Exploring the Relationship among Dimensions of Flight Comprehensive Capabilities Based on SEM

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Abstract. The structural equation model is constructed to explore the relationship among basic cognitive abilities, personality traits and mental health of pilots. A framework of hypotheses is established to test the relationship among the three dimensions based on theories in the literature. Data is gathered from 65 pilots using 3 questionnaires. The model shows that both personality traits and mental health can affect the cognitive functions significantly, and that emotion characteristic, character traits and working attitude will also have an impact on a pilot's basic cognitive ability by affecting his mental health state. The results suggest that not only flight cognitive abilities but also personality traits and mental health can affect a pilot in terms of flight performance.

Keywords: flight comprehensive capability, flight aptitude, personality traits, mental health, SEM.

1 Introduction

Since the early days of aviation history, cognitive and psychomotor skills have been seen as important aspects of being a good pilot. Moreover, personality traits of pilots have also attracted many researchers' attention. Research strategies such as observation of pilots and participant observation have been used to examine which personality traits are important in pilot selection. In particular, dated back to 1921, Dockeray and Isaacs concluded in their study on psychology in aviation that "quiet methodical men were among the best flyers" because of their "power and quick adjustment to a new situation and good judgment" [1]. In 1950s, Saul Sell and his colleagues led a project in the United States to find suitable personality measure for pilot selection. They evaluated a total of 26 personality measures and found that personality tests were better predictors of long-term criteria compared to ability tests[2][3]. With the introduction of computers in testing, a number of new personality-related concepts have also been evaluated on pilots, including measures of risk taking, assertiveness, field dependency, and attitudes [4]. Mental health is another topic that has so far been emphasized in some degrees during the evaluation process on pilots. To meet social demands or solve work-related tasks, the individual relies on different sets of resources, including knowledge, experience, and personal attributes [5]. Some theories describe mental problems as the

result of factors or elements that have a negative impact on the individual. Other theories are concerned with stress, negative emotion and physical reactions.

However, few studies on the relationship among cognitive abilities, personality traits and mental health in aviation can be found in the literature. This paper tries to fill this gap and proposes to study the relationship among the three dimensions based on the structural equation model (SEM).

2 Theory and Hypotheses

2.1 Research Structure of Flight Comprehensive Capabilities

The concept of flight comprehensive capabilities is the core of flight abilities. It can be defined broadly as every internal factor that contributes to consistent behavior in different situations or, narrowly, as encompassing only cognitive functions, personality, emotions and motivation. In this study we build up a system of flight comprehensive capabilities with three dimensions including basic flight cognitive ability, personality traits and mental health. Basic flight cognitive ability is defined as a cognitive process of acquiring, processing, memorizing and applying information, including attention, working memory, judgment and decision making, speech comprehension, logical reasoning and spatial cognitive ability. Personality traits are analyzed by a matrix of character traits, emotion traits, intellect and working attitude. Character traits are personal notions that describe how a person appears to others. Emotion traits are described as emotional stability and mental experience. Intellect is a capacity for rational thought or inference or discrimination, and a willingness to pursue and explore the unfamiliar experience. Working attitude reflects individual achievement motivation, responsibility sense and self-discipline. Mental health can be defined as the psychological state of a pilot who is functioning at a satisfactory level of emotional and behavioral adjustment, which reflects his emotion, level of stress and adaptability. This paper will discuss mental health from these three aspects.

2.2 Theory and Hypotheses

A. Relationship between personality traits and flight cognitive ability. Personality traits play an important role in explaining a pilot's behavior. Pilots with certain personality characteristics such as achievement motivation and emotional stability have better flight performance. Early studies also showed that intellect reflects an individual's level of cognitive abilities, and therefore is very important. Moreover, experimental results showed that those who had the most positive attitudes towards their job performed slightly better [6]. Base on these arguments, we establish several hypotheses on the relationship between personality traits and flight cognitive abilities, as shown in Table 1.

