both the null and alternative forms and followed by the statistical analyses intended to address each.

Research question 1 is addressed by the following hypotheses:

$H1_0$: There is no difference in the means of successful candidates and unsuccessful candidates on any of the discriminant predictors: personality factors. So for group means on the discriminant function analysis , $H1_0$: $\mu_s = \mu_u$.

$H1_a$: There is a difference in the means of successful candidates and unsuccessful candidates on the discriminant predictors: personality factors. So for group means on the discriminant function analysis $H2_a$: $\mu_s \neq \mu_u$.

For RQ1, the dependent variable is dichotomous – whether or not the individuals are successful on the NRC exam – and the independent variable is continuous – personality factor scores. I intended to address H1 and H2 by comparing the means of the two groups on personality factors via discriminant analysis. However, without participation from the comparison group, those that failed to pass the NRC exam, I could not conduct the planned discriminant analysis.

Research question 2 is addressed by a second set of hypotheses:

$H2a_0$: There is no significant correlation between any personality factor and ILCs' final NRC written exam scores, H_0: $r = 0$.

$H2a_a$: A significant correlation exists between any personality factor and ILCs' final NRC written exam scores, H_a: $r \neq 0$.

$H2b_0$: There is no correlation between any personality factor and ILCs' final NRC simulator portion exam scores, $H2b_0$: $r = 0$.

$H2b_a$: There is a significant correlation between at least one personality factor and ILCs' final NRC simulator portion exam scores, $H2b_a$: $r \neq 0$.

$H2c_0$: There is no significant correlation between any personality factor and ILCs' final NRC exam scores (pass/fail), $H2c_0$: $r = 0$.

$H2c_a$: There is a significant correlation between at least one personality factor and ILCs' final NRC exam scores (pass/fail), $H2c_a$: $r \neq 0$.

For RQ2, the first two hypotheses the variables are continuous so I analyzed both (H2a and H2b) with Pearson's product-moment correlation. For the third hypotheses, one variable, final NRC exam score is dichotomous (pass/fail); therefore, I intended to use a special case of Pearson's correlation, the point-biserial form to analyze the relationship. However, as I stated above, a lack of participation from the comparison (fail) group precluded this analysis. In hypotheses 1 and 2, for RQ2, I may reject the null hypotheses if the analysis revealed a correlation not equal to zero.

Research Question 3 was addressed by my third set of hypotheses:

$H3a_0$: There is no significant linear relationship between any personality factor and ILCs' final NRC written exam scores, $H3a_0$: $B_{1=} B_2 = \ldots = B_k = 0$.

$H3a_a$: A significant linear relationship exists between at least one personality factor and ILCs' final NRC written exam scores, $H3a_a$: $B_1 = B_2 = \ldots = B_k \neq 0$.

$H3b_0$: There is no significant relationship between any personality factor and ILCs' final NRC simulator exam scores, $H3b_0$: $B_1 = B_2 = \ldots = B_k = 0$.

$H3b_a$: A significant relationship exists between at least one personality factor and ILCs' final NRC simulator exam scores, $H3b_a$: $B_1 = B_2 = \ldots = B_k \neq 0$.

$H3c_0$: There is no significant relationship between any personality factor and ILCs' final NRC exam scores (pass/fail), $H3c_0$: $B_1 = B_2 = \ldots = B_k = 0$.

$H3c_a$: A significant relationship exists between at least one personality factor and ILCs' final NRC exam scores (pass/fail), $H3c_a$: $B_1 = B_2 = \ldots = B_k \neq 0$.

The first and second hypotheses for Research question two have continuous variables: Independent – personality factor scores, and dependent – scores on the written or simulator portion of the NRC exam. Therefore the first two hypotheses (H3a & H3b) may be analyzed with multiple regression. However, the final hypothesis, H3c, includes a dichotomous dependent variable – the overall result on the NRC final exam (pass/fail) – so I planned to analyze the data with logistic regression to address $H3_c$. However, as I noted above, due to a lack of data from the comparison (fail) group, I could not conduct the planned analysis for the final hypothesis in RQ3. I used a data codebook to track the statistical analyses process.

Threats to Validity

The design of the current study was intended to minimize threats to internal and external validity. The use of an established valid and reliable instrument, the narrow population definition, and the time frame of personality test administration were all intended to lower the potential for external validity threats. The use of the NEO-PI-3 has been well established as a predictor of job related outcomes (Barrick & Mount, 2005) as extensively discussed earlier in this paper. The narrow population studied in this research design generally lowered the external validity threat and improves generalizability of the results of this study. This is due to the homogeneous nature of the population of nuclear power operator license candidates as a result of selection criteria as outlined earlier in this paper. In addition, this population selection may provide some measure of control for cognitive differences also, because the candidates that were assessed have all passed a number of cognitive assessments and knowledge tests in order to be considered for licensing. The internal validity of this study, or the accuracy of conclusions or predictions from the data, is certainly vulnerable to confounding variables and various unknown effects that may contribute to ILC success beyond personality. As such, caution must be employed when discussing causality or implying that personality alone may be predictive of ILC success. Rather, the discussion about the study results in chapter 5 is focused on the incremental predictive validity afforded by personality assessments in addition to other predictive measures that utilities may currently use for selection, such as bio-data or cognitive tests.

Summary

I designed this study to be correlational and non-experimental in nature. My aim was to identify whether certain personality factors are held in common by successful nuclear operator license candidates and if any of those factors are more predictive of success than others. I employed parametric statistics including t-tests, product-moment and bi-serial correlation, multiple regression and the non-parametric correlation test Spearman's Rho to analyze and draw conclusions from the data gathered in order to answer the three proposed research questions. At the completion of the description of my data gathering and analyses in Chapter 4, I discuss the overall results of my study and implications for further research in Chapter 5.

Chapter 4: Results

Introduction

This chapter presents the results of the correlational study of personality factors and nuclear power initial license candidates. This results section details the statistical analysis methods I used to analyze the data set collected over a period of four months. Included is a review of the research questions and hypotheses, followed by a summary of the actual methodology I used to collect and analyze the data on this topic. Further, this section includes basic descriptives of the data as well as the results of analyses I used to answer the research questions.

Research Questions and Hypotheses Testing

The following questions (RQs) guided my research:

RQ1: Do successful initial operator license candidates (ILC), as differentiated from unsuccessful candidates, have certain personality factors in common as measured by the NEO-PI-3?

RQ2: Which, if any, of the common personality factors of successful ILCs correlate with successful completion of the licensing process, including a) the written portion, b) the simulator portion, and c) the final score (pass/fail) of the NRC licensing exam?

RQ3: Which personality factors are most predictive of the success of ILCs on a) the written test, b) the simulator portion, and c) the final score (pass/fail) of the NRC licensing exam?

The hypotheses I used in order to answer the above RQs are as follows:

I addressed research question 1 using the following hypotheses:

$H1_0$: There is no difference in the means of successful candidates and unsuccessful candidates on any of the discriminant predictors: personality factors. So for group means on the discriminant function analysis , $H1_0$: $\mu_s = \mu_u$.

$H1_a$: There is a difference in the means of successful candidates and unsuccessful candidates on the discriminant predictors: personality factors. So for group means on the discriminant function analysis $H2_a$: $\mu_s \neq \mu_u$.

I addressed Research question 2 using a second set of hypotheses:

$H2a_0$: There is no significant correlation between any personality factor and ILCs' final NRC written exam scores, H_0: $r = 0$.

$H2a_a$: A significant correlation exists between any personality factor and ILCs' final NRC written exam scores, H_a: $r \neq 0$.

$H2b_0$: There is no correlation between any personality factor and ILCs' final NRC simulator portion exam scores, $H2b_0$: $r = 0$.

$H2b_a$: There is a significant correlation between at least one personality factor and ILCs' final NRC simulator portion exam scores, $H2b_a$: $r \neq 0$.

$H2c_0$: There is no significant correlation between any personality factor and ILCs' final NRC exam scores (pass/fail), $H2c_0$: $r = 0$.

$H2c_a$: There is a significant correlation between at least one personality factor and ILCs' final NRC exam scores (pass/fail), $H2c_a$: $r \neq 0$.

I addressd Research Question 3 using a third set of hypotheses:

$H3a_0$: There is no significant linear relationship between any personality factor and ILCs' final NRC written exam scores, $H3a_0$: $B_1 = B_2 = \ldots = B_k = 0$.

$H3a_a$: A significant linear relationship exists between at least one personality factor and ILCs' final NRC written exam scores, $H3a_a$: $B_1 = B_2 = \ldots = B_k \neq 0$.

$H3b_0$: There is no significant relationship between any personality factor and ILCs' final NRC simulator exam scores, $H3b_0$: $B_1 = B_2 = \ldots = B_k = 0$.

$H3b_a$: A significant relationship exists between at least one personality factor and ILCs' final NRC simulator exam scores, $H3b_a$: $B_1 = B_2 = \ldots = B_k \neq 0$.

$H3c_0$: There is no significant relationship between any personality factor and ILCs' final NRC exam scores (pass/fail), $H3c_0$: $B_1 = B_2 = \ldots = B_k = 0$.

$H3c_a$: A significant relationship exists between at least one personality factor and ILCs' final NRC exam scores (pass/fail), $H3c_a$: $B_1 = B_2 = \ldots = B_k \neq 0$.

For RQ1, my goal was to analyze the data received via discriminant analysis to determine if membership in either the pass group or fail group could be determined by personality factors. However, over the four months of data collection, no NEO-PI-3 personality tests were completed by individuals who failed to complete license class. For this reason, this research question could not be satisfactorily answered. In the discussion section of this document, I make study design recommendations to address this research question in the future.

For RQ2, I analyzed the data using Pearsons product-moment correlation to determine if a relationship exists between any personality factor and two of the outcome

variables, written score and simulator score. The results of these analyses are summarized below. However, I could not analyze final NRC exam results by point bi-serial correlation, as proposed, because of the lack of participation from candidates that failed to pass the NRC exam. Therefore, the H3c of RQ2 could not be answered within the context of this study. In Chapter 5 I include recommendations for future studies which might capture this data. Finally, I analyzed RQ3 data using multiple regression analyses to determine whether any personality factor is predictive of the success of initial license candidates on the two continuous outcome variables, written score and simulator score. Final NRC exam results could not be analyzed with logistic regression, as planned, because of the lack of participation from those who did not pass the exam.

Data Collection

As outlined in Chapter 3, I made contact with two major utility owners, Entergy Nuclear and Exelon Nuclear, and requested their participation in the study. Corporate training and operations management from both utilities agreed to participate and support this research. Both expressed interest in the outcome because of the continual struggle with throughput that I describe in the introduction to this study. One participating utility reported to me in an email that 149 individuals began the licensing program fleet-wide at some point in 2011-12, and 109 completed and were successfully licensed in 2014 (73% throughput, representing a loss to the utility of conceivably $20 million dollars). This data highlighted for me the ongoing nature of this issue and further supported the need for this study.

Each utility provided me a corporate coordinator as a single point of contact and as a conduit for all data requests. I was provided data use agreements and confidentiality agreements that were signed by senior corporate representatives of both utilities. After I attained Walden University Insitutional Review Board (IRB) approval to conduct the proposed research, the utilities provided me names and email addresses of all of the initial license candidates who attempted to gain a license to operate in 2014. The utilities provided 177 total potential participant names and email addresses. I sent informed consent emails (see Appendix B), approved by the Walden IRB, with an embedded link to the NEO-PI-3, to each of those potential participants. One wave of participants was provided in late May, 2015 and invitations were sent out the same week. A second wave of participants were provided two weeks later, in mid June, and received invitations that same week. Several obstacles extended the data gathering phase from the utilities until the end of September, 2015, when the study was closed. The final count of participants who completed the NEO-PI-3 and agreed to allow me access to their NRC exam scores was 75. However, the number of complete records provided by utilities totaled 39. The small data set necessitated imputation of some variables for analysis purposes as described in the next section.

Descriptives

I gathered the data over the four month period of this study in order to answer to the associated research questions as outlined above, focusing particularly on whether and which personality factors could predict success for initial license candidates in nuclear power plants. There are approximately six-thousand nuclear operators in the United

States, according to the 2010 estimate from the U.S. Bureau of Labor and Statistics (USBLS, 2013). The sample gathered for this study of 75 is approximately 1.3% of that total. G*Power analyses I carried out prior to the commencement of this study indicated that a sample size of at least 74 should be used for multiple regression, a threshold this data set just barely met. However, the sample size required for meaningful interpretation of correlation analyses was set at 111, a threshold which the gathered data set did not meet. Some missing data, both written and simulator scores, necessitated the use of imputed data techniques in order to achieve a robust sample for analysis, as described in the results section below.

As I stated previously, 177 potential participants who met the criteria for inclusion in the study were invited to take the NEO-PI-3 via an informed consent email. Of those, 75 participants completed the NEO-PI-3. I requested NRC exam results from the utilities for all 177 potential participants, which the utilities agreed to provide in the Data Use Agreement. Data were requested for all potential participants, rather than just those who completed the NEO-PI-3 in order to maintain the confidentiality of those participants. Data I gathered from utilities resulted in 39 complete records, and 75 records in total. I maintained all participant data in password protected Excel spreadsheets until data collection was complete, then transferred to SPSS, version 21 for data analysis. Data points were triple-checked for errors upon transfer. I scrubbed all data of identifying information when I transferred to SPSS for analysis.

