

## Research Article

# Research on Influencing Factor Selection of Pilot's Intention

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The physiological, psychological, and physical characteristics of the pilot will have an impact on flight safety, mainly in the pilot's intention. In another word, this means the pilot's psychological experience of flight status under the influence of various factors and the preference for decision-making or behavioral value that is displayed. The pilot's intention is to reflect the cognitive state that the pilot showed during the maneuvering of the aircraft. The exploration of intention is very important for the study of automatic pilot and flight control active safety system. Also, it is an important concept often involved in the study of human factors in flight, especially the microbehavior of pilots. Pilot's intention is taken as the study object in this paper; physiological-psychological-physical parameters are obtained through analyzing their influencing factors from the simulating flight experiments designed. The random forest analysis method is used to rank the main influencing factors affecting the pilot's intention, and the factor sequence is formed. The results provide a good foundation for further research on the pilot's intention identification.

## 1. Introduction

With the rapid development of the social economy and the gradual improvement of people's living standards, the demand for population movement and cargo transportation has increased. At the same time, the high-tech-based air transportation industry has flourished and the structure of civil aviation accident factors is also changing. The proportion of traditional mechanical and electronic equipment failures is decreasing, while the proportion of human factors is increasing significantly [1]. According to domestic and foreign research on human factors in flight, the physiological and psychological characteristics of pilots are closely related to flight safety. The psychological characteristics caused by physiological changes are important factors affecting the behavior of pilots [2]. The difference in pilot's behavior is the result of different physiological, psychological, and physical characteristics, including age, personality, and operational experience. Therefore, the physiological, psychological, and physical characteristics of the pilot have an important impact on flight safety.

Intention is a kind of thinking activity produced in the human brain. It is the result of the pilot's perception, judgment, and decision-making on the external information

(containing environment, aircraft, and other state information) [3]. Meanwhile, it has the laws of generation, transfer, and reduction. Intention is the reflection of the human brain on the objective material world (it is also the sum of various psychological processes such as feelings and thoughts). It is influenced by physiological characteristics and has "subjectivity" within a certain range. The intention is a comprehensive manifestation of the pilot's physiological, psychological, and physical characteristics. Based on the concept of motor vehicle driver's intention [4, 5], combined with the pilot's special environment and process of maneuvering the aircraft, the pilot's intention is divided into three dimensions: speed intention ( $I_1$ ), lateral intention ( $I_2$ ), and vertical intention ( $I_3$ ). Each group of consecutive intentions is divided into three mutually exclusive discrete domains [6, 7]. They are shown in Table 1.

The pilot is in a complex system in which the three factors of human-aircraft-environment interact. The pilot's intention is affected by a combination of objective factors such as pilot, crew, aircraft, and environment. The real-time dynamic identification of the pilot's intention is instructive for the pilot's next-time maneuvering behavior and is a prerequisite for pilot behavior prediction and calibration. Although different pilots have various external manifestations, the root

TABLE 1: Pilots' intention set.

Speed intention ( $I_1$ )	Lateral intention ( $I_2$ )	Vertical intention ( $I_3$ )
Accelerate intention ( $I_{11}$ )	Turn left intention ( $I_{21}$ )	Climb intention ( $I_{31}$ )
Decelerate intention ( $I_{12}$ )	Turn right intention ( $I_{22}$ )	Descend intention ( $I_{32}$ )
Constant speed intention ( $I_{13}$ )	Constant heading intention ( $I_{23}$ )	Constant altitude intention ( $I_{33}$ )

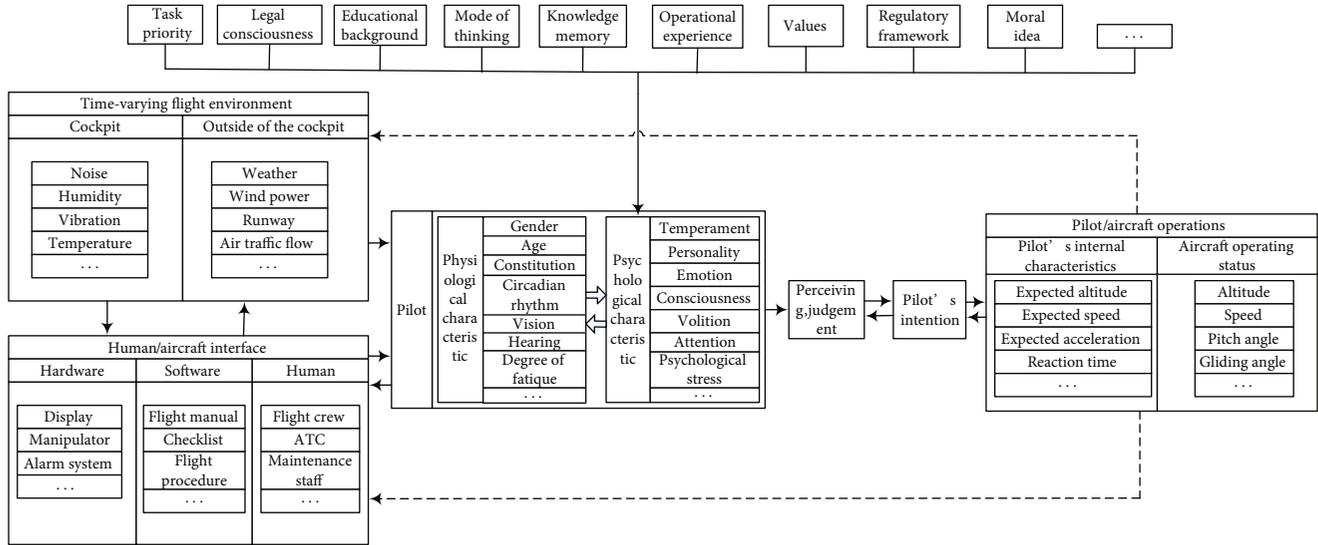


FIGURE 1: Mechanism of pilot's intention.

cause of this difference is the pilot's internal factors, his/her physical and mental state. Physiological characteristics are the essential material that underlies the psychological factors, which are ultimately reflected in the pilot's psychological characteristics. In addition, internal factors such as flight urgency, flight experience, education, and values are closely related to the physiological, psychological, and physical characteristics of the pilot. The mechanism of the pilot's intention is described in Figure 1.

