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Piloting an aircraft is a difficult task that requires high-level cognitive abilities. Few studies have investigated the use of cognitive assistants to support pilots. This study is a first step toward an in-flight assistant for light aircraft pilots. We applied a user-centered approach to develop BLEXVFR, a mobile application that enables pilots to access information and program alerts. A pilot study in a simulator with four pilots showed that the user experience of BLEXVFR was at least comparable to existing applications.

CCS Concepts: • **Human-centered computing → HCI design and evaluation methods**; *Interactive systems and tools*; Touch screens.

Additional Key Words and Phrases: general aviation; mobile application; navigation application; user-centered design

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1 INTRODUCTION

Piloting an aircraft takes place in a complex, changing and dynamic environment. It requires high-level cognitive abilities including Executive Functions which contribute to planning actions, processing large amounts of information, storing data in short term memory, or regulating the behavior in case of a stressful event [8]. Moreover, an attentional effort is necessary to continuously integrate various information displayed on the cockpit instruments or coming from the outside world [9]. In the context of General Aviation (i.e. civil aviation that is not commercial air transport or aerial work operation), pilots are often alone on board (with no copilot) and generally have less training and experience. Light aircraft are also less equipped with assistance systems than aircraft from Commercial Aviation, thus enhancing the need for the development of tools that can support the pilots. Previous studies on aviation in HCI have mainly focused

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on Commercial Aviation [4, 13, 16] rather than General Aviation. In this work, we aim at supporting General Aviation pilots. They have to memorize a large amount of information (e.g. coming from air traffic control). Usually this is done by taking notes on a paper sheet, which is not very practical during flight. Consequently we have chosen to focus on information display during flights and what tool would be appropriate. In order to enable the use in any aircraft, we designed a mobile system (i.e. a system that is not integrated in the aircraft and can be carried along by the pilot).

2 RELATED WORK

2.1 Existing mobile applications for pilots in General Aviation

Different air navigation applications are already widely used by pilots in General Aviation. *Active Checklist* is intended to help the pilot by providing checklists, i.e. lists of tasks that need to be performed, during the different phases of the flight. It also analyzes the different phases of flight and proposes related information. Another example is *VFR Time* which manages the timing during the different flight phases. It is possible to enter the execution times of certain actions (take-offs, landings, etc.) which will then allow the system to inform the pilot. *AirMate* is a comprehensive navigation application. It allows the pilot to enter his complete flight plan and to visualize a map with useful information for the air navigation. Like *Active Checklist*, the application proposes the pilot to note information and then to retrieve it later. Finally, *SDVFR* is a comprehensive and widely used navigation application[1]. It allows the pilot to enter his complete flight plan and then to carry it out in real time by visualizing the information that will be necessary. The information displayed on the screen is customizable. *SDVFR* proposes access to manuals, to weather data, to data related to the terrain but also to the navigation data such as the radio frequencies.

All applications mentioned here offer simple interactions, mainly based on single taps. *Air Mate* and *SDVFR* offer the possibility to move the map view by tapping and moving the finger. They also allow to zoom in and out of the map using two finger pinch. Moreover, *SDVFR* proposes a long press allowing to add a navigation point to the map. A navigation point can be moved by "drag and drop". These are standard gestures commonly used to interact with mobile devices [18].

2.2 Aeronautics and HCI

Prior studies in HCI on in-flight assistance and the use of tactile devices in the cockpit, have often focused on commercial aviation. Previous work [4, 13] suggests to address the limitations of modern touch-based interfaces in the cockpit by tangible interactions. Pauchet et al. [16] proposed an adaptive touch interface that changes its shape according to the pilot's gaze direction. The surface remains flat while the pilot is looking at the screen (and acts like a touchscreen device). Knobs emerge from the surface when the pilot looks away, allowing him to interact with the device without having to look at it. In a more general context, Cockburn et al. [5] demonstrated the difficulties of using tactile devices in the cockpit due to vibrations and proposed a touchscreen stencil overlay to help stabilize the finger in a turbulent environment. In another study, braced touch proved to be an interaction technique that is usable in a turbulent environment [6]. Previous studies also suggest not to overload the auditory channel [14, 17] which is already heavily used in aviation (e.g. radio communication between pilots and air traffic controllers). Finally, when designing for aeronautics, one has to consider inattentional blindness and deafness which occur in situations with high cognitive demand [7, 15, 19].

