The Literature Review of Human Factors Research on Unmanned Aerial Vehicle – What Chinese Researcher Need to Do Next?

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Abstract. This study reviewed the literature on human factors issues in unmanned aerial vehicles. Cultural differences on human factor in unmanned aerial vehicles were considered in this study between China and the United States to find the future research directions for human factor specialists in China. After a screening and selection process in the literature search, eighty papers were included in full paper reading and discussed in this study. According to the results, there was still a gap between research development of human factors in unmanned vehicles in China and that in the United States, no matter considering the quantity or quality of papers in two countries. Five topics, human factors identification, display and interface, automation and system, crew performance, and election and training, may be Chinese researchers' future research directions.

Keywords: Literature review · UAV · Human factor

1 Introduction

The UAV (Unmanned Aerial Vehicle) is operated remotely by pilot on ground-based controller with communication system. As a typical human-computer interaction system, human factors issues are critical to reliability of UAVs.

Human factor problems have been encountered since uninhabited aerial vehicles were used for military and civilian missions. Data links broken down while operators hardly realized readily. It was also difficult for human to keep vigilance for long periods of time and exploit imagery on multiple stream at a time [1].

Tvaryanas et al. (2006) found that 60.2% of 221 mishaps associated with causal causes of operators' errors at the organizational, supervision, preconditions, and operator levels [2]. Oncu and Yildiz (2014) revealed that among 68 accidents due to casual factors, 65% of the factors were relevant to humans [3]. Identification of human factors as different categories is particular concern to improve the UAV flight safety, such as Displays and Controls, Automation and System Failures, and Crew Composition, Selection and Training [4]. Williams's (2004) investigation showed that the effect of human factor issues was related to particular UAV systems, the type of automation incorporated, and the user interface employed, based on the data from Army Navy and Air Force [5].

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With worldwide concerned in aviation accident analysis, human factors study is an important theme to research.

Besides, the uniqueness of Chinese culture may have a potential influence on the human factors issues in UAVs. On the one hand, human factors issues are often misunderstood and ignored with predilection toward technological solutions. Domestic human factor researches on UAV are comprehensive, but a gap exists as compared with those in the United States. On the other hand, the culture of a country has impact on crew performance in Unmanned Aircraft Systems. There are five dimensions of national culture differences identified in Hostede's culture model [6]. Power distance tend to be higher for China than the USA. Individualism is prevalent in Western countries, while collectivism prevails in China. Uncertainty avoidance is one uniquely Western dimension and a long-term orientation is mostly found in China [7]. All these characteristics make Western thinking analytical and Eastern thinking synthetic [8] and may result in unique behavior potentially. UAV pilots with various national cultural backgrounds do different analysis facing the same condition, consequently causing diverse human factor errors. Accordingly, developers can design specific interfaces and automation system based on different mind to adapt to human using habits. In addition, improving efficiency of pilot selection and training can help to enhance human reliability of UAV with consideration of dimensions of national culture.

Thus, it is necessary to review human factors research of UAV in China. Human Factors Analysis and Classification System (HFACS) is a reductionist tool for analyzing human performance failures within a mishap database and widely used in aviation accident analysis to identify recurrent human factors error. Moreover, the completeness of HFACS analysis was improved by the AcciTree model with reliable graphic part and logical taxonomic part enhancing [9]. In terms of relations among accident factors, Edwards and Hawkins regarded accident causes as inappropriate interactions among human, aircraft and environment in software–hardware–environment–liveware–liveware (SHELL) model [10].

Although the above methodology has been adopted by domestic researchers, their analysis is mainly on the basis of American military accident data. There is rarely relevant study on Chinese UAV applications in the existing literature published. Existing literatures provide varieties of human factors issues in UAVs and suggest directions of future research for Chinese scholars.

2 Method

This study conducted a literature review in terms of human factors research on UAV from 1998 to 2007. The literature search process was detailed in Fig. 1.

