Enhancing the Human-Machine Interface: An Analysis of Unmanned Aerial Systems (UAS) Using the System Usability Scale (SUS)

Ivan de Souza Rehder [1], Andrew Sarmento, Ana Carolina Russo, Moacyr Machado Cardoso Junior, Emilia Villani

[1] Centro de Competência em Manufatura – Instituto Tecnológico de Aeronáutica (ITA)
São José dos Campos – SP – Brazil

ivan@ita.br, andrewgps@ccm-ita.org.br, ana.russo@ccm-ita.org.br, moacyr@ita.br, evillani@ita.br

Abstract. *This study assessed the usability of an Interactive System for Unmanned Aerial Systems (UAS) using the System Usability Scale (SUS). A simulation-based experiment involved 24 pilots with varying experience levels. Results showed an average SUS score of 67.4, indicating reasonably positive usability perception. Participants without prior piloting or aeronautical experiences scored lower, while those with military or technical backgrounds scored higher. These findings highlight the importance of considering user backgrounds for effective UAS control and offer insights for usability improvements.*

1. Introduction

The adoption of unmanned systems, such as Unmanned Aerial Vehicles (UAVs) and Unmanned Aerial Systems (UAS), is on the rise in the aviation industry. These systems offer advanced flight capabilities and increased payload capacity (Fricke & Holzapfel, 2016). However, there has been a tendency to overlook the importance of human elements within the system, as the focus has primarily been on aircraft technology (Rowe et al., 2017). The unique characteristics of UAS introduce unconventional human factors that differ from traditional aviation practices (Landry, 2018).

Significant contributions to accidents and incidents in UAV operations have been attributed to human error and deficiencies in the human-machine interface (HMI) (Pestana, 2011). Overreliance on automation without maintaining situational awareness can lead to delayed decision-making and errors when unexpected events occur (Engsley et al., 1997).

This study aims to evaluate the usability of the Interactive System by utilizing the System Usability Scale (SUS) questionnaire. Scenarios and tasks will be defined using a prototype Human-Machine Interface (HMI) that simulates UAS operations in a combat environment. The objective is to contribute to the development of optimized HMI designs that reduce cognitive workload, improve decision-making, and enhance situational awareness in critical operational conditions.

The findings of this research will have practical implications for the effective and safe control of UAVs in various applications, including surveillance, search and rescue, and military operations. By evaluating human performance under critical operational conditions and developing optimized HMI solutions, the aim is to enhance overall effectiveness and safety in UAV control.

2. Methodology

This study involved the participation of 24 pilots with varying levels of experience, ranging in age from 20 to 50 years. Each operator conducted two flights, each lasting 30 minutes, as part of a simulation-based experiment. Throughout the study, four repetitions were performed for the operators, following a structured process for the pilot participants.

For the operators, the flights were conducted in three different settings. In the first setting, two operators were assigned to work together, one assumes navigation while the other operates the electro-optical POD. In the second setting, only one operator was responsible for controlling the UAV, allowing for the assessment of individual performance. In the third setting, one operator used voice commands to control the UAV, investigating the impact on operation and mental workload.

Performance data (NASA-TLX and ISA), physiological measures (Eye Tracker , GSR and ECG), and SUS questionnaires were collected during the flights for the operators, while the pilot participants' data collection included physiological measurements, workload assessments, and baseline comparisons. This methodology allowed for a detailed analysis of the effects of the different settings on UAV operation and provided valuable insights for the development of guidelines and best practices in the field of unmanned aerial systems operation. Figure 1 illustrates the testing process.

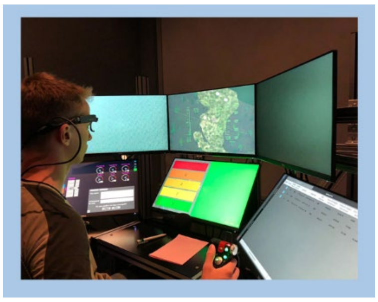

Figure 1 - Pilot in the simulation

The SUS questionnaire was chosen as the instrument for Usability Evaluation in this study due to its cost-effectiveness and the small number of questions. The SUS, developed by Brooke (1996), is a 10-question survey designed to measure the usability of a variety of products and services.

At the end of each test, the pilot responded to the following questions:

- I think that I would like to use this simulator frequently.
- I found the simulator unnecessarily complex.
- I thought the simulator was easy to use.
- I think that I would need the support of a technical person to be able to use this simulator.
- I found the various functions in this simulator were well integrated.
- I thought there was too much inconsistency in this simulator.

- I would imagine that most people would learn to use this simulator very quickly.
- I found the simulator very cumbersome to use.
- I felt very confident using the simulator.
- I needed to learn a lot of things before I could get going with this simulator.

The responses were rated on a scale from 1 to 5, as follows:

- Strongly Disagree - 1
- Disagree - 2
- Neither Agree nor Disagree - 3
- Agree - 4
- Strongly Agree - 5

To calculate the SUS score, first sum the score contributions from each item. Each item's score contribution will range from 0 to 5. For items 1,3,5,7 and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SUS.