[1]SDVFR had 4.8 stars on the Appstore on Mai 26th 2021 https://apps.apple.com/fr/app/sdvfr/id916562607. See also https://skydreamsoft.fr/en_US/

Table 1. Participants characteristics. Design Process steps: I = Interview, B = Brainstorming, W = Design Walkthrough, P = Pilot study

Participant	Gender	Age	Flight Experience (hours)	Design process steps
P1	F	59	2000	I, B, P
P2	M	22	50	I
P3	M	61	3000	I, B, W, P
P4	M	50	6000	I, B
P5	M	52	12000	I
P6	M	21	75	B, W
P7	M	25	200	B, W, P
P8	M	21	50	B, W, P
P9	M	24	200	B, W
P10	F	23	50	B

3 THE DESIGN PROCESS

To design a system that meets the users' needs, in our case pilots of General Aviation, we applied a user-centered design approach [2] and involved users at every stage of the design process. Our design process consisted of interviews, brainstorming sessions, design walkthroughs with a first version of the prototype and a pilot study with a second version of the prototype. Due to restrictions during the COVID crisis, we had to adapt the process to comply with the local instructions and some steps had to be conducted online. Ten pilots were involved in the process. Table 1 shows the participants gender, age, flight experience and the design steps they were involved in.

3.1 Interviews

We conducted semi-structured interviews with five pilots (P1 to P5) with at least 50 hours of flight experience and an average of 4600 hours (min = 50, max = 12000, SD = 4155). Interviews were conducted online. The questionnaire inquired about pilots habits to memorize or retrieve information during flights, recent flight experiences and critical experiences they have encountered in the past. We observed that some pilots (but not all) take handwritten notes during flights and use a personal symbology (such as underlining text or using pictograms to highlight important pieces of information). Less experienced pilots note more information, due to their lack of experience.

3.2 Brainstormings

To gather more information about how and when pilots need to memorize information, we conducted two brainstorming sessions. Eight of the ten pilots were involved (P1, P3, P4, P6, P7, P8, P9 and P10), split into two groups of four participants. Three facilitators were present during each session. Both sessions were handled virtually, using videoconferencing tools and Miro Boards. The sessions were organized as follows : the participants were first given 10 minutes to come up with as many ideas as possible to answer the following question: "When do you have to memorize information (such as when receiving instructions from air traffic controllers)? Which device do you find efficient to take notes and use them later in another situation? And how do you use it to memorize information?". Then all participants shared their ideas and discussed them, and finally the participants had to vote for the three ideas that they considered the most relevant. We then asked them the opposite question: "What would be inefficient to memorize information (such as air traffic controllers' instructions) and to access them later on?". The participants were given another 10 minutes to answer before discussing it together and voting for the most relevant suggestions.

3.2.1 *Results from the brainstorming session and next steps.*

The answers we collected can be summed up from both questions in both sessions as follows : the system should be usable without any training since General Aviation pilots will not receive specific training for it, it should not be intrusive (i.e., it should not overload visual and auditory channels which are already heavily used in the cockpit), it should be fast (in a critical context like aviation the pilots cannot afford any delay) and suitable for operational use. One idea that participants came up with is to display information while at the same time accessing a map of the area with the flight plan. This is in line with applications which pilots are already using, such as *SDVFR*.

From this brainstorming session, we concluded that our system should not provide too much auditory feedback, since the pilots explicitly mentioned this. We also decided to use a geographic map in line with existing applications. Moreover, we were aiming at including some automatic information in order to speed up the information retrieving.

3.3 First prototype

The inputs gathered during interviews and brainstorming allowed us to build a first version of a prototype. We aimed for a mobile application that shows a map, provides information related to the flight and allows to take notes. Moreover, most information should be communicated visually in order to avoid auditory overload.