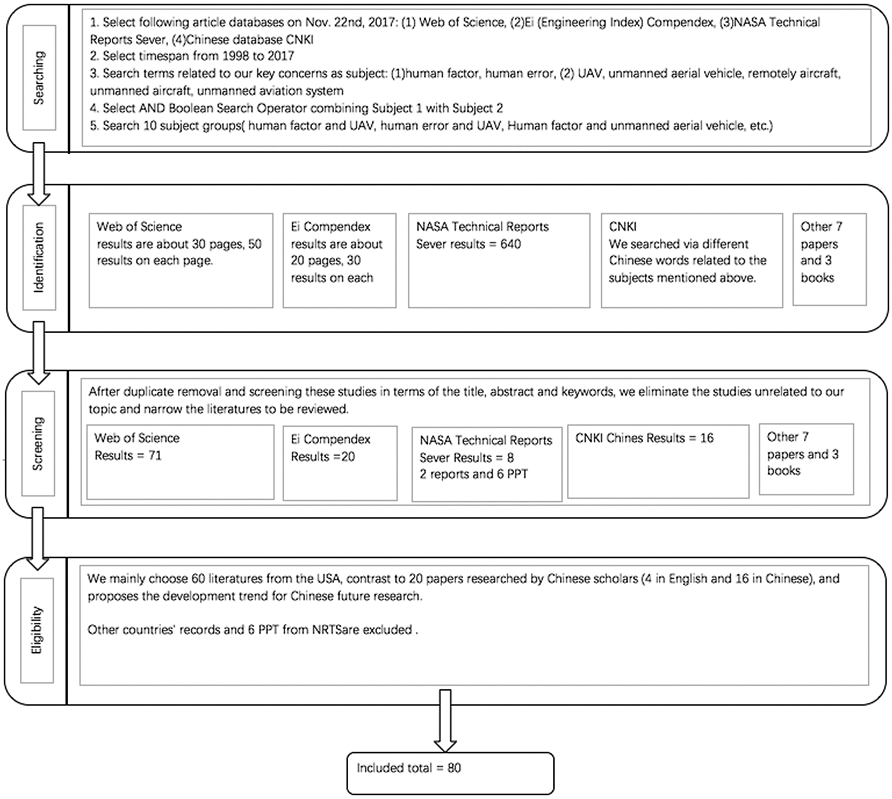

Fig. 1. Literature search process

2.1 Literature Sources

In order to make a comprehensive review, the literature sources derive from academic publications, public reports, conference papers and books. Our databases cover “Web of Science”, “Ei (Engineering Index) Compendex”, NASA Technical Reports Sever and Chinese database “China Knowledge Resource Integrated Database”.

2.2 Search

Use “AND” Boolean search operators to narrow the search field. Search with the keywords “human factor”, “human error” and “UAV”, “unmanned aerial vehicle”, “remotely aircraft”, “unmanned aircraft”, “unmanned aviation system”.

2.3 Eligibility Criteria

There is a mass of relevant literatures on the field of human factors or UAV. We need to combine both two subjects and narrow the list of literatures. By screening these studies in terms of the title, abstract and keywords, we eliminate the studies unrelated to our topic and narrow the literatures to be reviewed to 80 articles.

3 Results

This study reviewed 80 papers, 60 from the United States and 20 from China. In Chinese papers, 4 papers were written in Chinese and 16 were written in English by researchers from China.

Since the military in the USA has a relatively rich experience of UA utilization and mass of data accurately recorded about incidents (Williams 2004) [5], American scholars have conducted much more researches on human factor issues in last 20 years. There are more than 50% of literatures published by American scholars, especially from 1998-2007. Obviously, the USA is in a dominant position in human factors field compared to any other countries. Although some scholars abroad have studied these issues, their research information is gathered from Hunter, Shadow or Pioneer serving in military of the USA. Hence, this paper mainly reviews literatures from the USA, contrast to human factor issues with China, and proposes the development trend for Chinese future research.

After initial review, we found some focuses among these articles. Scholars and engineers put on similar emphasis in various workshops, conferences and books. In order to make further investigation, qualitative literatures in hand have been classified according to their research field, namely human factors identification, display and interface, automation and system, crew performance, selection and training and some other issues showing in Table 1.

Table 1. The classification of material

No	Field	The USA	China (English)	China (Chinese)
1	Human factors identification	19	1	4
2	Displays and interface	10		5
3	Automation and system	12		
4	Crew performance	12		
5	Selection and training	3	1	7
6	Others	3	2	
Total		60	4	16

4 Discussion

4.1 Human Factors Identification

Human factors identification is basic analysis of UAV accidents. Generally, accidents are classified into broad categories based on whether it is related to human factor failures firstly. In the second stage, HFACS is popularly applied. It is a model divided human-related failure into four levels, which are further subdivided into 19 categories.

