Consideration of Cultural Differences in Future Workplace Design for Single Pilot Operations

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ABSTRACT

Future innovations in aviation such as enhanced automation and single pilot operations are projected to change human pilots' roles, tasks, and occupational structures, requiring adaptations in the human-machine interactive interface. The integration of human users with these interfaces, however, remains the greatest challenge. Research is required to understand how to select an appropriate level of automation for future work, and whether skills and experience gained on present generation aircraft can be transferred onto upcoming, next-generation interfaces and occupational roles. Using the Values Survey Module to gauge pilots' (N=40) cultural attitudes on Hofstede's dimensions, this study compares pilots' intrinsic behavioural preferences with three experience factors of age, qualification level, and total flight hours. It was discovered that the dimension of *Power Distance* was correlated with age, and that *Individualism*, *Masculinity*, and *Uncertainty Avoidance* attitudes were more reflective of extrinsic, surface-level behaviours. An understanding of how different experience factors influence non-technical skills in the long term has the potential to create a better fit between the human and the machine by taking into account role-relevance and changes in cognitive models of operators.

KEYWORDS

Culture, Single Pilot Operations, Automation

Introduction

New technical innovations such as enhanced automation, artificial intelligence, and human augmentation technologies are providing aircraft operators with greater resources to improve both safety and efficiency. However, the full application and acceptance of these innovations are limited by non-technical issues associated with integrating human users into these rapidly changing interfaces (Harris, 2020). Although recent projections predict that the human will still play a key operational role in future aviation in spite of advances in single-or-remote-piloted aircraft and AI technologies, changes in human-machine dynamics and role functions are expected (Chartered Institute of Ergonomics & Human Factors, 2020). The human-machine cultural interfaces – "situations where members of one culture encounter people or artefacts from other cultures" (Merritt and Maurino, 2004) – will definitely be altered as a consequence of technological developments and role changes.

One approach being adopted for the development of single pilot aircraft is through autonomous systems, focusing on the replacement of human co-pilots with on-board technology. The technology must be considered as a part of the crew with which the human pilot interacts (Hodgson, Siemieniuch and Hubbard, 2013). Future workplace designers need to determine an appropriate level of authority to give to this digital crew member which balances ease of use with the ability for

human intervention (Aerospace Technology Institute, 2019). However, the determination of this ideal level of automation is difficult, as "different people employ different strategies when making automation use decisions" (Parasuraman and Riley, 1997). Task-relevant exposure, as well as cultural differences in self-confidence, have been shown to affect the level of trust given to automation (Chan and Li, 2020; Rau, Choong and Salvendy, 2004). An inappropriate level of automation trust will lead to either overreliance or underutilisation of automation system innovations (Parasuraman and Riley, 1997).

Another future technological approach is the distributed crewing concept, where the on-board co-pilot is displaced to roles in the wider system such as that of a ground support pilot or super dispatcher (Aerospace Technology Institute, 2019). Performance issues arising from the redistribution of tasks, including miscommunication, false alarms, or different performance expectations, may affect the user acceptance levels of these new technological concepts (Parasuraman and Riley, 1997). The shift from highly-rehearsed skills (manual flying) to knowledge-based reasoning (delegated authority between ground and air roles) also brings into question whether present qualifications are transferrable into future aviation roles (Aerospace Technology Institute, 2019). Cultural differences in the acceptance of uncertainty and propensity to cooperate with others, for example, may change the thresholds at which these issues become problematic. A clearer picture of where target users lie on these thresholds, and whether these thresholds change over time, becomes important in integrating human users into future technological environments.

Hofstede's cultural dimensions of *Power Distance* (PD), *Individualism* (IDV), *Masculinity-Femininity* (MAS), and *Uncertainty Avoidance* (UA) provides validated measures of individual behaviours. High scores on these dimensions respectively represent the acceptance of an unequal, hierarchical distribution of power (high PD); preference to take care of one's self over concern for the society in which they belong (high IDV); preference for competitiveness over cooperation (high MAS); and discomfort with uncertainty and ambiguity (high UA) (Hofstede, Hofstede and Minkov, 2010). These dimensions have been shown to influence a system's usability by means of cognitive load, user acceptance, objective usability, and context of use (Ford, Kotzè and Marcus, 2005). In particular, high PD has been considered as a causal factor in numerous aircraft accidents where lower ranking crew members (typically the First and Second Officers) blindly followed inappropriate commands from higher ranking crew members (the Captain) or automated aircraft systems that were considered as authoritative (Aerospace Technology Institute, 2019; Chow, Yortsos and Meshkati, 2014).

