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An Analysis of the Factors Influencing Score Achieved during Pilot Training*

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Human error is considered a causal or contributory factor in a major part of aviation incidents. It's also known from relevant research and reports that even the smallest error made by a person can cause fatal results in the aviation sector. In this study, the relationship between factors that contribute to trainee error based on scores achieved in pilot training, such as personality traits, psychomotor abilities, audio-visual memory capacity and quantitative skills of pilots, are determined by means of a multiple regression analysis. In the study, the total number of errors that a sample of 24 civilian student pilots made in initial and advanced flight training was evaluated. According to the results of the regression analysis, it was determined that the errors student pilots made during these flight training periods had a close relationship to their personality traits. For this reason, while selecting student pilots, it's necessary to predict a student pilot's personality traits. Additionally, by taking the factors that are the focus of this study into consideration, the selection of suitable student pilots having a low probability of making errors is possible.

Key Words: Trainee Pilot Error, Personality Traits, Psychomotor Abilities, Audio-visual Memory Capacity, Quantitative Skills

1. Introduction

Human error is an important contributory factor in aviation accidents. Despite the difficulties in determining the rate of aviation accidents resulting from human error, many researchers have studied this issue. In some of the literature, human error was indicated as the reason for between 60–80% of aviation accidents.[1–3)] A study conducted by Boeing found that 55% of airline accidents that took place between 1959 and 2005 were caused by such human-related factors.[4)] Additionally, it was noted that the decrease in human error relating to aviation accidents was not in parallel with the decrease concerning mechanical and environmental factors even though the rate of aviation accidents was seen to decrease over a 20-year period. The reasons why aviation accidents based on engineering and mechanical errors decreased faster than those concerning human error were identified as being due to the fact that the technology used in aviation has developed significantly over the past 50 years and the post-accident analyses of mechanical and engineering problems has become easier.[1,5)]

It's known that the number of accidents resulting from pilot error, or in other words "human error," is high. "Pilot error is any act of commission or omission by a pilot who fails to meet accepted professional performance standards, and/or may reasonably be considered by an accident investigation board to increase the likelihood of an aviation mishap."[6)]

The above-mentioned literature review indicates that, in aviation accidents, the main cause is pilot error. In the literature, the relationship between aviation accidents and factors such as a pilot's age, sex, personality traits, alcohol use, behavioral attitudes, experience and exposure to risk were examined.[7–14)] In addition, studies have been conducted on the effects of airline training and procedures, issues of crew resource management, organizational culture, resting requirements of the pilot (fatigue), task, equipment design, environmental conditions, weather conditions, mechanical failures, design, high cockpit temperature, noise level in the cockpit, time of day, location of the accident and stress on aviation accidents.[7,15,16)]

In the literature, there are many studies conducted on the personality characteristics of pilots in pilot selection and training. Fitzgibbons et al.[17)] investigated a widely used general personality inventory, the NEO-PI-R, using 93 pilots. They found that the basic "pilot personality profile" is of an emotionally stable individual who is low in anxiety, vulnerability, angry hostility, impulsiveness, and depression. This person also tends be very conscientious; being high in deliberation, achievement-oriented, competence and sense of duty, and to be trusting and straightforward.

Bartram[18)] studied pilots in the UK Army Air Corps and found that those who pass training are more stable, extroverted, tough-minded, and independent than those who fail training.

Personality traits that are important to be considered during the selection are achievement-oriented traits like motivation, rigidity, mobility and vitality. Interpersonal behavioral traits like extraversion, empathy, aggressiveness and dominance, emotional stability and positive coping skills are also pertinent.[19)]

Dillinger et al.[20)] states that the first studies concerning personality concentrated on defining personality characteris-

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tics that can estimate the successful adaptation of candidates for military aviation. In these first studies, it was mentioned that the military pilots were more achievement-oriented, outgoing, active, competitive, dominant and less introspective, emotional, sensitive and self-effacing than their counterparts who don't fly. It was also seen that most of the studies concerning pilot personality factors included military flight crews, and very few of the studies examined the role of personality on the performance of civilian pilots. For this reason, it was emphasized that very little information is known about personal profiles of commercial or general aviation pilots.

In the Handbook of the 16 Personality Factor,[21] it's stated that military student pilots have personal profiles that are similar to civilian pilots, except for the factors being highly dominant, self-sufficient, and having low super-ego and self-sentiment.

Koçarslan[22] conducted a study to establish the validity of the Turkish Armed Forces Personality Battery (TAFPB) in selecting Turkish Air Force Academy (TAFA) cadets. Data of the TAFPB, 16PF, Brief Symptom Inventory (BSI), psychomotor scores and objective and subjective performance measures was collected from first-, second- and third-year students. In total, the data of 647 TAFA cadets was evaluated. Criterion-related validity was measured by analyzing the correlation of TAFPB with objective (i.e., academic and sports scores) and subjective (i.e., commander evaluation, flight, military scores) performance. Correlations and a series of regressions pointed out that TAFPB predicts significantly objective performance. TAFPB has incremental validity over 16PF and BSI in explaining objective performance.

