The Influence of Personality Traits on Users' Preference for eVTOL Control Parameters

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The electric vertical takeoff and landing (eVTOL) is believed to be the future of transportation. Startup companies have proposed eVTOLs with simplified control systems. A typical example is the single-joystick control system, which controls the longitudinal, lateral and yaw movement of the eVTOL by a single joystick. However, little is known about what control parameters can meet the users' needs of eVTOL dynamics. Thus, a flight simulator experiment with 46 participants was conducted on a six-degree-of-freedom (6-DOF) eVTOL flight simulator. We investigated how users' personality traits can affect their preferred eVTOL control parameters, which were identified by an adaptive staircase procedure. Then, hierarchical clustering based on the preferred control parameters revealed two distinct user groups. Further, higher conscientiousness, emotional stability, and extraversion were associated with a higher preference for more sensitive control parameters. These findings highlight the importance of considering individual heterogeneity when designing the eVTOL control systems.

INTRODUCTION

As urban air mobility (UAM) continues to develop, eVTOL vehicles are expected to play a crucial role in future transportation systems. Though fully autonomous eVTOLs are expected to be the future, human operators may still be needed for safety considerations (Bauranov & Rakas, 2019). At the same time, being different from pilots in aviation, the eVTOLs are expected to be operated by more diverse populations (Emerson et al., 2023). Thus, to cater to the needs of the general public, some eVTOL manufacturers have started to innovate the eVTOL control systems by reducing the number of inputs based on single-input mode (AeroHT, 2024). Specifically, the longitudinal, lateral, yaw and vertical movements can be controlled by a single joystick, while the control system automatically coordinates the pitch and roll movements. Given that no standards regarding this new input mode have been proposed yet, what the control parameters should be with this new setup and whether and how heterogeneous users prefer the parameters differently are still unclear. Thus, understanding individual differences in eVTOL operation is essential for improving pilot licensing, training, and human-machine interaction design, given the complexities of dynamic flight environments.

Personality has long been recognized as an influential factor of cognitive processing, behavioral regulation, and task performance in complex operational environments (Matthews, 2008; Fein & Klein, 2011; Mumford et al., 1993). As one of the commonly used personality models, the Five-Factor Model (FFM) categorizes personality traits into Conscientiousness, Emotional Stability (reverse Neuroticism), Extraversion, Agreeableness, and Openness to Experience, with each of them being linked to distinct behavioral tendencies (McCrae & John, 1992). In aviation psychology, these traits are particularly relevant, as pilots must demonstrate high levels of cognitive control, adaptability, and stress management in demanding flight conditions (Davies et al., 2013; Kanki et al., 2019). However, empirical studies examining how personality traits manifest in eVTOL control are limited. Previous research (Costa & McCrae, 2008) has demonstrated that individuals with higher levels of conscientiousness tend to exhibit more rigorous and organized behavioral patterns, while those with higher emotional stability are generally better at coping with stress and rapidly changing task environments. Extraversion has also been recognized as one of the most influential traits in personality research (McCrae, 2020), with higher extraversion associated with greater enthusiasm and proactive engagement. Meanwhile, agreeableness is associated with traits such as politeness and friendliness, whereas openness is linked to strong curiosity and a willingness to embrace new experiences. Building upon this theoretical foundation, we hypothesized that these personality characteristics may also be associated with user preferences for eVTOL single-joystick control parameters.

Thus, as a preliminary study, in a flight simulator experiment, we evaluated new eVTOL users' preferences on the controlling parameters of eVTOL with a single-input control system. Hierarchical clustering and ANOVA analysis were conducted to identify heterogeneous user personalities and their association with the parameter preferences.