Existing studies involving airline pilots suggest that the cultural dimensions of flight crew can change over time. A study conducted in a Norwegian airline found that flight crews' cultural dimensions changed before and after a gap of 10 years, but provided no explanation for the observed changes (MjØs, 2002). Helmreich & Merritt (1998) suggested that changes in rank can partly explain changes in attitudes toward hierarchy and unequal distributions of power between bosses and subordinates. Chan & Li (2020) supported this with their discovery that task-relevant exposure affected attitudes towards hierarchical relations (reflective of PD), concern towards automation usage (reflective of UA), and desire for high earnings and career advancement (reflective of MAS). Shared training backgrounds were found to lower pilots' PD levels (Chan and Harris, 2019), possibly suggesting that experience in terms of qualification-specific exposure may influence cultural behaviours. Thus, the goal of the present study was to investigate how experience

factors, namely *age*, *qualification*, and *total flight hours*, influences pilots' cultural values as assessed by Hofstede's dimensions.

Method

Participants

This experiment involved 40 participants aged between 25 to 65 years (M=41.56, SD=11.23). They were either current pilots or collegiate aviation students. Flight experience ranged from student pilots with 10 hours' flight experience to airline Captains with 20,000 total flight hours (TFH) (M=8297.23, SD=5920.68). Reported cultural backgrounds included Western (n=26), Asian (n=10), mixed African-Western (n=1) mixed Asian-Middle-Eastern-Western (n=1), mixed Asian-Western (n=1), and Caribbean (n=1). As data was collected from human participants, ethics approval was provided by the Cranfield University Research Ethics System (CURES/12290/2020). As stated in the consent form provided to the participants, participation was voluntary with no identifying information collected, and participants had the right to terminate the survey at any time.

Materials

Data collection was carried out using a survey incorporating demographic items of *age*, *qualification level*, and *TFH* with cultural behaviour items drawn from Hofstede and Minkov's (2013) *Values Survey Module* (VSM). Qualification levels were split into two hierarchical groups of *Captains* (n=16) and *Co-Pilots* (n=19). Results from non-airline pilots (i.e. those who were not Captains or Co-Pilots) were excluded from *qualification level* analyses. Items directly imported from the *Values Survey Module* consisted of 16 items which assessed participants' culturally influenced values and sentiments on five-point Likert scales (see Table 1). These items were combined following VSM formulae to calculate Hofstede's dimensions of *power distance* (PD), *individualism* (IDV), *masculinity-femininity* (MAS), and *uncertainty avoidance* (UA).

Table 1: Survey items assessing cultural behaviours and their corresponding dimensional scales (adapted from Hofstede, Hofstede and Minkov, 2010)

Power Distance (PD)	• How important is it to be consulted by your boss in decisions involving your work? • To have a boss you can respect? • Are subordinates often afraid to contradict their boss? • An organisation structure with two bosses should be avoided?
Individualism-Collectivism (IDV)	• How important is it to have security of employment? • To have sufficient time for personal life? • To have a job respected by family and friends? • To do work that is interesting?
Masculinity-Femininity (MAS)	• How important is it to have pleasant people to work with? • To get recognition for good performance? • To live in a desirable area? • To have chances for promotion?
Uncertainty Avoidance (UA)	• How would you describe your state of health these days? • How often do you feel nervous or tense? • Can one be a good manager without having a precise answer to every question from subordinates? • A company's rules should not be broken even if it would be in the organisation's best interest?

Research Design

The survey was digitally hosted on the Qualtrics platform and anonymous hyperlinks were distributed by chain-referral sampling using email lists. On opening the hyperlink, participants were directed to a participant information and consent page. If they consent to participation, the webpage gets redirected to the series of survey questions.

This analysis utilised responses collected from September to December 2020. Survey items were compiled into cultural dimension indices (PD, IDV, MAS, UA) following Hofstede & Minkov's (2013) methodology and analysed using SPSS. Pearson's product-moment correlations were computed with participants' age, qualification, and TFH as independent variables, and cultural dimensions of PD, IDV, MAS, and UA as dependent variables, to establish whether associations existed. Regression analyses were run, where appropriate, to assess whether experience factors of age, qualification, and TFH were valid predictors of PD, IDV, MAS, and UA dimensions.

Results & Discussion

Age Predicts Power Distance

The *Power Distance* dimension was significantly, positively correlated with age ($r(38)=0.408$, $p<0.01$). The results suggest that older pilots have a higher degree of acceptance and expectation for an unequal distribution of power between superiors and subordinates (see Figure 1). Not surprisingly, age was positively correlated with qualification level ($r(32)=0.708$, $p<0.01$) and TFH ($r(37)=0.822$, $p<0.01$), with older (higher age) participants typically higher qualified and with more flight hours (see Table 2).