Carretta et al.[23] state that, in addition to personality, ability is required for success as a pilot. They specified that pilots should have certain personality characteristics such as achievement motivation, aggressiveness, stress tolerance, risk taking, cooperativeness, assertiveness, leadership and decisiveness. In addition, situational awareness, memorization, reasoning, perceptual speed, time-sharing selective attention, response orientation, spatial orientation, divided attention, psychomotor coordination, control precision and visualization were ability factors in their study.

In addition to personality characteristics in pilot selection and pilot training, some researchers focused on the necessity of including other variables. Bates et al.[24] indicate that the predictor variables are factors that should explain pilot performance variance. They state that there are five general categories of predictor variables of pilot performance. The most to least robust predictor variables are: 1) psychomotor coordination, 2) background information, 3) information processing ability, 4) general cognitive ability and 5) personality traits.

Damos[25] emphasizes that research shows structured selection systems can identify applicants who possess the knowledge, skills abilities and personality traits most valued by a particular aircraft operator, and who will succeed as pilots in that operator's line of operations.

Carretta and Ree[26] tested 678 Air Force pilot training candidates with a paper-and-pencil aptitude battery and computer-administered tests of psychomotor skills, information processing and attitude toward risk. A self-report of flying experience was also collected. These data were used in regression analyses to determine which variables provided the best prediction of two flying criteria: pass-fail flight training and class rank at the end of flight training. The paper-and-pencil tests were found to be the best predictors in their study.

Kantor and Carretta[27] developed a computerized battery of tests to identify candidates who wouldn't complete pilot training or be recommended for a fighter assignment after training. All or part of the battery of 15 tests was given to 1,622 Air Force pilot candidates prior to training, and their scores were regressed against flying performance measures. They stated that two psychomotor tests and tests of perceptual speed, decision-making speed, and memory function were found to be significant predictors of flying performance.

Griffin and Koonce[28] provided a historical perspective of the use of psychomotor, perceptual-cognitive paper-and-pencil, and automated tests for the selection of pilot trainees by the U.S. military services. They stated that The U.S. Army and Air Force are now using a combination of paper-and-pencil and automated psychomotor-cognitive tests for initial selection (Air Force) and helicopter assignment (Army).

When the literature was evaluated, it can be seen that the factors causing pilots to make errors in pilot training were mostly examined separately. However, like separately examining the influence of personal, cognitive, psychomotor and quantitative skills of a pilot in aviation accidents, a combined examination of the effect of these factors in aviation accidents is also important. Additionally, due to the difficulty of collecting data concerning factors causing a pilot to make errors, statistic-based analyses were inadequate.

In this study, some of the factors that have an influence on trainee error based on scores achieved during pilot training, such as variations in personality traits, psychomotor skills, audio-visual memory capacity, quantitative skills, and the effects of these variables are investigated. In addition to these factors, the results of an oral examination conducted with student pilots at the time of entering the Department of Flight Training and the results of the quantitative section of the university entrance exam in Turkey (ÖSS-SAYISAL) are regarded as factors influencing the trainee error during pilot training. It was believed that these two factors can bear a close relationship to errors made during flight training. This study was carried out with the assistance of 24 civilian student pilots in the Civil Aviation School in Turkey.

1.1. A general outlook on the factors affecting scores achieved during pilot training

Personality traits determine how a person reacts to different events and situations. The traits of a pilot have an important influence on flight performance and flight safety. Personality is defined by Cattell as "that which permits a prediction of what a person will do in a given situation."[19] Maschke and Goeters[29] state that the importance of personality increases from initial flight training to qualified airline pilot.

Table 1. 16PF scale names and descriptors.[37)]

Descriptions of low range	Primary scales	Descriptions of high range
Reserved, Impersonal, Distant	Warmth (A)	Warm-hearted, Caring, Attention to others
Concrete, Lower mental capacity	Reasoning (B)	Abstract, Bright, Fat-learner
Reactive, Affected by feelings	Emotional stability (C)	Emotionally stable, Adaptive, Mature
Deferential, Cooperative, Avoids conflict	Dominance (E)	Dominant, Forceful, Assertive
Serious, Restrained, Careful	Liveliness (F)	Enthusiastic, Animated, Spontaneous
Expedient, Nonconforming	Rule consciousness (G)	Rule-conscious, Dutiful
Shy, Timid, Threat sensitive	Social boldness (H)	Socially bold, Venturesome, Thick-skinned
Tough, Objective, Unsentimental	Sensitivity (I)	Sensitive, Aesthetic, Tender-minded
Trusting, Unsuspecting, Accepting	Vigilance (L)	Vigilant, Suspicious, Skeptical, Wary
Practical, Grounded, Down-to-Earth	Abstractedness (M)	Abstracted, Imaginative, Idea-oriented
Forthright, Genuine, Artless	Privateness (N)	Private, Discreet, Non-disclosing
Self-assured, Unworried, Complacent	Apprehension (O)	Apprehensive, Self-doubting, Worried
Traditional, Attached to familiar	Openness to change (Q1)	Open to change, Experimenting
Group-orientated, Affiliative	Self-reliance (Q2)	Self-reliant, Solitary, Individualistic
Tolerates disorder, Unexacting, Flexible	Perfectionism (Q3)	Perfectionistic, Organized, Self-disciplined
Relaxed, Placid, Patient	Tension (Q4)	Tense, High energy, Driven

