Effects of Personality Traits on Human Operators in Nuclear Power Plants

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1. Introduction

As we experienced severe accidents of nuclear power plants (NPPs) like Three Mile Island (1979), Chernobyl (1986), and Fukushima Daiichi (2011) accidents, the safety operation of NPPs becomes a key issue for prosperity and survival of nuclear power generation. It is widely known that the performance of the human operator is one of the crucial factors to ensure safe operation of NPPs. It was revealed that all three severe accidents involve human error to a certain degree [1].

For the safety of NPPs, systematic and managerial approaches have been implemented to reduce human errors by establishing human factor regulations and guidelines and by conducting deterministic safety analysis. Despite all these efforts, human operators may encounter unexpected plant conditions. The unexpected plant conditions can have significant impacts on human information processing and enable wide range of error mechanisms and error types [2]. Thus, many efforts have been conducted to apply cognitive characteristics into design and operation in NPPs by developing cognitive models [3][4] and second generation human reliability analysis (HRA) methods [2][5][6]. However, these methods do not consider different individual characteristics of human operators, also known as personality, as performance shaping factors.

In the field of psychology, which is the primary domain of personality research, several studies showed that personality have the correlation with perceived workload and job performance [7]–[10]. In other industries like aviation, railway, and military, countermeasures to prevent human error based on personality are already implemented [11]. Although nuclear industry requires high reliability more than other industries and there is the recognized significance of individual differences on performance of operators, such differences have not been systematically applied to nuclear industry yet. Thus, this paper examines effects of personality to perceived workload and job performance for human operator based on the research results in psychology and other industries.

2. Background

2.1 The concept and characteristics of personality

Although there were many arguments about definition of personality, a consensual view shows that personality is "an individual's characteristic pattern of thought, emotion, and behavior, together with the psychological mechanisms—hidden or not—behind those patterns" [12][13]. It refers simultaneously to characteristics: a) ascribed to individuals, b) stable over time, and c) psychological in nature [13]. Since personality has properties of human nature and consistent patterns, it affects significant impacts on human information processing especially when human operators conduct knowledge-based tasks.

For a long time, the psychology community has been engaged in discussion on how many personality traits or dimensions are necessary to describe personality [14]. The big five personality dimensions in Table I have been adopted as the dominant personality framework [14].

Table I: Big Five Personality Dimensions

	Characteristics of Individuals with Low Scores	**Characteristics of Individuals with High Scores**
Extraversion	Passive, Quiet, Introverted, Reserved	Talkative, Energetic, Enjoys social situation
Agreeable-ness	Cold, Cynical, Unpleasant	Cooperative, Avoids conflict, Credible
Conscientious-ness	Unreliable, Disorganized	Organized, Goal oriented, Responsible
Emotional Stability	Uneasy, Worried, Nervous, Emotional	Calm, Comfortable, Deals with stress
Openness to Experience	Conventional, Practical	Intellectual, Open to new experiences

The most comprehensive instrument to measure personality traits is Costa and McCrae's (1992) 240-item NEO Personality Inventory, Revised (NEO-PI-R) [15]. The NEO-PI-R is too lengthy for many research purposes, so a number of shorter instruments have been developed, such as the 44-item Big-Five Inventory (BFI), the 60-item NEO Five-Factor Inventory (NEO-FFI), etc.

2.2 Perceived workload and job performance

Despite over 50 years of workload research, there is yet to be an universally agreed upon definition about workload [16]. Early concepts of workload focused on the objective physical demands imposed by the task, but the focus shifted to operators' experienced workload or perception of task demands [16]. In this paper, the term "taskload" and "perceived workload" are used for "the objective physical demands" and "the operators' experienced workload" respectively to avoid confusion, and these terms are frequently used in field of workload [17][18][19][20].

There are subjective and objective metrics to measure perceived workload [16]. Subjective metrics include self-report questionnaires in which the National Aeronautics and Space Administration Task Load Index (NASA-TLX) is a high reliable one. Objective metrics include performance indicators and physiological response. Performance metrics consist of primary and secondary task measures since performance metrics indirectly estimate workload level based on task performance. Physiological metrics are based on the premise that varying levels of perceived workload produces changes in physiological response, such as electroencephalography, cardiopulmonary, and eye tracking.