Table 2: Pearson's Correlations of Experience Factors and Cultural Dimensions (N=40)

	Age	Qualif.	TFH	PD	IDV	MAS	UA
Age	-						
Qualification	.708**	-					
TFH	.822**	.596**	-				
PD	.408**	.264	.180	-			
IDV	-.132	-.261	-.131	-.068	-		
MAS	.083	-.125	.110	.198	-.079	-	
UA	-.071	-.062	-.134	.342*	-.042	.356*	-

*p<0.05; **p<0.01

To follow-up, hierarchical multiple regression was performed to investigate whether qualification and TFH influenced the ability to predict PD from respondents' age. It was found that when age was the sole variable, regression results were significant with 16.6% of the variance in PD explained ($F(1,32)=6.39$, $p<0.05$). However, the subsequent entry of *qualification* and *TFH* as additional variables into the regression model did not significantly improve the prediction of PD ($F(3,30)=2.32$, n.s.). The finding that age had a greater effect on PD attitudes than qualification or TFH (see Figure 1) suggests that pilots' PD attitudes are determined intrinsically, and effects of extrinsic qualification or experience factors such as training and TFH may play a lesser role.

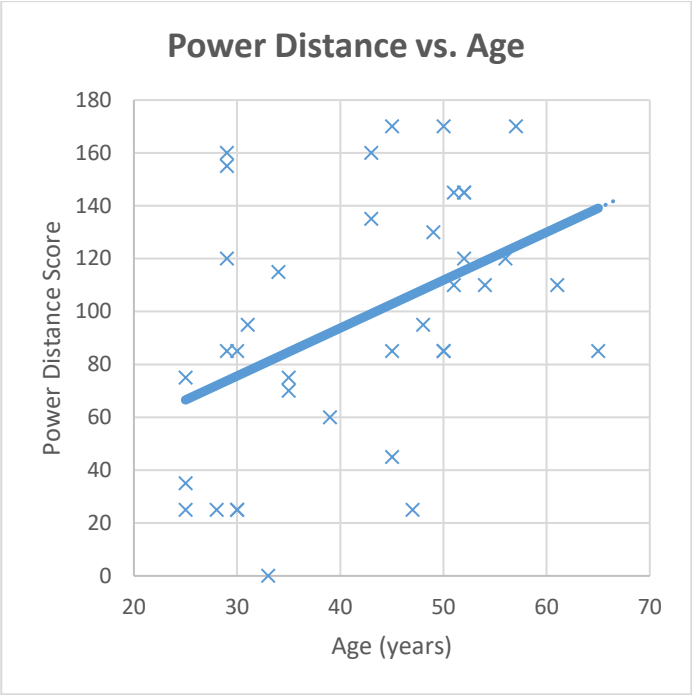

Figure 1: Power Distance scores by respondent age

As the PD dimension reflects attitudes toward hierarchical relations, there are implications for anticipated changes in the future technological environment. For example, improved automation capabilities and distributed crewing concepts may create complex system-wide changes in power hierarchy as the roles and abilities of the system players are transformed, thus changing the human-machine cultural interface (Merritt and Maurino, 2004). In the development and transition stages of future aviation technologies, adaptive strategies based on the users' PD levels may be desirable to ensure an ideal level of automation use (Parasuraman and Riley, 1997). Similarly, the generation gap in PD between pilots of different ages may also create challenges in the development of single pilot operations, as flight deck designs have to be suitable for both experienced pilots transitioning from current technologies and younger pilots who may be trained completely under the new regimes (Harris, 2020). If the PD dimension is determined more so by age than other experience factors, then the transferability of previous experience to next generation technologies may be limited.

Total Flight Hours had No Influence on Cultural Attitudes

Statistical results from Pearson's correlations and regression analyses discovered that TFH did not produce statistically significant correlations with any cultural dimension (see Table 2). This meant that TFH was not a key factor in altering pilots' culturally-influenced non-technical behaviours. This is contrary to previous research which found that non-technical measures such as automation use, leadership, and situational awareness differed between high-hour and low-hour pilots (Todd and Thomas, 2012). Closer inspection of the data reveals that the small sample size used in this study, together with the wide range of participants' TFH, may have unduly affected the results. Further investigation using a greater number of data points will be desirable as the *TFH-cultural dimensions* relationship has important implications for future aviation. For instance, a key challenge for future single pilot operations is of how to provide pilots with the experience necessary for Captaincy if flight hours cannot be acquired in a co-pilot role (Harris, 2020). If it can be confirmed that TFH does not significantly affect pilots' cultural behaviours, then competency based training

and facilitative design concepts, rather than quantitative experience measures such as hours-based training requirements, may prove to be more relevant in training and development.