Psychomotor skill is defined as "the voluntary muscle movements that contain both mental process and motor activity."[30)] and psychomotor skills are generally acquired and used by means of experience and training.[31)]

Audio memory is the capability of storing verbally presented data for processing, analyzing it mentally and then remembering it.[32)]

Visual memory is the ability to recall previously seen visual stimuli, including the shape, detail, position or other important features.[33)]

Quantitative skill is defined as "the power of understanding quantitative relations, expressing cases in mathematical relations and conducting arithmetic operations rapidly and correctly."[34)] Schmidt and Hunter[35)] emphasize that "intelligence is the widest form of all mental human abilities, and abilities which are narrow scoped in comparison with intelligence contain verbal ability, quantitative ability and spatial ability."

2. Data Collection

2.1. Trainee error based on score achieved during pilot training

In order to determine trainee error based on the score achieved during training, student pilots' grade sheets concerning flight training missions in the initial and advanced flight training periods were examined, and the total number of grades evaluated as 'unsatisfactory' or 'fair' in grade sheets was accepted as 'the total number of errors made by the student pilot concerning flight training.' Evaluation of any event shown in the pilot's grade sheet as 'unsatisfactory' or 'fair' by the instructor pilot shows an error of the student pilot's flight performance and flying ability in that particular event. In this study, a total of 60 different pilot grade sheets concerning initial and advanced flight training sessions were examined. Each of grade sheets of the pilots examined covered 26 different events. It was seen that the number of 'unsatisfactory' and 'fair' grades in the pilot grade sheets concerning initial flight training was greater than those concerning advanced flight training. The number of errors made by 24 student pilots during initial flight training phase was 1,756 and for the advanced flight training phase the number was 329.

2.2. Factors affecting trainee error based on score achieved during training

2.2.1. Personality traits

In this study, a 16PF questionnaire was used for measuring the personality traits of student pilots. The 16PF scale names and descriptions are illustrated in Table 1. The 16PF questionnaire was given to the student pilots using a computerized environment, and the raw scores were obtained and converted to 'stens.' In the converted results, the value of each personality factor is between 1 and 10. The raw scores attained were converted to "stens" (uniform interval, 10 standard score) by means of standardization tables. In this distribution, having a width ranking from 1 to 10, the average standardization sampling was 5.5 (e.g., 5 and 6 stens). The points beyond a plus-or-minus standard deviation of 2.5 points of this value, are classified as high or low, respectively. The high or low scores obtained from the personality factors were interpreted using interpretation tables prepared specifically for this purpose.[36)]

2.2.2. Psychomotor skills

The scores obtained by student pilots during the student selection flights under real flight conditions and the supervision by instructor pilots during the selection period when entering the Department of Flight Training were used to determine the psychomotor abilities of the student pilots. The candidates' skills shown when flying aircraft in the student selection flights, which was performed in the selection of student pilots for the Department of Flight Training, was regarded as being a measure of the psychomotor abilities of the student pilots.

During the student selection flights, the instructor pilot first tells the candidate student the procedures to be carried out and evaluated (i.e., students required to complete them), and then the student is shown what sh/e is to do. Secondly, the instructor pilot and candidate student perform these procedures together. Finally, the candidate student is asked to perform the procedures practiced earlier. In the selection

for the Department of Flight Training, two sorties are made. The different scores the candidate receives for the first and the second sorties are taken into account to determine the candidate's final student selection flight score. Flight forms, in which evaluation criteria are arranged for student selection flights, are filled in by the instructor pilot and are evaluated numerically for each of the candidates. The candidate's flight preparation, spatial abilities, psychological adaptation, trainability, variation from the standards determined for level flight, ascending and descending, and psychomotor skills in using an aircraft are the criteria evaluated in the student selection flights. The scores that the 24 student pilots involved in this study achieved during the student selection flights were evaluated based on a scale of 100 points.

