Aviation Psychology

Applied Methods and Techniques

Ioana V. Koglbauer

Sonja Biede-Straussberger

(Editors)

With a foreword by
Peter Jorna
(Past President EAAP)

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Dedication

The editors and contributing authors dedicate this book to Professor K. Wolfgang Kallus. Over several decades, Wolfgang's contributions have benchmarked the theoretical and methodological foundation for advancements in the research and application of aviation psychology. Among the contributions we would like to highlight: dedicated teaching at the University of Graz; creating and organizing the International Summer School on Aviation Psychology (ISAP) from 2003 to 2019; conducting research projects with EUROCONTROL, Austro Control GmbH, and the aviation industry. At a time when many psychologists focused their research on isolated phenomena, Wolfgang fostered an interdisciplinary approach and brought together in his projects a diverse bunch of experts such as psychologists, psychophysiologists, engineers, pilots, air traffic controllers, and medical experts. With the International Summer School on Aviation Psychology, Wolfgang gathered together renowned international experts who gave presentations and workshops to a mixed audience consisting of psychologists, students, and people involved in aviation operations. Wolfgang fostered professional excellence, interdisciplinarity, and connectivity that are core values of the aviation psychology community and of the European Association for Aviation Psychology (EAAP). In 2012 Wolfgang was presented with the EAAP Award for his outstanding international commitment and achievement in aviation psychology and human factors. Many chapters of this volume address areas that have been advanced by the contributions of Wolfgang, his students, and his collaborators. Wolfgang valued a multidimensional approach for accessing information and consequently for understanding human behavior. He addressed the individual and organizational perspective in order to highlight how individual behavior and performance are influenced by the organization. Furthermore, he investigated in parallel subjective and objective data, including psychophysiological measures. Wolfgang approached the dynamics of human behavior with particular interest in stress and recovery. He valued the integrative and interdisciplinary ways of working, created and facilitated international research networks, and inspired new generations of aviation psychologists. While the editors aimed to create a volume on current topics in aviation psychology, this book also honors Professor K. Wolfgang Kallus.

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Foreword

Peter Jorna

Human Factor(s): What Do You Do With It?

That was the title of my first colloquium presentation at the Netherlands Aerospace Laboratory (NLR) around 1990. The audience at that time was made up of all kinds of engineers, some scientists, and a couple of engineering pilots. All of them wondering why all these wonderful aircraft were crashing due to pilot error. Workload was apparently an issue and several attempts had already been made to model the human mathematically as a biological part of the aircraft control loop. But pilots did not recognize themselves or their personalities in the description of a variable amplification factor in complex equations that were meant to simulate the effects of their workload. This approach was not accepted as being very useful. It faded away …

The presentation explained that humans as test subjects (now called "participants") are indeed an important part of the control loops, but that the test procedures that had been used to date were either not including the human as a to-be-tested part of the system at all or the tests were way too crude to have any predictive value. Test pilots were the main representatives of flight crew, but they were exceptionally well trained. Thus, they did not really represent "the minimum pilot" who sometimes has to perform under harsh working conditions, being tired, distracted, recently divorced etc. A different, more system- and context-oriented testing perspective was needed.

Some steps were taken over the following years.

Go Beyond Selection

The Royal Netherlands Navy at that time had an issue with pilots who were able to fly the new maritime patrol aircraft but had problems when combining the flying with fighting. Hunting submarines at low altitude above the sea was not only exciting and risky, but also required the use of an additional computer screen on the flight deck showing tactical information and instructions, creating a "dual-task situation" in psychology language. Some licensed pilots could not do that and were not able to obtain operational status.

The management response in those days was (most often) to seek the problem in the humans (blame culture), and thus improved selection was the way to go. Selection research following navy trainees during their career confirmed there were individual differences in the capability of (male) pilots to do two things at the same time (either parallel or by fast serial task switching), but training was also an important factor. The aviation industry had no idea about the existence and relevance of individual differences between users of new technologies: An illustration of the fact that simply adding a display aimed at improving mission performance by presenting extra data to the pilot is not an instant guarantee that it will pay off for everybody. On the contrary, the licensed pilots who could not become operational were now a major cost factor for the navy.