METHODS

Participants

In total, 46 participants (9 females and 37 males) participated in the flight simulator experiment, with ages ranging from 22 to 63 years (M = 31.85, SD = 8.13). Participants exhibited varied flight experience: eight participants (one female and seven males) had prior aviation experience with fixed-wing aircraft or helicopters, and four of these individuals held Civil Aircraft Pilot Licenses, including private and commercial pilot licenses. Additionally, 11 male participants had varying degrees of experience operating drones, with two holding Civil Remote Pilot Licenses or certifications. Other participants had minimal prior experience with eVTOL or other forms of urban air mobility. Their familiarity was limited to brief exposure through flight simulators used in this study. Given that we used a 6-degree-of-freedom (6-DOF) simulator, the Motion Sickness Susceptibility Questionnaire Short-form (MSSQ-Short, Golding, 2006) and the 6-item Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ, Golding et al., 2021) were used to identify and exclude individuals who are susceptible to motion and visually induced sickness. The study was approved by the Human Research Ethics Committee of The Hong Kong University of Science and Technology (Guangzhou) (Approval No.: HSP-2024-0084).

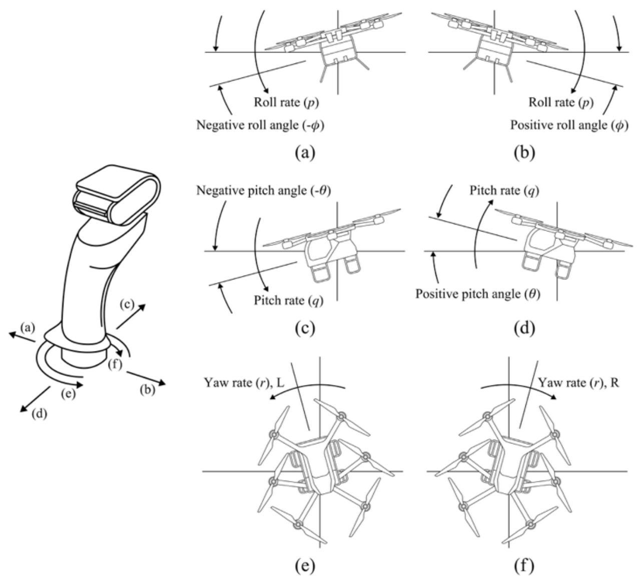


Figure 1. Mapping between joystick movements and eVTOL attitude control parameters.

Apparatus

The experiment was conducted on a 6-DOF eVTOL flight simulator developed by XPeng AeroHT, which integrated an Mixed Reality (MR) environment to simulate an immersive eVTOL cockpit. Participants wore an MR headset (model Varjo XR-3) and used a realistic single-input joystick that integrates both button and stick-based controls to interact with the eVTOL flight simulator.

Simulating a real eVTOL product, the single-input joystick enables control over eight parameters related to aircraft attitude and angular motion. As shown in Figures 1a and 1b, lateral movement of the joystick to the left or right induces roll motion, generating a negative or a positive roll angle ϕ, with roll rate p indicating the speed of this change. Figures 1c and 1d illustrate that pushing or pulling the joystick forward and backward initiates pitch movements, which result in either a negative or a positive pitch angle θ. A larger deflection corresponds to a greater pitch angle, leading to faster steady-state speeds. The rate of this motion is represented by pitch rate q. As depicted in Figures 1e and 1f, yaw control is achieved by twisting the stick left or right, with the magnitude of the twist determining the yaw rate r. Releasing the joystick causes the aircraft to gradually decelerate until it stops completely and maintains a hovering state. The speed or yaw rate at which the joystick is operated does not affect the angular or linear acceleration, but the target angular velocity or speed in the corresponding directions. In other words, all these parameters can decide how sensitive the eVTOL is, with regard to the joystick movement – the larger the parameters, the more sensitive the eVTOL dynamics are.

Procedures

Before the experiment, all participants were required to complete an online questionnaire, including a survey regarding their demographic information (i.e., age, gender, educational background, and annual income), and the Chinese version of Ten Item Personality Measure (TIPI, Gosling et al., 2003), adopted from Lu et al (2020). The TIPI is a brief personality assessment tool designed to measure the Big Five personality traits based on the FFM, ranging from 1 (Disagree Strongly) to 7 (Agree Strongly).

Then, all participants received training on basic control operations and completed a five-minute independent practice flight. The basic control training covered the use of the joystick, interpretation of flight indicators, and the execution of the control operations.

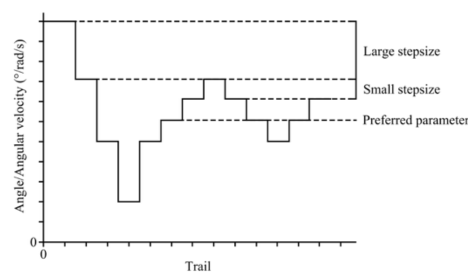


Figure 2. Adaptive staircase procedures for parameter adjustment.

