Applied Ergonomics 51 (2015) 85–101

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

An ergonomics based design research method for the arrangement of helicopter flight instrument panels☆

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ARTICLE INFO

Article history:
Received 10 February 2014
Accepted 18 April 2015
Available online 19 May 2015

Keywords:
User-centered design
Helicopter flight instrument panel
User-interface arrangement

ABSTRACT

In this paper, we study the arrangement of displays in flight instrument panels of multi-purpose civil helicopters following a user-centered design method based on ergonomics principles. Our methodology can also be described as a user-interface arrangement methodology based on user opinions and preferences. This study can be outlined as gathering user-centered data using two different research methods and then analyzing and integrating the collected data to come up with an optimal instrument panel design. An interview with helicopter pilots formed the first step of our research. In that interview, pilots were asked to provide a quantitative evaluation of basic interface arrangement principles. In the second phase of the research, a paper prototyping study was conducted with same pilots. The final phase of the study entailed synthesizing the findings from interviews and observational studies to formulate an optimal flight instrument arrangement methodology. The primary results that we present in our paper are the methodology that we developed and three new interface arrangement concepts, namely *relationship of inseparability*, *integrated value* and *locational value*. An optimum instrument panel arrangement is also proposed by the researchers.

1. Introduction

User-interfaces constitute the conceptual space where information and force are interchanged between the user and the machine for the operation of a man-machine system. This interaction is vital for a safe, effective and comfortable operation of every man-machine system. The goal and the structure of a user-interface varies according to the type of the product or system. With technological advancements, user-interfaces become more complex with new functions and components. In general, air transport vehicles have more complex user-interfaces than most other modes of transport due to safety concerns and the complexity of their underlying technological infrastructure. As a complex machine, the helicopter is a good example for such a transport vehicle. Lovesey (1975) defines the helicopter pilot as an operator who works under most difficult circumstances because of the helicopter's high maneuverability, instability of its technological nature and resulting control difficulties and problems.

As rotary-wing aircrafts, helicopters have significant technological and usage advantages compared to fixed-wing aircraft. These advantages are the primary factors that led to their increased usage. Its vertical landing and takeoff capability and high maneuverability allows the helicopter to be used in a wide range of purposes such as search-and-rescue, firefighting, television broadcast, air-ambulance, film and documentary production and air-taxis. However, despite the wide use of helicopters, methods used in the design and arrangement of the flight instrument panels of rotary wing aircraft are old.

There are three main goals in this research:

- Goal 1: To investigate the role of basic principles of user-interface design of Sanders and McCormick (1993), in the context of flight instrument panel arrangements of civil helicopters.
- Goal 2: To develop a new methodology to optimize display arrangements of flight instrument panels of civil helicopters, based on users' opinions and assessments
- Goal 3: To identify new concepts which will play a role in the arrangement methodology developed.

☆ This paper is based on research conducted as part of the author's PhD dissertation in the Industrial Product Design Department at Istanbul Technical University. A part of this research was presented at the AHFE 2012 – 4th *International Conference of Applied Human Factors and Ergonomics, San Francisco, CA.*

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http://dx.doi.org/10.1016/j.apergo.2015.04.011
0003-6870/

Two different research methods constituted the structure of the research. In the first stage interviews were conducted individually with helicopter pilots. In this stage interface arrangement principles of Sanders and McCormick (1993) were investigated as well as pilots' personal experiences and opinions. These basic principles, which are generalized principles for all types of user-interfaces, are well established and accepted for decades in the field of ergonomics. The rationale behind the investigation of these principles is to explore their role in the arrangement of helicopter flight instrument panels as well as in the development of the new arrangement methodology. This part of the research provided verbal and quantitative data. A paper prototyping study constituted the second stage of the research. In this stage, the pilots that were previously interviewed were asked to generate their own instrument panel arrangements. The paper prototyping stage of the research provided visual and quantitative as well as verbal data. The data resulting from these two research processes was used to develop the new arrangement method, which is the primary result of the research. The arrangement method developed can be described as the synthesis of quantitative, qualitative, descriptive and visual data generated during the study.

