MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY OF UKRAINE
Aviation Psychology Department

8th Scientific Workshop on Aviation & Emergency Psychology

SWAEP-2013

November 19-20, 2013

Trends and Ideas of Human-Machine Systems Improvement in Aviation

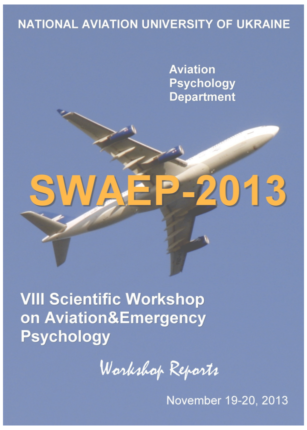
Oleksandr Petrenko

Language: English

Conference Paper
Presented at the 8th Scientific Workshop on Aviation & Emergency Psychology,

November 19-20, 2013

National Aviation University
Kyiv, Ukraine



Citation:
Petrenko, O.V. (2013). Trends and Ideas of Human-Machine Systems Improvement in Aviation. *In Proceeding of the 8th Scientific Workshop on Aviation & Emergency Psychology* (pp. 15–20). National Aviation University
https://doi.org/10.5281/zenodo.20136140

TRENDS AND IDEAS OF HUMAN-MACHINE SYSTEMS IMPROVEMENT IN AVIATION

Oleksandr Petrenko

National Aviation University (NAU), Aviation Psychology Department
Kyiv, Ukraine

The article contains a survey of several approaches to the integration of human and machine components of a socio-technical system under conditions of growing automation capabilities. Some data concerning pilots' perception of a highly automated cockpit are presented. The article considers a number of promising areas of innovation. It offers the idea of tuning onboard systems to the individual-typological characteristics of a particular operator in addition to adapting interfaces to the current human condition. The paper discusses the perspectives of language modality in human-machine interaction. The author believes that the personality-centered approach provides the best basis for the psychological weltanschauung of aviation developers under present conditions and especially in the long term, given the structure of a pilot's psychological difficulties in a highly automated cockpit.

Keywords: *human-machine interaction, human-machine interface, heuristic problems, speech modality, personality-centered approach.*

Introduction

Improvement of human-machine systems is associated not merely with the improvement of machines on the one hand and personnel training on the other. It concerns ensuring the best possible consistency between human and machine units whose properties are fundamentally different. As experience shows, despite these differences, it is possible to achieve the necessary consistency between human and machine components in relation to the specific tasks of the system and the content of human-machine interaction..

S. Gerathewohl wrote about a subtle manifestation of the psychological coupling of a human and an aircraft, noting that a pilot experiences special mental states and feelings that provide the best human-machine interaction.

At an early stage of computer hardware development, J.C.R. Licklider envisioned that humans and machines could be coupled together and work interactively. He wrote: «Man-computer symbiosis is an expected development in cooperative interaction between men and electronic computers. It will involve very close coupling between the human and the electronic members of the partnership. The main aims are 1) to let computers facilitate formulative thinking as they now facilitate the solution of formulated problems, and 2) to enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs. In the anticipated symbiotic partnership, men will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations… Preliminary analyses indicate that the symbiotic partnership will perform intellectual operations much more effectively than man alone can perform them» [6, p. 4].

Movement toward such a partnership in the era of expanding information technologies not only accelerates but also becomes more controversial. It requires a comprehensive assessment of the meaning and implications of ideas and constructive decisions related to the implementation of information technologies intended to support and deepen human-machine interaction in aviation.

A Need for Innovation

So, the key manifestation of human-machine symbiosis is achieving high human efficiency while reducing the psychological costs of work.

It is known that a human operator in a highly automated cockpit faces many difficulties, and the total psychological load at certain periods of time can be even higher than in cockpits with lower levels of automation.