B. Relationship between mental health and flight cognitive abilities. Mental health has a direct effect on an individual's job performance. A critical stress situation may

arise when something unusual takes place during a flight. Examples of stress situations include an indication of technical difficulties or a rapidly deteriorating weather condition. Moreover, Bad interpersonal relationship or work-life conflicts may also result in a negative emotion. It is important to analyze typical reactions in such situations, be aware of how the crew responds to stress and negative emotion, and understand how it affects decisions made during the flight. According to the review provided by Orasanu [7], mental issues such as stress, depression, anxiety and so on, may have the following effects: (1) people make more errors; (2) attention is reduced; (3) working memory is reduced; (4) change of strategy: speed gains preference to accuracy. Thus, cognitive functions are subject to a number of stress-related consequences in terms of how we perceive our surroundings, process information, and make decisions. Table 2 shows hypotheses that we would like to test on the relationship between mental health and flight cognitive abilities.

C. Relationship between personality traits and mental health. There is little doubt that some working environments are generally considered stressful. However, people with certain personality characteristics experience stress or negative emotion more often and more intensely, or have stronger adaptability than others. Studies have shown that many organizations tend to reward certain types of workers, who are characterized by irritability, aggression, hostility, and ambition, because these factors usually indicate a personality of achievement striving. However, on the other hand, these personality characteristics may cause emotional problems for the individual and his or her surroundings such as stress and burnout. Furthermore, people with active coping techniques (i.e., who act strategically to handle difficult situations) generally score lower on burnout than people who use more emotion-focused coping techniques (e.g., the person attempts to deal with emotions by seeking comfort in other people) [5]. Earlier studies have found that stress can be triggered also by high interpersonal demands; while later studies have shown that individual difference is an important factor as well. Based on these studies, we build up the hypotheses on the relationship between personality traits and mental health, as shown in Table 3.

Table 1. Hypotheses on the relationship between personality traits and flight cognitive ability

H#	Hypotheses
H1	Intellect has a direct positive relationship with spatial imagination & image-thinking
H2	Intellect has a direct positive relationship with speech comprehension
H3	Intellect has a direct positive relationship with spatial cognitive & logical reasoning
H4	Intellect has a direct positive relationship with spatial perception ability
H5	Intellect has a direct positive relationship with judgment & decision making
H6	Intellect has a direct positive relationship with working memory & attention.
H7	Character traits has a direct positive relationship with speech comprehension
H8	Character traits has a direct positive relationship with judgment & decision making
H9	Working attitude has a direct positive relationship with spatial imagination
H10	Working attitude has a direct positive relationship with speech comprehension

Table 2. Hypotheses on the relationship between mental health and flight cognitive ability

H#	Hypotheses
H11	Adaptability has a direct negative relationship with spatial imagination & image-thinking
H12	Adaptability has a direct negative relationship with speech comprehension
H13	Adaptability has a direct negative relationship with spatial cognitive & logical reasoning
H14	Adaptability has a direct negative relationship with space perception ability
H15	Adaptability has a direct negative relationship with judgment & decision making
H16	Adaptability has a direct negative relationship with working memory and attention
H17	Stress situation has a direct negative relationship with spatial imagination & image-thinking
H18	Stress situation has a direct negative relationship with spatial cognitive & logical reasoning
H19	Stress situation has a direct negative relationship with working memory & attention
H20	Emotion health has a direct negative relationship with spatial imagination & image-thinking
H21	Emotion health has a direct negative relationship with speech comprehension
H22	Emotion health has a direct negative relationship with judgment & decision making
H23	Emotion health has a direct negative relationship with working memory & attention

Table 3. Hypotheses on the relationship between personality traits and mental health

H#	Hypotheses
H24	Emotion characteristics has a direct negative relationship with adaptability
H25	Character traits has a direct negative relationship with adaptability
H26	Working attitude has a direct negative relationship with adaptability
H27	Emotion characteristics has a direct negative relationship with emotional health
H28	Working attitude has a direct negative relationship with stress situation

As a summary, Fig.1 presents the theoretical framework of all the above hypotheses on the relationship among flight cognitive abilities, personality traits, and mental health.