Although there are many factors that can influence operators' performance, perceived workload is closely related to variance in performance [18]. Changes in performance that occur in response to increasing perceived workload can be relatively smooth and linear if perceived workload can be handled by human operators. However, performance is rapidly dropped when perceived workload exceeds a certain point [21]. Psychological and physiological changes of human operators caused by the excessive perceived workload expedite performance degradation.

3. The Current Status of Personality Research in NPPs

As a result of reviewing Korea Institute of Nuclear Safety (KINS) regulations, Nuclear Regulatory Commission (NRC) regulations, and International Atomic Energy Agency (IAEA) reports, no direct guidance was found regarding the personality. Although personality tests are required to screen out potential problem employees according to ANSI/ANS 3.1-1993, the regulation considers personality testing as part of fitness-of-duty requirements for operators [22]. Human cognitive characteristics are considered in second generation HRA methods in probabilistic safety assessment, but there is no consideration about personality itself. Only a few researches have been recently conducted about personality in NPPs.

Cynthia [22] conducted experiments to identify personality traits which affect successful works of nuclear operator in the initial licensing process. The data on written exam, simulator exam, and overall pass/fail results for each candidate on the NRC exam and the candidate scores on the NEO-PI-3 personality inventory were used to identify the relationship between initial operator license success and personality traits. For reactor operators (ROs), there are positive correlations between successful completion of the licensing process and Conscientiousness in written exam ($r = .503$, $p = .028$) and in simulator exam ($r = .392$, $p = .097$). For senior reactor operators (SROs), there are a negative correlation between successful completion of the licensing process and Extraversion in written exam ($r = -.395$, $p = .003$) and a positive correlation between successful completion of the licensing process and Conscientiousness in simulator exam ($r = .407$, $p = .002$). This experiment shows that some personality traits are correlated with initial operator license success, and the correlated personality traits are different dependent on job demands.

Lee [11] investigated the effect of personality type on human performance tool compliance in NPPs. The questionnaire was developed based on big six personality traits models which have honesty in addition to big five personality dimensions and human performance tools which include task preview, questioning attitude, stopping when unsure, self-checking, effective communication, and a phonetic alphabet. The correlation result reveals that the types of Honesty, Extraversion, Conscientiousness, and Openness to experience show a higher utilization of human performance tools, and different types of human performance tools are correlated with different personality traits.

4. Effect of Personality on Human Operators

4.1 The relationship between personality and job performance

In psychology field, meta-analyses have shown repeatedly that personality traits can predict job performance well under certain conditions [7][8][9][23]. In order to utilize personality traits beyond finding a correlation between personality traits and job performance, general job demands and specific situation context were considered in personality researches.

Depending on strong personality traits, people have different adequate job demands in Table II [9][24][25][26]. For instance, there are two representative types of reactor operators: ROs and SROs. ROs mainly manipulate the controls of a nuclear reactor which may alter reactivity and change the power level, but SROs conduct supervisory tasks and have responsibility for directing the operation of nuclear reactors. Thus, different sets of personality traits are correlated with ROs and with SROs respectively because their job demands are not same [22].

Table II: The Relationship between Personality Traits and Job Demands

Personality Traits	Job Demands
Conscientious-ness	Detail, Precision, Rule-following, Deadlines, High Quality Task Completion
Extraversion	Interpersonal Interactions, High Energy, High Profile
Agreeableness	Helping Customers, Reliance on Others for Task Completion
Openness to Experience	Creativity, Learning, Adventure, Frequent Travel
Emotional Stability	Responsibility with no Control over Outcomes