## 2. Literature Review

In recent years, many domestic and foreign scholars have studied the effects of physiological and psychological characteristics of pilots on their microscopic behaviors and cognitive processes from different perspectives. At the level of the physiological characteristics of pilots, relevant scholars have done a lot of research. Beukers et al. [8] and Zaal et al. [9] explored the characteristics of the visual and motor behavior under crosswinds when the pilot is controlling the aircraft in order to make the pilot's experience in simulated flight and real flight closer. Onur et al. [10, 11] probed the pilot's vestibular and visual signals. Meanwhile, the research established a pilot expectation model that satisfies the optimal state of the aircraft based on the pilot's multimodal characteristics by using the pilot control theory. Mario et al. [12] identified the time-varying response of the pilot's estimated visual and force feedback during the compensatory tracking task based on the regular recursive least square method. The results show that the method can be used to estimate the

reaction in the real human body when the pilot is in the time-varying condition. The EMG (electromyography) of the pilots during the flight simulation and the flight training of the pilots in a special environment (e.g., takeoff and landing of seaborne carrier aircraft) was evaluated by Zhang et al. [13]. Results indicate that effective training reduces the muscle fatigue of pilots and thus contributes to the success of the mission. The research of the psychological characteristics of pilots is a complex process. Relevant scholars at home and abroad mainly study the problems faced by pilots in the cognitive process. Zhengxiang et al. [14] used the six-degree-of-freedom flight simulator to obtain physiological signals such as heart rate (HR), respiratory depth (RD), respiratory rate (RR), scan rate (SR), and pupil diameter (PD). Meantime, they also identified the cognitive processes at different flight stages. Onur et al. [15] established the Pilot Perception Model (PPM), which is used to predict the behavior of pilots in cognitive processes. The analysis of the mutual correlation of the pilot's heart rate, respiration, pupil diameter, facial thermal imaging, and mental workload has been done by Marinescu et al. [16]. The result is theoretically important to design, operation of the aircraft cockpit, and reduction of pilots' cognitive load in the future. According to the typical correlation analysis method, Jaquess et al. [17] analyzed pilots' heart rate, EEG (electroencephalograph), and other characteristics, which shows that pilots' attention reserve decreased with the increase of task demand and cognitive load. Harrivel et al. [18] studied the Aircraft State Awareness (ASA) due to crew reasons aimed at exploring the flight performance of pilots and optimizing human-machine automated interactions.

Mainly based on EEG data, Attention-related Human Performance Limiting States (AHPLS) were analyzed, including attention limitations, attention shift, startle/surprise, and confirmation bias.

Intention is the comprehensive reaction of objective things in the human brain and an important part of the process of human cognition. Different pilots are prone to different handling intentions in different flight environments. Relevant scholars have gradually paid attention to the impact of pilots' intention on "human-aircraft-environment interaction" on flight safety. Degani et al. [19, 20] and Oishi et al. [21, 22] consulted issues such as pilot mismatches between aircraft operating conditions and automated control systems (which is pattern confusion). In the modeling analysis process, discrete automation models are built based on discrete flight mode information and the continuous state of automation is not considered. Das et al. [23] and Bass et al. [24] only modeled a series of discrete and continuous automatic modes and did not model the pilot. Xiaoru et al. [25] researched out the relationship between the pilot's psychological load and his cognitive ability based on data such as the pilot's electrooculogram obtained by the pilot's controlling simulator. The results showed that with the pilot's psychological load increasing, the cognitive ability has also been declining. Tangwena et al. [26, 27] solved the cognitive problems of pilots in the process of human-aircraft interaction and studied the microscopic behavior of pilots from the physiological, psychological, and behavioral aspects. Nandiganahalli et al. [6, 7, 28] and Lyu et al. [29] proposed a pattern confusion detection framework based on pilot's intention for UI (User Interface) verification. What is more, the automatic system control strategy is abstracted into a continuous intention state on the foundation of methods such as Finite State Machine (FSM) and Random Linear Hybrid System (SLHS) (for example, dividing the continuous aircraft state into three mutually exclusive discrete domains which includes speed intention, lateral intention, and vertical intention). At the same time, the pilot's negligence of the ATC command, control delay, task neglect, etc. are abstracted into discrete intent states. This provides a theoretical basis for the research of pilot's decision-making and automation system control strategies.

In the past research on the microinfluencing factors of pilots, domestic and foreign scholars have carried out extensive and in-depth mining on the cognitive process and microscopic behavior of pilots from the physiological and psychological characteristics of pilots and have obtained many research results. However, the pilot's intention is an important part of the microbehavior and cognitive process which is influenced by these physiological and psychological factors. Due to the diversity and complexity of these factors when the pilot is in the complex human-aircraft-environment, they must be fully considered. Predicting the pilot's intention based on factors is the premise to calibrate and verify the dynamic measurement mode. It is important to analyze the factors of affecting the pilot's intention aiming at avoiding interferences that are caused by information overlapping when multiple variables exist. In this paper, with the comprehensive consideration of the physiological

and psychological parameters of the pilot, the relevant experiments are designed to obtain each indicator that affects the pilot's intention. The experiment consists of many parts such as the dynamic simulation flight test and static questionnaire test. Random forests are used to extract and rank the influencing factors to determine the sequence of factors affecting the pilot's intention and to narrow the range of influencing factors. The results of this study provide a good basis for further research on the identification of pilot intention.

### 3. Methods

*3.1. Influencing Factor Selection Model of Pilot's Intention Based on Random Forest.* The random forest (RF) algorithm was first proposed by Breiman as a new machine learning method consisting of multiple decision trees [30]. It overcomes the shortcomings of the traditional decision tree which has a poor ability in convergence and generalization and uses the mean decrease impurity obtained by all decision trees to quantify the importance of features. It is commonly used to calculate the mean decrease impurity by the Gini coefficient, that is, the statistical score  $VIM_j^{(Gini)}$  of the variable  $X_j$  is expressed. The basic steps for selecting the influencing factors based on random forest are as follows.

The  $VIM_j^{(Gini)}$  represents the average variable of the node splitting impurity in the  $j$  variable in all trees of the RF:

$$GI_m = \sum_{k=1}^K \hat{p}(1 - \hat{p}_{mk}). \quad (1)$$

$K$  is the number of categories in the bootstrap sampling set.  $\hat{p}_{mk}$  is a probability estimate that belongs to class  $k$  at node  $m$ . When the sample is multiclass data  $K = 9$ , the Gini coefficient of node  $m$  is

$$GI_m = 2\hat{p}_m(1 - \hat{p}_{mk}). \quad (2)$$

$\hat{p}_m$  is the probability estimate of the sample belonging to any class at node  $m$ .

