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To be or not to be? Assessment on using touchscreen as inceptor in flight operation

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Abstract

Introduction. The innovative concept on applying touchscreen controls on the flight deck design had been discussed for a long time. However, there are some potential risks on touchscreen applications constrained by the issues associated with turbulence and pilots' inadvertent activation. **Research questions**. This research aims to evaluate human-computer interactions and handling quality using touchscreens as inceptor in flight operations. **Method**. The scenario was set to conduct an instrument landing on the final approach using Future System Simulator (FSS). There are 8 commercial pilots (flight hours M = 4475.0, SD = 2742.1) using three different inceptors including traditional sidestick, touchscreen and gamepad for ILS landing. **Results**. There was a significant difference among three inceptors on handling quality in both landing without turbulence (F (2,14) = 6.25, p =.01, η_p^2 = .47) and landing with turbulence (F (2,14) = 3.93, p =.04, η_p^2 = .36) scenarios. Furthermore, post Hoc comparisons revealed that the handling quality of touchscreen was significantly lower than sidestick and gamepad. **Discussion**. By analyzing participants' empirical experiences, the touchscreen inceptor was rated as the lowest handling quality among three inceptors due to the novel and lack of practice effects in flight operations. However, there is a potential on the information supply for touchscreen inceptor based on pilots' feedbacks. **Conclusion**. Touchscreens provide numerous benefits for making flight decks simpler, but the usage as an inceptor is still in its infancy and there are still lots of problems that need to be fixed. Future Systems Simulator (FSS) is a highly reconfigurable modular flight simulator that allows pilots/researchers to explore the potential on future flight decks design for single pilot operations. There are some potential benefits on the implementation touchscreen inceptor for future flight deck design if the human-centred design principle can be integrated in the early stage.

Keywords: Flight Deck Design, Human-Computer Interactions, Handling Quality, Turbulence, Situation Awareness

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1. Introduction

The control inputs of the aircraft have undergone several innovations along with the technologies of the avionics development. The earliest aircraft were based on mechanical manoeuvring, a relatively simple and basic form of operation in which control inputs movements were communicated directly to the actuators via components such as rods, ropes and pulley sets. A mechanically constructed control column that could be used to transmit the pilot's forces therefore became one of the most important components in the flight deck. From the 1970s, aircraft flight control systems were gradually taken over by telecontrol systems, whereby the movements of the control column were converted into electrical signals via servo mechanisms and transmitted via cable to the actuators. In 1988, the airbus A320 became the first digital fly-by-wire airliner, and the sidestick had been installed on all subsequent Airbus aircraft (Li et al., 2018; Traverse et al., 2004). Although the control of aircraft has evolved from mechanical transmission to the now widely used fly-by-wire, there has been little revolutionary iteration of the control column used. In the case of airlines like Boeing and Airbus, for example, the main control column available are the sidestick and the yoke. Despite the addition of new features, these control columns retain almost the same functionality and operation as the earlier aircraft. In contrast, the rest of the flight deck has changed a lot with technological innovations, becoming more integrated and cost-efficient overall.

As airliners have evolved, components in the flight deck have been integrated again and again, with large electronic screens replacing gauges, where the pilot is kept almost exclusively in front of large screens and important information is integrated into the screen display. This provides a good basis for the use of touch screens in the flight deck. For example, the Boeing 777X demonstrated touchscreens installed in the flight deck to better enhance human-aircraft interaction (Boeing, 2016). There are several significant advantages to introducing touchscreen to flight decks. The most obvious is its excellent level of integration on different layers of systematic information (Yang et al., 2019). By reducing the distance between input and output, it allows for a better division of functional blocks and a reduction in pilot workload (Rouwhorst et al., 2017). At the same time, it further enhances the simplicity of the flight deck and makes it easier to update (Cockburn et al., 2019). At the same time, there are obvious disadvantages to the use of touchscreen in flight decks: the accuracy of touchscreen operation is significantly reduced in the event of vibration. Several studies are currently trying to solve this problem (Alapetite et al., 2018; Sadia et al., 2022). Due to the significant advantages of the touchscreen, many studies are trying to use it to do some of the tasks in the flight deck, such as navigation and checklist completion (Sadia et al., 2022; van Zon et al., 2020). However, most of this work is simple tap input, and so far, no research has attempted to integrate the inceptor functionality into touchscreen. The aim of this study is to investigate the advantages and disadvantages of touchscreen as an inceptor compared to sidestick, a traditional inceptor, and gamepad, using Cooper-Harper scale (CH) and Situation awareness Rating Technique (SART). Therefore, research questions are as followings:

RQ1: How would the touchscreen as inceptor affect handling quality on experienced pilots compared with sidestick and gamepad?