In the formal experiment, we adopted the adaptive staircase procedures (Levitt, 1971), to obtain users' preference on eight flight parameters, as illustrated in Figure 2. Participants were instructed to apply full joystick deflection for each parameter, and verbally reported if they felt comfortable with the current parameter setup. Comfort or discomfort was subjectively determined based on physiological sensations such as dizziness, tension, fear, or any physical unease caused by the motion behavior of the system. The experimenter adjusted the parameter up or down based on the participant's feedback using predefined step sizes. If the participant reported discomfort, the corresponding parameter was decreased; otherwise, it was increased. The testing process was terminated when the parameter oscillated around a specific value for three consecutive iterations, which was identified as the preferred parameter setup for a participant.

Importantly, all measurements of control parameter preferences were conducted under decoupled conditions, meaning that each trial focused on measuring parameters related to flight attitude and angular motion in a single direction, in order to avoid interaction effects and ensure clarity in participant feedback. The entire experiment lasted approximately 30 minutes for each participant.

Statistical Analysis

All preferred joystick control parameters were first standardized using Z-score normalization to protect the commercial confidential information and eliminate the influence of measurement unit differences. Minor variations in statistical estimates are expected due to scale transformation. Then, a hierarchical clustering analysis using Ward's method was conducted to identify distinct user clusters based on similarities in joystick parameter preferences.

Next, ANOVA was conducted to explore relationships between identified clusters, personality traits, and demographic variables. Specifically, mixed linear model analysis was built using the Proc Mixed procedure in SAS OnDemand, with the clusters as the independent variable (IV) and all other variables as dependent variables (DVs). The variance explained (R^2) by the parameter-based clustering model was also provided, quantifying the contribution of IV in explaining DVs. The R^2 was calculated using the general linear model (GLM) in SAS.

RESULTS

Clustering Results

The effective sample size after clustering was $N = 41$. Five participants were excluded due to system failures (two pilots, one drone operator and two others). As shown in Figure 3, two clusters were identified based on participants' preferred control parameters. In general, the participants from Cluster 1 were more inclined to prefer less sensitive, or conservative control parameter settings, compared to the participants from Cluster 2.

Specifically, as shown in Figure 4a, compared to those in Cluster 2, participants in Cluster 1 exhibited lower preferred values for positive pitch angle, with an estimated difference (Δ) of −1.3732, 95% confidence interval (95%CI) of [−1.8894, −0.8570], $F(1,32) = 29.36$, $p < .0001$, explaining approximately 47.9% of variance ($R^2 = 0.4785$). A similar pattern was also observed for negative pitch angle and pitch rate preferences, with Cluster 1 preferring lower settings compared to Cluster 2 (negative pitch angle: $\Delta = -1.3271$, 95%CI = [−1.8224, −0.8318], $F(1,32) = 29.79$, $p < .0001$; $R^2 = 0.4821$; pitch rate: $\Delta = -1.1004$, 95%CI = [−1.7243, −0.4765], $F(1,32) = 12.91$, $p = .0011$; $R^2 = 0.2874$).