The importance of the variable  $X_j$  at the node  $m$  is also the importance of the node  $m$  itself; namely, the change in the Gini coefficient of the node  $m$  before and after the branching is

$$VIM_{jm}^{(Gini)} = GI_m - GI_l - GI_r. \quad (3)$$

$GI_l$  and  $GI_r$ , respectively, represent the Gini indices of the two new node splits by the node  $m$ .

If the variable  $X_j$  appears  $M$  times in the  $i$  tree, the importance of the variable  $X_j$  in the  $i$  tree is

$$VIM_{jm}^{(Gini)} = \sum_{m=1}^M VIM_{jm}^{(Gini)}. \quad (4)$$

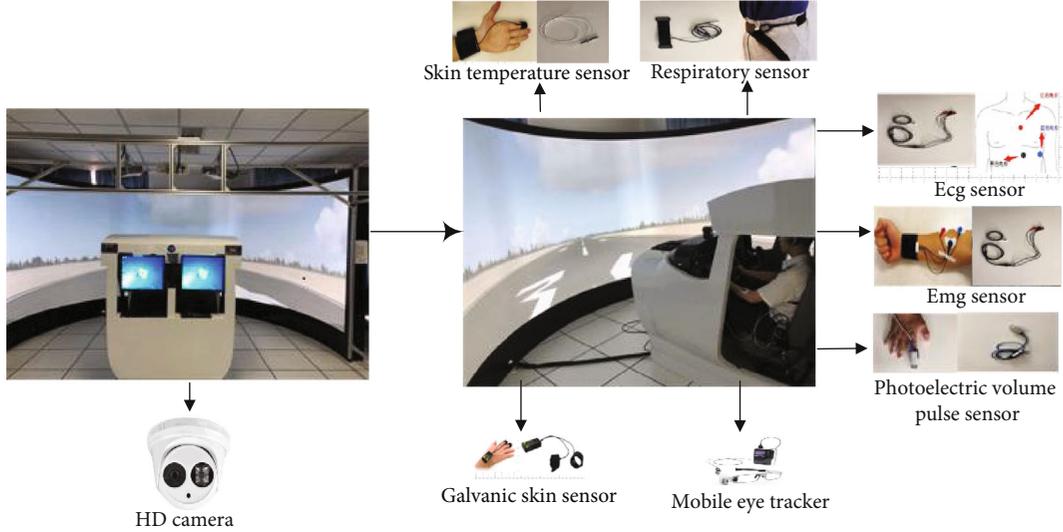


FIGURE 2: Dynamic acquisition system for comprehensive human-aircraft-environment information.

The importance of Gini of variable  $X_j$  in RF is defined as

$$\text{VIM}_j^{(\text{Gini})} = \frac{1}{n} \sum_{i=1}^n \text{VIM}_{ij}^{(\text{Gini})}, \quad (5)$$

where  $n$  is the number of RF reclassification trees.

According to the above calculation, the statistical component of the characteristic variable  $X_j$  ( $j = 1, 2, \dots, M$ ) can be obtained. The statistical component scores of each feature variable are compared after multiple iterations. The larger the statistical score, the more important the feature variable is; namely, the greater the influence of the variable on the sequence of the class, the higher it is in the ranking of the impact factors.

### 3.2. Data Acquisition

**3.2.1. Experimental Subject.** The sample size of the experiment was 75 male flying cadets who had obtained a Private Pilot License, Commercial Pilot License, and Instrument Rating License. Their age ranged from 25 to 30 years old, and the mean value is 27. Their flight hours are between 250 and 300 hours, and the average flight time is 275 hours.

**3.2.2. Experimental Instruments.** This experiment is mainly carried out on a high-level simulator. The experimental equipment especially includes the dynamic acquisition system for comprehensive human-aircraft-environment information (including Mangold-10 multichannel physiological instrument, Tobii S600 high-precision eye tracker Polar watch, BioHarness portable physiological measuring instrument, and high-definition camera), high-level simulation platform, Psytech-PT811 comprehensive response tester, DXC-6 type evaluation instrument, and Carnegie 16 personality questionnaire. Some experimental equipment is depicted in Figure 2.

**3.2.3. Experimental Content.** 75 flying cadets were selected in this experiment. They were numbered from 1 to 75. And then, their age and flight hours were recorded. Experiments were designed to obtain data on the physiological, psychological, physical, and other external factors of each flying cadet. The 3D virtual flight scene of the simulator provides the pilot with realistic visual, auditory, and tactile feelings. The flight scene is an airfield traffic pattern, including acceleration, deceleration, climb, descent, and change of heading. The path of flight is indicated in Figure 3. At the same time, the contents and methods for determining the physiological, psychological, physical, and other factors of flying cadets are displayed in Table 2.

**3.2.4. Data Processing.** In this paper, the physiological, psychological, physical, and other factors of the pilot are selected as the nodes of the random forest, and the influencing factors are screened in combination with the differences of the pilot's intentions. According to the statistical analysis results of the 75 experimental samples, using physiological characteristics including heart rate, skin electricity, respiration, hearing, choice reaction time, operational response time, speed estimation capability, and discriminative response time as examples for analysis, the values of pilot's intention and the influencing factors are assigned. The mapping content and assigned values of each dimensionless and dimension variable are revealed in Table 3.