The participant demographics are as follows. Three participants were female, the balance of the participants were male (n = 72). As I noted earlier, I anticipated that

females would be underrepresented in the sample, as they are in the population of licensed operators. Further, the participants included 19 Reactor Operators (ROs) and 55 Senior Reactor Operators (SROs). The data provided by the utilities included names of those who did not pass the NRC exam, however none of those who did not pass the NRC examparticipated, so no comparison between pass and fail groups could be made. I removed one case due to validity concerns on the NEO test. The test was flagged by the vendor because the participant engaged in random response patterns and answered "no" to the validity question. The basic descriptives of the data set are captured below in Table 2. The mean Written Score for all participants (M = 88.82, SD = 4.50) was lower than the mean Simulator Score (M = 97.48, SD = 3.59). I reported the NEO-PI-3 results as standardized T-scores, with a mean of 50 and a standard deviation of 10. In general the participants had low Neuroticism (N = 40.46, SD 10.27), high Agreeableness (N = 49.51, SD = 8.69), while the remaining factors fell within the normal range (McCrae & Costa, 2010).

Table 2

Descriptive Statistics of 2014 License Candidate Participants

	Written Score	Simulator Score	NRC Final	N	E	O	A	C
Mean	88.82	97.48	*N/A	40.46	50.08	52.99	49.51	51.34
S.D.	4.50	3.59	*N/A	10.27	8.56	9.50	8.69	8.26

Notes. Valid N = 74; Missing 35 Written and Simulator Scores. NEO-PI-3 Factor Measures: N = Neuroticism, E = Extraversion, O = Openness, A = Agreeableness, C = Conscientousness. *Dichotomous variable = All participants passed.

Results

Once I had received all participant data, I entered all data into SPSS Version 21 for analysis. Basic descriptives were obtained as I reported above. The data set was missing 35 written and simulator scores. No other data were missing. In order to make the data set more usable, I excluded cases with missing scores. However, this resulted in a very small sample (n = 39), which would prove challenging to use for any of the planned analyses. I then opted to impute the missing scores based on the scores provided using multiple imputation (MI). Multiple imputation is an effective way to improve the usefulness of a data set while minimizing any detrimental effects on statistical inference (Graham, 2009). I considered the imputation of the missing simulator and written scores with MI appropriate for several reasons. First, the missing scores (n=70) represent only 9.45% of the 740 data points, and the missing scores are less-than 50% (47.3%) of each data category making MI a good choice, as it has been shown to be appropriate up to 50% missing data (Graham, 2009). Second, given the fact that all participants were reported as having passed the NRC exam and therefore could only have received a score between 80 and 100 on both simulator and written exams, the narrow range of available scores made the use of MI more reasonable, because the MI procedure preserves, or estimates in an unbiased way, means, variances, and covariances (Graham, 2009; Van buuren, Brand, Groothuis-Oudshoorn & Rubin, 2006). Being aware of this, I took steps to preserve the unique features of both written and simulator data categories by limiting the available imputed variables to greater-than or equal-to scores of 80 and less-than or equal-to scores of 100. In a final test of whether MI could be used, I conducted a Little's MCAR test

prior to MI, which showed that the data were not missing completely at random ($\chi 2=21.47$, $p=.03$), meaning MI is better choice than other imputation models such as expectation-maximization (Van buuren, et. al, 2006). The fact that the data are not missing at random is not surprising given the paired nature of the written and simulator scores, and the fact that all subjects passed the final NRC exam. A visual inspection of histograms [see Figures 1-7 below] for all variables in both data sets confirmed approximate normal distributions. For the remainder of this results section, results from both the smaller data set resulting from exclusion of cases with missing data (n = 39) along with the pooled data (n = 74) resulting from MI will be reported. Descriptive statistics on the pooled data were very similar to the smaller set. Both the mean Written Score and Simulator Score in the pooled data increased by less than one point in the pooled data, which was the only change from the initial data set. The descriptive statistics for the pooled data are captured in Table 3.

Table3
Descriptive Statistics of 2014 License Candidate Participants

	Written Score	Simulator Score	NRC Final	N	E	O	A	C
Mean	89.34	96.96	*N/A	40.46	50.08	52.99	49.51	51.34
S.D.	4.22	2.96	*N/A	10.27	8.56	9.50	8.69	8.26

Notes. Valid N = 74; pooled data. NEO-PI-3 Factor Measures: N = Neuroticism, E = Extraversion, O = Openness, A = Agreeableness, C = Conscientousness. *Dichotomous variable = All participants passed.

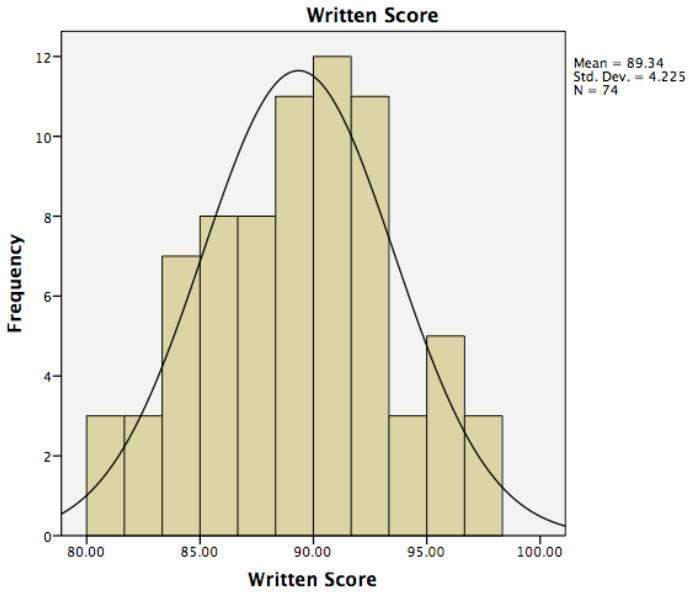

Figure 1. Written score distribution.

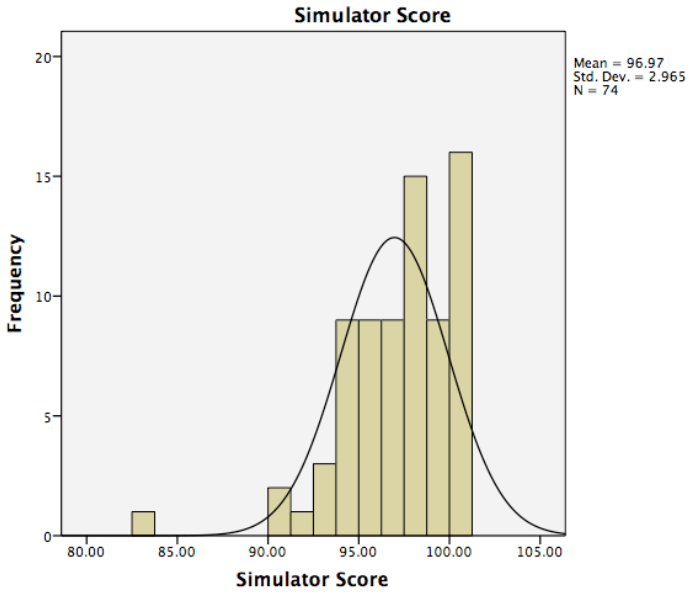

Figure 2. Simulator score distribution.

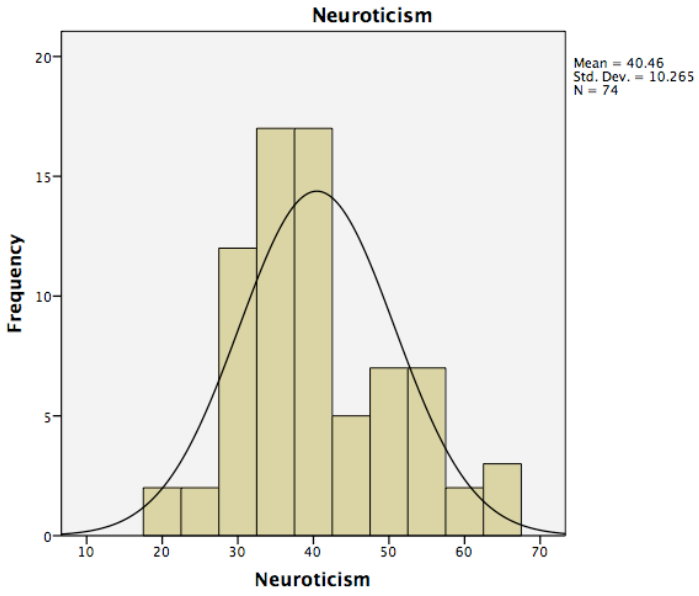

Figure 3. Neuroticism score distribution.

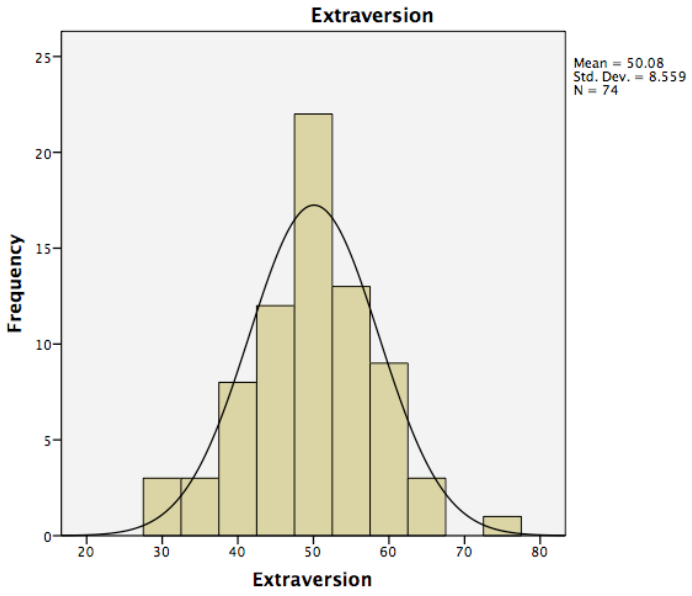

Figure 4. Extraversion score distribution.

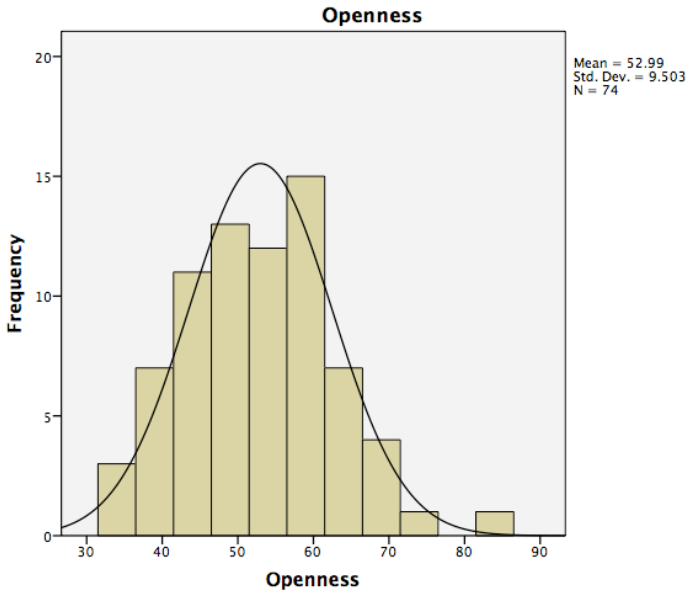

Figure 5. Openness score distribution.

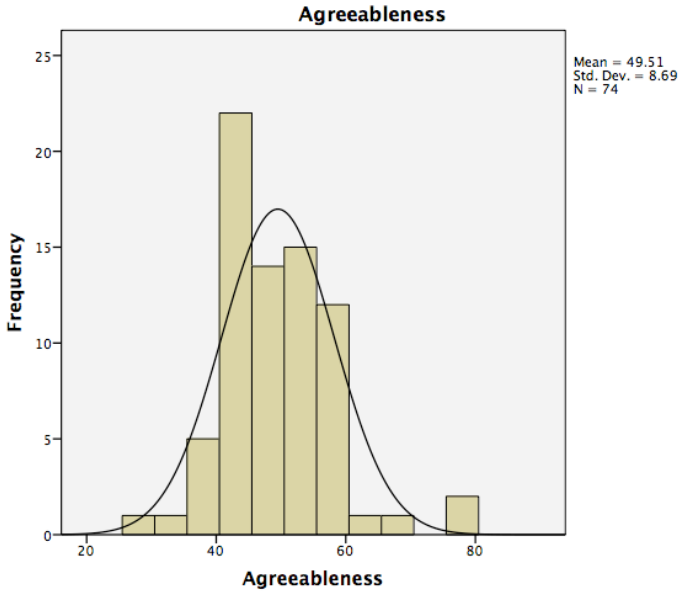

Figure 6. Agreeableness score distribution.