Tvaryanas (2006) investigated 221 RPA mishaps and identified recurring human factors failures on account of operator, organization, preconditions and supervision levels [2]. In his further review of 95 mishaps, two more factors were recognized, namely fatigue trouble and motivational deficiency [11]. Williams (2004) has found that human error contributed to 61% of UAV mishaps. The largest percentage of accidents causes was attributed to unsafe acts according to HFACS analysis classification [5]. The Department of Defense (DOD) has used the HFACS taxonomy successfully for ten years to recognize the human factors failure in UA mishaps (Oncu and Yildiz 2014). The results of their study revealed that 287 causal factors were attributed to 68 accidents and 65% of the factors were associated with humans [3].

Organizational climate, one of human errors in HFACS, covers kinds of element influencing organization atmosphere, including cultures, policies, relationships, and command and control structure. Cultural difference should be one of organizational climate taken into consideration in human factor analysis. However, existing researches have not referred to this question in Western countries. There is significant cultural difference between Asia and Western countries, especially in China. Chinese scholars hardly pay attention to the gap of national culture. Lei (2014) put forward an associative hazard analysis technique to improve completeness of HFACS [9]. Cui (2015) constructed fuzzy cognitive map to predict UAV accidents [12]. Other Chinese papers mainly review causes analysis based on the US military UAV accidents and emphasize important role of human factors in UAV development. Future work will concern Chinese characteristic for human error elimination.

4.2 Displays and Interface

As a typically human-computer system, instrument display and automation system interface are important human factor elements. It is necessary to take these factors into consideration for system design and instrument arrangement.

The pilot of an unmanned aircraft has no access to auditory, tactile, olfactory and sufficient visual information with familiar vestibular cues as conventional aircraft [13]. Prabhala et al. (2003) pointed out although automation is designed for reducing operator workload, the complexity of the system is increased by human factors, such as skill degradation, workload, situational awareness, trust and biases [14]. Developing appropriate interface is able to improve usability and reliability of UAVs. Van Breda (2005) find result that humanized human-machine interfaces design can compensate specific lack of visual information and significantly increase operator performance [15]. Hocraffer and Nam (2016) summarized current situation of UAV management interfaces in terms of the advantages, limitations and assessment method. They have offered proposal to give suggestion about further research on multiple types of feedback, such as tactile, motion, auditory, augmented reality, etc., to improve operator situation awareness [16]. Peschel (2013) researched the human-machine interaction technologies among micro and small UAVs. Significant interface limitations may lead interaction conflicts unexpectedly between mission specialist role and micro UAV operators [17]. In terms of display of UAV, Easier access to information can optimize UAV operations based on the proximity principles [18].

Chinese scholars has conducted several researches on this field. Mi and Yang (2013) has reviewed articles covering current development, limitations, challenges, and provided reference for human-computer interaction in UAV swarms. They had measured relationship between automation and human-computer interaction [19].

4.3 Automation and System

Automation systems enables aircraft to be controlled by pilots located remotely. Equipment executes various tasks via different systems, namely "aviate", "navigate", "communicate", and others. Technology development shapes system capabilities and potential in the future. Practical system is critical to assist controller in operating. Reliable automation can help reduce workload, cut down task interference and allow pilots to better handle multiple tasks during flight control [20]. Michael (2012) discussed challenge and opportunities of unmanned air system. The appropriate allocation of crew control and autonomous vehicle control affected mission capability and flexibility of UAVs [21]. It is important to make system easy to use to enable human control reliable. Among the articles we reviewed, various perspectives are considered to address human factors associated to UAV systems.