Perhaps better test and validation should be recommended already during the design stage?

Go Beyond Subjective Opinion(s)

Asking for user opinions is an easy and very tempting method to check your design. But do the users understand the new design? Are they in favor of it or afraid that it will change their jobs? The EUROCONTROL PHARE program (Programme for Harmonised Air Traffic Management [ATM] Research in Europe) included my so-called ground human machine interface (GHMI) project. In this project several human factors specialists and psychologists teamed up to develop a detailed specification of the human–machine interface for future ATM. There was no explaining to others how to do it, but just do it by ourselves. That task allocation was a really good idea made by Mick van Gool who was the PHARE program manager at the time. Part of this project allowed for some experimental research. The big discussion at that time was whether automation in the form of computer advice to the controller would be a help or a burden.

The reasoning was as follows. If the controller would compare the advice with their own idea, it would involve an extra task, thus a burden. In the case of high task/traffic load, the task of comparing advice with one's own idea could be simply dropped, meaning that the advice of a software tool would be ignored. Alternatively, one could simply follow the advice under high individual workload conditions, but in that case the controller would be "out of the loop." A clear dilemma to be solved.

A simulation study at NLR by Brian Hilburn made a comparison between controllers working with various levels of automation support and the "normal" manual control mode. The results revealed clear and consistent workload benefits as a function of the level of automation and in comparison |XI| with manual control as a reference. Benefits were reflected in physiological measures (e.g., heart rate, heart rate variability, pupil size) indicating both lower mental effort or stress and better performance (response times to datalink communication). All these measures indicated the positive effects of automation, and thus less burden and not more. Except for one other measurement: the subjective ratings of workload by the controllers. This measure was the only indicator that went up. A big surprise and a clear dissociation between measures.

Closer analysis and friendly discussions with controllers revealed that their cognitive reasoning was, "I have to do my normal work and deal with additional tools," so "more tools must mean more work." This lesson learned about possible dissociations between measurements has been experienced more often in research on workload, and therefore it is always necessary and mandatory to measure performance, mental effort, and subjective appreciation in concert. Know your methods and how to apply them!

Validate With Humans in the Loop

These experiences showed us that all technical claims assuming better human performance or reduced workload by adding some technology need to be validated and proven. Merely adding colors to a computer screen does not justify the claim that colors will decrease workload. Evidence is always better. Asking pilots and air traffic controllers will provide you with valuable and interesting opinions, but beside the reliability or validity issue there is the popular saying: "Ask 10 pilots and you will get 20 different opinions." Who has the right opinion? This is a necessary and informative method, but not sufficient.

Take Objective Measures Related to the Human Task

Making a detailed (and agreed upon) task description is the starting point, as it already helps to reduce misinterpretations between the various disciplines involved.

Also measures for various task performance aspects should be defined as objectively as possible; for example, in terms of time, the quality of human performance and its measurable influence on system parameters. Task definition (what is allocated to the human) is a good starting point, but is only completed if you can define measurements. When is a task performed better, and how can I detect and measure this? Note that task considerations are now also integrated in the airworthiness regulations of |XII| aircraft. Rule 25.1302 addresses the certification of “installed systems for use by the flight crew” and it requires a task-based perspective for defining the system challenges in terms of information required, controls needed, and automation support that is understandable and predictable for the users. A real human factors regulation.

But it is even better to also have an idea or hypothesis about the estimated and actual level of effort, especially mental effort, because good performance should be maintainable for a full mission or working period. In this respect, psychophysiological methods came to the rescue. Heart rate and heart rate variability (HRV) provided indications of both physical as well as mental aspects of work, including emotions.

Hard data always work better, also in certification to convince people, including managers and agencies.

