TREND ANALYSIS OF UNMANNED AERIAL VEHICLES (UAVs) RESEARCH PUBLISHED IN THE HFES PROCEEDINGS

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The present study was designed to examine the research trends in the literature focusing on Human Factors issues relevant to Unmanned Aerial Vehicle (UAV) systems. As these UAV technologies continue to proliferate with increasing autonomy and supervisory control requirements, it is crucial to evaluate the current and emerging research trends across the generations. This paper reviews the research trends of 228 papers matching our search criteria. The search retained only relevant and complete papers published over the past thirty years (1988-2017) in the Proceedings of the Human Factors and Ergonomics Society. Results were tabulated, graphed, and discussed based on research categories, topic areas, authors' affiliation, and sources of funding. Results showed a substantial increase in the number of articles in the last two decades, with most papers driven by academic institutions and military and government agencies.

The proliferation of unmanned aerial vehicles (UAVs) has markedly increased in recent years. This is due their widespread applications in military, civilian, commercial, and homeland security environments. A recent report estimated the UVS market reached 13.22 Billion in 2016. This figure is projected to reach $28.27 Billion by 2022 (marketsandmarkets.com, 2016). This market trend highlights the growth of UAV technologies with regard to various domains of applications. Out of this growth emerge many resulting opportunities and challenges for using such UAV technologies. Since numerous countries worldwide are now increasingly engaged in using such autonomous aerial systems for a variety of applications, collaborative efforts among some countries are underway in the fight against terrorism, enhancements of homeland security, and first response capacities to various earthquake and hurricane disasters. Hence, the adaptation and utilization of such UAV/UAS technologies will require a global coordination among various entities to optimize their utility and sustainability.

Such progress has also revealed many Human Factors problems (Gilson, Richardson, & Mouloua, 1998; Mouloua et al., 2001a and 2001b; Mouloua, Gilson, & Hancock, 2003). As we continue to increase automation of various UAV/UAS task operations and allocate supervisory roles of multiple vehicles to one single operator, we must recognize the important need to address the various human factors and engineering problems resulting from improper system designs (Mouloua et al, 2001a; Mouloua et al., 2001b). In this paper, we review such Human Factors problems or challenges as they relate to their respective surveillance, inspection, and search and rescue operations. We also review and evaluate their strategic capabilities and effectiveness in the context of both civilian and military applications. In addition, we identify the specific design challenges, operator performance and workload limitations, selection and training for these UAV/UAS systems. Finally, we highlight some of the major opportunities with regard to their utilization. Although unmanned aerial vehicles (UAVs) seem now to be ubiquitous, their widespread use in military operations was not seen until the turn of the present century. The most significant advances in UAV technologies were made in the late 1980's and early 1990's with breakthroughs seen in the computer and aviation industries. With these advancements in technology and the ever increasing application of UAVs, persisted the necessity to recognize and incorporate human factor concerns in system design, operator training, and deployment coordination (Mouloua, Gilson, & Hancock, 2003). Traditionally, UAVs have been designed for missions such as search and rescue in areas inaccessible by humans, surveillance and intelligence gathering, combat support, as well as remote delivery of payloads. These missions have proven to be critical for national defense and homeland security. As we continue to further develop these technologies for new applications, we must recognize the needs to further address some of their challenges (Gilson, Richardson, & Mouloua, 1998; Mouloua et al., 2001a and 2001b; Mouloua, Gilson, & Hancock, 2003).

There are several UAV classifications as described, for example, in the results section here. These include: unmanned aerial systems, unmanned aerial vehicles, remotely operated vehicles, autonomous systems, and drones, which are all used for various missions such as search and rescue, and surveillance (Mouloua, Gilson, & Hancock, 2003). These systems have also been used in numerous military applications such as protecting troops, suppressing enemy air defenses, providing intelligence, and reducing the risk of danger and casualties. Their popularity continues to rise because of the opportunities they provide for the military and civilian markets. Current reports indicate that the UAV market will continue to grow over the next decade, and even the trends we described initially might underestimate this growth.

The present study was designed to examine the research trends in the literature focusing on human factors issues associated with Unmanned Aerial Vehicle (UAV) systems. We reviewed the research trends of 228 papers matching our search criteria as described in the method section below. Although we initially identified over 700 articles, we retained only relevant and complete papers published over the past thirty years (1988–2017) in the Proceedings of the Human Factors and Ergonomics Society for the current survey.