Gloria (2005) researched the tailoring of synthetic overlay technology [22]. Brandon (2015) analyzed lighting system for safe remote sensing during night time [23]. James (2008)' paper probes into the motion platforms of tele-operated system and employs motion cueing to increase UAV operator performance [24]. Savla (2008) proposed several coordination strategies for target assignments between operators and UAVs [25]. Colombi (2013) identified what system design induced human errors using HFACS and predicts future application areas of new system development [26]. Cooke (2014) made an overview of human systems integrations issues surrounding Remotely Piloted Aircraft System [27]. Kaliardos (2014) identify human factors challenges to integrating different flight systems for UAV operators and other pilots [28]. Feng (2016) proposes an approach to solve uncertainties and imperfections in interactions with human operators [29]. Balog (2017 65) provide a review of recommendations and guidelines adopting in small UAS to improve task efficiency [44].

4.4 Crew Performance

Humans are an integral part of the overall UAV system. Crew performance have direct impact on aircraft flying. Since tele-operated or supervisory form of control, there is a time delay between remote control command input and aircraft response. Pilot may be unable to detect and respond to problems in a distance in sufficient time as well. Crew performance faces more challenges among UAV operators than common aviation due to wireless communication control. Crew performance is an important concern. Among articles we review, the amount of papers about this issue is on the second place. Scholars carry out much research on this topic.

It is convinced that split attention, fatigue and inappropriate workload are persistent threats of UAV operations. As early as 1998, MJ Barnes conducted simulation experiments to examine crew performance in controlling the UAV [30]. Split attention is one of reason leading to flight control problems. Walters (2000) develops fatigue algorithm to explore how fatigue, crew size, and rotation schedule have effect on UAV operator workload and performance [31]. The results of this study indicate reduction number of crewmembers results in more crashes, more time to search for targets and less number of targets detected. Tvaryanas (2004)'s paper address crewmember performance in terms of the comprehensive influence of manpower shortage, deficient rest between work shifts, and lower efficiency [32]. Tvaryanas (2009) studies fatigue in pilots before and after shift work adjustment resulting from lack of opportunities for recovery and enough sleep [33]. Mouloua (2001) also addresses workload concern for the development of functional UAV systems [34]. Dixon et al. (2005) argue that the automation involving to work has positive effects on human performance and reduce workload [20]. Murray (2013) provided a mathematical model for simultaneously routing UAVs and scheduling human operators, subject to operator workload considerations [35]. Research proved that time pressure affected autonomous UAV operator task performance and workload [36].

Mental health is another object to research. Chappelle (2014) repeats a survey to assess mental health among United States Air Force aircrew operating Predator/Reaper remotely piloted aircraft [37]. Wohleber (2015) examined the consistency of stress responses to different sources of stress during simulated multiple UAV operation.

There is hardly an article published in China referring to crew performance. According to existing papers, fatigue, split attention, workload and pressure are critical issues to explore for Chinese scholars and engineers. In addition, Chinese operator characteristic need to be considered due to the specific national culture background.

4.5 Selection and Training

Base on system interface, instrument display and flight mission, UAV operators need specific selection and training mode, especially differs from traditional aviation pilots [38]. UAV operators hold the similar view that there is cultural difference existing between remotely controlled aircraft and mainstream aviation according to interview UAV operators (Hobbs 2006) [39]. It is important to make careful selection criterion, train high-quality UAV operators and effectively evaluate their training results.

Complex human-computer systems require carefully selected operators, who will interact with the system (Carretta 2015) [40]. And the reliability of automated systems should be taken into consideration when multi-UAV operators test. (Lin 2016) [41]. Analysis of UAV mishaps associated with flight control problems provide theoretical support to maximize operator efficacy and apply to training practice. The research results gave reference to human computer interface design and help to make appropriate business decisions for staffing and training, thereby human workload reduce and system performance improve (Liu 2015) [36]. Menda et al. (2011) conduct experiment and present early findings that Functional Near-Infrared Spectroscopy (fNIR) application could enhance UAV operator training, evaluation and interface development [42]. Li (2015 21) analyze eye-movement experiments and make conclusion that there are individual differences in various aspects of psychological conditions, knowledge levels, hobbies and interests. However, professional training can impose positive influences on the professional skills of trainees in a certain kind of a field [43].

Among articles we review, a number of Chinese scholars regard the training issue as an important topic. Some of them discussed development of selection and training in USA as reference for domestic application. Others explore UAV operators training for military and civilian UAV in China. According the articles that we review, it is necessary to improve practical training in present institution. Systematic training, including theoretical knowledge study, simulated training and practice skill training, is a major tendency of future development.

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