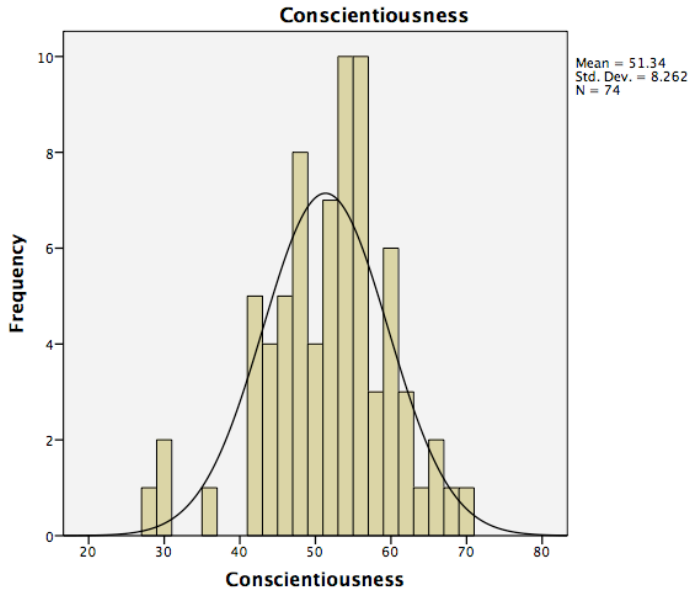

Figure 7. Conscientiousness score distrubution.

Research Question 1: Results

RQ1: Do successful initial operator license candidates (ILC), as differentiated from unsuccessful candidates, have certain personality factors in common as measured by the NEO-PI-3? Though participant names and contact information were provided that included individuals who had not passed the NRC exam, no individual who failed the NRC exam or who was removed from class prior to the exam, participated in this study. Subsequently, analysis cannot be performed that would address RQ1. Discussion about the implications of this result and suggestions to address this question in future research can be found in Chapter 5 of this study.

Table4
Correlation Study for SROs and ROs

RO OR SRO		N	E	O	C	A	Simulator	Written
RO	Neuroticism	1	.459*	-.248	.003	-.066	-.030	.148
	Extraversion	.459*	1	-.298	.189	.159	-.221	.412
	Openness	-.248	-.298	1	-.277	.157	-.014	-.264
	Conscientiousness	.003	.189	-.277	1	.004	.392	.503*
	Agreeableness	-.066	.159	.157	.004	1	-.014	.390
	Simulator Score	-.030	-.221	-.014	.392	-.014	1	.124
	Written Score	.148	.412	-.264	.503*	.390	.124	1
SRO	Neuroticism	1	-.244	.054	.172	-.388**	.074	.044
	Extraversion	-.244	1	.002	.213	.112	-.015	-.395**
	Openness	.054	.002	1	.321*	-.129	.064	-.018
	Conscientiousness	.172	.213	.321*	1	-.246	.407**	-.023
	Agreeableness	-.388**	.112	-.129	-.246	1	-.115	-.017
	Simulator Score	.074	-.015	.064	.407**	-.115	1	.200
	Written Score	.044	-.395**	-.018	-.023	-.017	.200	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
Note: NEO-PI-3 Factor Measures: N = Neuroticism, E = Extraversion, O = Openness, A = Agreeableness, C = Conscientousness; Simulator = NRC Exam Candidate Simulator Score; Written = NRC Exam Candidate Written Score

Research Question 2: Results

RQ2: Which, if any, of the common personality factors of successful ILCs correlate with successful completion of the licensing process, including a) the written portion, b) the simulator portion, and c) the final score (pass/fail) of the NRC licensing exam? Part "c" of RQ2 cannot be answered with the data gathered during this study, as noted above. However, the first two parts of this question can be addressed by the data.

Part a. This portion of my research question is whether personality factors of successful ILCs correlate with success on the written portion of the NRC exam. I

separated the data by role, either RO pr SRO to further analyze results. First, for ROs there was a strong positive correlation between Conscientiousness and written score, r (17) = .503, p = .028. Second, for SROs, I found a moderate, but statistically significant, negative correlation between Extraversion and written score, r (53) = -.395, p = .003. Correlation matrices are shown in Table 4 above. In both ROs and SROs, there was a statistically significant relationship between a personality factor and written score, so I reject the null hypothesis for RQ2a.

Part b. This portion of the research question is whether success on the simulator portion of the exam is correlated with any NEO personality factor. For SROs, one significant finding emerged from the correlation study using the larger data set (see Table 4). I found a moderate, but significant, positive correlation between SRO simulator score and Conscientiousness, r (53) = .407, p = .002. In ROs, a moderate positive correlation between Conscientiousness and simulator score can also observed on Table 4, though it was not statistically significant, r(17) = .392, p = .097. Therefore, I reject the null hypothesis for SROs because a statistically significant correlation was found between Conscientiousness and simulator score. The null hypothesis cannot be rejected for ROs, as no significant correlation was detected. However, the sample size for ROs was very small (n = 19), just over 17% of the sample size required to detect significance. I discuss the implications of this result further in Chapter 5.

During correlation analysis, I detected some co-linearity between NEO factors (see Table 4), likely due to the small sample size (n = 74). When correlation analyses were initially conducted with the smaller set (n = 39), I observed multiple issues with

colinearity of NEO factors. Therefore, I used the larger set in all reported correlation analyses. In addition, no significant correlations emerged with the smaller set. As I noted earlier the ideal minimum size for this portion of the study was determined to be 111, which would require over 30% more data than was available in my sample. Through observation of scatter plots of each NEO factor and each of the DVs, generally linear relationships were observed (see Figures 8 – 27). However, I also ran rank-order correlation analysis with the results summarized in Table 5 below.

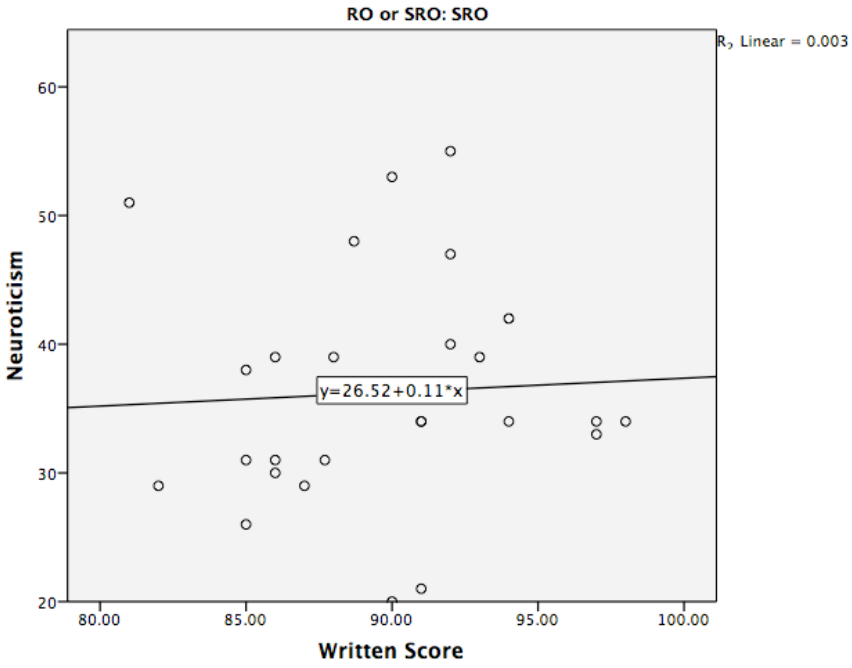

Figure 8. SRO neuroticism written score scatterplot.

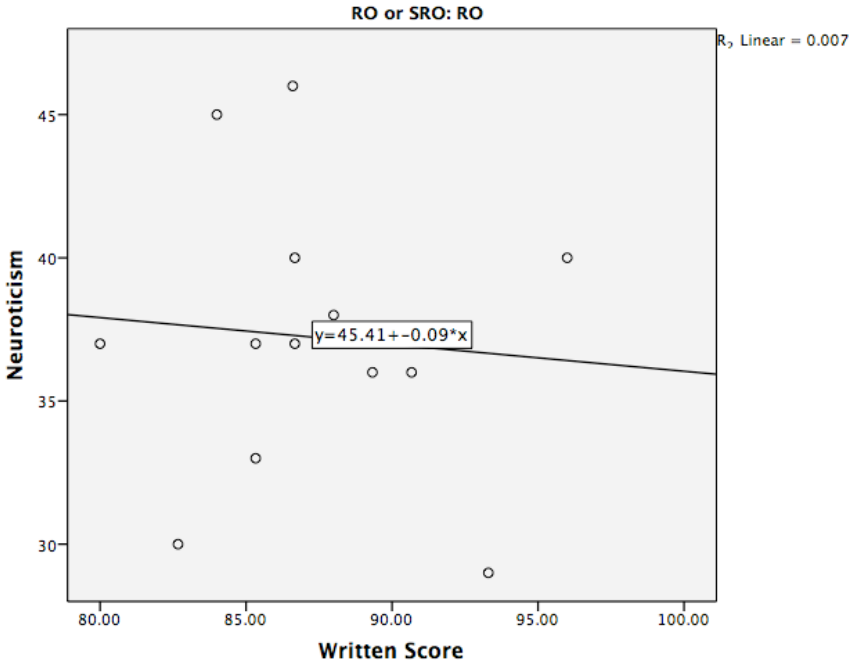

Figure 9. RO neuroticism written score scatterplot.

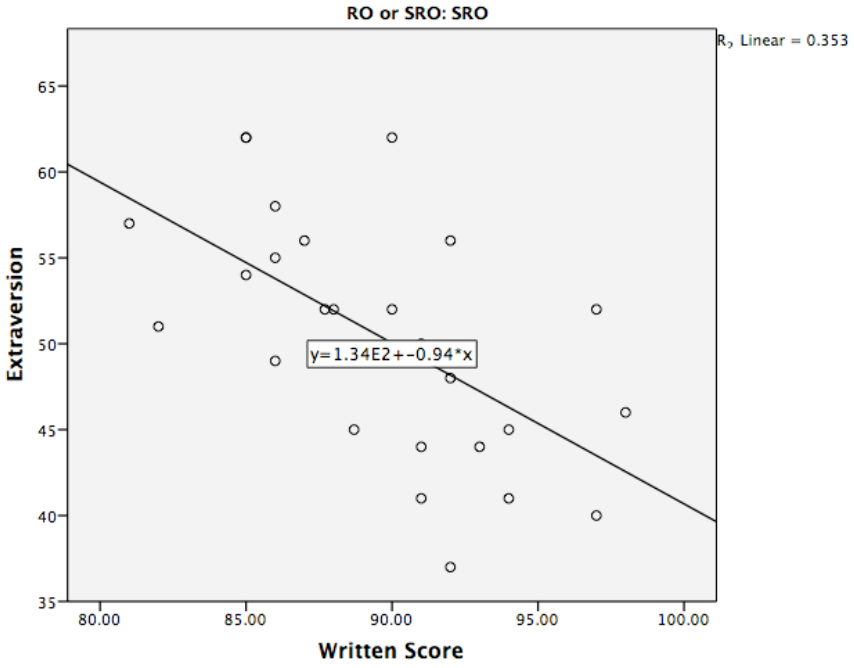

Figure 10. SRO extraversion written score scatterplot.

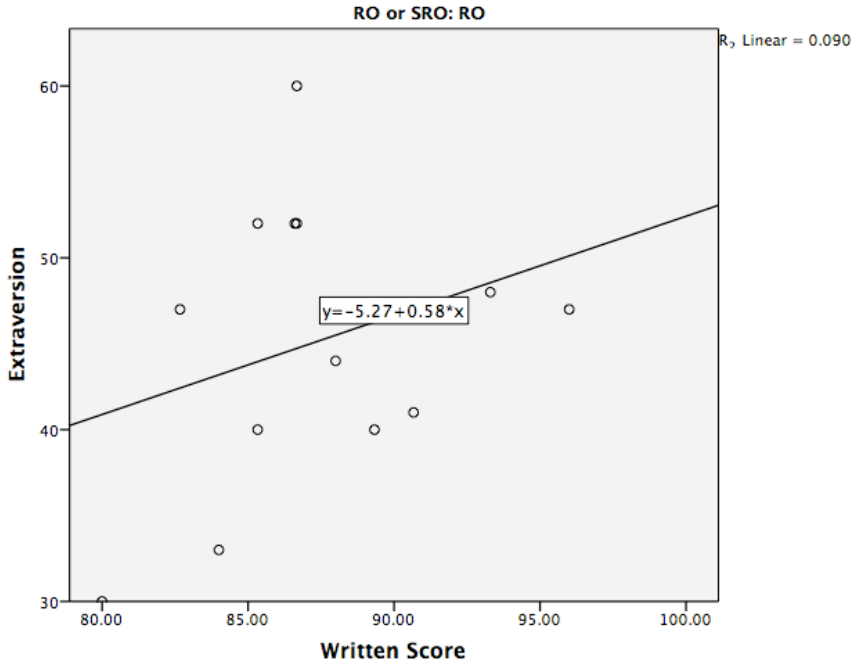

Figure 11. RO extraversion written score scatterplot.