METHODOLOGY

We reviewed the research trends of UAV literature published in the Proceedings of the Human Factors and Ergonomics Society. 228 articles matching our search criteria were included in our trend analyses.

The Human Factors Proceedings are the flagship of the Human Factors and Ergonomics Society's Annual Meetings. They serve as a useful reference tool for educators, students, researchers, practitioners, and policymakers in related fields. Therefore, it was deemed necessary to undertake such a thorough trend analysis of the Proceedings in order to provide a synopsis of the current state of UAV research and emerging trends.

Our search within Sage Journals was limited to 16 precise search terms, with the requirement of the inclusion of these keywords in the articles' title or abstract for incorporation in our results. The 16 keywords specific to our investigation include: "Unmanned Aerial," "Unmanned Combat," "Unmanned Pilot," "Uninhabited Aerial," "Remote Pilot," "UAS," "UAV," "UCAV," "Drone," "Autonomous Systems," "Autonomous Vehicles," "Remotely Piloted," "Remotely Operated," "Unmanned Vehicles," "RPV," "ROV." This method was used because there is a considerable proportion of articles offhandedly mentioning keywords used in the term search. Upon retrieving the articles, data were entered into an Excel form to codify articles by decade, search term, content area, cluster, authors' affiliation, and source of funding. They were then tabulated based on their number of occurrences, and distributions. These graphical representations are shown in the results below.

RESULTS AND DISCUSSION

Preliminary analyses revealed that publications involving UAV research have increased in recent years. UAV research was not very prevalent in the years 1988-1997. A noted increase can be seen in UAV research beginning in year 1998, as Figure 1 shows. Figure 2 reveals the drastic increase in attention to UAV research in the past three decades, with the period from 2010-2017 representing the largest proportion of articles when compared to previous epochs.

Using a keyword search in the Proceedings restricted to abstract and title, our search yielded a total number of 772 papers containing our keywords. After further examination, 535 papers were deemed to be relevant to the keyword search analysis (see Figure 3).

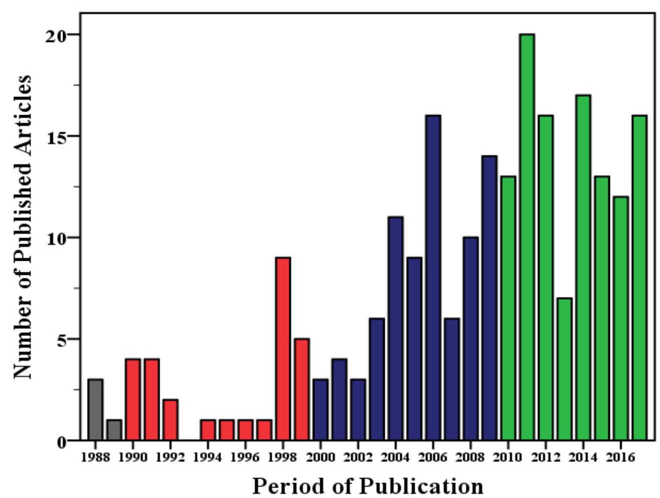

Figure 1. Number of Published Articles by Year

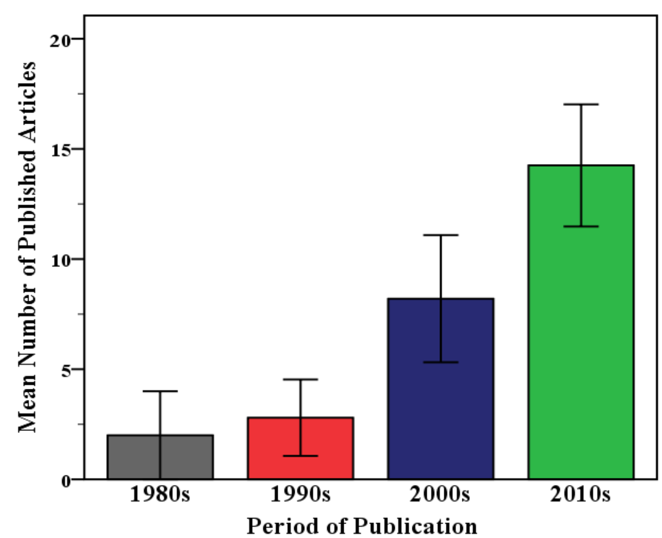

Figure 2. Mean Number of Articles by Decade. Error bars represent ±2 SE.