The problem of human adaptation to activity conditions in highly automated cockpits can be addressed by introducing an elaborate training system. Nevertheless, the problem is not completely solved. We conducted a survey (2013) involving pilots of airlines based in Ukraine flying Boeing 737-500 aircraft [7]. The pilots were asked to assess how the modern level of cockpit automation had influenced their work using bipolar scales (Figure 1). The general picture is positive according to the average data. On the other hand, the responses of individual pilots demonstrated that the problem is evident, as can be seen from the considerable variation in the ratings shown in the figure. It is important that on the scale "more stressful – calmer work" some respondents placed two marks on opposite sides despite the instructions given.

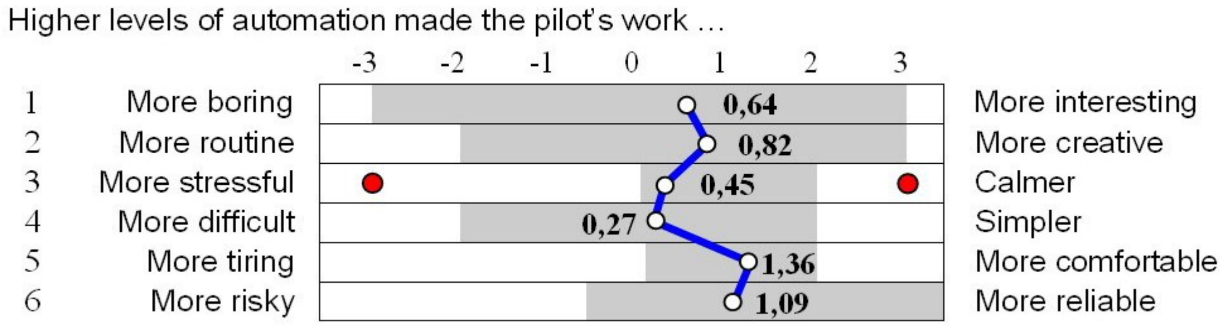


Figure 1. Pilots' perception of a highly automated cockpit.

Answering the question about difficulties occurring during transition training for this type of aircraft, the respondents admitted that they had experienced difficulties in the training process:

- Difficulties in understanding the logic of automation interaction (45% of respondents);
- Difficulties in transferring from a multi-member crew to a two-member crew because of function redistribution (12% of respondents).

Moreover, the respondents reported adaptation difficulties related to the large number of control rather than executive functions; difficulties in perceiving visual information; and doubts concerning the reliability of automation.

The data obtained prove that a pilot training system alone is not a comprehensive means of solving problems related to automation. It is obvious that such systems are effective, but further hardware and software development aimed at improving human-machine interaction is truly needed. Let us consider some guidelines for continuing innovation.

The Development of Human-Machine Interfaces

The higher the level of aircraft cockpit automation, the more difficult it becomes to assess the risk of crew activity failure under working conditions characterized by patterned control procedures.

One aspect of solving this problem concerns the introduction of technologies taking into account the human state in information display systems and the creation of Cognitive Adaptive Man-Machine Interfaces [1]. The functioning of such interfaces is carried out taking into account instrumental data concerning the current human state together with data about the condition of the controlled object, environment, and situation, which makes it possible to avoid human information overload and harmonize human interaction with the machine.

Our studies are aimed at exploring the possibilities of "adjusting" human-machine interaction to the typological characteristics of an operator. The idea consists in creating a system that will enhance human capabilities through the individualization of information presentation. While the CAMMI approach allows identification of the moment of operator overloading (Dorneich et al.), one of our ideas is to create a system capable of individualizing information presentation.

To solve this problem, it is necessary to study and formalize the regularities of interrelations between different psychic functions, as well as the individual characteristics and typological differences of interaction between different psychic processes. Discovering these regularities will allow not only better current assessment of the reliability of the human element, but also realization, at a new level, of adaptive information models aimed at minimizing the risks of faulty actions connected with human information overload.

We were interested in two principal cases involving voice interaction under conditions of performing a background cognitive task requiring a psychomotor response. In the first case, a human operator generated different voice messages (Figure 2), while in the second case, the operator perceived and processed different voice messages (Figure 3).