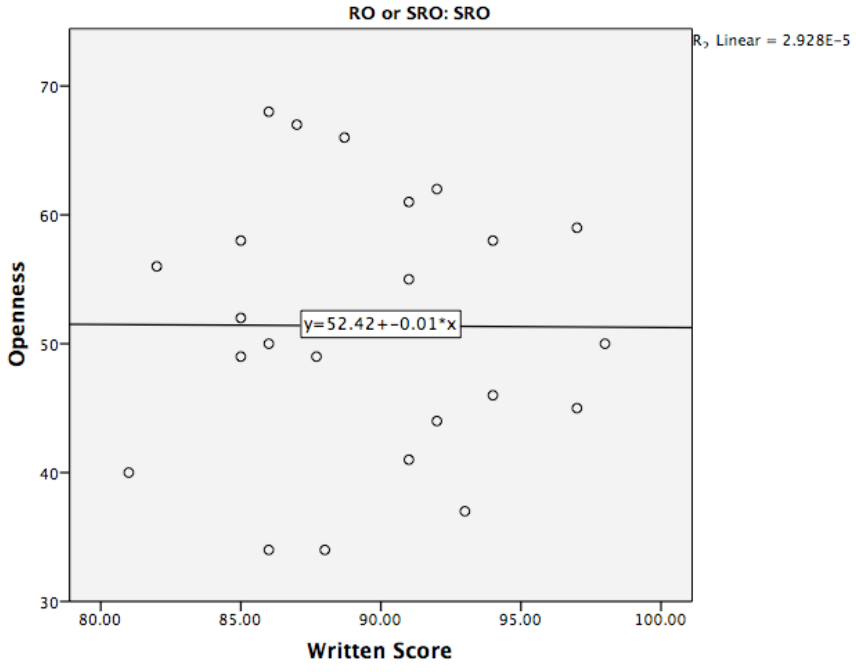

Figure 12. SRO openness written score scatterplot.

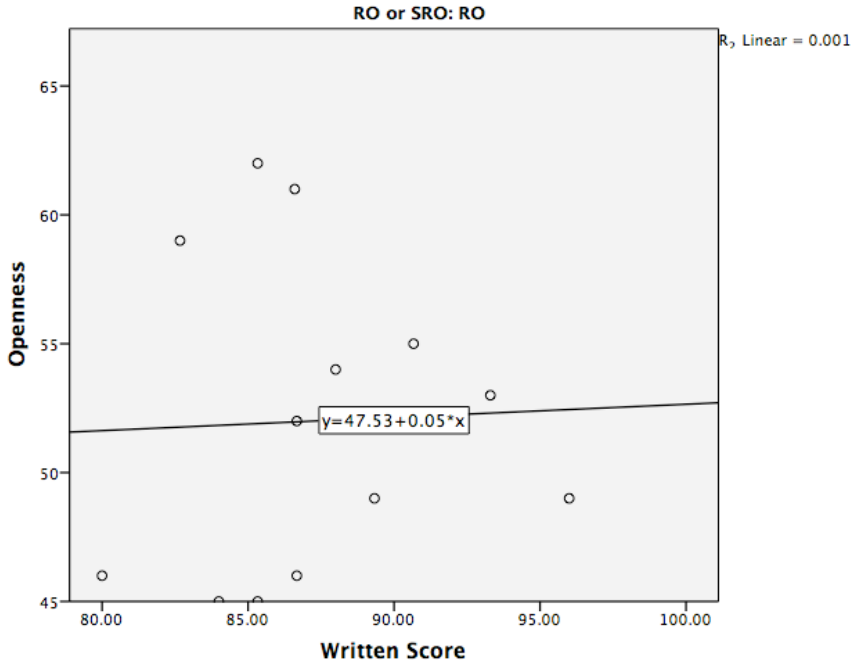

Figure 13. RO openness written score scatterplot.

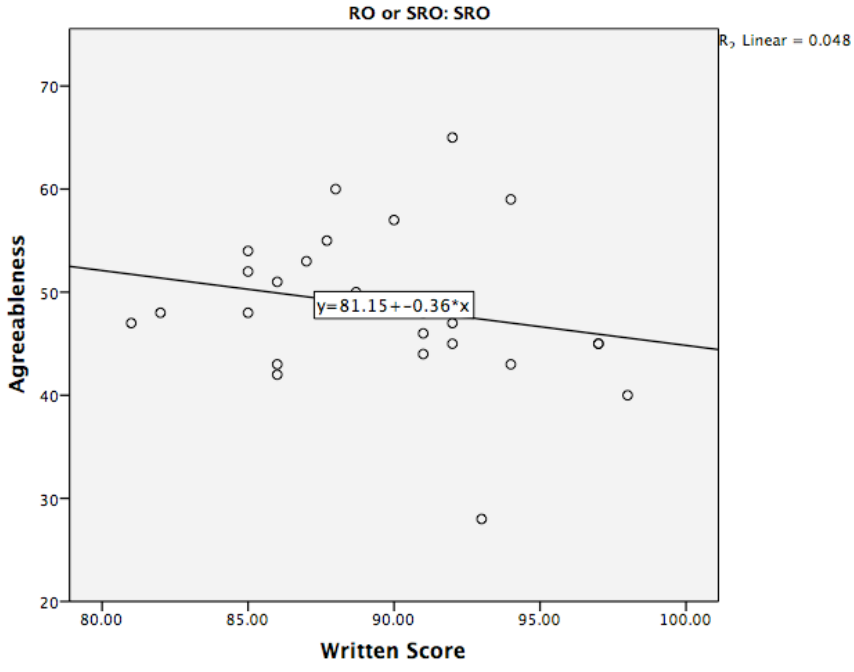

Figure 14. SRO agreeableness written score scatterplot.

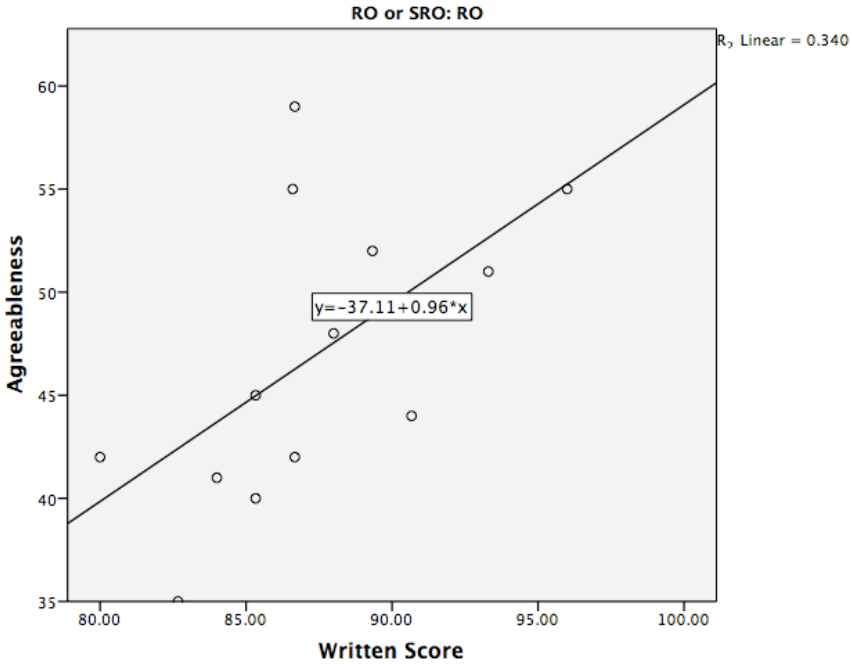

Figure 15. RO agreeableness written score scatterplot.

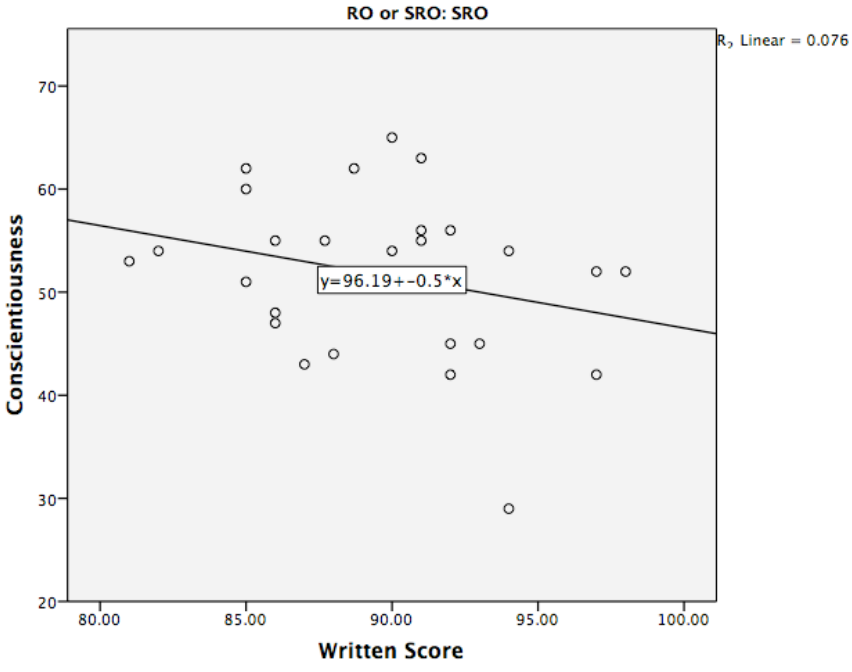

Figure 16. SRO conscientiousness written score scatterplot.

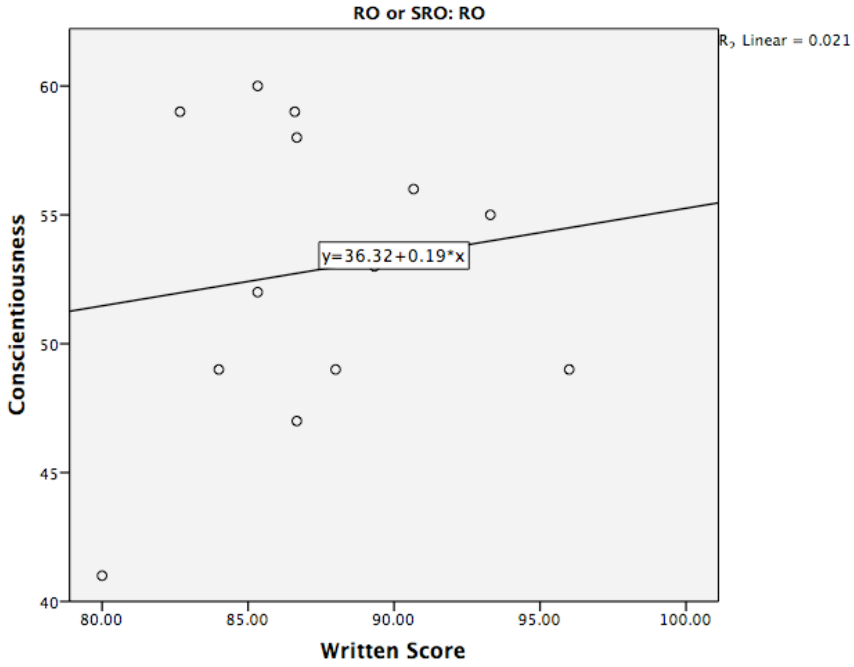

Figure 17. RO conscientiousness written score scatterplot.

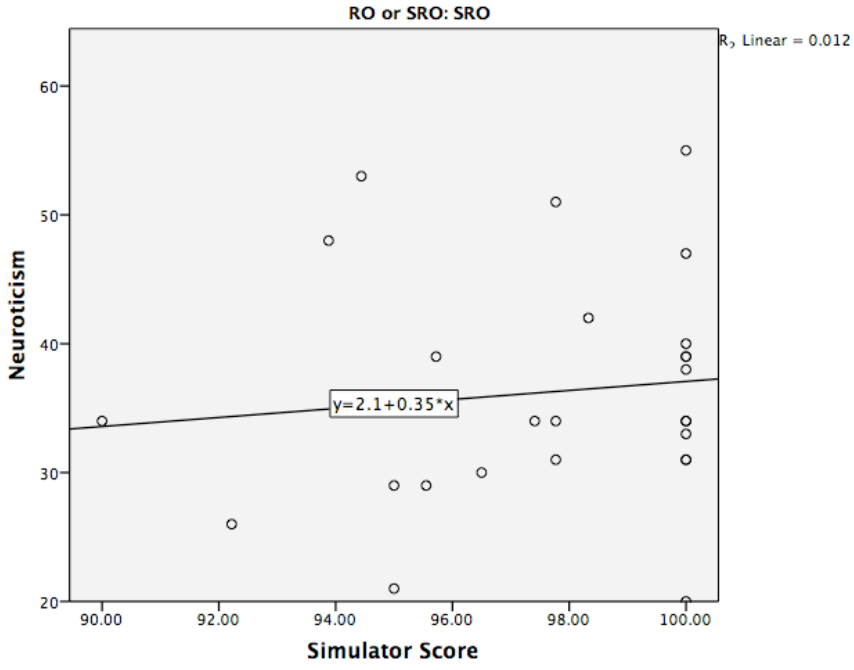

Figure 18. SRO neuroticism simulator score scatterplot.

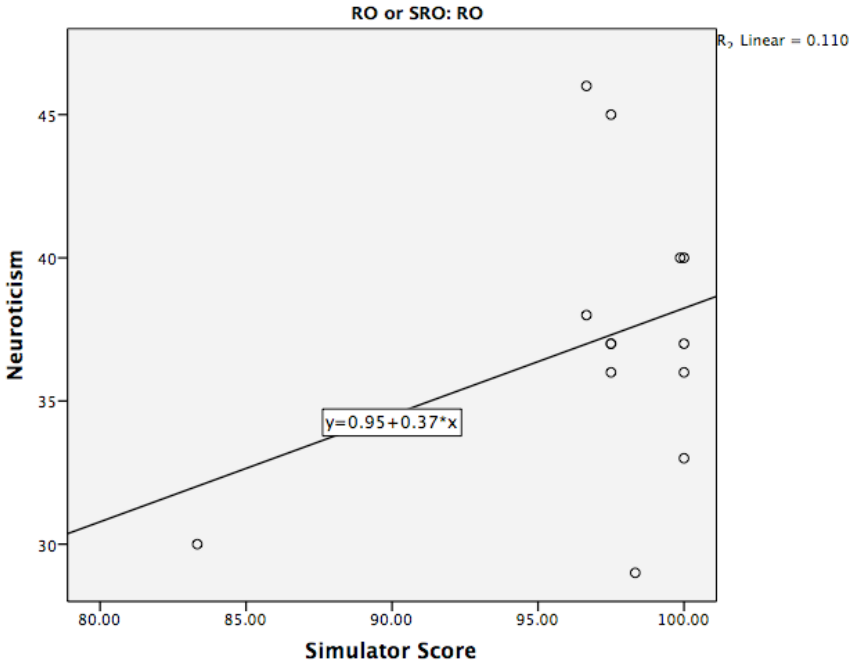

Figure 19. RO neuroticism simulator score scatterplot.