Dimension is an important concept in physics. It usually requires dimensionless processing in theoretical and numerical calculations, standardizing different dimensional or dimensionless data. The standardized methods deal with dimensionless data commonly including min-max, Z-score, and decimal scaling. Among three methods, Z-score is one of the most effective methods widely used for dimensionless processing [34]. The mean and standard deviation of all the characteristic variables were calculated before starting

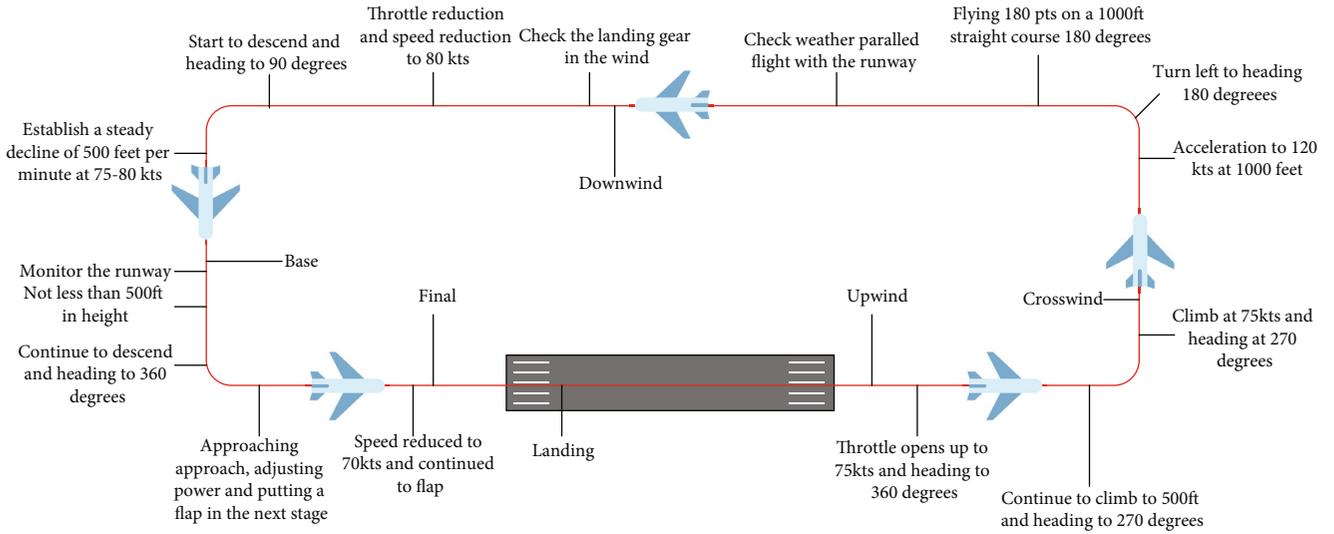


FIGURE 3: Flight diagram of the airfield traffic pattern.

processing. Feature variables become dimensionless according to

$$\bar{X} = \frac{(X_j - \mu_j)}{\sigma_j}, \quad (6)$$

where  $X_j$  is the original value of the characteristic variable.  $\mu_j$  and  $\sigma_j$  are the mean and standard deviation of the characteristic variable  $X_j$ , respectively.  $\bar{X}$  is the result after the dimensionless processing of the characteristic variable. Such processing makes theoretical and numerical calculations simpler and more convenient. When the physical equation is converted to a specific mathematical equation, it is convenient for mathematical processing. It can be seen from Table 2 that the physiological characteristics of the pilot correspond to dimensionless and dimension variables. In order to establish a random forest for describing the influencing factors of pilot's intention, the characteristic variables of all samples are calculated in equation (6) to achieve dimensionless processing. The processing results are shown in Table 4. The experiment is to diagnose and sequence all the influencing factors aiming at achieving the screening of factors affecting the pilot's intention. The calculation results of the Gini coefficient based on random forest fully reflect the average variable of node splitting impurity in each decision tree of RF. Obviously, the more obvious the difference in the average variable, the better the results will be. That is to say, the differences between diverse intentions of the pilot should be fully reflected which are caused by different influencing factors.

## 4. Results

**4.1. Qualitative Analysis.** One-way analysis of variance (one-way ANOVA) is utilized to detect whether different intentions had a significant effect on changes in physiological characteristic parameters. If the effect is significant, a detailed

analysis of the changes in physiological characteristics under different intentions is performed. The results of one-way ANOVA based on MATLAB are given in Table 5.

As can be seen from the above table, the movement parameters are significantly affected by different pilots' intentions ( $P < 0.005$ ). The physiological characteristics could be analyzed in this paper.

**4.2. Quantitative Calculation.** According to the data after the dimensionless processing in Table 3, the probability estimation values belonging to the  $k$  class at  $m$  are calculated based on formula (1).  $\hat{p}_{mk} = C_{x_j}/K$  in formula (1), where  $C_{x_j}$  represents the sample subset of the sample set  $m$  belonging to the pilot's intention of the class  $k$ .

The experiment divides the  $K$  class into  $i$  parts based on a certain pilot's physiological characteristic variable  $X_j$  ( $1 < j < 8$ ), namely,  $K_1, K_2, \dots, K_i$ . According to formula (2), the Gini index of  $K$  is defined as

$$VIM_{jm}^{(Gini)} = \frac{K_1}{K} GI(K_1) + \dots + \frac{K_i}{K} GI(K_i). \quad (7)$$

Firstly, the importance of the pilot's characteristic variable  $X_j$  at any node  $m$  in the random forest model is calculated according to equation (3). Secondly, if the pilot's characteristic variable appears  $M$  times in the  $i$  tree of the random forest, we calculate the importance of the characteristic variable according to formula (4). Finally, on the basis of formula (5), the importance of the characteristic variable  $X_j$  in the random forest model of  $n$  decision trees is calculated.

The importance of the Gini coefficient of the physiological characteristic variable is calculated. At the same time, a scatter plot of Gini coefficient importance is drawn, as shown in Figure 4.

According to the Gini coefficient importance of each comparing column in Figure 4, the degree of influence of each factor on the pilot's intention is determined, and the

TABLE 2: Content and method for determining some physiological, psychological, and physical factors.