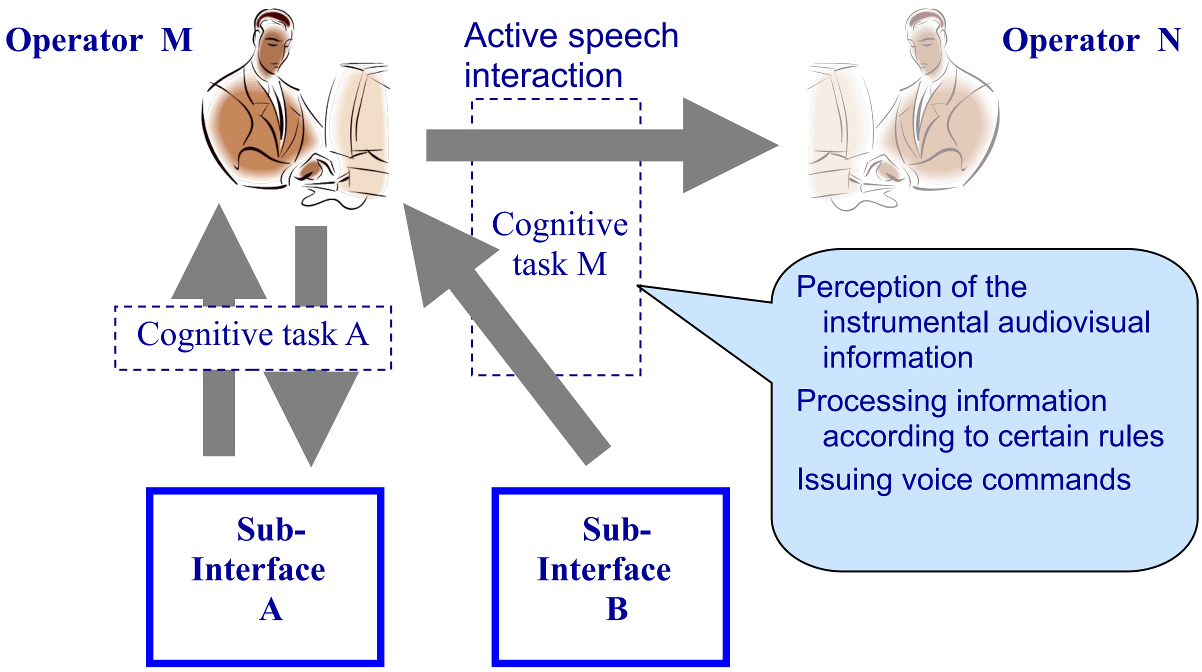


Figure 2. The case in which a human operator generated different voice messages while performing a background cognitive task requiring a psychomotor response.