2.2.3. Audio memory capacity

In order to measure the audio memory capacity of the student pilots, the scores they achieved in the audio memory test during the selection period for entering the department were used. This audio test, which is performed under laboratory conditions, is a test that measures the candidates' ability to keep what they hear in mind. In the audio memory test, different letter groups are read to candidates in each question, and after a short while, letter groups that are similar to or different from those letters are presented with the optional choices of 'a, b, c or d.' The candidates are required to determine whether or not the letters they remembered are given in the options, and carefully mark their answers on an answer sheet. The scores that the candidates achieved in the audio memory test were evaluated based on a scale of 100 points.

2.2.4. Visual memory capacity

In order to measure the visual memory capacity of the student pilots, the scores they achieved in the visual memory test during the selection period for entering the department were used. The visual memory test is a test that measures the candidates' abilities to remember object pictures and double-digit numbers shown to them simultaneously in their minds under time pressure. The object pictures and numbers are shown using a delineascope for a time period varying from 15 to 30 s. Since the answers are recorded on an answer sheet, the candidate's attention is also measured at this stage. The scores that the candidates achieved in the visual memory test were evaluated based on a scale of 40 points.

2.2.5. Quantitative skills

In order to measure the quantitative skills of the student pilots, the scores they obtained for the mathematics and physics test during the selection period for entering the department were used. It was regarded that the mathematics and physics test is reliable and valid to measure the students' quantitative skills. The mathematics and physics test was given under limited time, and serve the purpose of measuring discernment and judgment. The mathematics and physics ability test was given the title, "Test-1." This test consisted of 25 mathematics and 25 physics questions. The contributions of the mathematics and physics sections to Test-1 are equal. The level of difficulty of the questions was created to equal the level of difficulty of questions in a university entrance exam. The scores that the candidates achieved in the mathematics and physics test were evaluated based on a scale of 100 points.

2.2.6. Quantitative section scores of university entrance exam (ÖSS-SAYISAL) and oral examination

In the oral examination, which was conducted during the selection period for entering the department, a candidate's physical appearance, speech, ability to express him/herself, foreign language (English) level, motivation, interest in aviation, personality, and ability to communicate in a social environment were evaluated.

In this study, the scores students obtained for the oral examination during the selection period for entering the department and the data concerning quantitative section scores of the university entrance exam (ÖSS-SAYISAL) were used.

3. Proposed Approach and Results

In this section, primarily the School of Civil Aviation from which the data within the scope of this study was collected, the instructor pilots responsible for flight training, the student pilots who participated in this study, the phases of flight training given at the school and the flight evaluation forms are introduced. Next, multiple regression analyses containing the factors that have an influence on trainee error based on the score achieved during pilot training obtained from the data of 24 student pilots at the School of Civil Aviation are given. In addition, trait profiles obtained from the 16PF questionnaire given to the student pilots are explained.

3.1. Methodology

3.1.1. School of Civil Aviation

This study was conducted at the School of Civil Aviation, which offers flight training in Turkey. At this school, student pilots are trained to be qualified to international standards for the civil aviation sector. By the end of flight training, which is maintained in line with the requirements of the International Civil Aviation Organization (ICAO), Joint Aviation Requirements–Flight Crew Licensing (JAR-FCL) and national requirements, student pilots graduate from this school as pilots with a commercial pilot license(A)/instrument rating (CPL(A)/IR) in credit of the airline transport pilot (ATP(A)). Students who begin training in the department take theoretical classroom lessons in the first one-and-a-half years (three semesters) of training. Afterwards, flight training is performed using a fleet of single-engine aircraft (i.e., Cessna 172 and TB-20) and twin-engine aircraft (i.e., Beechcraft C-90). Additionally, flight training is supported using flight simulators.

3.1.2. Instructor and student pilots

Instructor pilots at the School of Civil Aviation are the trainers responsible for theoretical ground lessons, flight simulator activities and flight training. Instructor pilots measure the flight performance and flying skills of student pilots by means of flight evaluation forms. Only one instructor pilot is assigned for the flight training of each student pilot. So there is no possibility of being biased in the data sets.

This study covers a total of 24 civilian student pilots who had completed theoretical ground lessons, initial and ad-

Table 2. Descriptions of the phases in flight training.

Initial flight training	Stage 1 (First solo) Stage 2 (Air maneuvers) Stage 3A (Visual cross-country)
Advanced flight training	Stage 3B (Basic instruments) Stage 4 (Radio instruments and radio instruments cross-country)
Multi-engine flight training	Stage 5 (Multi-engine and crew cooperation)

vanced flight training. The average age was 24 and 96% of them were male.

3.1.3. The stages of flight training

Flight training at the School of Civil Aviation consists of three main periods: initial, advanced and multi-engine flight training. In total, the initial, advanced and multi-engine flight training periods consist of five stages. Table 2 provides descriptions of the main flight training corresponding to these five stages.