3 Data Gathering

The structural equation model (SEM) is a statistical technique for testing and estimating causal relations using a combination of statistical data and qualitative causal assumptions [8]. We distributed a packet of 3 questionnaires to 65 pilots aged 20 to 60 years old. The three questionnaires are Flight Cognitive Capability Test, the Symptom Checklist-90 (SCL-90), and the Sixteen Personality Factor Questionnaire (16PF). Then the theoretical model was established to explore the relationship among basic flight cognitive ability, personality traits and mental health. Latent variables and manifest variables in the SEM are shown in Table 4.

Fig. 1. Theoretical hypotheses of the study

Table 4. Latent variables and manifest variables

Latent variables	Manifest variables
Emotion characteristics(P1)	Emotional Stability, Apprehension, Liveliness, Tension
Intellect (P2)	Reasoning, Abstractedness, Openness to Change
Character traits (P3)	Warmth, Dominance, Vigilance, Privateness
Working attitude (P4)	Rule-Consciousness, Social Boldness, Sensitivity, Self-Reliance, Perfectionism
Spatial imagination & image-thinking (N1)	Flight cognitive Capability Test
Speech comprehension (N2)	
Spatial cognitive & logical reasoning (N3)	
Spatial perception ability (N4)	
Judgment & Decision making (N5)	
Working memory & attention (N6)	
Emotion health (E1)	Depression (DEP), Anxiety (ANX), Hostility (HOS), Phobic Anxiety (PHOB)
Stress situation (E2)	Somatization (SOM), Paranoid Ideation (PAR), Obsessive Compulsive (O-C), Interpersonal Sensitivity (I-S), Psychoticism (PSY), Positive Symptom Distress Index (PSDI)
Adaptability (E3)	

4 Data Analysis and Results

4.1 Model Modifying and Evaluation

SEM is a kind of linearity modeling tool using statistical data, which is suitable for the problem with unobservable variables especially [9, 10]. The modeling criterion is as follows. First, the smaller the ratio of chi-square and the degrees of freedom is, the better the goodness between model and practice is; second, P-value is used to test the significance level of model variables, whose value should be less than 0.1; third, the value of Comparative Fit Index (CFI) , Incremental Fit Index (IFI) and goodness of fit index(GFI) should all be greater than 0.9, while the value of Standardized Root Mean Square Residua (SRMR) should be less than 0.08.

The model is iteratively modified according to the modification indices obtained from the model itself until the estimating value is suited for the requirement of criterion. After the iterative process of testing and modifying, the goodness-of-fit statistics of the primitive model and the final revised model are shown in Table 5.

Table 5. Goodness of fit statistics

Goodness of fit statistics	primitive model	final model	Recommended values for fit
CMIN/DF	1.535	1.296	<=2
IFI	0.825	0.907	>0.9
GFI	0.656	0.696	>0.9
CFI	0.818	0.903	>0.9
RMSEA	0.091	0.068	<0.08
SRMR	0.1024	0.0955	<0.08
PGFI	0.554	0.568	>0.5
PNFI	0.559	0.601	>0.5

4.2 Results

Table 6 lists the results for the hypotheses. After deleting those invalid paths, the internal relationship will be easily found with the help of those paths showed in Fig.2.

This model is proved to be higher goodness of fit in relationship among three dimensions than the original one. The SEM model shows that both personality traits and mental health have an effect on the cognitive functions. All sub-dimensions of personality traits expect for intellect have an effect on pilots’ basic cognitive abilities by affecting their mental health states. Each of the three sub-dimensions of mental health has a significant effect on the basic cognitive abilities of pilots; emotion characteristics, character traits and working attitude all have significantly direct effects on the adaptability in mental health; however, the direct influence of intellect on mental health is not significant. In addition, the intellect in personality traits has a great

direct influence on the basic flight cognitive abilities. Meanwhile, character traits dramatically affect comprehension, attention and so on. Spatial sense, comprehension, attention and working memory are affected significantly by emotion health and stress level of a pilot's mental health.