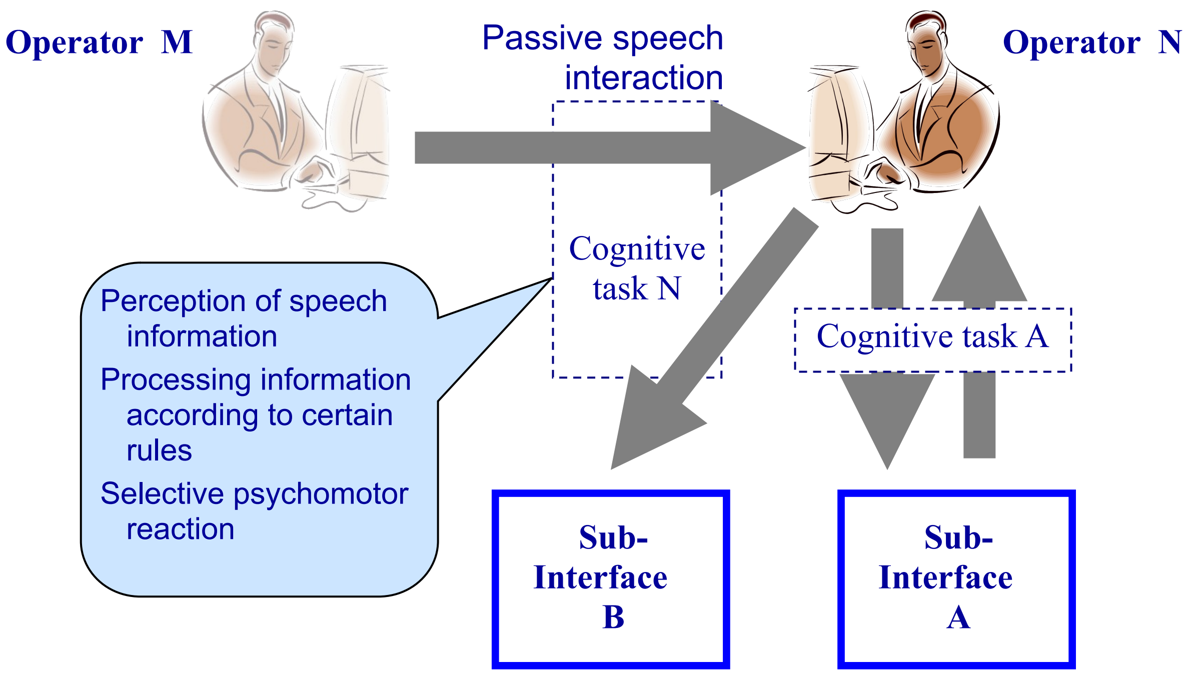


Figure 3. The case in which a human operator perceived and processed different voice messages while performing a background cognitive task requiring a psychomotor response.

To conduct our study, we used an integrated stand providing an opportunity to simulate the joint work of two operators. Each of them was simultaneously engaged in different control contours and processed information of different modalities while performing combined tasks with different goals under conditions of current language interaction between partners (Figure 4). Two experiments were integrated into a single experimental situation as complementary elements.

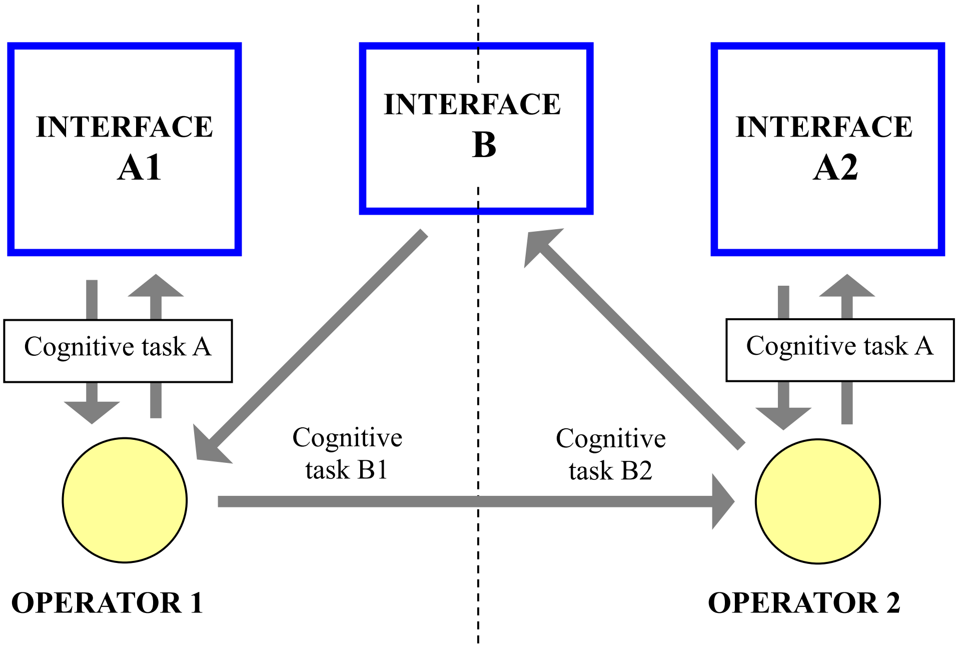


Figure 4. A scheme of an integrated stand for studying interference between different psychic functions of an operator.

Judging by the first results of the empirical studies initiated, we may suggest that the typological characteristics of a human operator are determined by a wide range of individual peculiarities, including individual cognitive style, psychic asymmetry profile, neurodynamic characteristics, and certain personality features.

Information concerning the typological characteristics of crew members can be used together with information about their current condition. While the current state is subject to instrumental monitoring, data concerning typological characteristics can be entered into airborne systems before the beginning of work with the help of a personal key together with the information stored in it.