None of the student pilots who participated in this study had participated in multi-engine flight training when this study was conducted. Since it was thought that errors made in flight simulator training would not match the results achieved in flight training, simulator training, flights performed without the presence of an instructor pilot (solo flights) and multi-engine training were not covered within the scope of this study.

3.1.4. Grade sheets

In flight evaluation, certain forms known as 'grade sheets' are used. The grade sheets, which are used for evaluating flight performance of the student pilot, are completed to recognized standards. In the general evaluation of grade sheets and evaluation of the events covered in the grade sheet, a scale of five standards identified as 'Outstanding, Excellent, Fair, Unsatisfactory and Demonstration' are used. Instructor pilots input the performance of the student pilots into the system as a measurable score by means of this scale of five standards while they are evaluating the flight missions. This 5-grade scale is the grading of the possible trainee error during flight training. The descriptions of "Unsatisfactory" and "Fair," as written in the School of Civil Aviation's Flight Training Manual, are provided below.

"Unsatisfactory": It means that the student pilot does not have satisfactory knowledge and flying capabilities to perform the events specified in the mission guide as per standards and timely, or he is not confident. Namely, the variations of the student pilot from the desired standards in the flight are considered as pilot's error potential. However, if the student pilot makes any vital, mission-critical errors which violate the flight safety at the ground works till flight or works post-flight, he is considered as poor by the instructor pilot.

"Fair": The student pilot can perform the event at limited level specified in the mission guide at acceptable standards by ensuring the flight safety. In other words, there are errors lowering the performance during the flight mission.

Table 3. The dependent and independent variables used in the analyses.

	Dependent variables
y_1	Total number of 'unsatisfactory' and 'fair' scores achieved in initial flight training
y_2	Total number of 'unsatisfactory' and 'fair' scores achieved in advanced flight training
y_3	Total number of 'unsatisfactory' and 'fair' scores achieved in initial and advanced flight training
	Independent variables
x_1	Quantitative section score of the university entrance exam (ÖSS-SAYISAL)
x_2	Score of the visual memory test (Visual)
x_3	Score of the audio memory test (Audio)
x_4	Student selection flight score (Selection flight)
x_5	Scores of the mathematics and physics tests (Test-1)
x_6	Score of the oral examination (Oral examination)
x_7	Value of the 'A' (Warmth) personality factor
x_8	Value of the 'B' (Reasoning) personality factor
x_9	Value of the 'C' (Emotional stability) personality factor
x_{10}	Value of the 'E' (Dominance) personality factor
x_{11}	Value of the 'F' (Liveliness) personality factor
x_{12}	Value of the 'G' (Rule consciousness) personality factor
x_{13}	Value of the 'H' (Social boldness) personality factor
x_{14}	Value of the 'I' (Sensitivity) personality factor
x_{15}	Value of the 'L' (Vigilance) personality factor
x_{16}	Value of the 'M' (Abstractedness) personality factor
x_{17}	Value of the 'N' (Privateness) personality factor
x_{18}	Value of the 'O' (Apprehension) personality factor
x_{19}	Value of the 'Q1' (Openness to change) personality factor
x_{20}	Value of the 'Q2' (Self-reliance) personality factor
x_{21}	Value of the 'Q3' (Perfectionism) personality factor
x_{22}	Value of the 'Q4' (Tension) personality factor

3.2. Results

3.2.1. Multiple regression analysis

The multiple regression analyses conducted for this study were conducted using MINITAB 17 (www.minitab.com). A regression analysis is made to determine the relationship between the variables that have a cause and effect relationship. An analysis was also conducted to make estimations or predictions concerning this subject.[38] In this analysis technique, a mathematical model is used to explain the relationship among more than two variables. This model is known as a multiple regression analysis, and is shown as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots + \beta_{22} x_{22} + \varepsilon \qquad (1)$$

In analyzing the factors influencing the score achieved during pilot training, three different phases—the initial flight training phase, advanced flight training phase and a phase combining both initial and advanced flight training—were covered, and a backward elimination method was used to determine the best model. The dependent and independent variables used in the analyses are given in Table 3.

The results of the multiple regression analysis made using a backward elimination approach so as to determine the factors influencing the score achieved during pilot training are given in Table 4.

In all of the multiple regression analyses, the p value is less than 0.05 ($p < 0.05$).

The results of t-tests aimed at checking the consistency of variables included in the reduced model gained for the initial

Table 4. The multiple regression equations and performance indicators determined using means of flight training data.