We first produced paper mockups to quickly represent the ideas before developing high fidelity prototypes on an Android tablet (Huawei Mediapad M55). The first version of the prototype (Fig. 1) included the following features:

- Flight information panel: allows the pilot to find in real time the most important parameters of the aircraft (ground speed, altitude, heading, current latitude and longitude of the aircraft).
- Frequency of the Flight Information Service (FIS): depending on the geographic zone, pilots need to call air traffic controllers on specific radio frequencies.
- Timeline: schematic representation of the flight plan. It shows the different stages of the flight, the estimated arrival times at each point, the fuel estimates, the points that have been passed, etc. Touching a point on the timeline allows the pilot to access additional information on this point (e.g., minimum altitude of overflight).
- Fuel estimation: provides an estimate of the current fuel level and calculates fuel estimates at upcoming points.
- Speed vector: provides a visual indication of where the aircraft will be in 2, 3, 5 and 10 minutes if the pilot maintains its current heading and ground speed (black line with circles 2, 3, 5 and 10 in Fig. 1). The prototype receives data such as speed and heading from the flight simulator via UDP packets.. This feature is also present in other systems and is important because it allows pilots to understand the future aircraft's trajectory.
- Alert programming by means of a "circle gesture": by drawing a circle with the finger (around a beacon or an airfield for example, or on any point of the map) an alert is programmed. When the aircraft approaches the point the assistant triggers a notification. This is particularly useful when air traffic control asks the pilot to call back at a certain point. This is a novel feature which is not available in existing systems.

3.4 Design Walkthrough

In order to obtain early feedback from pilots, we conducted design walkthrough sessions with the first version of the prototype. The purpose of this step is to identify as many problems as possible before implementing the final prototype. Five pilots were involved in this step of the process (P3, P6, P7, P8 and P9), each of them reviewed the features systematically with the facilitators' help. One session was done online, and four sessions were done on-site.

Figure 1 shows a screenshot captured during a virtual session of design walkthrough. The design walkthrough allowed us to identify a list of items to be modified for the next version of the prototype (see below).

Fig. 1. Online design walkthrough session. (Left) screen of the facilitators presenting the prototype. (Top right) facilitators presenting the prototype to the participant (bottom).

3.5 Functional prototype

Based on the feedback collected during the design walkthrough, we conducted another iteration of the functional prototype. The list of features for this version is the one described in subsection 3.3 with the following changes:

- Navigational markers: common navigational markers are displayed on the map (VFR[2] reporting points, airfields, etc.). These markers are reference points for pilots during their navigation.
- SDOACI map background: the map background was switched from google maps to an aeronautical map which was kindly provided upon our request by the developers of SDVFR.
- Flight information panel: as mentioned above. During the design walkthroughs pilots considered the latitude and longitude not helpful, so we removed them.

4 PILOT STUDY

The aim of this experiment was to check that our system (called BLEXVFR) would allow pilots to perform routine piloting tasks in a manner equivalent to other systems. We used SDVFR as a reference system since this system is widely used by General Aviation pilots including those who participated in our study.

4.1 Participants

Four pilots (P1, P3, P7, P8) took part in this experiment. Pilots had at least a flying experience of 50 flight hours and were familiar with flight simulator environments. All participants filled a written consent form. All participants had participated in at least another step of the design process described above.

[2]VFR : Visual Flight Rules

Fig. 2. The experimental setup: FlightSimulator2020 displayed on a computer screen, yoke, pedals, joystick and the tablet.

4.2 Simulation environment

The study was conducted using the amateur flight simulator Microsoft FlightSimulator2020 on a computer. The participant was seated in front the screen at a comfortable distance. The simulator was connected to flight rudder pedals and a Honeycomb Alpha Flight Controls yoke system as shown in Fig 2. Our prototype and the reference application were displayed in a HUAWEI MediaPad M5 tablet.

4.3 Scenarios

For this experiment we created two flight plans (equivalent in terms of difficulty). Each flight lasted approximately 35 minutes. The participants were asked to perform one flight using SDVFR as a reference and the other one using BLEXVFR. The scenarios and applications were counterbalanced across participants as described in Table 2. Before the beginning of the simulation, the participants were instructed to contact the air traffic controllers (simulated by one facilitator) at some key navigation points and to switch the fuel tank when the fuel was below a given threshold. Then they were given the flight plan and had 10 minutes to familiarize with the system before conducting the flight.

4.4 Measures

After each flight, participants were asked to fill forms to evaluate their perceived workload by using NASA-TLX [10], their user experience by using Attrakdiff [11, 12] and the usability of the system by using the SUS [3] questionnaire. They were also asked to answer some open-ended questions.

5 RESULTS AND DISCUSSION

We used the usability scale defined by Bangor et al. [1] to assess the SUS results. Scores for both prototypes were above acceptable, and for BLEXVFR they were even excellent (SDVFR: mean = 70, SD = 12.9; BLEXVFR mean = 89.4, SD = .5).