RQ2: How would the touchscreen as inceptor affect experienced pilots' SA compared with sidestick and gamepad?

2. Method

2.1. Participants

There were 8 participants were invited for this research, from 24 to 63 years old (M = 40.1, SD = 11.7). The fixed-wing flight experience of participants was from 800 to 8000 h (M = 4475.0, SD = 2742.1), the simulator experience was from 30 to 500 h (M = 247.5, SD = 157.4). The data of this paper was gathered from human participants and only for research propose, approved by Cranfield University Research Ethics System (CURES/14853/2021). Each participant would be presented the contract prior to the trial, only if they sign a contract will the experiment be carried out, and they had the right to end the experiment at any stage of the experiment and request that all data be deleted.

2.2. Apparatus and Materials

This research was conducted in the Rolls-Royce Future Systems Simulator (FSS) which was granted the iF DESIGN AWARD in 2021. The FSS is a highly reconfigurable modular flight simulator with information presented on up to four large reconfigurable touchscreens and two smaller side screens. This allows pilots to explore the potential impact on future flight decks design for single pilot operations including smarter, more autonomous engines, as well as revolutionary new technologies. Participants would be required to complete two tasks in the simulator: landing without turbulence and landing with turbulence. The turbulence was generated using a sum-of-sines algorithm. Under each of the two tasks, participants used three inceptors to perform the ILS landing: the sidestick, the gamepad from Microsoft and the touchscreen in the simulator (Fig.1a).

There were two assessment tools including Cooper-Harper Scale (CH) and Situation awareness rating scale (SART) to investigate pilots' feedbacks on the use of the touchscreen as inceptor. Cooper-Harper Scale was developed for evaluating aircraft handling qualities designed in 1969 (Mitchell, 2019). The scale is from 1 (the best handling quality) to 10 (the worst handling quality). Situation awareness rating scale was widely used for SA measurement, it contains 10 different questions, which is divided into three dimensions: demand, supply and understanding (Endsley et al., 1998). Participants had to complete those two surveys on the completion of each inceptor trail on both landing with turbulence and without turbulence scenarios (Fig.1b).

(a) (b)

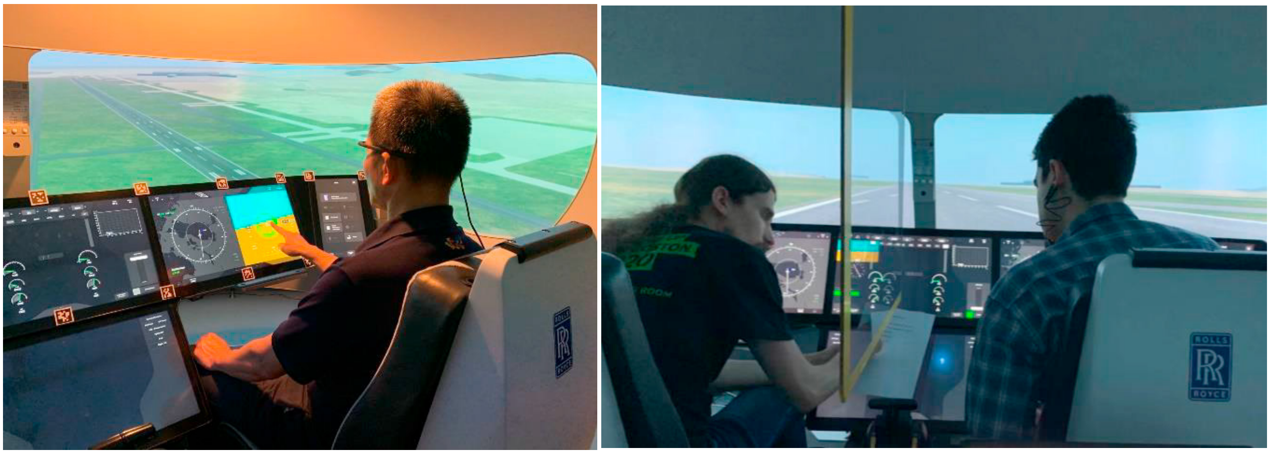


Fig. 1. (a) Participant using touchscreen as inceptor on the landing scenario; (b) Participants fill in the questionnaire after trials completion