This research was conducted in part to address the design and ergonomics research concerns of "ArıKopter" Project, the civil helicopter development and production project conducted by ROTAM (*Rotorlu Hava Araçları Tasarım ve Mükemmeliyet Merkezi — Rotor Aircraft Research Center*) in Istanbul Technical University. The research is based on traditional flight instrument panel systems because of the budgetary limitations of ArıKopter project. Glass-cockpits are subject for a future research. Therefore, the displays used in the research phases where obtained from the ROTAM project and the instrument panel of a Bell 407 helicopter was used because of its similarity in terms of shape and dimensions to the ArıKopter Project.

2. Review of approaches in user-interface design and arrangement

2.1. General approaches in user-interface arrangements

In general, user-interfaces can be divided in two general groups: *traditional user-interfaces* and *graphical user-interfaces*. Traditional user-interfaces are composed from separate displays and controls whereas graphical user-interfaces are computer-based systems. In graphical user-interfaces information is displayed to the user via computer monitors. This present study is based on and limited on traditional user-interfaces. An extensive body of literature can be found on graphical-user-interfaces especially in the field of computer science and human–computer interaction. Both types of user-interfaces are largely found in various types of consumer products and systems as well as in transportation vehicles and systems. Methods based on visual analysis play an important role in the design and arrangement of user-interfaces. Visual analysis is based on direct observation of user actions in the process of use of a certain product or system. Chapanis (1965) describes visual analysis methods as a data basis to refine existing products or systems. Chapanis (1965) categorized visual analysis methods into four main groups, which are concisely summarized below. These methods have advantages as well as disadvantages.

- User-opinions

The opinions and experiences users of a current product or system are the primary source of data about the usage of a product or system. However there is the disadvantage in which a person who uses the product for a long time may not identify its usability faults. Users may be blind to faults and errors and may be reluctant for new designs and solutions. Questions which will be directed to the user must be carefully selected.

- Activity-sampling techniques

There are three types of activity-sampling techniques in order to observe a product or system systematically: *sampling of user activities, memo-motion study, unit-basis sampling*. In *sampling of user activities,* the researcher observes and records the user activities in pre-defined time periods (10 s, 1 min, or 30 min etc.). The recorded data can be used to calculate percentage of duration of a certain step in comparison to the whole activity. McFarland and Moseley (1954) used this technique to improve dashboard design of intercity buses. In *memo-motion study* very short sampling intervals, shorter than 2 s, are used to record the user activities. In this case, the user activity is electronically recorded and that can be re analyzed. In *unit-basis sampling,* the research is focused mainly on a single type of activity that is a part of a task which consists of different activities.

- Process-analysis techniques

Also called functional analysis, process-analysis techniques depends on to observing and to recording each step of the work studied, and is widely used to improve and to arrange user-interfaces. There are several types of process-analysis techniques. Developed by Frank Gilbreth, *flow charts* are used to describe various standardized sub-steps of a certain work process. They represent the whole process of the usage of a certain product or system in the form of a diagram in which, various components of the process are represented by different geometrical forms as a coding approach. They are usually utilized to analyze different steps of a process that is investigated. The diagram is generally represented in the form of a line to represent time. *Flow diagrams* are similar to *flow charts,* but they include the space, where the interaction between the user and the machine occurs, as an additional component. The visual appearance of a flow diagram is very similar to the real picture of the interaction space where the interaction occurs.

Nemeth (2004) describes *flow diagrams* as a class of methods (FRD-functional requirements analysis, action-information analysis, decision-action analysis, FAST-functional analysis system technique) similar to flow charts in which the location of the work is included in this research. Channell (1947) used a flow diagram technique to analyze and improve the cockpit of a multi-engine military aircraft. Using this technique they divided the cockpit in seven sub-areas. *Multiple process analysis* technique investigate the simultaneous work process of multiple operators or components of a particular product or system. Here, data is represented in a process chart format for each operator in a single chart called *multiple flow chart.* Time values are also added for each action represented in the chart. A two-pilot helicopter can be a good example of problem which can be studied using this technique. *Multiple flow charts* were used by Chapanis (1965) to observe and study the landing process of a R5D aircraft. *Time line analysis* uses *time line diagrams* to evaluate or assess and predict the task performance of a user of system or product as well as of a user-interface. In a *time line diagram* each action is shown in rectangular shapes in different sizes according to its duration. The technique can be used to predict the workload levels of a solution under development, and to analyze multi-user systems. The time line analysis technique can be used as a flow analysis tool as well as a secondary technique for refinement of a task analysis. The review of the outcomes of time line diagram will allow reorganizing tasks in order to fit the time allocated for the task (Nemeth, 2004).