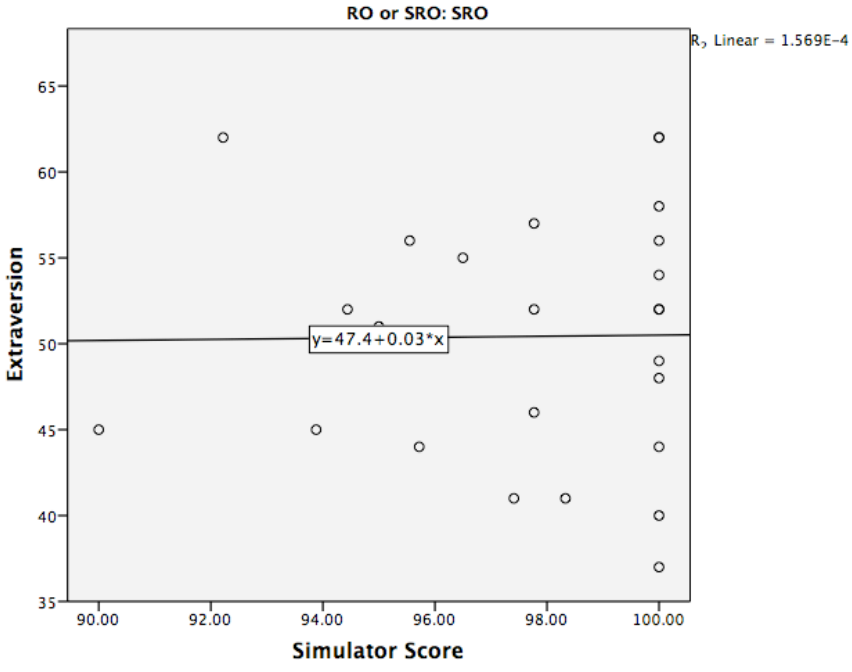

Figure 20. SRO extraversion simulator score scatterplot.

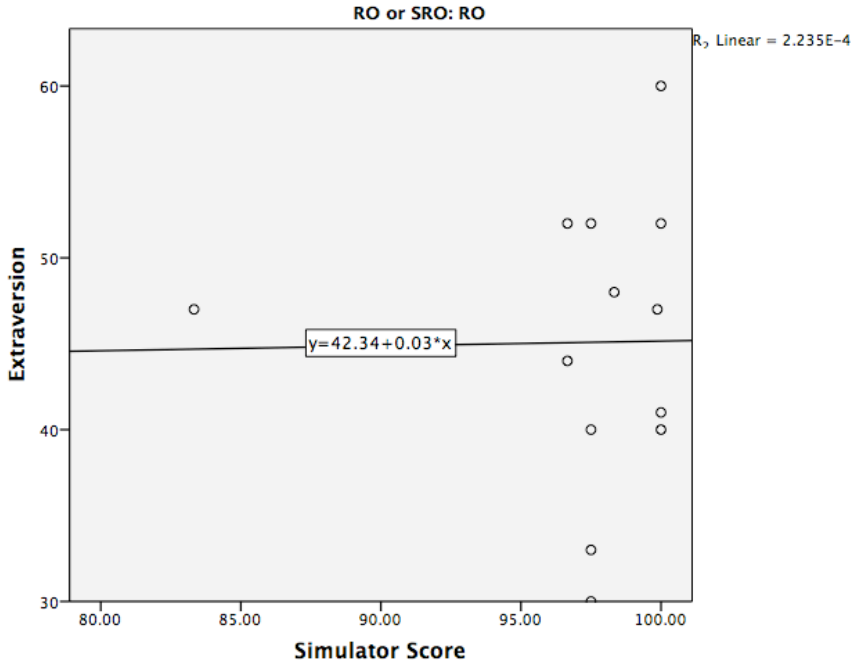

Figure 21. RO extraversion simulator score scatterplot.

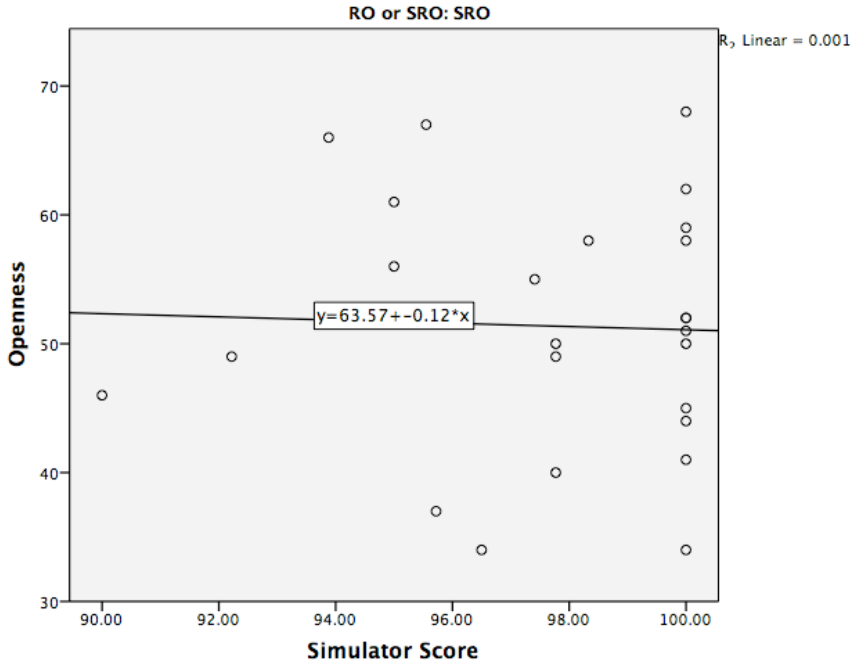

Figure 22. SRO openness simulator score scatterplot.

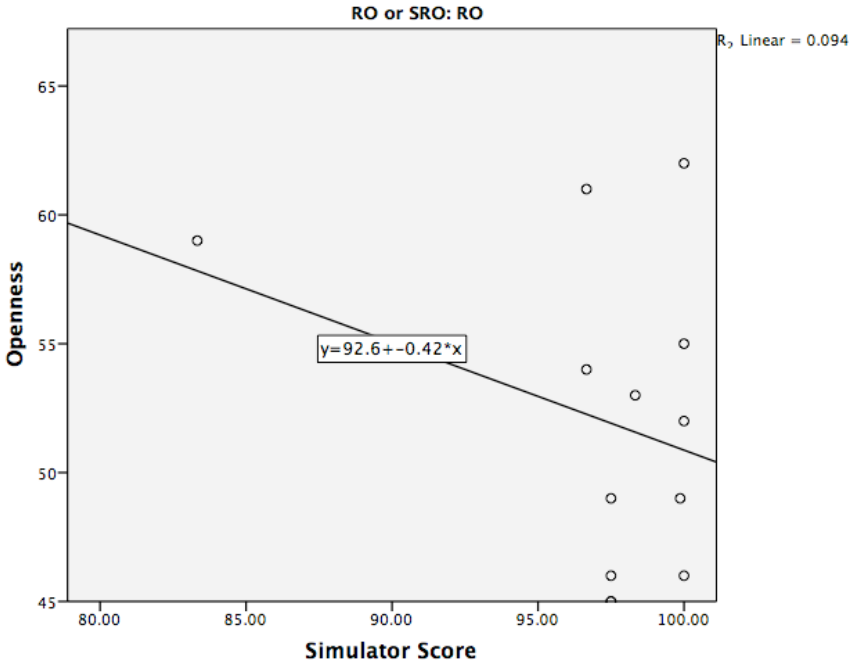

Figure 23. RO openness simulator score scatterplot.

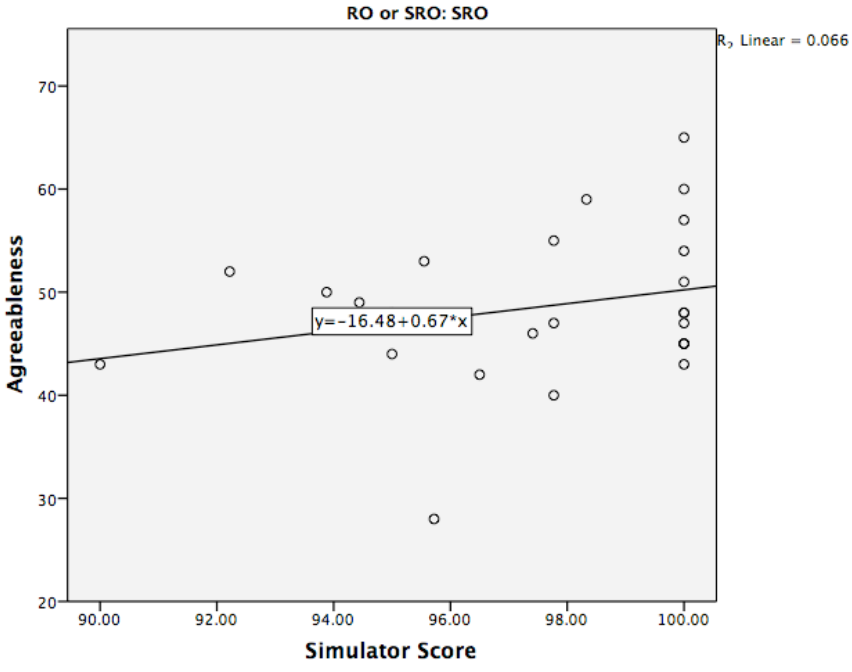

Figure 24. SRO agreeableness simulator score scatterplot.

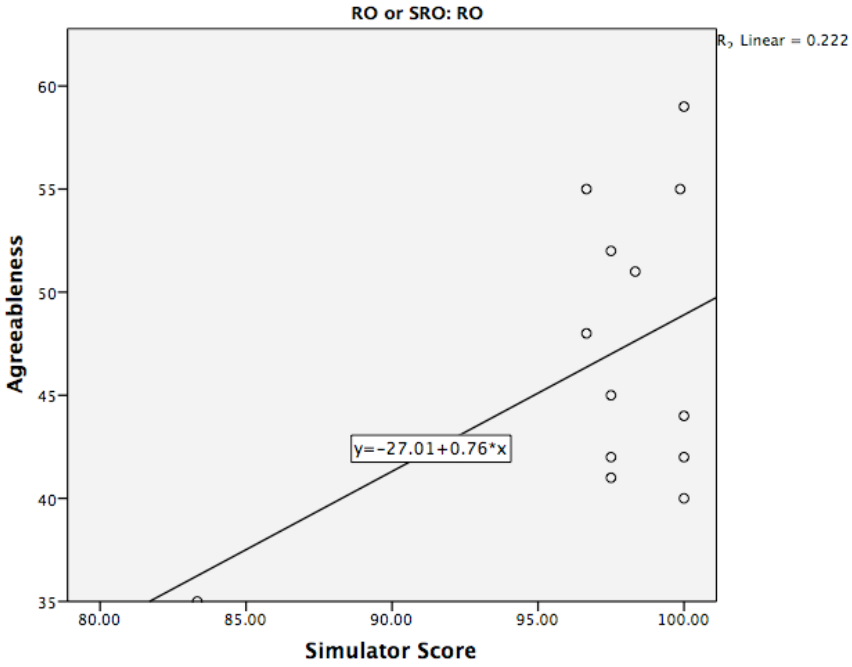

Figure 25. RO agreeableness simulator score scatterplot.

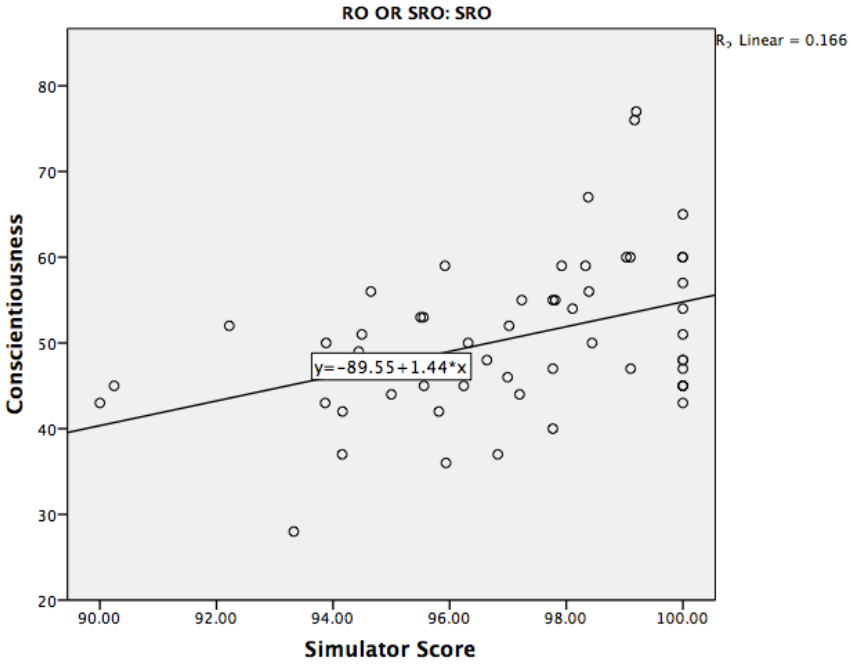

Figure 26. SRO conscientiousness simulator score scatterplot.