Test index	Test content	Test method
Physiological factors	Heart rate	Heart rate (HR) can be used to characterize a person's health and mental state. The pilot's heart rate can be reflected by the average heart rate (times/min). During the simulated flight, the heart rate sensor in the Mangold-10 multichannel physiological instrument was used to obtain the heart rate when the pilot was maneuvering the aircraft. The procedure was recorded with an HDTV camera, and the average of the heart rate was calculated.
	Skin conductance	One of the direct indicators of sympathetic nervous system evaluation is cutaneous electricity. It can also be used as an indirect indicator of a person's mental state and alertness level. The experiment usually uses the mean value of the skin electrical response to reflect the pilot's skin conductance. During the simulated flight, the skin conductance response of the pilot was obtained using a skin conductance sensor in the Mangold-10 multichannel physiological instrument. The experiment used an HDTV camera to record the process and calculated the average value of the skin's conductance response values.
	Breathing	Breathing is utilized to characterize a person's level of stress or excitement. The pilot's breathing changes can be reflected by the average of the respiratory rate (times/minute). The respiratory rate was obtained using a BioHarness portable physiometer. The process was recorded with an HDTV camera. The average of the respiratory rate was gotten in this experiment.
	Hearing	Hearing can distinguish the position of the object and make up for the lack of vision. The pilot's hearing can be reflected by their auditory response time, which is the time interval from the appearance of a simple hearing stimulus to its response. The auditory response time was obtained using a Psytech-PT811 integrated reaction tester. During the test, the subject pressed the right index finger onto the start position button. When the instrument heard the beep, immediately remove the finger and then press the start button. The procedure was recorded with an HDTV camera, and each subject performed multiple sets of experiments and recorded the average auditory response time (milliseconds).
	Choice reaction time	Choice reaction time means that two or more stimuli are present during the test and the time it takes to require for the subject to respond differently to each stimulus. The Psytech-PT811 comprehensive reaction tester was used to obtain the choice reaction time. During the test, the subject pressed the right index finger onto the start position button, and the eye looked at the screen signal source. When any of the red, yellow, blue, and green colors appear on the screen, the subject releases the finger to press the corresponding color on the instrument and then returns to the start button. The procedure was recorded with an HDTV camera. Each subject performed multiple sets of experiments and recorded the average choice reaction time (milliseconds).
	Operational response time	The operational response time is the time interval from the appearance of the stimulus to the completion of the action. The Psytech-PT811 comprehensive reaction tester was used to obtain the operational response time. During the test, the subject pressed the right index finger onto the start position button. When the start button was pressed, the screen showed a semicircular spot. The light spot is bright, and the subject uses the right index finger to press the corresponding button on the instrument and then return to the position of the start button. The procedure was recorded with an HDTV camera, and each subject performed multiple sets of experiments and recorded the average operational response time (milliseconds).

TABLE 2: Continued.

Test index	Test content	Test method
Speed estimation capability	The speed estimation capability is used as a pilot's ability to perceive and predict the surrounding objects. Also, it is utilized to measure the pilot's spatial location of the distance.	Measurements were performed using a DXC-6 type evaluator. The screen presents a light spot that moves from left to right and changes in speed. There is a vertical line in the center and right side of the screen, and the light point disappears when it moves to the center vertical line. The answerer needs to estimate the time when the light spot reaches the vertical line on the right side and press the enter key at the moment when the light spot is touched on the right vertical line. The procedure was recorded with an HDTV camera, and each subject performed multiple sets of experiments and recorded an average estimated time.
Discriminative response time	Discriminative response time refers to the time taken from the stimulus presentation to the psychological operation between the stimulus being confirmed and reacting. Two or more distinct stimuli may appear in the experiment when the reaction is identified. Participants were asked to respond to only one of the stimuli and to refrain from responding to any other stimulus.	The discriminative response time was obtained using a Psytech-PT811 comprehensive reaction tester. During the test, the subject pressed the right index finger onto the start position button and the eyes looked at the screen signal source. When a valid stimulus color appears, the subject presses the corresponding color button on the instrument. Do not respond to the color of the invalid stimulus that appears; otherwise, remember the error and then return the finger to the start button. Recorded with an HDTV camera, each subject performed multiple sets of experiments and recorded the average discriminative response time.
Personality	Personality refers to a person's stable attitude toward reality and the personality characteristics expressed in habitual behavior corresponding to this attitude. Personality embodies the social attributes of character, and the core of character differences between individuals is the difference in personality.	This paper used the Carnegie 16 personality questionnaire, which has good validity, reliability, and short test time and is widely utilized.
Attention	Attention is the point and concentration of mental activity on certain objects. It is a common psychological feature in the psychological processes of perception, memory, thinking, and imagination. The attention of the pilot in the cockpit is critical to flight safety.	The pilot wears an eye tracker to calculate the gaze duration of each gaze point in the simulated cockpit. The proportion of each area is counted, and all test numbers record the percentage of the number of fixation points as the judgment index.
Psychological factors	Attitude is the stable psychological tendency of an individual to hold a particular subject. The attitude of the pilot will affect their behavior. Poor attitudes could lead to mishandling of pilots, resulting in flight accidents.	This paper used the questionnaire in [30] for measurement. The options of questions are referred to the Classical Mental Scale with the purpose of assign scores in descending. The smaller the score, the better the safety attitude of the pilot who chooses this option. Test results require standard conversion [31].
Emotion	Emotion is a general term for a series of subjective cognitive experiences. It is the psychological and physiological state of multiple emotions, thoughts, and behaviors. Both positive and negative emotions trigger motivation for action.	After designing the simulator experiment, use the high-definition camera to record the whole process and select three kinds of music random play with fast pace, regular, and slow rhythm. It is determined that the emotional state of the subject is divided into two parts, namely, the real-time recording of the emotional state of the subject and the personal correction of the subject during the video playback after the end of the experiment. Drawing on the research triggered by driver emotions, this paper defines three emotional states: calm, neutral, and excited, with test values between 0 and 1. The calmer the pilot's mood, the lower the score; the more excited the emotion, the higher the score [32].

TABLE 2: Continued.

Test index	Test content		Test method
Physical factors	Rudder pedal force	The pilot controls the aircraft and the strength of the rudder on both feet.	The rudder pedal force value is obtained using a pressure sensor in the Mangold-10 multichannel physiological instrument. Record with an HDTV camera and calculate the average of the rudder pedal force.
	Handle force of joystick	The pilot controls the aircraft and the strength of holding the joystick with both hands.	During the simulated flight, the grip force was obtained using a pressure sensor in the Mangold-10 multichannel physiological instrument. The process was recorded with an HDTV camera, and the average of the grip strength of the joystick was calculated
Other factors	Task priority	Task priority is used to measure the impact of different missions on pilot behavior.	Depending on the time required, task urgency is divided into three types: slow, regular, and emergency. According to the flight tasks at each stage, the tasks that are required to be completed in a short period of time are initially set as urgent tasks, the opposite are slow task. The tasks with a regular urgency are between the above two tasks. The three tasks are assigned 1, 2, and 3, respectively [33].

TABLE 3: Mapping content and value of each variable.