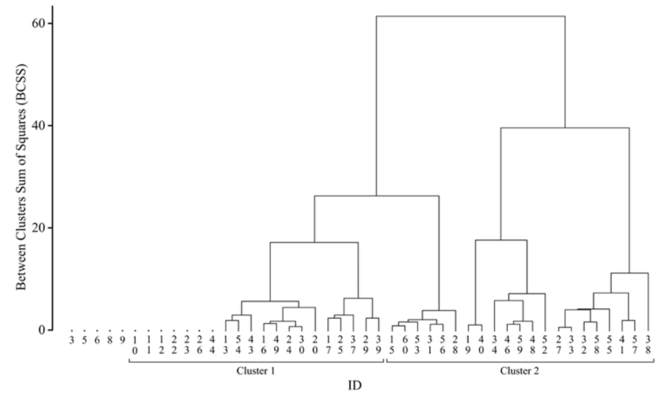
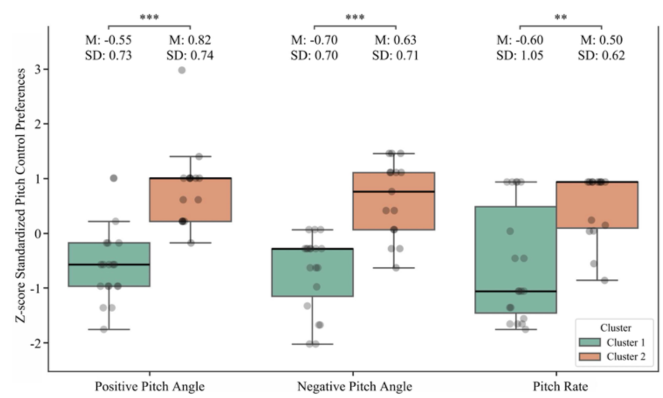
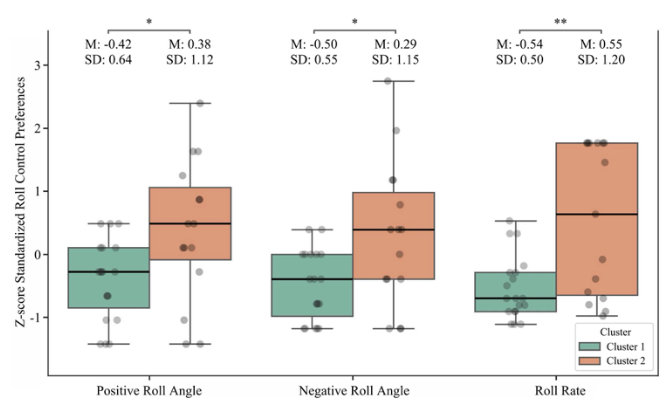


Figure 3. Hierarchical clustering dendrogram using Ward's method.



(a)



(b)

Figure 4. Differences between clusters in standardized a) pitch control preferences and b) roll control preferences. Note: In this figure and the following figures, the asterisk marks significant effects (*: $p < .05$; **: $p < .01$; ***: $p < .001$). In this and the following plots, boxplots present the minimum, 1st quartile, median, 3rd quartile, and maximum.

Similar results were also observed in preferences for roll control parameters. As shown in Figure 4b, compared to those in Cluster 2, participants in Cluster 1 preferred lower positive roll angle settings ($\Delta = -0.8033$, 95%CI = [−1.4255, −0.1810], $F(1,32) = 6.91$, $p = .0130$; $R^2 = 0.1777$), negative roll angle preference ($\Delta = -0.7844$, 95%CI = [−1.3959, −0.1729], $F(1,32) = 6.83$, $p = .0136$; $R^2 = 0.1758$) and roll rate settings ($\Delta = -1.0874$, 95%CI = [−1.7055, −0.4694], $F(1,32) = 12.84$, $p = .0011$, $R^2 = 0.2864$). However, no significant differences were observed for yaw-related parameters ($p > .05$) between the participants from the two clusters.

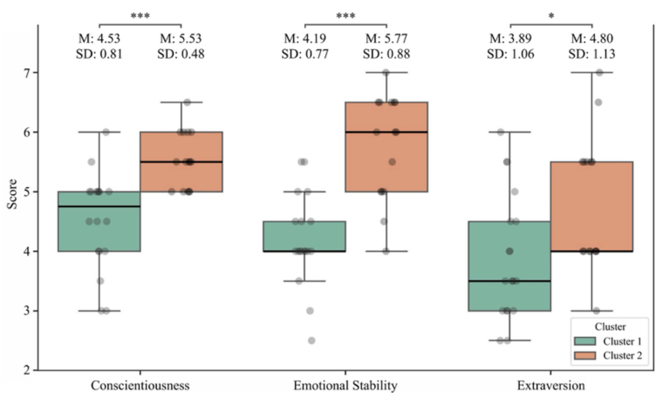


Figure 5. Differences of conscientiousness, emotional stability, and extraversion across the two identified clusters.