Only 228 papers were retained. This reduction was due to overlapping keyword terminology used within the majority of the examined articles. Results indicated that a keyword search of "Unmanned Aerial" yielded a total of 122 articles out of an initial 535 (22.80%) papers published in the HFES Proceedings, followed by "Unmanned Vehicles" (113 papers; 21.12%), "UAV" (80 papers; 14.87%), "UAS" (38 papers, 7.10%), "Unmanned Pilot" (36 papers; 6.73%), "Autonomous Systems" (30 papers; 5.81%), "Uninhabited Aerial" (29 papers; 5.42%), "Remotely Operated" (28 papers; 5.23%), "Autonomous Vehicles" (19 papers; 3.55%), "Remotely Piloted" (17 papers; 3.18%), "Unmanned Combat" (7 papers; 1.31%), "Remote Pilot" (5 papers; 0.93%), "UCAV" (3 papers; 0.56%), "Drone" (3 papers; 0.56%), "ROV" (3 papers; 0.56%), and finally RPV (2 papers; 0.37%). Figure 3 highlights these distributions as a function of keyword.

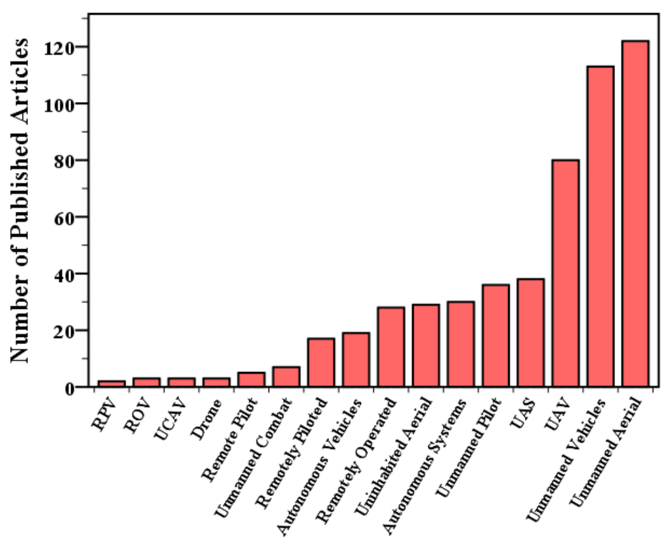

Figure 3. Number of Published Articles by Keyword

Our trend analysis by content area yielded multiple classifications because of the various relevant areas. Specifically, System/Display Design had the highest number of papers at 36 (15.79%) followed by Team Performance (26 papers; 11.40%), Individual Performance (25 papers; 10.96%), Multiple UAV Control (21 papers; 9.21%), Human-Machine Interaction (20 papers; 8.77%), Trust in Automation (16 papers; 7.02%), Interfaces (14 papers; 6.14%), Selection/Training (13 papers; 5.70%), Workload (12 papers; 5.26%), Cognition (11 papers; 4.82%), Situation Awareness (11 papers; 4.82%), Communication with Manned Vehicles (10 papers; 4.39%), Alerts (5 papers; 2.19%), Ergonomics (5 papers; 2.19%), and finally Decision Making (3 papers; 1.32%). Figure 4 depicts the number of published articles for each content area, while Figure 5 shows the number of published articles for each content area by decade.