Variable name	Mapping content	Values
Y (dimensionless)	The types of pilot’s intention: accelerate, decelerate, constant speed, turn left, turn right, constant heading, climb, descend, and constant altitude were recorded as Y11, Y12, Y13, Y21, Y22, Y23, Y31, Y32, and Y33, respectively.	The behavior of the pilot maneuvering the aircraft and changes in the cockpit flight instrument were observed during the video playback. The values of Y11, Y12, Y13, Y21, Y22, Y23, Y31, Y32, and Y33 were assigned according to the proportion of each type of intention.
X1 (times/second)	Heart rate	The initial value of X1 is given by the average value of the pilot’s heart rate $X1 = (1/S) \sum_{l=1}^S X1_l$ ( $X1_l$ is the heart rate per $l$ second, where $l = 1, 2, 3, \dots, S$ ).
X2 ( $\mu\Omega$ )	Skin conductance	The initial value of X2 is given by the average of the pilot’s skin conductance $X2 = (1/S) \sum_{l=1}^S X2_l$ ( $X2_l$ is the value of skin conductance per $l$ second, where $l = 1, 2, 3, \dots, S$ ).
X3 (times/second)	Breathing	The initial value of X3 is given by the average of the pilot’s breathing $X3 = (1/S) \sum_{l=1}^S X3_l$ ( $X3_l$ is the value of breathing per $l$ second, where $l = 1, 2, 3, \dots, S$ ).
X4 (second)	Hearing	The initial value of X4 was assigned by the auditory response time test values.
X5 (second)	Choice reaction time	The initial value of X5 was assigned by the choice reaction time test values.
X6 (second)	Operational response time	The initial value of X6 was assigned by the operational response time test values.
X7 (second)	Speed estimation capability	The initial value of X7 was assigned by the speed estimation capability test values.
X8 (second)	Discriminative response time	The initial value of X8 was assigned by the discriminative response time test values.

sequence of factors in a descending degree of influence is as follows:

$$X6 > X5 > X7 > X8 > X1 > X4 > X2 > X3 \quad (8)$$

In other words, the sequence is as follows: operational response time > choice reaction time > speed estimation

ability > discrimination reaction time > heart rate > auditory response time > skin conductance > breathing.

The psychological characteristics included pilot’s personality (noted as X9), attention (noted as X10), attitude (noted as X11), and emotion (noted as X12). The psychological characteristics selected were all dimensionless variables, and the data acquisition methods are shown in Table 2. The physical characteristics included pilot’s rudder pedal force (noted

TABLE 4: Sequence of physiological factors after data processing.

No.	X1	X2	X3	X4	X5	X6	X7	X8
1	0.87	0.75	0.82	0.36	0.28	0.19	0.21	0.19
2	0.88	0.84	0.79	0.37	0.26	0.21	0.19	0.20
3	0.23	0.82	0.83	0.35	0.24	0.19	0.22	0.23
4	0.61	0.91	0.91	0.36	0.19	0.20	0.23	0.31
5	0.62	0.58	0.81	0.33	0.18	0.18	0.29	0.18
6	0.97	0.83	0.76	0.32	0.22	0.22	0.23	0.20
7	0.23	0.64	0.88	0.38	0.23	0.19	0.21	0.22
8	0.98	0.97	0.92	0.35	0.17	0.20	0.27	0.24
9	0.89	0.74	0.87	0.39	0.23	0.23	0.22	0.30
10	0.59	0.56	0.88	0.31	0.25	0.17	0.31	0.18
11	0.13	0.86	0.81	0.32	0.27	0.19	0.18	0.22
12	0.45	0.68	0.75	0.33	0.18	0.16	0.26	0.23
13	0.61	0.79	0.92	0.29	0.13	0.21	0.28	0.19
14	0.98	0.52	0.87	0.37	0.25	0.19	0.27	0.31
15	0.86	0.93	0.92	0.34	0.29	0.24	0.29	0.22
16	0.89	0.92	0.74	0.35	0.18	0.19	0.18	0.25
17	0.78	0.74	0.88	0.28	0.19	0.18	0.22	0.21
18	0.81	0.81	0.79	0.38	0.21	0.23	0.20	0.24
19	0.79	0.79	0.82	0.30	0.27	0.21	0.17	0.27
20	0.85	0.75	0.84	0.33	0.19	0.16	0.27	0.23
21	0.96	0.56	0.73	0.27	0.27	0.19	0.24	0.18
22	0.45	0.82	0.77	0.31	0.31	0.17	0.18	0.23
...	...	...	...	...	...	...	...	...
65	0.63	0.58	0.91	0.32	0.22	0.18	0.19	0.32
66	0.94	0.96	0.86	0.35	0.24	0.22	0.21	0.17
67	0.61	0.66	0.72	0.37	0.25	0.17	0.19	0.25
68	0.86	0.82	0.79	0.32	0.16	0.24	0.23	0.24
69	0.74	0.68	0.76	0.35	0.20	0.18	0.18	0.19
70	0.39	0.78	0.93	0.32	0.22	0.21	0.16	0.21
71	0.95	0.91	0.85	0.31	0.19	0.20	0.21	0.22
72	0.46	0.79	0.91	0.29	0.23	0.19	0.18	0.19
73	0.71	0.82	0.78	0.32	0.24	0.14	0.30	0.24
74	0.84	0.69	0.89	0.34	0.18	0.19	0.19	0.18
75	0.53	0.77	0.82	0.37	0.23	0.21	0.22	0.22

as X13) and handle force of joystick (noted as X14). The physical characteristics selected were all dimension variables, and the data acquisition methods are shown in Table 2. The other characteristics included flight hours (noted as X16) and education level (noted as X17); in addition to the task priority (noted as X15), data acquisition methods are also shown in Table 2).

The pilot's psychological, physical, and other characteristics were then analyzed through qualitatively and calculated quantitatively for using the same method, and the results are shown in Figures 5–7.

It can be seen that during the flight of the pilot to complete the airfield traffic pattern, the different characteristic variables will have different importance with the identifying accuracy of the random forest model changing. The impor-

tance of each variable to the pilot's intention identification is different.