Accept the Help of Our Psychophysiology Friends

My first great helper in getting psychophysiology accepted was Glenn Wilson from the Wright Patterson Air Force Base in the United States. He managed to get some heart rate data measured from pilots in real jet aircraft flying missions as well as in the simulators. Not easy to obtain.

What a difference in response between real flying and simulation! The data clearly revealed the limits in simulator realism. Pilots know that simulators do not kill.

My second great helper was Wolfgang Kallus, a German gentleman who got lost in Austria in the wonderful and beautiful town of Graz. He used psychophysiology in an impressive way and was also involved in the ongoing mission to convince people that aviation psychology is absolutely relevant and necessary for design, operational performance, and safety. Find the problems with human–machine interaction before the accidents!

Do not Just Criticize, but Educate

Wolfgang quickly realized that education is a key factor for progress in the field of aviation psychology and human factors in its application and integration in aviation. There are excellent psychologists who know a lot about the human brain and behavior, but many are ignorant about flying machines or air traffic control decisions. No one in aviation will take them seriously if they do not speak “the language.” So, the psychologists need to be educated about systems and operations in order to become *aviation psychologists*.

|XIII| Similarly, there are pilots, controllers, maintainance technicians etc. who all have a great interest in the fascinating human factors of their own work area but lack detailed education about psychology, let alone understand its methodologies. Wolfgang and his excellent team brought such people with all their different backgrounds together in Graz. And it worked! Wolfgang was the first to organize an International Summer School on Aviation Psychology (ISAP) that provided dedicated familiarization, education, sharing, and training in aviation psychology. For everybody.

Wolfgang and his highly appreciated teams were awarded the special trophy of the European Association for Aviation Psychology (EAAP) for their contributions to aviation psychology and its applications in human factors.

Now There Is a Book on *How to Do It!*

The ISAP and EAAP work together in sharing information and experience, but Wolfgang went a little further. He did his very best to refine and expand all kinds of methods and procedures to improve the impact (a bad word to use in the aviation context, but a reminder of why we do this …) of aviation psychology on the safety, well-being, and performance of all humans working in or using aviation.

Many collaborators, former students, and friends of Wolfgang contributed to this volume. This book presents some of the recent lessons learned in applying aviation psychology and human factors, and what methods work best for what purpose.

We hope that the tradition of ISAP will continue and that the book may have regular updates in the future. Use the book as a source and inspiration for others in the future.

Now the task we all have for the continuation of what has been accomplished: Tell and help others!

Professor Peter Jorna
In tribute to Professor
Wolfgang Kallus
Friends and allies in
the “battle” for human
factors integration

Preface

Sonja Biede-Straussberger and Ioana V. Koglbauer

The idea for this book arose from a discussion of the current status of aviation psychology at a professional meeting with key European players involved in professional domains such as universities, institutes, and the European Association for Aviation Psychology (EAAP). This meeting took place in Toulouse, one of the European bases of aviation. Toulouse is an exciting place, connecting major aviation contributors, such as a worldwide leading aircraft manufacturer and related industries, a civil aviation organization, along with schools providing operational and professional education for this sector.

Aviation is a field that connects people and countries, to exchange and to explore, and as such it is not surprising that the people participating in this meeting were former students of Wolfgang Kallus, who, as psychologists, pondered ideas to reinforce the role of aviation psychology and human factors in the industry. One of these questions addressed the ways of working that professionals in the field use to make sure that a full integration of aviation psychology is no longer a wish but a reality across the aeronautical system. A way to support this is by sharing knowledge and experience, and thus the idea for the topic of this book was born.

Practical application of aviation psychology covers the design and assessment of various areas such as human roles, human–machine systems, procedures, airspaces, and airports. It requires an interdisciplinary approach from their initial design through to operational deployment. However, published research in aviation psychology reflects only a small part of the actual work done. A large part of research and development is conducted behind closed doors in the industry. Results of cooperations between industry and academia are not published for various reasons, among which are questions of competitiveness, security, or simply the time available to share lessons learnt.