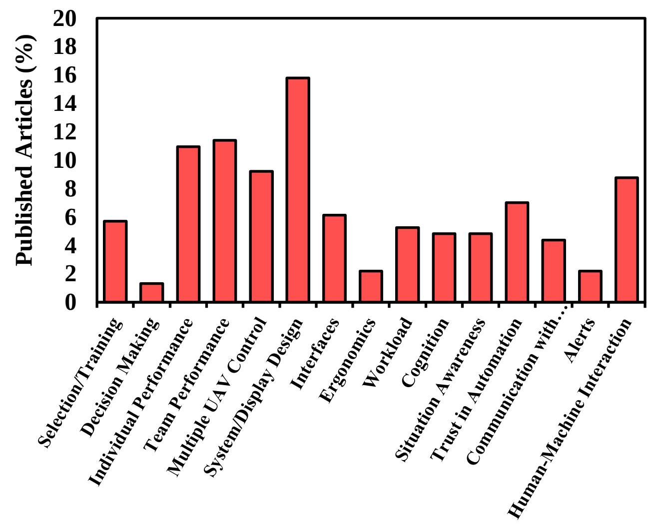

Figure 4: Percentage of Published Articles by Content Area

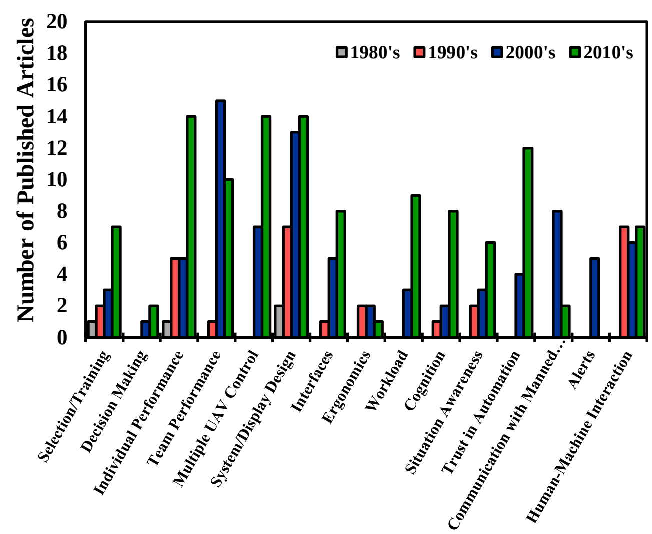

Figure 5. Number of Published Articles by Decade × Content Area

Figure 6 shows the number of published articles by cluster. The present results clearly showed that there was a substantive increase in the number of papers published related to system/display design. Further cluster analysis, grouping the same content areas within a distinct category, was also computed to derive the number of published papers and percentage for each of the four clusters. Results indicated that cluster 1, Cognitive Ergonomics, had the highest (85 papers; 37.28%) number of published papers, followed by UAV System Design (76 papers; 33.33%), Human Performance (54 papers; 23.68%), and finally Selection/Training (13 papers; 5.70%), see Figure 6.

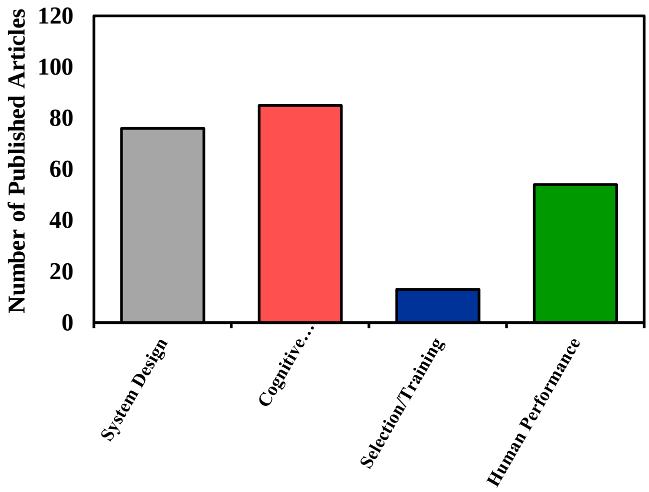

Figure 6. Number of Published Articles by Cluster

Figure 7 depicts the percentage of published articles by authors' affiliation. As it can be seen, Academia alone is the largest contributor to the 228 published UAV articles in the HFES Proceedings at (28.51%; 65 papers), followed closely by joint Academia & Military/Government collaborative research (19.74%; 45 papers) and joint Military/Government & Industry collaborative research (19.30%; 44 papers). Other contributing affiliations included Industry research alone (9.21%; 21 papers), joint Academia & Industry collaborative research (8.77%; 20 papers), Military/Government research alone (7.02%; 16 papers), and Academia & Military/Government & Industry collaborative research (7.46%; 17 papers). These trends of authors' affiliation highlight the main contributing organizations involved in Human Factors and Ergonomics education, research, and practice. These trend analyses elucidate the important role that academia and military/government agencies play in driving research on unmanned aerial vehicles.