Personality Associated with Clusters

Next, we investigated whether the personality traits differed between the identified clusters. As shown in Figure 5, compared to those in Cluster 2, participants in Cluster 1 exhibited lower levels of conscientiousness ($\Delta = -1.0056$, 95%CI = [−1.4927, −0.5184], $F(1,31) = 17.72$, $p = .0002$; $R^2 = 0.3638$), emotional stability ($\Delta = -1.5722$, 95%CI = [−2.1591, −0.9853], $F(1,31) = 29.85$, $p < .0001$; $R^2 = 0.4906$) and extraversion levels ($\Delta = -0.9111$, 95%CI = [−1.6919, −0.1303], $F(1,31) = 5.66$, $p = .0237$, $R^2 = 0.1545$).

DISCUSSION

In a flight simulator study conducted on a 6-DOF motion platform, we explored how personality traits can affect pilots' preferences in control parameters of eVTOLs with a novel control system, the single-joystick control system.

First, we identified two groups of participants who exhibited significantly different preferences for eVTOL control parameters, with one group preferring more sensitive control parameters, while the other preferred more conservative ones. This result reveals the heterogeneity in user preferences for eVTOL control, similar to what has been observed in the driving domain (Mian & Jaffry, 2020) and aviation domain (Wang et al., 2020). Thus, future eVTOL designers may still need to consider the user preferences to optimize the dynamic responses of the eVTOLs, especially when the products are targeting the general users.

In addition, our results provide empirical evidence for the association between personality traits and user preferences for single-joystick control parameters in eVTOLs. Specifically, participants with higher levels of conscientiousness and emotional stability preferred more sensitive control settings. It is likely that those with higher levels of conscientiousness and emotional stability were more confident in their control abilities, and they can tolerate more sensitive control parameters. Similar trends have been observed from conventional aircraft and helicopter pilot training studies, where individuals with greater emotional stability tend to exhibit higher confidence in their control abilities (Luciani et al., 2022), while those with higher conscientiousness show greater task focus and more stable control behaviors (Hidalgo-Muñoz et al., 2021). Thus, future eVTOL control system design may be tailored to meet the needs of pilots with different personality traits to improve the usability of the eVTOL control system.

Further, we found that those with a higher level of extraversion also preferred more sensitive control parameters. It is possible that extraverted individuals have more effective flight training outcomes due to more proactive engagement (Barron et al., 2016). This may have made them more confident in their control skills and thus prefer more sensitive control settings. Such results indicate that tailored training programs based on personality traits may be considered, improving training efficiency and reducing the time needed for novices to achieve operational proficiency. For example, trainees with high levels of extraversion could receive training on higher sensitivity control settings to facilitate adaptation to advanced eVTOL operations.

Finally, the absence of significant effects regarding the relationship between yaw-related parameters and personality may suggest that users' sensitivity to yaw dynamics is comparatively lower. Specifically, participants usually experience yaw movement when taking any vehicles, while the roll and pitch movements are usually absent or minor in vehicles. This result indicates that participants may transfer their riding experience from other transportation modes to eVTOL riding.

Nevertheless, several limitations should be acknowledged in our study. First, the relatively small sample size limits the generalizability of the conclusions. Future research should consider a larger pilot population with a more varied personality and demographic background. Further, using self-reported personality measures alone may introduce biases. For example, conscientiousness is often subject to socially desirable responses (Khorramdel et al., 2014). Thus, future studies should consider incorporating objective personality assessments (Breuer et al., 2023). Finally, the simulated flight experience may differ from real-world operations. Future research should validate our findings in complex and realistic flight tasks to obtain a better understanding of the relationships among personality traits, operational stressors, flight performance and individual preferences.

CONCLUSION

As one of the first studies to explore the optimization of eVTOL flight control parameters from a personality perspective, based on a flight simulator experiment, this study highlights the role of individual differences in pilots' eVTOL preferred control parameters, with conscientiousness, emotional stability and extraversion being identified as influential factors. These results have implications for pilot training, human-machine interaction, and adaptive automation design. For example, by integrating personality-based parameters into eVTOL control systems, training programs could be tailored to speed up the training process, and automation systems could be refined to accommodate individual preferences and optimize the operating efficiency. Future research should explore these relationships in more complex flight scenarios and examine how personality-driven variations in control behavior impact eVTOL control performance.

CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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