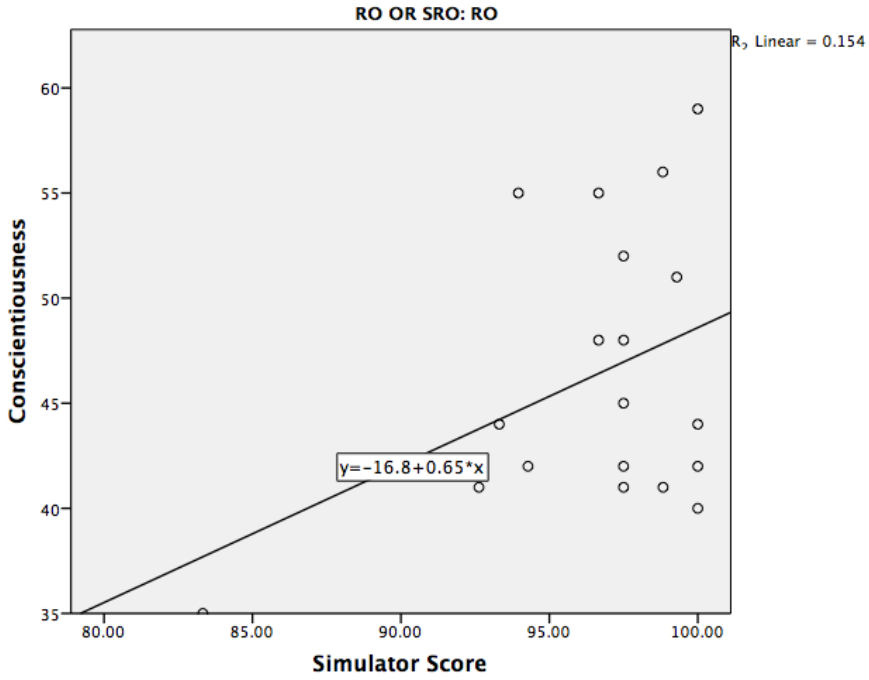

Figure 27. RO conscientiousness simulator score scatterplot.

When I subjected the data to the non-parametric test, similar results emerged from as summarized in Table 5 below. I found a moderately strong positive correlation for ROs between Conscientiousness and written score, $r_s = .517$, $p = .023$. Additionally, I observed a small, but significant negative correlation for SROs between Extraversion and written score, $r_s = -.372$, $p = .005$., and I found, a small, positive, statistically significant, correlation for SROs between simulator score and Conscientiousness, $r_s = .384$, $p = .004$. Colinearity between NEO factors was less an issue with the non-parametric test (see Table 5), though Agreeableness and Neuroticism still showed a significant negative relationship, which raised my concern about colinearity for regression purposes. I discuss the outcomes of all the analyses and how these results impact the generalizability of my study further in Chapter 5.

Table 5
NEO Factors with Simulator and Written Scores

Spearman's Rho		N	E	O	C	A	Simulator	Written
RO	Neuroticism	1.000	.218	-.254	.109	-.097	-.198	-.023
	Extraversion	.218	1.000	-.304	.279	.138	-.201	.351
	Openness	-.254	-.304	1.000	-.304	.361	.216	-.218
	Conscientiousness	.109	.279	-.304	1.000	-.128	.151	.517*
	Agreeableness	-.097	.138	.361	-.128	1.000	.148	.175
	Simulator Score	-.198	-.201	.216	.151	.148	1.000	-.049
	Written Score	-.023	.351	-.218	.517*	.175	-.049	1.000
SRC	Neuroticism	1.000	-.218	.034	.183	-.269*	.058	.160
	Extraversion	-.218	1.000	-.055	.251	.049	.011	-.372**
	Openness	.034	-.055	1.000	.221	-.046	.055	-.038
	Conscientiousness	.183	.251	.221	1.000	-.218	.384**	-.082
	Agreeableness	-.269*	.049	-.046	-.218	1.000	-.078	-.018
	Simulator Score	.058	.011	.055	.384**	-.078	1.000	.182
	Written Score	.160	-.372**	-.038	-.082	-.018	.182	1.000

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
Note: NEO-PI-3 Factor Measures: N = Neuroticism, E = Extraversion, O = Openness, A = Agreeableness, C = Conscientousness; Simulator = NRC Exam Candidate Simulator Score; Written = NRC Exam Candidate Written Score

Research Question 3: Results

RQ3: Which personality factors are most predictive of the success of ILCs on a) the written test, b) the simulator portion, and c) the final score (pass/fail) of the NRC licensing exam? As in both RQ1 and RQ2, it is not possible to address the "c" part of this research question, due to the absence of participation from those who did not pass the

NRC exam. However, I performed regression analyses for the five NEO factors and both outcome variables. The larger set (n = 74) was used for all regression analyses.

Part a. The question of which, if any, of the five NEO factors are most predictive of success for ILCs on the written portion of the NRC exam was analyzed with multiple regression. The multiple regression was used to predict written score from the five NEO factors, Neuroticism, Extraversion, Openness, Agreeableness and Conscientiousness. The assumptions of linearity, homoscedasticity, independence of errors and normality of residuals were met. However, the regression model including the five NEO factors failed to predict the outcome variable written score $F(5, 68) = .590$, $p = .708$, $R^2 = -.03$. Therefore, I fail to reject the null hypothesis for RQ3a Regression coefficients and standard errors are reported in Table 6.

Table 6
Written Score Regression Analysis

	B	SE_B	*β*
Intercept	87.394	6.651	
Neuroticism	0.027	0.052	0.066
Extraversion	-0.071	0.061	-0.145
Openness	-0.034	0.055	-0.077
Agreeableness	0.082	0.064	0.170
Conscientiousness	0.042	0.066	0.083

Note: *B = Unstandardized regression coefficient;* SE_B *= Standard Error of the Coefficient; β=Standardized Coefficient*

Part b. The second part of RQ3, the question of which, if any, of the five NEO factors are most predictive of ILC success on the simulator portion of the NRC exam, was analyzed as well with multiple regression. The assumptions of linearity, homoscedasticity, independence of errors, and normality of residuals were met. One unusual point was determined to be an outlier but was not excluded from the regression equation, as it was within ±3 standard deviations of the mean. The regression model which included the five NEO factors significantly predicted the outcome variable ILC simulator score F(5, 68) = 3.168, p = .012, R2 = .13. However, Conscientiousness was the only factor that reached statistical significance in the model, $p = .001$. The null hypothesis for RQ3b is rejected. Regression coefficients and standard errors of this regression model are also reported in Table 7.

Table 7
Simulator Score Regression Analysis

	B	SE_B	β
Intercept	94.765	3.677	
Neuroticism	-0.019	0.029	-0.076
Extraversion	-0.068	0.034	-0.233
Openness	-0.002	0.031	-0.006
Agreeableness	0.012	0.037	0.040
Conscientiousness	0.121	0.036	*0.414

Note: * $p = .001$; *B = Unstandardized regression coefficient; SE_B = Standard Error of the Coefficient; β=Standardized Coefficient*

Summary

The missing data points in the complete data set proved challenging to the analysis and necessitated the my of multiple imputation to arrive at a usable data set (n = 74), which I subsequently used in all reported analyses. RQ1, which asked the question of whether successful ILCs had certain personality traits in common as compared to unsuccessful ILCs, could not be adequately addressed by the data, because unsuccessful ILCs -- participants who had failed the NRC exam -- did not participate in this study. During hypothesis testing for RQ2, a strong positive correlation was found between the NEO factor Conscientiousness and the Written Score for RO candidates, whereas a more moderate, negative correlation was found between Extraversion and Written Score for SRO candidates. Because both of these findings were statistically significant, I rejected the null hypotheses for the first part (a) of RQ2, which asked if any of the common personality factors of successful ILCs correlate with successful completion of the written score portion of the licensing exam. I failed to reject the null hypothesis for the second part of RQ2, part (b), because though I detected a moderate positive correlation between Conscientiousness and Simulator Score for a subset of the data, SRO candidates, I did not find statistically significant correlations in the data set as a whole. Part (c) of RQ2 could not be answered because all participants passed the final NRC exam, so there was no comparison group. Finally, though RQ3 part (c) could not be answered for the same reason, I tested the hypotheses for parts (a) and (b) with regression analyses, resulting in failure to reject the null hypothesis for part (a) – written score – while I rejected the null hypothesis for part (b) – simulator score. So, my regression analyses showed that NEO

factors, particularly Conscientiousness, predicted Simulator Score for ILC candidates, regardless of role. I engage in a discussion of the implications of these results and suggestions for future research in Chapter 5.

Chapter 5: Discussion

Introduction

The problem of throughput in nuclear power--the ratio of intitial license candidates who begin the training process to become licensed nuclear power operators, to those who actually complete the process and become licensed--is certainly complex. It is likely that there exist a number of causative factors behind the issue. This study was designed to examine only one potential variable in ILC success, the personality factors of successful initial license candidates, to determine if a measure of normal personality might be leveraged as a select-in criteria to improve throughput. This study, even with a less-than optimal sample size, demonstrated the potential for personality factors to predict ILC success. The analyses in Chapter 4 showed correlations between personality factors as measured by the NEO-PI-3 and both written and simulator portions of the NRC exam. Further, regression analyses showed that personality factors, particularly the Conscientiousness factor, predicted success on the simulator portion of the NRC exam. This study gives some insight into the throughput problem by confirming that personality is related to the success of initial license candidates. The remainder of this chapter is devoted to a discussion of the impact and possible interpretation of these findings, limitations of the current study, recommendations for further research, and discussion of the positive social change impact of these results.

Interpretation of Findings

As noted earlier in this dissertation, the use of a measure of normal personality to select-in candidates for the role of a licensed operator is not standard practice in nuclear

power. The standard approach is to rely heavily on cognitive assessments, interviews, and recommendations to predict ILC success (NEI, 2011). Results of this study do indicate that ILC success is related to certain personality facets, though more study is needed to confirm and extend these findings. The results of this study certainly confirm what has been found generally in personality studies on job outcome measures, that personality factors may be validly and reliably used along with other success indicators such as cognitive assessments (Barrick & Mount, 2005; Chamorro-Premuzic & Furnham, 2010; Heggestad & Gordon, 2008). In particular, Conscientiousness is repeatedly noted as a key success factor across myriad job settings (Barrick, et. al, 2001) and most particularly in high performing team settings like nuclear power utilities (Shanteau, Fullagar, & Hemenover, 2002). In an example specific to the setting of this study, the nuclear operator competency model developed for the O*NET database (O*NET, n.d.), noted earlier in Chapter 2, points to attributes that are synonymous with the underlying facets of Conscentiousness as measured by the NEO-PI-3. It is not surprising, then, to see a strong relationship between ILC success and the Conscentiousness level in this study. Whether or not Conscientiousness effectively discriminates between success and failure of initial license candidates could not be established by this study because of the lack of participation from anyone in the failure group. However, this study does extend the literature on Conscientiousness as a predictor of job outcomes as it was predictive of simulator score on the NRC exam for successful participants. In addition, this study adds to the considerable body of knowledge on the five-factor theory that undergirds instruments such as the NEO-PI-3 by applying this theory to a novel setting--U.S.

commercial nuclear power. This study also serves to extend the literature on the use of personality assessments to provide incremental validity in predicting job outcomes in HRO settings--specifically nuclear power. The outcomes noted in this study may also be utilized by researchers aiming to predict training setting outcomes, as the nuclear power ILC process is at its core a very lengthy training process (NRC, 2004).

It is interesting to note that the correlation analyses I produced in this study point to a relationship with both the written and simulator portion of the NRC exam process. Though the predictive capacity of personality factors was not established in this study for written score, it bears suggesting that further study is needed here because the results of the correlation analyses suggest a relationship of some kind exists. The correlation analysis also indicated that a negative relationship exists between Extraversion and Written Score in the SRO subset. This result may be of interest to leadership researchers, as the Extraversion factor is the topic of much research in leadership literature (Abatecola, Mandarelli, & Poggesi, 2013). Because the correlation with Extraversion was a moderately strong inverse relationship with written score, more study is warranted, perhaps on the facet level, to determine which aspects of the Extraversion factor are most related to academic outcomes such as those seen with Written Score in this study. Further discussion on the study of facet level personality traits in this population and setting is contained in the recommendation section below.

Limitations

As I noted in the limitations section of Chapter 1, it is likely that the narrow focus on personality factors for this study may have excluded other factors that significantly

contribute to the success of ILC candidates. Certainly, other individual differences such as cognitive ability, or experience level, play a role in the successful completion of a rigorous academic pursuit such as the ILC training process. I did not formally consider candidate cognitive ability and experience in this study. However, because of the timing of the personality assessments (post NRC exam) and the fact that all participants passed both the simulator and written portion, albeit with varying scores, some of the variance due to other factors like academic ability or experience may have been controlled for. The participants in this study all had to at least possess the academic ability and experience necessary to pass the final NRC exam, which gives more weight to the thought that the individual differences I identified resulted from other factors, such as personality.