The Attrakdiff questionnaire provided a quantitative measure of the user experience on four scales : 1) the pragmatic quality (BLEXVFR = 2, SDVFR = 0.8), 2) the hedonic stimulation quality (BLEXVFR = 0.5, SDVFR = -0.1), 3) the hedonic

Table 2. Counterbalanced scenarios

Participant	Flight #1	Flight #2
P1	Flight Plan 1 X BLEXVFR	Flight Plan 2 X SDVFR
P3	Flight Plan 1 X SDVFR	Flight Plan 2 X BLEXVFR
P7	Flight Plan 2 X BLEXVFR	Flight Plan 1 X SDVFR
P8	Flight Plan 2 X SDVFR	Flight Plan 1 X BLEXVFR

Table 3. NASA-TLX Scores

	Mental demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
BLEXVFR	17.5	10	18.8	17.5	25	32.5
SDVFR	42.5	17.5	17.5	30	32.5	38.8

identity quality (BLEXVFR = 0.6, SDVFR = 0), and 4) the overall attractiveness (BLEXVFR = 1.8, SDVFR = 0.9). Scores between 0 and 1 show that the system serves its purpose (both hedonic scales for BLEXVFR). Scores above 2 mean that this is a strength of the system, which is the case for the pragmatic quality and almost for overall attractiveness for BLEXVFR. In our test, none of the systems scored negatively which would indicate pain points.

We also measured the perceived workload using the NASA-TLX questionnaire. The scores of each sub-scale are presented in Table 3. For this first version of BLEXVFR, we wanted the perceived workload to be lower or equal to the one perceived using SDVFR. The only sub-scale that does not meet this expectation is "Temporal Demand". We think that can be explained by the "alert" features in BLEXVFR which demand an immediate action from the pilot.

Our system shows encouraging results with however some limitations. First, only four participants tested our prototype so far. This means that we could not run any statistical tests, and findings from this pilot study should be considered as trends which need to be verified in a larger user study. In this pilot study we compared our prototype BLEXVFR to the existing system SDVFR. However, only a subset of features was compared since our prototype does not yet provide the full set of features present in SDVFR. In the future we aim at completing our prototype with the missing features, like a semantic zoom on the map and on the timeline. Moreover, we intend to iteratively improve the design of the prototype. For instance, so far we have chosen the circle gesture for programming alerts. Previous work has shown that turbulences have an impact on gestural interaction with mobile devices [5, 6]. In our future work, we intend to test different gestural interactions with regard to this and select the interaction technique that is best adapted for aviation. Finally we aim at evaluating the entire system in a longer study. The simulation environment is adapted for a preliminary evaluation but does not reflect ecological conditions in an airplane. For instance, we couldn't test whether our system was usable during turbulences. In the future, we would like to test our system in a flight simulator with more realistic conditions or in a real airplane.

6 CONCLUSION AND FUTURE WORK

In this study, we presented a first step toward a mobile assistant for light aircraft pilots. We used a user-centered approach with General Aviation pilots to develop and evaluate our prototype BLEXVFR. Our pilot study shows that the user satisfaction and user experience for BLEXVFR is at least comparable to an existing similar application. Next steps for this research are to refine the design of our prototype based on the findings of the design process. We also aim to evaluate our system in a more ecologically valid context and with a larger number of participants. To date, few studies in HCI have focused on evaluating cognitive assistants for pilots, and more specifically for General Aviation pilots. We believe that those assistants have the potential to improve safety of aviation in the future.

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REFERENCES

[1] Aaron Bangor, Philip T Kortum, and James T Miller. 2008. An empirical evaluation of the system usability scale. *Intl. Journal of Human–Computer Interaction* 24, 6 (2008), 574–594.

[2] Michel Beaudouin-Lafon and Wendy E Mackay. 2007. Prototyping tools and techniques. In *The human-computer interaction handbook*. CRC Press, 1043–1066.

[3] John Brooke et al. 1996. SUS-A quick and dirty usability scale. *Usability evaluation in industry* 189, 194 (1996), 4–7.