The average System Usability Score is 68 points. If the score is lower than this, it is likely that the user is experiencing usability issues with the product.

3. Results and discussions

The SUS results are presented in Table 1 and Table 2.

Table 1 - SUS score for none previus piloting experiences (Variable 1)

Interviewed ID	SUS Score	Previous piloting our aeronautical experiences
P10	40	None
P11	42,5	None
P5	52,5	None
P19	65	None
P21	65	None
P20	67,5	None
P16	70	None
P24	72,5	None
P12	80	None
P15	82,5	None
P9	85	None

Table 2 - SUS score for Previous piloting our aeronautical experiences (Variable 2)

Interviewed ID	SUS Score	Previous piloting our aeronautical experiences
P17	55	Aerospace engineer

P14	57,5	Conventional military pilot
P7	57,5	Conventional military pilot
P8	60	Engineer
P3	65	Conventional military pilot
P22	65	Aerospace engineer
P6	67,5	Conventional military pilot
P13	72,5	Conventional military pilot
P1	75	Military test pilot, Conventional military pilot
P4	75	Conventional military pilot
P2	80	Aerospace engineer
P18	80	Conventional military pilot
P23	82,5	Conventional military pilot

Upon scrutinizing the outcomes, it is salient that the mean ratings across both conditions warrant attention. Participants in 'Variable 2,' those endowed with prior experience, bestowed average scores approximately three points higher than participants in 'Variable 1,' suggesting that antecedent experience may exert a constructive influence on perceptions of usability.

An intriguing facet pertains to the dispersion of the ratings. 'Variable 1' exhibited substantially higher variance than 'Variable 2.' This observation may imply that the assessments from participants lacking prior experience were more widely distributed around the mean, while participants with prior experience demonstrated greater concordance in their evaluations, indicating heightened consistency in perceptions of usability.

However, a judicious consideration of the statistical implications arising from these findings is essential. When scrutinizing the hypothesis positing that no substantial discrepancy exists in usability between the two groups, the results proffered inadequate evidence to warrant the negation of the null hypothesis. This inference implies that, predicated upon the available dataset and the conducted tests, the proclamation that prior experience begets significantly superior usability cannot be confidently asserted.

It is imperative to underscore that this conclusion does not belittle the relevance of prior experience. The results imply that, in the context of usability, prior experience may not serve as the ultimate determinant. Nevertheless, it is paramount to account for the potential influence of other factors upon user perception, encompassing design, interface, functionality, and other contextual elements.

4. Preliminary conclusions

In summary, this research addressed the question of whether prior experience significantly impacts usability, using the System Usability Scale (SUS) as an investigative tool. The results indicate that, although participants with prior experience (referred to as 'Variable 2') demonstrated slightly higher average scores and lower variance, statistical analyses confirm the absence of a substantial difference in usability when compared to participants without prior experience (referred to as 'Variable 1').

This suggests that, in the context of usability evaluation, prior experience may not be the sole predominant factor. The consistency in usability perceptions within the 'Variable 2' group prompts the need for further investigation into the elements influencing this coherence. Future studies could potentially elucidate the subtle interactions between different facets of user experience, system familiarity, and usability. Insights gained from research of this nature have the potential to enhance the design and implementation of products, systems, and services, consequently expanding user satisfaction and effectiveness. As the field of user experience continues to evolve, these findings offer a relevant contribution to the ongoing discourse on improving usability and optimizing user interactions.

References

Brooke, J. (1996). SUS: A “Quick and Dirty” Usability Scale. *Usability Evaluation In Industry*, *January 1996*, 207–212. https://doi.org/10.1201/9781498710411-35

Engsley, M. R., Onal, E., & Kaber, D. B. (1997). The Impact of Intermediate Levels of Automation on Situation Awareness and Performance in Dynamic Control Systems . *IEEE SIXTH ANNUAL HUMAN FACTORS MEETING*. https://ieeexplore-ieee-org.ezproxy.libproxy.db.erau.edu/stamp/stamp.jsp?tp=&arnumber=624849

Fricke, T., & Holzapfel, F. (2016, January). An Approach to Flight Control with Large Time Delays Derived from a Pulsive Human Control Strategy. *AIAA Atmospheric Flight Mechanics Conference* . https://doi.org/10.2514/6.2016-1033

Landry, S. J. (2018). *Handbook of Human Factors in Air Transportation Systems*. Taylor & Francis Group. https://ebookcentral.proquest.com/lib/erau/detail.action?pq-origsite=primo&docID=5160886#

Pestana, M. E. (2011). Flying unmanned aircraft: A pilot’s perspective. *AIAA Infotech at Aerospace Conference and Exhibit 2011*, *March*, 1–9. https://doi.org/10.2514/6.2011-1490

Rowe, L. J., Cooke, N. J., Bennett, W., & Joralmon, D. Q. (2017). *Remotely Piloted Aircraft Systems : A Human Systems Integration Perspective*. John Wiley & Sons Ltd. https://ebookcentral.proquest.com/lib/erau/detail.action?docID=4644543&pq-origsite=primo#