## 5. Discussion

The pilot's process of maneuvering the aircraft is a repetitive cognitive process of "perception-judgment-decision-execution," as illustrated in Figure 8. The physiology, psychology, physics, and various other features of the pilot may result in differences in manipulation intentions, which have a significant impact on each of the above cognitive processes. By identifying the pilot's intentions that reflect the individual differences of the pilots and applying the identification results to the active safety of aircraft driving, a humanized cockpit active safety early warning system could be established. The system could appropriately warn various pilots in a dangerous state according to different flight intentions to ensure that the pilot could more accurately and safely control the aircraft. The basis of identifying the pilot's intentions efficiently is to determine the factors that affect the pilot's intention.

Pilots' physiology, psychology, and physics are broad and complex research topics, and they have a significant influence on pilots' behavior. The effects of pilots' physiological, psychological, and physical characteristics on flight safety are mainly reflected in the pilot's intention [28, 29]. Pilots' intention refers to their psychological experience of actual flight conditions under the effect of various dynamic factors, as well as the decision-making and valuable microbehaviors that the pilot exhibit in accordance with the intention. It reflects the psychological state of aircraft operators in a time-varying dynamic environment, which is a difficult point in the field of flight safety. Related scholars began to pay attention to and carry out the research studies that refer to the impact of physiological, psychological, and physical characteristics on pilots' control behavior [35]. Some scholars simply study the physiological, psychological, and physical characteristics separately. For example, in the physiological characteristics of pilots, some scholars have studied the vestibular sensation, vision, heart rate, and breathing status [9, 12, 14, 16, 17]. In terms of psychological characteristics, some scholars have studied the pilot's attention, situational awareness, cognitive load, etc. [15, 18, 22, 25, 36]. In the pilots' physical characteristics, some scholars have studied the hand movements [26, 27]. Previous studies on the influencing factors of the pilot's microbehavior have focused on the impact of a single factor on it. The pilot's intention, as an important part of the microbehavior and cognitive process, is affected by the pilot's physiological, psychological, physical, and other various additional characteristics. Due to the variety and complexity of influencing factors, these factors need to be considered comprehensively. Focusing on this, starting with the study of pilot's intention, the flight simulator, dynamic acquisition system for comprehensive human-aircraft-environment information, and comprehensive response tester were used to collect pilot's physiological, psychological, physical, and other influencing factors from different perspectives in this paper. On the basis of ensuring the data is sufficient and true, this article explores the inherent mechanism of the pilot's

TABLE 5: Results of one-way ANOVA of pilots' physiological characteristics.

	Quadratic sum	df	Mean square	F	Significance
Heart rate (times/s)					
Intergroup	6474.400	6	435.600	302.746	0.000
Intragroup	424.700	115	1.025		
Total	6948.500	217			
Skin conductance ( $\mu\Omega$ )					
Intergroup	7613.600	7	527.700	416.682	0.000
Intragroup	375.500	211	1.256		
Total	7461.700	267			
Breathing (times/s)					
Intergroup	8734.700	8	502.500	475.401	0.000
Intragroup	419.800	244	1.201		
Total	8783.600	196			
Auditory response time (s)					
Intergroup	4643.800	5	798.400	365.324	0.000
Intragroup	275.68	184	1.121		
Total	4935.600	195			
Choice reaction time (s)					
Intergroup	4765.500	6	675.300	487.412	0.000
Intragroup	235.651	178	1.119		
Total	4658.400	225			
Operational response time (s)					
Intergroup	4463.786	7	452.234	450.143	0.000
Intragroup	198.543	191	.008		
Total	4577.165	238			
Speed estimation capability (s)					
Intergroup	4482.500	6	632.600	465.212	0.000
Intragroup	205.700	186	1.103		
Total	4314.600	207			
Discriminative response time (s)					
Intergroup	4713.512	6	458.400	478.114	0.000
Intragroup	192.734	178	1.125		
Total	4675.400	195			

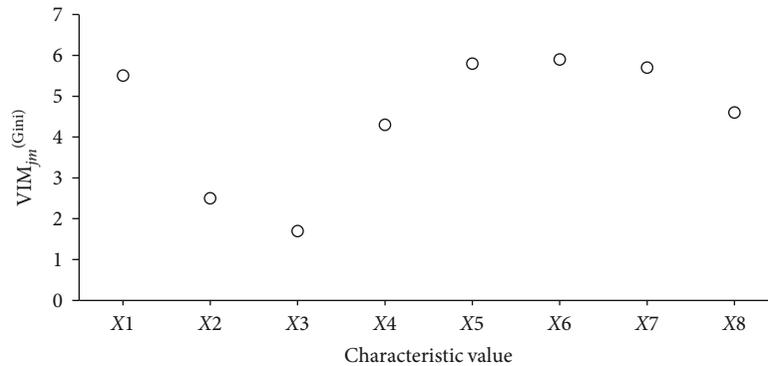


FIGURE 4: Gini coefficient importance scatter plot of physiological characteristics.

microbehavioral characteristics. The relatively single, static research trains of thoughts were abandoned, and a more comprehensive, systematic, and dynamic analysis of pilot's inten-

tion influencing factors was presented in this paper. It can be seen from research results that it can make up for the lack of current information sources on pilot's microbehavior research

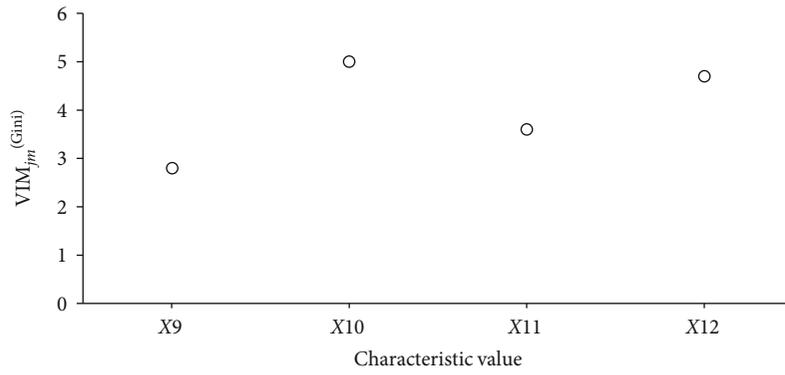


FIGURE 5: Gini coefficient importance scatter plot of psychological characteristics.