Multiple regression equations	S	R^2	Adj. R^2
$y_1 = -1716 + 1.05$ ÖSS-SAYISAL $+ 3.18$ Visual $+ 1.75$ Audio $+ 3.60$ Selection flight $+ 3.43$ Test-1 $+ 1.63$ Oral examination $+ 21.5$ A $+ 7.84$ E $+ 21.9$ F $+ 22.4$ G $+ 12.3$ N $+ 4.23$ O $- 11.5$ Q1 $+ 30.7$ Q2 $+ 20.5$ Q3 $- 20.8$ Q4	8.80126	99.2%	97.5%
$y_2 = -56.5 + 2.54$ Visual $- 2.33$ B $+ 5.05$ G $- 12.7$ I $+ 4.02$ L $+ 4.63$ M $+ 8.23$ N $- 4.22$ O $- 4.20$ Q1 $+ 6.38$ Q2 $- 5.34$ Q4	7.35806	84.5%	70.4%
$y_3 = -1631 + 0.934$ ÖSS-SAYISAL $+ 0.930$ Audio $+ 3.48$ Selection flight $+ 3.96$ Test-1 $+ 2.18$ Oral examination $+ 20.6$ A $+ 11.2$E $+ 14.5$ F $+ 26.7$ G $+ 13.4$ N $- 11.3$ Q1 $+ 29.1$ Q2 $+ 20.8$ Q3 $- 16.6$ Q4	20.1346	95.8%	89.3%

Table 5. The results of the coefficient test for initial flight training.

Predictor	Coef SE	Coef	T	p	VIF
Constant	−1716.26	91.42	−18.77	0.000	
ÖSS-SAYISAL	1.0542	0.1096	9.62	0.000	2.030
Visual	3.1838	0.6981	4.56	0.003	4.192
Audio	1.7472	0.1932	9.04	0.000	2.776
Selection flight	3.6044	0.3886	9.27	0.000	2.991
Test-1	3.4271	0.3555	9.64	0.000	2.735
Oral examination	1.6334	0.3461	4.72	0.002	2.449
A	21.487	2.179	9.86	0.000	2.117
E	7.841	1.742	4.50	0.003	3.288
F	21.945	2.156	10.18	0.000	2.724
G	22.420	2.024	11.08	0.000	2.463
N	12.328	1.338	9.21	0.000	1.489
O	4.230	1.511	2.80	0.027	2.249
Q1	−11.504	1.416	−8.12	0.000	2.604
Q2	30.685	1.946	15.77	0.000	1.974
Q3	20.519	1.541	13.32	0.000	1.903
Q4	−20.792	2.182	−9.53	0.000	3.103

flight training are given in Table 5. As seen in this table, for all of the variables, the p value is smaller than 0.05 ($p < 0.05$). When the values of the Variance Inflation Factor (VIF) in the statistical analysis are examined, it can be seen that there is no highly linear relationship between each of the independent variables covered in the multiple regression model and other independent variables because, for each of the variables, the VIF < 10. The tests, performed to explore the consistency of the variables included in the reduced models for the advanced flight training phase and the phase combining initial and advanced flight training, were made in the same way. It was seen that the variables were consistent for these flight training phases.

The order of importance of the factors affecting the score achieved during pilot training was determined and is given in Table 6 for each of the analyses using the sequential sum of squares (Seq SS) in the table of variance analysis applying a reduced model gained from three different multiple regression analyses in the study.

3.2.2. Personality traits obtained from the 16PF questionnaire

The total number of errors made in initial flight training is greater than that in advanced flight training. The main reason for this is the fact that student pilots learn most of the theoretical and practical information concerning flight during initial flight training rather than during advanced flight training. Therefore, the results of the regression analysis used to determine the factors influencing trainee error in initial flight training are more critical than those in advanced flight training.

The order of importance of the first six variables of the personality traits obtained from the multiple regression analysis during initial flight training is 'G, Q3, Q2, Q4, Q1, A' and the rate of $SS_{\text{first six variables}}/SS_{\text{total}}$ is 51.25%.

Since the total number of errors (=329) in advanced flight training was less than that (=1,756) in initial flight training, it was considered unnecessary to examine the factors in the regression analysis in a detailed way for this flight training phase.

3.2.3. Fitness check of multiple regression model

In case a hypothesis concerning a regression coefficient is tested or a prediction interval is created for a future value of 'y,' it is assumed that the error term (ε) suits normal distribution with a zero average and constant variance. A diagrammatic analysis of residuals performed to test the validations of these assumptions also evaluated compliance of the regression model.

In this study, at first, the residual values for the total number of errors made by the 24 student pilots in the initial flight training phase were obtained using MINITAB, with the results given in Fig. 1.

Based on the plot given in Fig. 1(a), the residuals of the multiple regression model for initial flight training confirm the normality assumption of the regression analysis (K-S = 0.137, $p > 0.150$).

The scatter plot of the residuals versus the estimated total number of errors obtained from the multiple regression model is shown in Fig. 1(b). It is clear that no abnormal structure is observed; thus, the multiple regression model for initial flight training data is considered appropriate for estimating trainee error based on the score achieved during pilot training in terms of the critical factors mentioned earlier. Similar analyses were completed for the data of the advanced flight training, and those analyses revealed that the multiple regression model for advanced flight training was also found to be appropriate.