But what are the enablers of successful applications of aviation psychology? Several may be listed, starting by ensuring the diversity of competencies that professionals require to flexibly adapt to the continuously evolving requirements of the aeronautical landscape. Other enablers include establishing efficient support to newcomers, or the regular evolution of learning curricula while taking on board the evolution of society. One of these enablers is sharing comprehensive views on key topics and lessons learnt regarding approaches, methods, and tools.

|XVI| Hence, the objective of this book is to provide the reader with a selection of views and practices highly relevant in aviation psychology. Aviation psychology is about the application of scientific knowledge on human behavior to the various areas of aviation, ranging from research, design, to operation. The human is a complex system with plenty of limitations and opportunities to fail due to their

inherent characteristics, but the human is also a creative and adaptive system. As such it is the leading element that can intervene and rescue a situation when things go wrong, that is able to innovate and improve, and that is dynamic and flexible to manage the variability of the working environment. One of these situations occurred when Kevin Sullivan experienced unexpected aircraft behavior in Qantas Flight 72. The pilot shares this experience in his book *No Man's Land*. The crew successfully landed the aircraft and hence saved the lives of the passengers on board thanks to the strengths of the humans in that situation. But more than that, it describes the role of psychology, as it relates the strong interplay between human and machine, but also between all the people and organizations involved, and the strong association between the time before and after the event. Another example of the unique capability of human performance was given by the air traffic controller Lou Ella Hollingsworth, who saved a crew's life in November 2012. She detected the incapacitation of the pilot flying a Piaggio P180 Avanti at high altitude because his speech on the frequency was slurred and incoherent. She thought the crew was suffering from hypoxia, as also suggested by another pilot who heard the communication on the frequency. Calmly and firmly, Lou Ella repeatedly advised the pilot to descend and put on his oxygen mask, thus finding a solution that was beyond typical air traffic control procedures. The pilot put on the oxygen mask, descended, recovered, and safely continued his flight. These and many other examples show that the human is the core element of the aviation system and, thus, human performance deserves special attention.

In the context of continuous changes in society and technology that impact aviation to a large extent, a deeper integration of the knowledge of psychology in organizations and in technical developments is essential. At the same time, taking a central view of the role of the human is necessary so as to meet the future expectations regarding the operational performance of the aeronautical system as a whole while ensuring human wellbeing and performance. Over the past few decades, the knowledge base of psychology has continued to grow, as it has in neighboring disciplines of psychology. Today, psychology can be seen as being increasingly diffused over the different areas of society, including aviation. Today, we also have more knowledge of neurosciences, anthropometrics, sociology, and anthropology, and of how phenomena are connected thanks to largely available and promoted data sharing.

|XVII| As such, it is a major challenge for any of us professionals to choose the appropriate knowledge to guarantee that the human element is receiving the right level of attention in the field. To make sure that we are doing aviation psychology right, we need to ensure that we effectively and efficiently use the experience and knowledge available. In the Foreword of this book, Peter Jorna described the learning of an organization over time with regard to how the view on human factors evolved and became increasingly integrated to solve actual problems. Today we have the opportunity to understand how such learning occurred in the

past. But we also have the opportunity to go one step further, by bringing together the knowledge that exists, what we have learnt, and how to connect it to anticipate the future. The challenge is to make sure we can share the lessons learnt. We want to avoid that future generations of professionals in the evolving fields of aviation experience the same situations as Peter reported in the Foreword. Especially in the context of increasing economic pressure and changing ways of working, human tendencies for regression and repeating the same story as already experienced in the past could prevail.

Thus, we want to use this opportunity to report on the experiences learnt in the past, to share knowledge that was gathered, and to build on the lessons learnt. The authors of this book work in the industry, in research institutions, public services or operations. They share their experiences with the application of different methods, some difficulties encountered, and an outlook ahead. Therefore, this toolkit of aviation psychology provides the reader with know-how that is otherwise not easy to access.