Table 6. Results of hypotheses testing

H#	Relationship	P-value		Support
H1	N1<--P2	0.411		NO
H2	N2<--P2	0.011	p<0.05	YES
H3	N3<--P2	0.821		NO
H4	N4<--P2	0.045	p<0.05	NO
H5	N5<--P2	0.169		NO
H6	N6<--P2	0.748		NO
H7	N2<--P3	0.398		NO
H8	N5<--P3	0.366		NO
H9	N1<--P4	0.015	p<0.05	YES
H10	N2<--P4	0.008	p<0.01	YES
H11	N1<--E3	0.813		NO
H12	N2<--E3	0.063	p<0.1	NO
H13	N3<--E3	0.795		NO
H14	N4<--E3	0.009	p<0.01	YES
H15	N5<--E3	0.038	p<0.05	NO
H16	N6<--E3	0.778		NO
H17	N1<--E2	0.061	p<0.1	YES
H18	N3<--E2	0.801		NO
H19	N6<--E2	0.739		NO
H20	N1<--E1	0.036	p<0.05	YES
H21	N2<--E1	0.046	p<0.05	YES
H22	N5<--E1	0.033	p<0.05	YES
H23	N6<--E1	***	p<0.001	YES
H24	E3<--P1	0.009	p<0.01	NO
H25	E3<--P3	0.01	p<0.05	YES
H26	E3<--P4	0.001	p<0.01	NO
H27	E1<--P1	0.443		NO
H28	E2<--P4	0.768		NO

*** stand for significant difference (p<0.001).

Fig. 2. Structural equation model of the study

4.3 Discussions

Theoretically, cognitive functions should be affected directly by personality traits. The model has shown that emotion characteristics, character traits and working attitude have effects on a pilot's basic cognitive ability through the way of affecting his mental health state. Emotion characteristics are recognized as emotional stability and the trend of mental experiences. Pilots in an instability mode tend to experience tension, worry and a lack of safety more often and to have mental issues more easily than those in a stability mode. According to Eysenck's awakening theory [11, 12], individuals have a high level of arousal to get the motivation to finish tasks in an emergency, which makes anxiety and stress more easily and affects cognitive functions further. Character traits are important for the development of positive emotion, good interpersonal skills and avoidance of mental problems. Past studies have found that most of the pilots have the extroversion personality [13, 14]. Researchers have become much aware of the importance of effective communication in multi-operator environments to support team performance [15]. In a high-risk situation, crew interactions with exact information and consentient situation perception can generate better decisions to solve problem compared to that of any individual. Working attitude not only directly affects spatial cognitive and speech ability, but also has impacts on a pilot's basic cognitive functions through the way of affecting his mental health. Pilots who have the most positive attitudes towards their job perform slightly better due to positive emotion and good adaptability. Meanwhile, intellect directly affects almost every aspect of cognitive functions. In particular, intellect has a more significant influence on speech and spatial ability than judgment and decision making. Furthermore, intellect has a more significant relationship with crystallized intelligence than fluid intelligence.

Moreover, it is necessary to add some more paths to the model according to the modifying results. These newly added paths further explain the relationship among stress, emotion health and adaptability. Persons with good adaptability can deal with stress problems on their merits. These people are characterized by self-assurance, extroversion, and optimism. It is easy for negative emotions to appear when something unusual takes place during their work or life. It has been proven that high workload and high risk of flight work lead pilots to experience stress more often and more intensely than people holding other jobs. At the same time, a negative emotion arises from extreme stress, and it could further affect various cognitive functions.

5 Conclusions

This study has proven again that not only flight cognitive abilities have impacts on pilots in terms of their flight performances, but also personality traits and mental health do so. In particular, interpersonal relationships, stress, emotional stability etc. have significant influences on a pilot's cognitive performance. Moreover, the relationship model has also shown that personality traits have an increasing effect on the cognitive operations with the increase of task difficulty and stress. Meanwhile, factors such as individual anxiety, depression and impulsivity also affect a pilot's flight performance. Furthermore, the research provides a tool to explore the relationship between pilots and their operational traits via QAR (Quick Access Recorder) data, which is useful for managing pilots' human errors.

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