4. Discussion

4.1. Multiple regression analysis

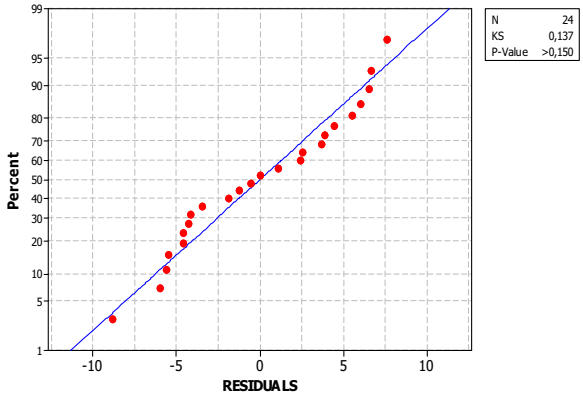
From the results of three different multiple regression analyses performed within the scope of this study (i.e., initial, advanced, combination of initial and advanced flight training), the following conclusions were formed:

1) The analysis results for initial flight training contained the analysis results for both initial and advanced flight training. All of the regression model variables in both initial and

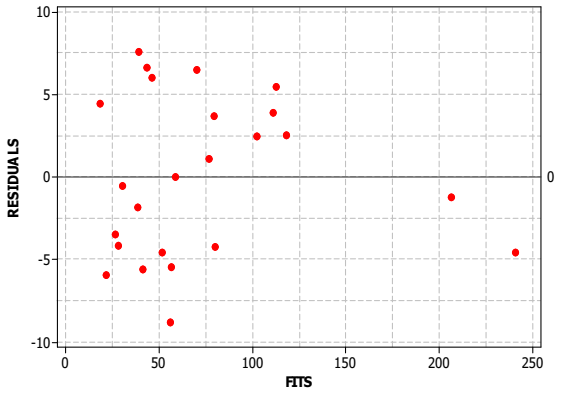
Table 6. Order of importance of factors affecting score achieved during pilot training.

Factors		Order of importance of factors involved in multiple regression analysis model		
Name	Code	Initial flight training	Advanced flight training	The situation in which initial and advanced flight training are evaluated together
Warmth	A	6	—	7
Reasoning	B	—	7	—
Emotional stability	C	—	—	—
Dominance	E	14	—	13
Liveliness	F	13	—	12
Rule consciousness	G	1	4	1
Social boldness	H	—	—	—
Sensitivity	I	—	8	—
Vigilance	L	—	11	—
Abstractedness	M	—	6	—
Privateness	N	15	9	10
Apprehension	O	16	5	—
Openness to change	Q1	5	2	3
Self-reliance	Q2	3	3	4
Perfectionism	Q3	2	—	2
Tension	Q4	4	1	6
Student selection flights score	Selection flight	7	—	5
Score of the oral examination	Oral examination	8	—	8
Scores of the mathematics and physics tests	Test-1	11	—	9
Score of the visual memory test	Visual	9	10	—
Score of the audio memory test	Audio	10	—	11
Quantitative Section Score of the University Entrance Exam	ÖSS-SAYISAL	12	—	—

—: Factors not covered in the reduced model.



(a) Normal probability plot of residuals for initial flight training



(b) Scatter plot of residuals versus fits (estimated total number of the errors) for initial flight training

Fig. 1. Results of analysis for checking fitness of the multiple regression model (initial flight training).

advanced flight training appeared in initial flight training, but with slight differences.

2) It was seen that, in the success of the advanced flight training, personality factors played an important role. For this reason, personality factors deemed to be crucial for the success of the student pilot during flight training.

3) Since the number of total errors made in the initial flight training was more than in the other phases, this phase can be used more efficiently for determining the factors that influence the success of flight training.

4) Since advanced flight training is performed following initial flight training, the number of total errors in this training phase is lower. Additionally, as seen in Table 6, except for personality factors, there isn't any other factor that has an influence on success during flight training.

5) It can be emphasized that, since the standard error value of the regression model built for combined initial and advanced flight training is more than the standard error values of the initial and advanced flight training regression models, the estimation error of the regression model built for the combination of these two periods of training will be more than the others (8.80126; 7.35806; 20.1346).

4.2. Personality traits obtained from 16PF questionnaire

As for the personality traits influencing the score achieved during pilot training, examination of the scores obtained from the 16PF questionnaire (i.e., three student pilots with the least total errors and three with the most total errors, as

well as all 24 student pilots) revealed the following conclusions:

1) Error rates correlated positively with personality factor 'G (Rule consciousness).' When the value of the personality factor 'G' increased, the number of total errors the student made increased. People who obtain high scores for personality factor 'G' are attached to the morals and values of society and behave in accordance with them. The important thing for these individuals is 'living in compliance with the values.'[36] Therefore, it can be interpreted that students who are attached to social values have difficulty adopting to international aviation rules that are taught during flight training, and therefore make errors.