2.3. Research design

This research involved in assessing HCI in flight operations using innovative touchscreen as control inputs compared with traditional sidestick and gamepad. Before the trial, all participants had been provided a consent form which consisted of all critical information related to the experiment and research design. Participants must read and signed the consent form. All participants undertook the following procedures; (1) complete the demographical information including age, gender, working experience and total flight hours (5 minutes); (2) briefing the purpose of the study and the processes on the two assessment tools (5 minutes); (3) seat in FSS for familiarized with touchscreen layouts on Primary Flight Display (PFD), gamepad and sidestick (5 minutes); (4) perform the scenario on instrument landing with turbulence and without turbulence using three inceptors randomly to eliminate practice effects. Participants were invited to complete two assessments including CH and SART after completing landing scenario (20-30 minutes); (5) debriefing and answering participants' questions (5-10 minutes). It took around 45 minutes for each participant to complete the experiments.

3. Result

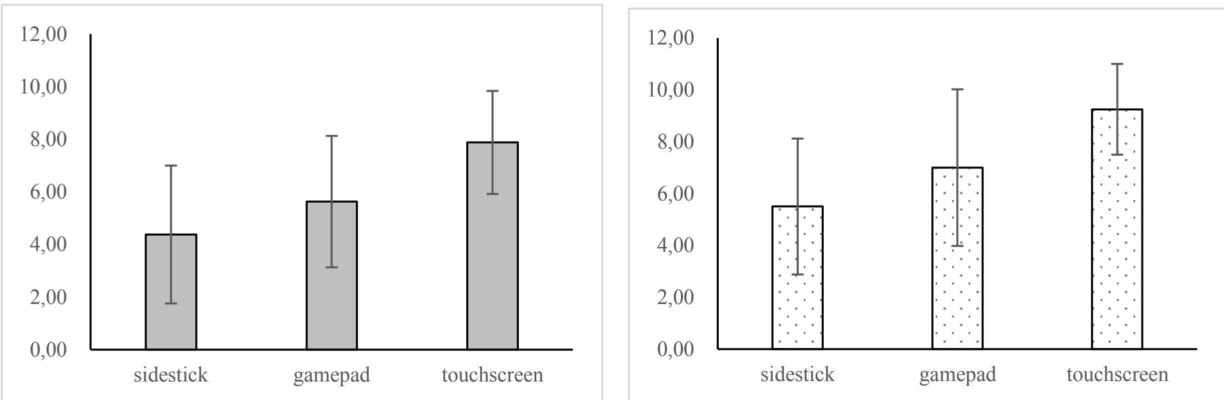
The one-way repeated measure was used for analysing the CH and SART score while participants using different inceptors (sidestick, gamepad and touchscreen) on performing ILS landing. In each scenario, participants' rating on two assessment scales were the dependent variables and three inceptors were independent variables. Descriptive statistics of CH and SART scores using three inceptors shown as table 1.

Table 1. Participants' means and standard deviations of different inceptors based on two different scenarios in CH and SART test

Scale	scenarios	sidestick		gamepad		touchscreen	
		M	SD	M	SD	M	SD
Cooper-Harper	LN	4.38	2.62	5.63	2.50	7.88	1.96
	LD	5.50	2.62	7.00	3.02	9.25	1.75
SART	LN	23.25	6.65	18.88	6.36	15.50	5.83
	LD	20.38	7.21	15.50	5.81	14.13	6.83

3.1. Cooper-Harper scale (CH)

A one-way repeated measure ANOVA on different inceptors (sidestick, gamepad and touchscreen) was conducted to analyse the CH results of pilots under landing without turbulence (LN) and landing with turbulence (LD). The handling quality is the inverse of the CH score, the higher the CH score, the lower the handling quality. There was a significant difference among three inceptors in LN scenario, $F(2,14) = 6.25$, $p = .01$, $\eta_p^2 = .47$. Furthermore, post Hoc comparisons revealed that the touchscreen was significantly higher than sidestick ($p = .02$). Similarly, there was a significant difference among three inceptors in LD scenario, $F(2,14) = 3.93$, $p = .04$, $\eta_p^2 = .36$, post Hoc comparisons revealed that the touchscreen was significantly higher than sidestick ($p = .03$) (Fig.2a & 2b).