[4] Juan Angel Lorenzo del Castillo and Nadine Couture. 2016. The Aircraft of the Future: Towards the Tangible Cockpit. In *Proceedings of the International Conference on Human-Computer Interaction in Aerospace* (Paris, France) *(HCI-Aero '16)*. Association for Computing Machinery, New York, NY, USA, Article 11, 8 pages. https://doi.org/10.1145/2950112.2964582

[5] Andy Cockburn, Carl Gutwin, Philippe Palanque, Yannick Deleris, Catherine Trask, Ashley Coveney, Marcus Yung, and Karon MacLean. 2017. Turbulent touch: Touchscreen input for cockpit flight displays. In *International Conference for Human-Computer Interaction (CHI 2017)*. 6742–6753.

[6] Andy Cockburn, Damien Masson, Carl Gutwin, Philippe Palanque, Alix Goguey, Marcus Yung, Christine Gris, and Catherine Trask. 2019. Design and evaluation of braced touch for touchscreen input stabilisation. *International Journal of Human-Computer Studies* 122 (2019), 21–37. https://doi.org/10.1016/j.ijhcs.2018.08.005

[7] Frédéric Dehais, Mickaël Causse, François Vachon, Nicolas Régis, Eric Menant, and Sébastien Tremblay. 2014. Failure to Detect Critical Auditory Alerts in the Cockpit: Evidence for Inattentional Deafness. *Human Factors* 56, 4 (2014), 631–644. https://doi.org/10.1177/0018720813510735 arXiv:https://doi.org/10.1177/0018720813510735 PMID: 25029890.

[8] Adele Diamond. 2013. Executive functions. *Annual review of psychology* 64 (2013), 135–168.

[9] Klaus-Martin Goeters, Peter Maschke, and Hinnerk Eißfeldt. 2004. Ability requirements in core aviation professions: Job analysis of airline pilots and air traffic controllers. *Aviation psychology: Practice and research* (2004), 99–119.

[10] Sandra G Hart and Lowell E Staveland. 1988. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In *Advances in psychology*. Vol. 52. Elsevier, 139–183.

[11] Marc Hassenzahl, Michael Burmester, and Franz Koller. 2003. AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. In *Mensch & computer 2003*. Springer, 187–196.

[12] Carine Lallemand, Vincent Koenig, Guillaume Gronier, and Romain Martin. 2015. Création et validation d'une version française du questionnaire AttrakDiff pour l'évaluation de l'expérience utilisateur des systèmes interactifs. *European Review of Applied Psychology* 65, 5 (2015), 239–252.

[13] Catherine Letondal, Jean-Luc Vinot, Sylvain Pauchet, Caroline Boussiron, Stéphanie Rey, Valentin Becquet, and Claire Lavenir. 2018. Being in the sky: Framing tangible and embodied interaction for future airliner cockpits. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*. 656–666.

[14] Christophe Lounis, Vsevolod Peysakhovich, and Mickael Causse. 2019. *Flight Eye Tracking Assistant (FETA): Proof of Concept*. 739–751. https://doi.org/10.1007/978-3-030-20503-4_66

[15] Arien Mack. 2003. Inattentional Blindness: Looking Without Seeing. *Current Directions in Psychological Science* 12, 5 (2003), 180–184. https://doi.org/10.1111/1467-8721.01256 arXiv:https://doi.org/10.1111/1467-8721.01256

[16] Sylvain Pauchet, Catherine Letondal, Jean-Luc Vinot, Mickaël Causse, Mathieu Cousy, Valentin Becquet, and Guillaume Crouzet. 2018. Gazeform: dynamic gaze-adaptive touch surface for eyes-free interaction in airliner cockpits. In *Proceedings of the 2018 Designing Interactive Systems Conference*. 1193–1205.

[17] Florine Simon, Anke Brock, and Mickael Causse. 2020. Designing a virtual cognitive assistant for pilots: a user-centered approach. In *ICCAS - International Conference on Cognitive Aircraft Systems*. Toulouse, France. https://hal-enac.archives-ouvertes.fr/hal-02962426

[18] Jessica J. Tran, Shari Trewin, Calvin Swart, Bonnie E. John, and John C. Thomas. 2013. Exploring Pinch and Spread Gestures on Mobile Devices. In *Proceedings of the 15th International Conference on Human-Computer Interaction with Mobile Devices and Services* (Munich, Germany) *(MobileHCI '13)*. Association for Computing Machinery, New York, NY, USA, 151–160. https://doi.org/10.1145/2493190.2493221

[19] Christopher D Wickens. 1980. The structure of attentional resources. *Attention and performance VIII* 8, 239–257.