2) Error rates correlated positively with personality factor 'Q3 (Perfectionism).' People who obtain high scores for personality factor 'Q3' are perfectionists. On account of this perfectionism, they sometimes cannot see the broader picture. It can be thought that perfectionist student pilots aim at perfection in flight training, and since they focus on details, they can make errors.

3) Error rates correlated positively with personality factor 'Q2 (Self-reliance).' People who obtain high scores for personality factor 'Q2' are independent and the thoughts and views of the group they are in have no influence on them. These individuals are introverted.[39] It may be thought that, since self-reliant student pilots do not take into consideration the assessments made by instructor pilots in flight training and make individual decisions without group consensus, they can make errors. When aviation accidents are examined, it is internationally accepted that crew cooperation in the cockpit is important.

4) Error rates correlated negatively with personality factor 'Q4 (Tension).' People who obtain low scores for personality factor 'Q4' are comfortable, peaceful and quiet individuals. They are content with what they have, do not ask for more, live for the moment, make no fuss over being successful and are not anxious about the future. It is known from literature that an increase in a person's stress level up to the critical point increases a person's performance. However, if the critical point is exceeded, work efficiency decreases rapidly.[40] In other words, being too relaxed or being too stressed makes an individual more susceptible to making errors. This supports the conclusion that student pilots who are too relaxed tend to make errors during flight training.

5) Error rates correlated negatively with personality factor 'Q1 (Openness to change).' People who obtain low scores for personality factor 'Q1' are individuals who resist change and, even if conditions in which they are in are bad, they refuse to change them. These people are conservative individuals who stick with tradition. Since they are traditional, they do little research.[39] It can be thought that student pilots who are not open to change have difficulty adopting to new theoretical or practical information concerning flight, and they can make errors.

6) Error rates correlated positively with personality factor 'A (Warmth).' People who obtain high scores for personality factor 'A' are individuals who choose to be in relationships with people. Their interests are focused on their relationships more than on their existence or inner world. They do not see the errors of the people around them or they refrain from criticizing them although they are aware of the errors.[39] Depending on these, since the interest of friendly student pilots to the people around them is so great, they cannot pay sufficient attention to flight training and may make many errors.

5. Conclusion

When relevant literature is examined, one or several factors that may cause a pilot candidate to make errors have been seen. However, in this study, factors affecting trainee error with an ever-increasing importance in the civil aviation sector are examined applying a proactive approach before aviation accidents take place. The total number of errors that student pilots made during flight training was been taken into account in this study. The fitness test of the multiple regression models for each flight training phase within the scope of this study was determined using residual value analysis.

When the analysis results of the initial flight training data were examined, the total number of errors made in initial flight training was greater than that in advanced flight training. It was found that the first six factors influencing this are: G (Rule consciousness), Q3 (Perfectionism), Q2 (Self-reliance), Q4 (Tension), Q1 (Openness to change) and A (Warmth). In literature reviewed, there were research studies mostly about personality traits considered to be important during the pilot selection period and pilot training. Furthermore, the relationship between a pilot's personality traits and errors made was not well documented. In this study, research studies that reported only a few important personal traits influencing trainee error during pilot training have been discussed.[18,20,22–27] It can be seen that most of these studies included the use of military flight crews, whereas few studies examined the role of personality on the performance of civilian pilots. For this reason, in research studies, it has been emphasized that very little information was known about the personal profiles of commercial or general aviation pilots. Q1 (Openness to change), Q4 (Tension), Q2 (Self-reliance) personality traits, which were found to cause errors in this study, have also been reported in other research studies. Finally, all of the important personal traits influencing errors are unique to this study.

The main contributions this study may make to the aviation sector and recommendations adopted by the administration of the School of Civil Aviation are specified below:

• When the results obtained from the analyses which were made using data concerning initial flight training, advanced flight training and the status in which the results of these two training phases are combined and examined, it was found that the dominant factor causing student pilots to make errors is personality traits. The personality traits of a student pilot have a very important influence on the success and performance of that individual during flight training. Therefore, the personality traits that cause student pilots to make errors as determined by this study should be taken into considera-

tion when selecting students for the Department of Pilot Training, and a separate point scoring system should be formulated for personality traits.

• In this study, a regression model was built to predict the number of errors a student pilot may make in each phase of flight training (initial and advanced). While building this model, the scores that student pilots obtained on tests taken on entry to the Department of Pilot Training were used. Using the estimation model of initial flight training in particular, the scores a new pilot obtains for exams during the selection phase for entering the Department of Pilot Training were entered into the model. In the event of a candidate being accepted into the department, the total number of errors he or she may make in each phase of flight training can be estimated. Estimation models can help decision-makers in their selection of student pilots for the Department of Pilot Training.

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