Figure 8 shows the percentage of published articles by source of funding. As it can be seen, it is evident the three major contributors to articles' funding are the branches of the U.S. military: comprising the U.S. Army (30.10%; 31 papers), U.S. Air Force (28.16%; 29 papers), and U.S. Navy (19.42%; 20 papers). A small outlier of articles were partially funded by multiple branches of the U.S. military (2.91%; 3 papers). NASA contributed funding to 6 articles (5.83%; papers) prior to the 2000s, but no further funding information was provided subsequently. Funding from government agencies in other categories comprised (10.68%; papers), including the Federal Aviation Administration (FAA), the Defense Advanced Research Projects Agency (DARPA), the Defence and Civil Institute of Environmental Medicine (DCIEM), the Defence Evaluation and Research Agency (DERA), the Defence Research and Development Canada (DRDC), and the National Science Foundation (NSF).

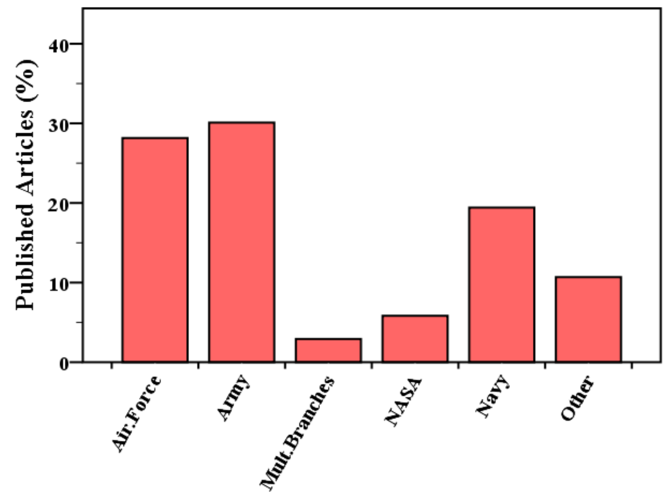

Figure 7. Percentage of Published Articles by Authors' Affiliation

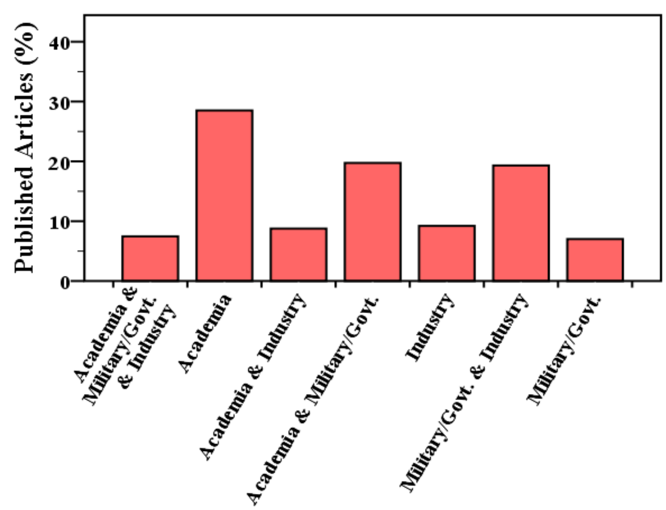

Figure 8. Percentage of Published Articles by Source of Funding

CONCLUSIONS

These trend analyses highlight the increasing interest in the human factors of unmanned systems operations because of various practical implications for workload and performance assessment, operator selection, assessment, system design, and training. As UAS systems continue to proliferate, and are characterized by increasing autonomy and supervisory control requirements, there is the need to articulate the underlying cognitive and ability skill sets supporting effective operator performance. From the foregoing set of analyses, there can be little doubt that these concerns with and interest in UAV's will continue to grow for decades to come. Such trends derive largely from the burgeoning of the capability of the technology itself. The influences of military necessity and hobbyist sophistication have brought these technologies within the purview of an ever-increasing segment of the population. Allied to this are the diminishing costs and added functionality of easily available aerial systems. Now allied to this comes the wave of innovation associated with automated ground vehicles (Hancock, 2018). Given these circumstances, we anticipate a significant, and even exponential increase in such works in the Human Factors and Ergonomics literature. The principles established, and knowledge gained and disseminated promises to exert a substantive impact on this burgeoning dimension of the technological world.

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- A complete list of all reviewed papers used in this trend analysis is available upon request.