I also did not consider contextual factors such as local corporate culture or expectations as factors affecting ILC success. This may be considered a limitation of my study, as well as a potential area for future research. For example, a comparison of ILC success in plants with "forced progression" policies based on seniority versus merit-based consideration for license class would be an excellent way to examine a known contextual factor. Though contextual factors were not directly controlled for, I took care to invite participation from each of the four NRC regions so that geographic and cultural diversity would be achieved. However, over half of the data provided by the utilities was missing location identifiers. Further, because the data set was small, I chose not to include the location data that was provided in order to preserve participant privacy. The lack of

consideration of other contextual factors that could affect ILC success remains a limitation of this study.

I had anticipated that the demographic profile of the participants would not be representative of the general population, and indeed that was the case. Only three females participated in the current study. With such a small number, no meaningful comparisons could be drawn based on gender. No other individually identifying information was gathered and data were aggregated without respect to other categories, which could be seen as a limitation even in this small data set. In a larger data set, it would be ideal to collect extensive demographic data including gender, race, age, and even additional biodata such as experience level and particularly whether candidates have had military experience. This lack of demographic information certainly limits the generalizability of the results.

This dataset is also limited in terms of the generalizability of results because of its small size. A larger dataset was impeded by several factors during the data gathering phase of this study. First, the vendor delivery system setup may have precluded some participation by requiring that I know the age of the participants prior to sending the invitation to the study. In addition, the vendor delivery system default settings for assessment expiration and the fact that the invitation to participate was sent from a "no-reply" email address were also obstacles to initial participation and likely resulted in lower participation overall. However, the dataset was most limited in size by the lack of follow-up data from the utilities. Though 177 potential participant email addresses were provided by the utlitites and 75 individuals chose to participate, only 39 complete records

were provided by utilities. Data were supplied in multiple formats and in many cases a portion of the data was missing, including such data points as the role (RO or SRO) of the individual and gender of the individual. It was particularly difficult to obtain the simulator score in a numeric form. Evidently, though a numeric simulator score is documented by the NRC on form ES-303 and provided to each site upon completion of the examination process, the sites do not typically track this actual number but rather record it only as pass/fail. Further, many of the site contacts were unaware that a numerical score was given by the NRC for the simulator operating exam, and most replied to coordinator email requests for the forms that they did not know what the form ES-303 was. I was able to receive more ES-303 forms from the utilities by sending the sample form to the corporate site contacts, who then passed it on to individual sites along with a request for ES-303s from 2014 license class participants. A sample of form ES-303 is provided in Appendix C of this dissertation as support for a discussion of its potential value to utilities in the recommendations section below.

Finally, this study is limited by small effect sizes. Several solid relationships between personality factors and ILC success were demonstrated by this study. Therefore, this study may be considered a pilot study for a future large-scale correlational study of personality in successful and unsuccessful license candidates. However, even the significant results found in this study are limited in their impact due to small effect sizes. Although the correlations I found with Conscientiousness and Extraversion and the outcome variables were statistically significant, the r^2 values were small to moderate, which is not surprising for such a small data set. The regression coefficient of

Conscientiousness on Simulator Score was statistically significant at the $p < .001$ level, but the model overall only accounted for 13% of the variance of participant Simulator Score, a fairly small amount. Again, a larger data set may have provided a bases for stronger recommendations, but some recommendations based on the results of this study are included below.

Recommendations

The literature on personality has established that the Five Factor Model can be reliably used to predict job related outcomes, and provides incremental validity over cognitive measures alone (Barrick & Mount, 2005). Yet, as I have noted previously, personality research directly aimed at the setting of this study, U.S. based commercial nuclear power utilities, is sparse to this point. The results of this study demonstrates both the need for more of its kind, and the challenge that can be expected by researchers attempting to conduct studies with this very insular and highly regulated culture.

A large, well designed study is needed to solidly confirm what the research in other HROs and generally in the personality-job outcome literature reflects: Personality matters. However, to conduct the study proposed above means gaining greater access to this population, and more specifically, motivating large-scale participation from individuals and individual site management to provide appropriate data. In the current study, I enjoyed excellent relationships with top corporate managers at two of the largest nuclear energy providers in the U.S., both of whom were very supportive during the design and implementation phases. The corporate contacts provided to me by the top

managers were organized and responsive, and made repeated appeals for data to individual sites on my behalf.

The problem with actual data collection was two-fold. First, the study design, specifically the retrospective timing of the study, may have limited the participation from those who did not pass the NRC exam. A better result might be seen in a longitudinal study that assessed personality at the outset of the candidate's licensing process and followed through to the NRC exam eighteen months to two years later. The resources required to conduct this study would necessitate support from multiple utilities, and perhaps other regulatory or supporting organizations such as INPO, NEI, or even the NRC. The second part of the data gathering challenge for this study was found in the manner in which individual sites maintain and report ILC success. As I have noted, the data points necessary for a study on this topic are not easily gathered, because individual sites only track the data they are required to track, namely whether individual candidates pass or fail the NRC exam. Actual simulator scores are not tracked consistently -- even though an exact score is given by the NRC (see Appendix C: Form ES-303 for an example of the simulator data provided by the NRC) and are only reported as pass/fail. Any further study on this topic would require a change in the way this data are tracked at the individual sites, which provides further evidence for the need to involve a regulatory or supporting organization such as INPO or the NRC. It is unlikely that sites would change the way they track and report data on ILCs unless they were provided support, or required by a regulator, to do so.

Further, there are several practices that U.S. nuclear utilities engage in that were encountered during the current study that would need to be considered in a future research design. First, the practice of using an audit exam, or a dummy version of the NRC exam, by the utilities to screen out potential failures prior to taking the NRC exam, is a challenge to any researcher studying this topic. A longitudinal study would need to factor in ILC performance on this audit exam to accurately measure performance, because the ILCs that fail the audit exam are not invited to take the final NRC exam. This is one way the utility maintains a good NRC exam pass rate, but the failure of a candidate on the audit exam is also a huge failure for the utility and the license candidate. At the point of failing the audit exam, which is given just weeks to a couple of months prior to the NRC exam, a huge investment has been made and lost by both the ILC (time and effort and often even a pay cut for the time they are in class) and the utility (at a cost of over $400,000 per candidate, as I have noted previously). This is an aspect of the ILC timeline that must be considered in a future study in order to fully understand and define the outcome variables.

Another factor practice that must be considered in future studies on this topic is the way utilities track class failures. Utilities do not differentiate between academic failures and removal from class for other reasons, such as voluntarily withdrawing for personal reasons, illness, significant life events, etc. So any data on class failures in a large-scale study would need to differentiate the reasons for class failures in order to draw meaningful conclusions from the data. Again, this will prove a challenge to access in organizations that do not formally track such data.

Further, candidate demographic data are not tracked as far as I could tell from the data provided. For example, at no point during the current study could I find any differentiation of ILCs based on gender or racial identity from any data provided from the individual site level, through the corporate utilities, to the NRC. This is unusual and interesting for many reasons given the interest in diversity both from a research perspective and a human resources perspective. Though this is not a topic of the current study, comparisons involving race and gender and ILC success in this setting would make interesting addition to the literature on this topic.

This study provides a foundation for further researcher on personality and ILC success on beyond the factor level of personality. As I have noted previously, in a small data set such as the one in this study, it is common to encounter issues of multicolinearity, especially in personality research, and though NEO factors are generally thought to be orthogonal (McCrae & Costa, 2010), the factors are still all measures of personality, and are therefore related in some way. A larger study would certainly provide additional insight into the nature of those relationships and may be designed more effectively were it to measure personality on a facet level.

One outcome of this study indicates that more research is needed to understand the predictive nature of Conscientiousness, for this population in particular. It is likely that the five facets that underlie Concientiousness, namely competence, order, dutifulness, achievement striving, self-discipline and deliberation, do not all contribute equally to the ability of Conscientiousness to predict the ILC simulator score outcome even in this study. In the same way, a larger study could further explore the negative

correlation I detected in this study between Extraversion and Written Score for SROs, by examining this relationship on a facet level as well.

It is interesting to note that though Conscientiousness and Extraversion showed the most promise for further study in the analyses I performed in this study, the overall mean level of Neuroticism for participants in this study in both the small data set (n = 39) and the pooled data set (n = 74) was nearly ten points below the general population mean. This raises an interesting question of why such a large departure from the general population mean exists and whether it may be utilized to differentiate between those in the talent pool who will become successful license candidates, and those who will fail. That question could not be addressed by the current data, because of the lack of a "failure" comparison group as noted earlier, but this observation presents further support for a longitudinal study of this population to investigate Neuroticism as a possible predictor for ILC success.

Though this study was based on a relatively small data set, it raised important questions and provides insight on the value of personality as an additional means of predicting ILC success. The incremental validity of personality in conjunction with cognitive measures, over the use of cognitive ability tests alone has been established in other settings. This study suggests that a FFM of personality may also provide the same advantage in the commercial nuclear power setting, though further study is needed.

Implications for Positive Social Change

The implications for positive social change highlighted by the current study are hinged on improving the selection process for initial license candidates in commercial

nuclear power utilities in the U.S. This study provided support for the notion that personality may be predictive of ILC success, particularly that Conscientiousness predicts ILC Written Score on the NRC exam. Given this result, both utilities and individual candidates may find a normal measure of personality based on the Five Factor Model, such as the NEO-PI-3, useful in the selection process in addition to the measures already in place.

Utilities may be able to use the results in this study to select candidates with higher levels of Conscientiousness as measured by the NEO-PI-3, though further study is needed to differentiate between successful and unsuccessful ILCs based on personality. In addition, the outcome of this study should generally encourage utilities to view personality measures as both correlated with written score outcomes, at least for SROs and simulator scores. This outcome positions a non-clinical personality measure as an effective means of predicting operating success for ILCs, rather than relying on cognitive measures alone.

Improving the return on investment for nuclear utilities is perhaps the most valuable of the potential positive impacts of adding a personality measure the license candidate screening process, at least in terms of resources. If the selection process only improves by selecting, or not selecting, one candidate, the utility saves nearly a half-million dollars (NEI, 2011). So, even a small improvement can have a large effect.

The use of personality measures as a routine addition to the ILC selection process, is supported preliminarily by the results of this study. On an individual level, the positive social impact of adding personality measures to nuclear utility selection may assist

individual candidates to make more informed career choices. So, rather than spend months or even years in an initial license program, individuals may choose not to pursue a license if the results of a personality assessment shows they are a poor fit for the role. This could save individuals in terms of their professional reputation, their finances, and the lost time and effort spent in initial license class when they could have continued on a more profitable career trajectory.

Of course, further study is needed to expand and extend the results of this study. It would be premature to make large policy shifts based a study with such a small sample size. However, the significance of these results demonstrate the need for a normal measure of personality to be considered for use on a broader scale in the selection of initial license candidates for roles as licensed operators. If the nuclear industry were to broadly implement the use of a five-factor measure, such as the NEO-PI-3, as a matter of course in their selection and/or on-boarding processes, as they currently do with the MMPI, it would be a major step towards further study of the usefulness of such a measure as a predictive tool for ILC success.

Conclusion

Ultimately, society as a whole is invested in the question of whether the right individuals are placed in the right roles in HROs such as commercial nuclear power plants. Safely and reliably operating nuclear power plants are vital to the health of the U.S. domestic power grid, and safe operation is dependent upon the licensed inviduals in the control room. In this study I found that certain aspects of personality, as measured by a Five Factor Model measure of personality, are related to, and actually predict success

for intial license candidates. These findings are in line with similar research in other HROs such as medicine and aviation (Fitzgibbons, Davis, & Schutte, 2004; Lievens, Coetsier, De Fruyt, & De Maeseneer, 2002). This study contributes to the literature on the use of personality in selection and the prediction of job outcomes, it contributes to the literature on the prediction of operations success in high reliability organizations, and it contributes to literature on personality and training outcomes by extending it into the novel setting of nuclear power utility operations training. Though I designed this study specifically to address the issue of throughput in initial license classes, it also opens the door to further study of many related topics in the unique and special setting that is U.S. commercial nuclear power.

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Appendix A: Participant Site Invitation

Email to Participating Nuclear Power Plant Sites

Dear Training Manager

I am a doctoral student in organizational psychology at Walden University. I am conducting dissertation research on the psychological characteristics of successful initial license candidates at U.S. commercial nuclear power plants. For this study, I am using a professional measure of normal psychology called the NEO-PI-3 and comparing the results to candidate pass rates on the NRC exam. I would like to request your permission to approach the members of your candidate class to ask for their participation in this study. The participants will be asked to take a brief personality assessment (the NEO-PI-3). In addition, I will request permission from the participants to receive their scores on both the written and simulator portion of their upcoming NRC licensing exam, as well as their final results (pass or fail). In exchange for providing access to your candidate class for this study, I can provide your organization with a summary of the results indicating whether personality facets are predictive of initial license candidate success. The participants can also request and receive a copy of their NEO-PI-3 assessment results from me confidentially and at no cost, in exchange for their participation in this study.