Transformation of Human Tasks and Requirements to Human Features

The creation of adaptive human-machine interfaces allowing reduction of the risk of human information overload is one of the key tasks in the development of human-machine systems.

In many cases where the human factor causes an emergency, we may admit an insufficient quality of human heuristic activity (scenario forecasting, understanding of the flight situation as a whole, working out new patterns of behavior, making decisions under conditions of insufficient information). This is an activity that humans perform better than machines, although airborne systems can assist them. The issue concerns not only relieving humans in order to provide them with more opportunities to solve heuristic tasks, but also providing direct assistance in the process of tackling such tasks. Achieving such a level of interaction between a human and a machine, we may speak about a fundamentally new situation in which a machine becomes a symbiotic partner of a human, while the human perceives it either as another crew member or as an extension of his own mind.

In such cases we deal with special teams referred to as hybrid. It has been shown that successful work in highly automated Human-Machine Interfaces (HMI), i.e. within a “hybrid team”, demands different personality traits and attitudes than work with a human partner [2].

Speech Modality Perspectives of Human-Machine Interaction

While solving heuristic problems in the cockpit, a human usually deals with more generalized levels of reality than those represented by instrument panel indicators. A question therefore arises as to which means of information transmission can be used more effectively in such situations.

We believe that verbal messages are adequate to these levels, since speech as a means of information transmission possesses peculiar possibilities for generalization and informational capacity. That is why the most important element of systems intended to help humans overcome flight difficulties may be subsystems realizing verbal human-machine interaction.

The analysis of possibilities provided by such systems, their implementation in aviation, and ways of reducing associated risks was conducted when the level of IT and computer development was still far from the present one [9]. At that time, the creation of hybrid teams was out of the question, and interest in the interaction between communication channels and technical systems was connected mainly with speech warning and voice control systems. Nevertheless, the main provisions formulated at that time remain relevant and provide a good basis for continuing research in this direction.

Unlike verbal exchange between people, which, being natural to them, is used to solve any task including the simplest one, verbal exchange between a human and a technical system is most beneficial when solving difficult tasks related to situation assessment and decision making. To realize such verbal exchange, it is necessary to use special phraseology expressed in laconic verbal forms suitable for reliable transmission of highly generalized messages concerning different classes of flight situations while at the same time remaining unambiguous in every possible context. There is also a need to prevent faulty language commands from the operator and misunderstandings likely to occur without special preventive measures.

We questioned pilots flying modern aircraft about their attitude toward the possibility of verbal exchange with onboard systems. Although we expected predominantly skeptical attitudes toward such a possibility, in fact only 27% of respondents expressed skeptical views. At the same time, pilots viewed more positively the prospect of developing systems of machine-to-human voice communication than the introduction of voice systems intended for machine control. Another regularity observed was that a positive attitude toward the possibility of voice communication with onboard systems positively correlated with a positive attitude toward cockpit automation.

Assuming that attitudes toward speech-based support systems are determined by individual peculiarities of the cognitive sphere, we compared groups of pilots who viewed such systems either predominantly positively or predominantly negatively, taking into account individual cognitive style data, verbal-logical thinking, and creative abilities. For this purpose, we used a cognitive style questionnaire (A. Harrison, R. Bremson [5]; adaptation by A. Alekseev) allowing assessment of individual inclinations toward synthetic, idealistic, pragmatic, analytical, and realistic styles, as well as tests of verbal-logical thinking and verbal creativity. It turned out that the groups of pilots who positively and negatively perceived the prospect of the wide usage of speech-based support systems in human-machine interfaces differed significantly in their inclination toward the analytical cognitive style (pilots with a more positive attitude toward such systems demonstrated higher indicators of analytical style). No differences were found in other styles, verbal-logical thinking, or verbal creativity.

Moreover, it was found that pilots giving more positive evaluations concerning the introduction of speech-based interaction systems also believed that work in automated cockpits is more interesting (Figure 1, scale 1) compared with work in cockpits of previous-generation aircraft. This fact, together with the discovered correlation between pilots' attitudes toward automation and toward language-based human-machine interaction, may be interpreted as evidence that the idea of designing interactive speech-based systems within human-machine interfaces correlates with pilots' understanding of general trends in cockpit automation and does not contradict their professional psychological outlook.