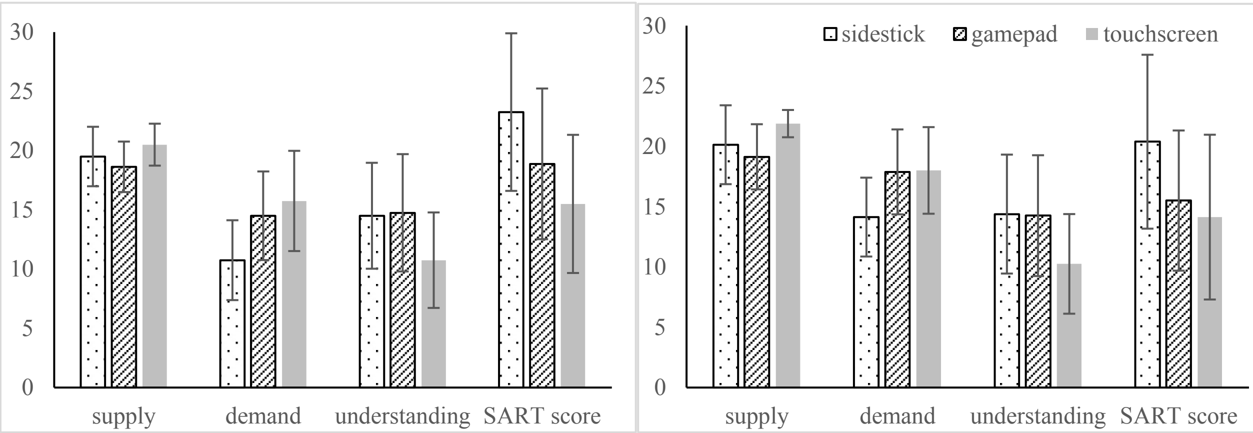
(a) ILS landing without turbulence (b) ILS landing with turbulence

Fig. 2. Participants' rating on Cooper-harper scale using three inceptors in landing without turbulence scenario (a) and in landing with turbulence scenario (b)

3.2. Situation awareness rating technique (SART)

The situation awareness rating technique could measure pilots' SA which consisted with three dimensions on supply, demand and understanding. In landing without turbulence scenario (LN), there was no significant difference among three inceptors on SART supply ($F(2,14) = 2.12$, $p = .16$, $\eta_p^2 = .23$), but the post Hoc comparisons revealed that the touchscreen was significantly higher than gamepad ($p = .04$). There was a significant difference among three inceptors on SART demand in LN scenario, F (2,14) = 4.65, p = .03, η_p^2 = .40. Post Hoc comparisons revealed that the touchscreen was significantly higher than sidestick (p = .04), and gamepad is significantly higher than sidestick (p = .03). There was a significant difference among three inceptors on SART understanding in LN scenario, F (2,14) = 6.62, p = .009, η_p^2 = .49. Post Hoc comparisons revealed that the touchscreen was significantly lower than sidestick (p = .04) and gamepad (p = .007). SART total score showed that there was a significant difference among three inceptors, F (2,14) = 6.07, p = .01, η_p^2 = .47, and post Hoc comparisons revealed that the touchscreen was significantly lower than sidestick (p = .03) (Fig. 3a).

There was a significantly different among three inceptors on SART supply in LD scenario (F (2,14) = 3.21, p = .07, η_p^2 = .32). Post Hoc comparisons revealed that the touchscreen was significantly higher than gamepad (p = .03). There was a significant difference on SART demand, F (2,14) = 3.92, p = .04, η_p^2 = .36. Post Hoc showed that the touchscreen was significantly higher than sidestick (p = .04). Furthermore, a significant difference on SART understanding among three inceptors was also found in LD scenario, F (2,14) = 5.68, p = .02, η_p^2 = .44. Though the inceptors were different from each other in three dimensions of SART, the SART total score in LD scenario had no significant difference, F (2,14) = 2. 83, p = .09, η_p^2 = .28 (Fig. 3b).



(a) ILS landing without turbulence (b) ILS landing with turbulence

Fig.3. Participants' rating on situation awareness rating technique on three inceptors in landing without turbulence scenario (a) and in landing with turbulence scenario (b)

4. Discussions

The trial of touchscreen as an inceptor is a preliminary concept on flight deck design to explore the potential for further application. The levels of applicability and user's acceptance on using touchscreen as inceptor are still unknown in the flight deck, as it didn't exist in current flight deck yet. Therefore, this research is a critical topic for human-centred flight deck design for safety, usability and cost-efficiency. CH rating scale is for evaluating aircraft handling quality with a specific definition of the pilot's task and of its performance standards. It accounted for the demands the aircraft placed on the pilot in accomplishing a given task to some specified degree of accuracy and could also be considered to assess workload (Cotting, 2011; Mitchell, 2019). The result of Cooper-Harper demonstrated that touchscreen inceptor was significantly higher on CH score than the sidestick in both ILS landing scenarios. It implied that handling quality of touchscreen as inceptor was poorer than traditional sidestick and gamepad inceptor. This may be associated with a variety of factors including familiarity with the inceptors. Commercial pilots with extensive expertise using the traditional sidestick than the innovative operational concept on touchscreen were invited to participate in this trial. As a result, participants were more likely to experience discomfort when using a touchscreen as control input to perform the most complicated task on ILS landing (Fig.2a & 2b). This result is consistent with previous social psychology research, where users prefer products or devices with a high familiarity (Chevalier et al., 2013). Participants also expressed concerns on the touchscreen as inceptor inducing fatigue on the fingers as using touchscreen inceptor required arm and fingers to be suspended in the air without physical supports, which would make users more likely suffering from physical fatigued and negative feedbacks and lower ratings (Harvey et al., 2011).