Specifically situational context also affects the relationship between personality traits and job performance. First, human operators deal with different characteristics of task depending on situation: skill-based task, rule-based task, and knowledge-based task. Gregory [26] conducted an experiment to identify the validity coefficients by occupation between personality traits and different jobs. Skilled and semiskilled jobs generally showed rather low validity coefficients than that of other sales and managerial jobs. This result provides an insight that personality traits barely affect to job performance when human operators are conducting rule-based works. Second, performance among human operators significantly changes in uncontrollable and unexpected situations. Human operators in NPPs are highly trained and procedures are well-developed to cope with anticipated accidents. Thus, personality traits of human operator in NPPs are likely to have little effects to their performance in a large percentage of cases. However, personality traits have a major influence to performance of human operators when human operators are in unexpected plant conditions which can have significant impacts to consequence of plant status. Therefore, specific situation context should be included into analysis when personality traits are examined and selected to reduce human errors in NPPs.

4.2 The relationship between personality and perceived workload

A review of personality research has shown that the relationship between personality and job performance are actively studied in psychology and other industries, but there are relatively little knowledge about the relationship between personality and perceived workload. Perceive workload is one of key factors affecting operators' performance by directly combining task difficulty and taskload and by indirectly inducing stress and psychological changes.

Perceived workload is affected by individual differences in personality and cognitive traits [27]. Hart and Staveland stated that workload is not an inherent property, but rather it emerges from that interaction between the requirements of a task, the circumstances under which it is performed, and the skills, behaviors, and perceptions of the operators [21]. Moreover, the workload experiences of different individuals faced with identical task requirements may be quite different since workload ratings reflect an operator's response to the task [27]. In order to identify the hypothesis that personality moderates perceived workload, an experiment was conducted [10]. The big five questionnaire was used to obtain scores on personality traits, and NASA-TLX was used to evaluate mental workload after actual activities carried out by the police officers. Only three out of five traits were significant predicts of perceived workload: Extraversion (B= .25, $p<.05$), Conscientiousness (B= -.28, $p<.05$), Emotional Stability (B= -.33, $p<.05$). The result showed that higher levels of Extraversion were associated with higher levels of perceived workload, whereas higher levels of conscientiousness and emotional stability were associated with lower levels of perceived workload.

In NPPs, factors that contribute to workload are divided to task-related and individual ones in Table III according to NUREG/CR-7190 [16]. The individual factors include cognitive traits at a certain degree, but personality is not included.

Table III: Factors that Contribute to Workload

Task-related Factors	Individual Factors
Demanding performance	Years of experience
Complexity of task	Sleep
Time pressure	Type of plants where one previously worked
Multi-tasking	Similarity of I&C layout to previously worked plants
Human System Interface	Amount of time on shift
	Time spent training
	Time in current NPP
	Stress coping techniques
	Accuracy of metal model

Likewise the relationship between personality and job performance, perceived workload varied by personality may be affected by general job demands and situational contexts. Therefore, general job demands and situational contexts should be included into analysis when the relationship between personality traits and perceived workload is examined and utilized to reduce human errors in NPPs.

5. Conclusion

The aim of this paper is to investigate the effect of personality traits on human operators in NPPs. From the personality study in psychology and other industries, it is confirmed that personality traits affect perceived workload and job performance. Likewise, recent efforts in the nuclear industry showed that personality traits are correlated to human performance, and specifically affect successful works of nuclear operator in the initial licensing process. Thus, personality traits can be utilized to select and train human operators.

In order to utilize personality traits in NPPs, general job demands and situational contexts should be included in the analysis for perceived workload and job performance. For example, personality traits have a strong correlation with knowledge-based tasks than rule-based task and skill-based task in aspect of task types. Also, perceived work and job performance of human operator in unexpected and uncontrolled situation vary more higher than one in normal and anticipated situation.

Although systematic and managerial approaches are well-developed to reduce human errors in NPPs, most of them are useful in the postulated situation. If a

critical situation proceeds uncontrollable and unpredictable, operators' judgements become most important way to stabilize the plant condition. In this situation, perceived workload and job performance among human operators may have a great difference dependent on their personality. Therefore, it will contribute the safety of NPPs to use personality traits in selection and training of human operators and to develop measures to compensate for the critical decrease of performance due to personality traits through personality research.

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