The Ideological Aspects of Innovation

The introduction of automation systems enables automation developers to be indirectly present in the cockpit together with the crew [4]. Creating modern socio-technical systems oriented toward humans at a fundamentally new level imposes special requirements on the integration of developers' and operators' psychological weltanschauungs. The problem of correlating these weltanschauungs has an objective basis connected with the different perceptual spaces characteristic of different professions [8].

Aircraft system designers have covered a long way from a machine-centric approach to an anthropocentric one. Nevertheless, it is still too early to speak about complete problem solving. Moreover, the activity of a designer pushes developers, if not toward a machine-centric approach, then toward a simplified understanding of anthropocentrism within the psychological framework of cognitive processes.

Professional stereotypes encourage aircraft developers to solve problems caused by automation through further automation measures, which in turn lead to further transformation of cockpit crew activity models. Such transformation causes specific difficulties for experienced crews in addition to the difficulties already characteristic of human activity in a highly automated cockpit.

As an example of a field in which the positions of aircraft developers and pilots become coordinated, we may consider the flight-test units of aircraft manufacturing plants. Thus, at the Antonov Design Bureau we can find examples of fighter pilots taking an active part in transforming developers' positions toward an outlook closer to that characteristic of cockpit crews. For such coordination to become successful, communication between developers and operators must take place already at the design stage.

Conclusion

In general, we claim that the new risks and new opportunities connected with further cockpit automation are integral to one another. Ultimately, the task is not to allow possibilities to transform into risks, but rather to encourage the transformation of risks into possibilities. For this purpose, it is necessary not to lose sight of the personality of the professional as a system-forming phenomenon behind other narrow specialized issues. Professional outlook, awareness of one's role and limitations, and heuristic potential are of the same importance under conditions of the "hybridization" of social and technical systems as the improvement of human-machine interfaces and activity algorithms.

Perhaps the widespread use of speech interaction between humans and intelligent aircraft systems will become one of the manifestations of the real domination of this ideology in aviation.

References

1. Dorneich M. C., Passinger B., Beekhuyzen M., Hamblin C., Keinrath C., Whitlow S., Vašek J. The Crew Workload Manager: An Open-loop Adaptive System Design for Next Generation Flight Decks // *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. – Las Vegas, NV, 19–23 Sept. 2011. – P. 16–20.
2. Eschen-Léguedé S., Knappe K., Keye D. Aspects of personality in highly automated Human-Maschine-Teams – Development of a questionnaire // *Reflexionen und Visionen der Mensch-Maschine-Interaktion – Aus der Vergangenheit lernen, Zukunft gestalten*. – R.22: Mensch-Maschine-Systeme, 33. ZMMS. – 2011. – P. 459–464.
3. Gerathewohl S.J. *Die Psychologie des Menschen im Flugzeug*. – Munchen: J.A.B. – 1954. P. 131-140.
4. Голиков Ю.Я., Костин А.Н. *Психология автоматизации управления техникой*. – М.: ИПРАН, 1996. – 160 с.
5. Harrison A. F., Bramson R. M. *The Art of Thinking*. – New York: Berkley Books, 1984. – P. 189–193.
6. Licklider J. C. R. Man-Computer Symbiosis // *IRE Transactions on Human Factors in Electronics*. – 1960. – Vol. HFE-1. – P. 4–11.
7. Petrenko O. Man-machine symbiosis in aviation: new risks and capabilities in view of information technology expansion // *Proceedings of the 17th International Symposium on Aviation Psychology*. – Dayton, Ohio: Wright State University, 6–9 May 2013. – P. 116–121.
8. Стрелков Ю. К. *Инженерная и профессиональная психология*. – М.: Издательский центр «Академия». – 2001. – 360 с.
9. Ушакова Т. Н., Павлова Н. Д., Зачесова И. А. *Речь человека в общении*. – М.: Наука, 1989. – С. 172–183.