The SART is a quick and accurate subjective scale for evaluating pilot's SA (Endsley et al., 1998). In this study, SART was used to analyse pilot's SA on using touchscreen as control inputs compared with traditional sidestick and gamepad. The findings demonstrated that participants' overall SA levels were the lowest using touchscreen inceptor than sidestick and gamepad. However, among the three sub-dimensions of the SART, touchscreen scored highest in both demand and support, though significantly lower on the dimension of understanding (Fig.3a). Under landing with turbulence scenario, similarly, touchscreen had a much higher supply score than sidestick and a significantly higher demand than sidestick, but no significant difference was found in calculated SART score (Fig.3b). It is interesting to observe that the touchscreen was rated as the highest on both supply and demand but the lowest on understanding. The potential application of touchscreen can integrate input and output in the same area for visual feedback (Albinsson & Zhai, 2003). While it shows many promises, one must consider human-computer interaction (HCI) challenges and pilots' situation awareness in the future flight deck design (Carroll & Dahlstrom, 2021). On the other side, the lack of physical feedback may also be the main reasons why touchscreen scores significantly lower than sidestick and gamepad in terms of understanding (Liu et al., 2022; Wan et al., 2017). The participants' decreased accessible cognitive resources may be the cause of the touchscreen's lower overall SA score. Pilots have limited cognitive resources on utilising an unfamiliar control input in flight operations which could result in a lower SA (Oliver et al., 2017).

It is understandable that pilots preferred sidesticks than touchscreens and gamepad as inceptor. The gamepad was also offered as a comparator to the touchscreen in order to determine how much proficiency influencing subjective evaluation. The results reveal that the gamepad rated somewhat better than the touchscreen while having a lower CH score and the SART total score than the sidestick. The proficiency had some bearing on the outcomes of all two subjective scales on current research. However, the performance of the gamepad is rather better than that of the touchscreen, even when used as an inceptor for the first time, suggesting that the touchscreen has some issues when used as an inceptor. The finding suggests that touchscreen is not yet mature enough to be used as an inceptor. In particular, the handling quality of touchscreen is significantly decreased under higher turbulence. Recently, there were some studies working on enhance the usability and reduced the influence of turbulence for touchscreen, for example, folding touchscreen, braced-finger for more stable interaction with touchscreen, providing visual and audio assistance, adding a graspable area for increasing stabilization and efficient touchscreen interface interactive selection (Cantu et al., 2021; Cockburn et al., 2019; Coutts et al., 2019; Dodd et al., 2019; Wan et al., 2017). There is optimism that as research and technology develop, the drawbacks of the touchscreen will be mitigated so that it may be utilised more successfully in future flight decks.

5. Conclusion

This research is the first attempt to use the touchscreen as an inceptor and to investigate the difference in handling quality and overall SA between the touchscreen, traditional sidestick and gamepad. The results demonstrated that experienced pilots still preferred sidestick as inceptor than touchscreens while compared to the ratings for handling quality and overall SA. However, the touchscreen could provide integrated information for high supply on SART score, which indicates touchscreen is particularly effective in integrating complicated information. In conclusion, touchscreens provide potential benefits for further development, though touchscreen applications are still in their infancy and are not yet fully established. There are limitations in this study, firstly, the sample of pilots was only recruited from experienced pilots and the experimental scenario was only selected for ILS landing with and without turbulence, which is not representative of all pilot groups and all scenarios in flight operations. Secondly, the research also lacked objective evaluations such as eye tracking and flight data related to pilots' performance. Despite these limitations might have impacts to the contributions on current research, there are some potential benefits on the implementation touchscreen for future flight deck design if the human-centred design principle can be integrated in the early.

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Declaration of Interest

The authors declared that they have no commercial or associative interest that represents a conflict of interest in connection with the work submitted.