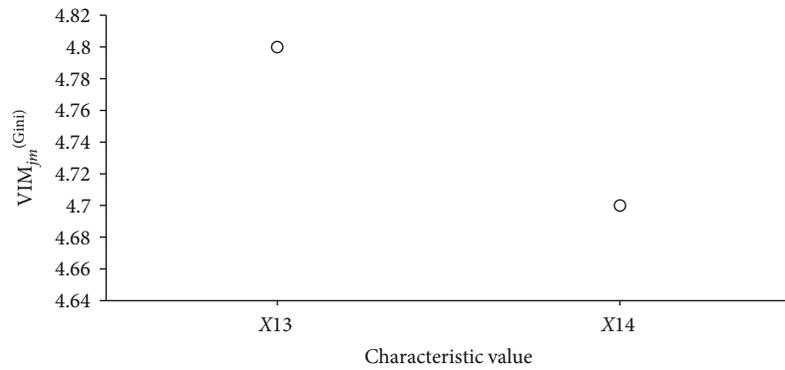


FIGURE 6: Gini coefficient importance scatter plot of physical characteristics.

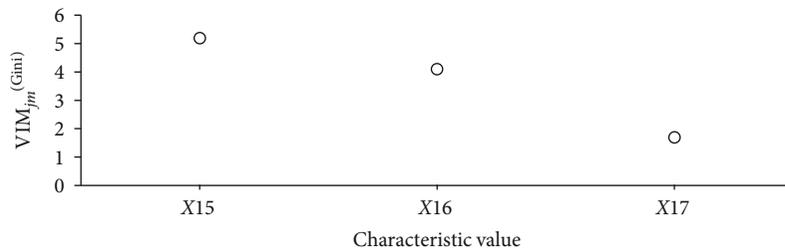


FIGURE 7: Gini coefficient importance scatter plot of other characteristics.

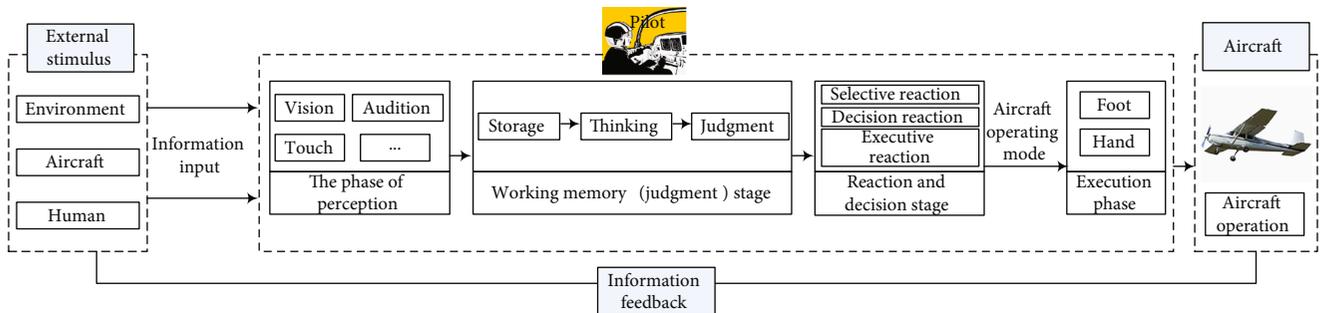


FIGURE 8: Cognitive process of pilots.

and provide a strong theoretical basis and technical support for the subsequent pilot's intention study [6, 27].

It is important to analyze influencing factors of pilot's intention in order to avoid the interference of message over-

lap caused by multiple variables and contributions. Traditional methods such as principal factor analysis screen linearly related feature variables in a single classifier. It is not completely suitable for pilots under the influence of

multisource dynamic nonlinear correlation data such as man-machine-environment [30]. The random forest analysis method could overcome the shortcomings of the local point correlation trend and information loss of traditional feature analysis methods. The random forest method has the salient aspects of nonnegative, symmetrical, and extensible and has certain advantages for processing multisource information.

It should be pointed out that the measurement of the physiological, psychological, and physical characteristics of the pilot is carried out under some situations and the results are easily affected by the operating environment. These situations do not take into account other complex environments, such as aircraft single-engine accidents, night flights, long-distance cruises, and more complicated situations. There are differences in the technical level between the simulated flight and the real flight in the flight simulation environment, which have an impact on the experimental results. The model used in the simulation is an abstraction of the real flight, with a certain subjectivity. The choice of experimental methods and subjects has these limitations. Thereby, future research should reduce the impact of factors such as the experimental environment and subject selection on influencing factors of pilot's intention. The research should continue to make the choice of influencing factors more accurate by improving experimental methods and expanding experimental sample size.

## 6. Conclusion

The judgment of the pilot's intention is the premise of the dynamic feature extraction and identification in the follow-up study. Pilot's intention is an important factor that affects the operation of aircraft, and the dynamic characteristics of pilots operating aircraft under various intentions have obvious differences. The selection of influencing factors for intention is the basis for correctly understanding pilot's intention. At the same time, it is also an important precondition for accurately identifying the pilot's intention and realizing human-aircraft-environment collaboration in the context of the "Internet of Things." It is also the basic requirement for the development of advanced autonomous control systems and intelligent cockpits, and it is an important content of flight human factor microresearch. The pilot's intention is influenced by a series of physiological, psychological, and physical factors of the pilot. In order to avoid the interference caused by the overlapping of information which will appear in the multivariable and multicontribution relationship, it is essential to analyze and extract the influence factor of the pilot's intention. In this paper, we design a number of experiments to obtain indicators such as physiological, psychological, physical, and other external factors of the pilot and also quantify the influencing factors. Then, the random forest analysis method is used to extract and rank the influencing factors, which forms the pilot's intentional affecting factor sequence. This research result reveals the formation mechanism of the pilot's micropsychology and behavioral intention in the process of controlling the aircraft to a certain extent and realizes the preliminary research on the mechanism of pilot's physiological, psychological, and physical

characteristics and intention coupling. This study provides a good foundation for further research on the pilot's intention identification and provides a theoretical basis for a comprehensive systematic study of dynamic feature extraction and pilot's behavior analysis. What is more, through the analysis of the dynamic characteristics of pilots under different intentions in complex flight environment, the comprehensive understanding of the psychological, physiological, and physical characteristics of the flying cadet and the pilot's microbehavior assessment system will be improved. Therefore, this study is of great practical significance to research the future active safety warnings for flight, pilot's microbehavior assessment, and flight safety.

## Data Availability

The participants' data used to support the findings of this study have not been made available because of participants' privacy.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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