If you are willing to participate, I will require email addresses for each of the candidates so that I can email information regarding the study and directions for participation to each candidate. I will follow this email with a phone call this week to confirm your participation.

Thank you,

Cynthia DeVita-Cochrane, MS.
Doctoral Student, Organizational Psychology

Appendix B: Informed Consent

Participant Informed Consent Email

Dear License Candidate,

You are invited to take part in a research study of normal personality in successful nuclear operator candidates. The researcher is inviting current nuclear operator license candidates to be in the study. This email is a part of a process called "informed consent" to allow you to understand this study before deciding whether to take part.

A researcher named Cynthia DeVita-Cochrane who is a doctoral student at Walden University is conducting this study.

Background Information:
The purpose of this study is to determine if personality traits can predict the success of nuclear operator candidates in passing the NRC exam and achieving a license.

Procedures:
If you agree to be in this study, you will be asked to:
Complete a brief measure of normal personality called the NEO-PI-3.
Allow the researcher to have access to your final NRC exam scores.

Voluntary Nature of the Study:
This study is voluntary. Everyone will respect your decision of whether or not you choose to be in the study. No one at your utility will treat you differently if you decide not to be in the study. If you decide to join the study now, you can still change your mind later. You may stop at any time.

Risks and Benefits of Being in the Study:
Being in this type of study involves some risk of the minor discomforts that can be encountered during any time of self-reflection, such as discomfort, frustration or possibly becoming upset. Being in this study would not pose risk to your safety or wellbeing

The potential benefit of this study is for the nuclear power industry to gain a better understanding of the role of normal personality traits in the success of initial license candidates.

Personal Benefit:
If you would like, a copy of the results of your NEO-PI-3 personality assessment will be provided to you. You may enjoy and grow from the knowledge provided by these results. If you would like to have a copy, simply reply to this email with your request and you will receive a copy via email after the study is complete. This copy will be password protected. The password will be sent to you via a separate email.

Privacy:
Any information you provide will be kept completely confidential. The only individuals who will have access to your data will be the researcher and her doctoral supervisor. The researcher will not use your personal information for any purposes outside of this research project. Also, the researcher will not include your name or anything else that could identify you in the study

reports. Data will be kept secure in password-protected files on the researcher's personal computer. Data will be kept for a period of at least 5 years, as required by the university.

Contacts and Questions:
If you have questions you may contact the researcher directly by a reply to this email, or you may call (*). If you want to talk privately about your rights as a participant, you can call Dr. L. E******* She is the Walden University representative who can discuss this with you. Her phone number is (*). Walden University's approval number for this study is **04-30-15-0043217** and it expires on **April 29, 2016.**

Please print or save this consent form for your records.

Statement of Consent:

I have read the above information and I feel I understand the study well enough to make a decision about my involvement. By clicking the link to access the personality test at the bottom of this page, I understand that I am agreeing to the terms described above.

Thank you for your participation.

<Link to NEO-PI-3 Here>

* Identifying information removed

Appendix C: NRC ES-303 Sample Form

ES-303, Rev. 9 Individual Examination Report Form ES-303-1

[redacted]

EX 6

U.S. Nuclear Regulatory Commission Individual Examination Report					
Applicant's [redacted]			Docket Number [redacted]		
I	R	Examination Type (Initial or Retake)	Facility Name: Vogtle		
		Reactor Operator	Facility Description	X	Hot
X		Senior Reactor Operator (SRO) Instant			Cold
		SRO Upgrade			BWR
		SRO Limited to Fuel Handling		X	PWR

Written Examination Summary	
NRC Author/Reviewer: M. Meeks	RO/SRO/Total Exam Points 75 / 25 / 100
NRC Grader/Reviewer: M. Meeks	Applicant Points 72 / 22 / 94
Date Administered: April 20, 2012	Applicant Grade (%) 96.00 / 88.00 / 94.00

Operating Test Summary	
Administered by: M. Meeks	Date Administered: March 26– April 13, 2012
Walk-Through (Overall)	S
Administrative Topics	S
Simulator Operating Test	S

Examiner Recommendations					
Check Blocks	Pass	Fail	Waive	Signature	Date
Written Examination	X			M. Meeks	05/10/2012
Operating Test	X			M. Meeks	05/10/2012
Final Recommendation	X			M. Bates	10 MAY 2012

License Recommendation			
✓	Issue License	Supervisor's Signature Malcolm T. Widmann	Date 05/10/12
	Deny License		

[redacted]

EX 6

Applicant Docket Number: [redacted]

Walk-Through Grading Details	Evaluation (S or U)	Comment Page Number
Administrative Topics		
a. Perform AFD Monitoring	S	
b. K_{eff} Determination for Shutdown Banks Withdrawn	S	
c. Determine Tagging Requirements	S	
d. Determine if Task Can Be Completed Without Exceeding any Radiological Limits	S	
e. Emergency Plan Classification and Notification (Administered by M. Bates)	S	
Systems: Control Room		
a. Control Rod Operability Test	S	
b. Transfer ECCS Pumps to Cold Leg Recirc	S	
c. Depressurize RCS to Reduce Break Flow to Ruptured SG (Administered by P. Capehart)	S	
d. Start an RCP with Subsequent Seal Failure (Administered by M. Bates)	S*	4
e. Transfer AFW Suction Source to CST 2 (Administered by P. Capehart)	S	
f. Dilute Containment with Service Air	S	
g. Return ESF Bus from Diesel Generator to Normal Supply	S*	5
h. N/A	N/A	
Systems: In-Plant		
i. Establish RWST Gravity Drain Through RHR Pumps to HLs (Administered by M. Bates)	S	
j. Establish Local Control of 1E Switchgear (Administered by P. Capehart)	S	
k. Placing the RHR 25kVA Inverter 1DD116 in Service (Administered by M. Bates)	S*	6

ES-303, Rev. 9 Individual Examination Report [redacted] Form ES-303-1

Ex 6

Applicant Docket Number: [redacted]

Senior Reactor Operator Simulator Operating Test Grading Details

Competencies/ Rating Factors (RFs)	RF Weights	RF Scores	RF Grades	Comp. Grades	Comment Page No.
1. Interpretation/Diagnosis					
a. Recognize & Attend	0.20	3	0.60		
b. Ensure Accuracy	0.20	3	0.60	**2.70**	
c. Understanding	0.30	**2**	**0.60**		7
d. Diagnose	0.30	3	0.90		
2. Procedures					
a. Reference	0.30	3	0.90		
b. EOP Entry	0.30	3	0.90	3.00	
c. Correct Use	0.40	3	1.20		
3. Control Board Operations					
a. Locate & Manipulate	0.34	3	1.02		
b. Understanding	0.33	3	0.99	3.00	
c. Manual Control	0.33	3	0.99		
4. Communications					
a. Clarity	0.40	3	1.20		
b. Crew & Others Informed	0.40	3	1.20	3.00	
c. Receive Information	0.20	3	0.60		
5. Directing Operations					
a. Timely & Decisive Action	0.30	3	0.90		
b. Oversight	0.30	3	0.90	3.00	
c. Solicit Crew Feedback	0.20	3	0.60		
d. Monitor Crew Activities	0.20	3	0.60		
6. Technical Specifications					
a. Recognize and Locate	0.40	3	1.20		
b. Compliance	0.60	3	1.80	3.00	

[Note: Enter RF Weights (nominal, adjusted, or "0" if not observed (N/O)), RF Scores (1, 2, 3, or N/O), and RF Grades from Form ES-303-4 and sum to obtain Competency Grades.]

Ex 6

CROSS REFERENCE:

Systems: Control Room "d"

JPM/TASK:

Start an RCP with Subsequent Seal Failure

EXPECTED ACTION/RESPONSE:

The applicant was expected to perform alarm panel checks as part of verifying no applicable alarms being lit prior to starting the RCP.

The applicant was also expected to recognize the ALB08-B05, RCP 2 CONTROLLED LKG HI/LO FLOW, alarm in a timely manner.

APPLICANT ACTION/RESPONSE:

The applicant did not perform alarm panel checks as part of verifying applicable alarms not lit.

The applicant started RCP #2 and secured the associated lift pump. Approximately two minutes after the RCP 2 CONTROLLED LKG HI/LO FLOW alarm annunciated, he recognized the alarm and correctly completed the task.

The applicant's performance was rated as satisfactory because performing alarm panel checks was not a critical step. Also, the task did not contain time critical acceptance criteria; therefore, the applicant's correct completion of all critical steps was evaluated as satisfactory.

LACK OF ABILITY/KNOWLEDGE:

The applicant demonstrated a weakness in thoroughly performing a procedure step that required a verification of applicable alarms not being lit. The applicant also displayed a weakness in recognizing an alarm, in a timely manner, that was directly associated with his task.

Ex 6

CROSS REFERENCE:

Systems: Control Room "g"

JPM/TASK:

Returning ESF Bus from Diesel Generator (DG) to Normal Supply.

EXPECTED ACTION/RESPONSE:

The applicant was directed to parallel Reserve Auxiliary Transformer (RAT) "B" to bus 1BA03, and then remove DG1B from bus 1BA03 in accordance with procedure 13427B-1, "4160V AC Bus 1BA03 1E Electrical Distribution System." At step 4.2.5.1 of this procedure, the applicant was expected to lower DG1B load to 3000 kW in maximum increments of 1000 kW and 500 kVAR in time increments of 5 minutes. When the applicant reached step 4.2.5.1, the diesel would be running with ~3250 kW load and ~300 kVARs lagging. Step 4.2.5.2 of the procedure directs the operator to concurrently unload the DG to 700 kW and 200-300 kVARs lagging after the diesel load has been stable at 3000 kW for a 5 minute period. None of the above-mentioned steps in the procedure were critical steps in the JPM.

APPLICANT ACTION/RESPONSE:

During the JPM, when the applicant performed step 4.2.5.1 of the procedure to unload the diesel, he lowered load from ~3200 kW to ~2100 kW and then waited 5 minutes. This was incorrect because diesel load was lowered below ~3000 kW.

During post-JPM questions with the examiner, the examiner asked the applicant to go back through the procedural steps of 4.2.5.1 and 4.2.5.2. At this time, the applicant stated that he should have only lowered load to 3000 kW instead of 2100 kW, and that he realized the mistake when he turned the page and read step 4.2.5.2. However, the applicant correctly performed all critical steps in the JPM. Therefore, the applicant was evaluated as successfully completing the JPM.

LACK OF ABILITY/KNOWLEDGE:

The applicant demonstrated a lack of ability to interpret and execute procedure steps.

Ex 6

[redacted]

APPLICANT DOCKET NUMBER: [redacted]

CROSS REFERENCE:

Systems – In-Plant JPM "k"

JPM/TASK:

Placing the RHR 25kVA Inverter 1DD1I6 in Service

EXPECTED ACTION/RESPONSE:

The applicant was also expected to direct installation of the annunciator card associated with ALB34-E07 and check that the alarm was lit in accordance with step 4.4.3 (b) of procedure 13011-1, "Residual Heat Removal System," Rev 69.

APPLICANT ACTION/RESPONSE:

The applicant also did not initially verify that the annunciator card associated with ALB34-E07 had been installed. However, the applicant did recognize his error when he was provided a cue that the alarm was dark. The applicant stated that he had thought that he had already performed those actions in accordance with a previous procedure step, but then he recognized that the previous step was associated with ALB34-F07 rather than ALB34-E07.

The applicant's performance was rated as satisfactory because he completed all critical steps correctly. The applicant did direct installation of the annunciator card associated with ALB34-E07 prior to proceeding to the next procedure step.

LACK OF ABILITY/KNOWLEDGE:

The applicant demonstrated a weakness in his ability to correctly complete procedure steps.

Ex 6

[redacted]

APPLICANT DOCKET NUMBER [redacted]

CROSS REFERENCE:

1.c: Interpretation/Diagnosis – Understanding

SCENARIO/EVENT:

Scenario 7, Event 6: The Refueling Water Storage Tank (RWST) Developed a Leak With RWST Sludge Mixing Isolation Valves Failed to Automatically Close

EXPECTED ACTION/RESPONSE:

The applicant, as Senior Reactor Operator (SRO), was expected to understand that the RWST sludge mixing valves should automatically close on a RWST LO LEVEL alarm, and ensure that the operators verify that the expected automatic actions do, in fact, occur.

APPLICANT ACTION/RESPONSE:

When the RWST LO LEVEL alarm annunciated, the applicant directed the ARP to be referenced and actions taken. The applicant verified that RWST levels were actually lowering on all channels and dispatched non-licensed operators to the area to investigate the problem. However, the entire crew (including the applicant) allowed the RWST leak to continue for approximately 11 minutes before they isolated the leak by manually closing the RWST sludge mixing isolation valves (1-LT-0991 and 1-LT-0990) using handswitches on the control room back-panel QPCP. The applicant ultimately determined that the valves had switches in the control room after referencing a piping diagram.

During post-scenario follow-up questions, the applicant stated that he did not initially think to check the RWST valves closed as part of verifying the automatic actions of the RWST LO LEVEL alarm response procedure because he was not sure they were in the control room. The applicant made one non-critical error associated with this rating factor, and was therefore evaluated with a score of "2" for this rating factor.

LACK OF ABILITY/KNOWLEDGE:

The applicant demonstrated a lack of knowledge of annunciator alarms, indications, or response procedures; as well as a lack of ability to locate control room switches, controls, and indications, and to determine that they correctly reflect the desired plant lineup.