Over the past few decades, the knowledge base on aviation psychology has also evolved in international standardization and regulation that set a global framework for professionals in the field. For example, for more than a decade, aircraft certification has required a human factors demonstration, and the role of aviation psychologists has been emphasized in a new rule on support. However, aviation psychologists need to assess, to select, and sometimes to develop new methods for addressing practical and theoretical challenges in their work. This book provides an overview of current themes, methods, and tools, and offers complementary views on topics presented in journals. These are selected to cover academic and industrial areas of interest, and have different foci such as psychophysiology, people in organizations, and design processes.

This book starts with an introduction of the Human Performance Assessment Process, which is now widely used in aviation ranging from assessment of aircraft to air traffic control. This process was developed to a large extent in SESAR 1, the first step of the European Single Sky Aviation Research Program between 2010 and 2016, and is currently the baseline for ensuring the study of human performance even beyond SESAR. What is es |XVIII| sential here is that the authors involved in this activity, together with many other experts, built on their own past experience to reinforce the integration of human factors in the industry and in operations. As such the authors not only connect countries (Austria, Germany, Italy, France), but also cover different organizations (from research to operations, from aircraft manufacturers to air traffic management). They overcame the challenge of remaining stuck in their own organizational constraints, and devoted themselves to building together for a common future based on the lessons they learnt. Everyone who wants to mitigate human performance issues – including automation issues – in the design phase of a concept and beyond, towards deployment, may find interest in reading this chapter. The chapter raises awareness of existing challenges and provides guidance on how to optimize human performance integration in system design. Together with the second chapter, it shows how aviation psychology builds bridges across disciplines and application fields. It takes two perspectives, first by integrating aviation psychology in engineering and design processes across multiple connected organizations and products, but also by bridging the gap between research and applications. In this context, professionals are also given the opportunity to choose the right methods and tools according to the available constraints. A dedicated chapter on bridging gaps highlights that the currently available criteria for selecting methods and tools are no longer sufficient, as we need to take a global system-of-systems perspective to identify the areas in which problems have to be addressed. For this purpose, the human-oriented approach of interactions with complexity (HOAC) is presented. One of the challenges the authors have encountered is to develop the right set of human factor criteria in an industrial context and make sure it is used throughout the design process. Keeping a system-of-systems perspective was always a key driver in their reflections.

A special chapter is dedicated to an organization-focused view regarding “Essential Tools for Safety Culture Development in Air Traffic Management.” Safety culture is a current topic in aviation psychology that is being regularly assessed and interpreted in aviation operations (e.g., air navigation services). The authors of this chapter have experience in airline and air traffic control operations, and share practical tips and tricks for a reliable, cost- and time-efficient application. This chapter raises awareness about scientifically validated tools for assessing, monitoring, and improving safety culture in aviation organizations. It provides an opportunity to learn how to successfully apply these tools in the operational context and how to make results tangible for operational staff. It also explains the derivation of meaningful results and interpretations of safety culture assessments.

Specific cognitive processes and the relationships to physiology are highlighted in the chapters on anticipation and spatial disorientation. One chap |XIX| ter is dedicated to anticipative processes both in flying an aircraft and in air traffic control. Pilots and controllers are expected to be “ahead” of a situation. What are the processes that enable them to see a situation developing in the way they want it to, instead of being surprised and reacting to a multitude of constantly changing elements? How can estimations of collisions be effectively improved to achieve an accuracy of a fraction of a second? How are anticipative processes reflected in human psychophysiology? This chapter presents theoretical and practical hands-on applications and answers these questions on anticipative processes. In addition, the reader will discover tools and examples for designing aviation systems that assist human operators in their anticipative processing. A promising outlook at new developments of anticipatory processes for artificial intelligence is deemed to inspire the next generation of researchers and practitioners in aviation psychology.

Another chapter on cognition is written by an expert in spatial disorientation research. This chapter serves as a