Integrating Cultural Dimensions in Workplace Design for Single Pilot Operations

The balance between intrinsic changes in PD and extrinsic changes behaviours related to IDV, MAS, and UA should be taken into account when developing future technologies, training, and legislation. For example, if the automation were to be considered as a crew member, it may be beneficial to determine how the target users' PD levels change over time and exposure when choosing an appropriate level of automation (Hodgson, Siemieniuch and Hubbard, 2013). Socio-demographic information, such as age, can also be utilised to modify job roles and interactions to better suit the target users of next generation technologies. For example, workplace designers can utilise information on the cultural dimensions of target users to create culturally congruent user interfaces. More machine or ground-based checking of the appropriateness of pilots' actions, for example, may suit high PD users by diminishing the need for intervention (Harris and Li, 2008). Therefore, as applied to the present finding of the positive correlation of PD with age, a recommendation is that automation alerts can be set to trigger at a lower threshold if the target users are of higher age.

The delegation of tasks between the single pilot and ground-based counterparts will similarly bring new challenges to crew resource management. The simplification of the crew briefing, for example, will change the pilot-support requirements derived from social and organisational cultures (Aerospace Technology Institute, 2019). A possible solution is to share the socio-demographic information of the single pilot with colleagues in the operational loop (ground pilots, dispatchers, monitors of engine parameters, and air traffic controllers), so that the style of communication can be customised to enhance interaction. When working with a high PD pilot who may be reluctant to question errors, the use of more consultative interactive styles (e.g. by the ground-based agents) may enhance monitoring and cross-monitoring between the various operational roles (Harris and Li, 2008).

That being said, the practical application of these cultural dimensions may be limited by further cultural concerns. For example, the right to privacy is considered central to individualistic societies, but not in collective ones (Hofstede, Hofstede and Minkov, 2010). Will users be willing to share their cultural dimensions scores with automated systems or colleagues in distributed roles? Changes in workplace designs will also likely require training on new concepts and principles – will users be responsive to new ways of doing things? Future changes in the organisational hierarchy as well as the distribution of operational knowledge may also alter the relative effects on both experience and cultural dimensions on operational outcomes.

Closer Inspection – Uncertainty Avoidance and Masculinity

The dimension of UA was significantly, positively correlated with MAS ($r(38)=0.356$, $p<0.05$). A closer look at the items which constitute these two dimensions offers a clue for the correlation (see Table 2). The high side of both UA and MAS are respectively represented by the avoidance of uncertainty (e.g. no uncertainty of job loss) and the desire for competitive rewards (e.g. chances for promotion and high earnings) (Hofstede, Hofstede and Minkov, 2010). The relationship of UA and MAS has been claimed as being influenced by the hierarchy of human needs. In conditions of high uncertainty, the need for *safety and security* (no job loss) is likely to prevail over all other needs. It is only when an adequate level of safety and security is achieved, then individuals will seek

masculine goals of *esteem* (promotion and high earnings) (Hofstede, Hofstede and Minkov, 2010). Therefore, in situations of high uncertainty the UA index will likely lead the MAS scores.

This study was carried out during the Covid-19 pandemic, when border closures and quarantine requirements have decimated the aviation industry. At the time of writing, 22 airlines have gone into bankruptcy or administration, and industry experts were predicting a 66% decrease in traffic for the year 2020 compared to the year before (International Air Transport Association, 2020; Wilson, 2020). The data was therefore collected during a time of high uncertainty in both economic and emotional accounts, and the results may be reflective of the UA-MAS relationship during uncertainty. Additional research on the link between the UA and MAS dimensions in the longer-term future are desirable to determine if the correlation remains in different socioeconomic situations. On a similar note, an extended study on how the pandemic situation affects PD may be of interest as changes to competing priorities (such as between continuity of flight operations and pandemic control measures), coupled with the fact that even supervisory personnel are lagging behind in ever-changing pandemic safety requirements, may alter the power dynamics in the aviation system.

Conclusion

Changes in human-machine interactions and job functions as a result of technical innovations will alter the cultural interfaces and user acceptability of future aviation systems. Future flight deck design shall embrace changing cultural characteristics of human operators in the aviation system, who may be pilots on the flight deck, ground pilots, dispatchers, monitors of engine parameters, or air traffic controllers. Comparing the relative influence of three experience factors of *age*, *qualification*, and *total flight hours* on dimensions of culture, it was discovered that age had the most significant influence on the *Power Distance* (PD) dimension which represents the degree of acceptance for an unequal distribution of power between superiors and subordinates. On the other hand, pilots' behaviours in relation to individual vs. group loyalty (IDV), assertiveness vs. cooperation (MAS), and discomfort with uncertainty and ambiguity (UA), were not changed by experience and exposure. An understanding of target users' cultural dimensions can assist in building better workplace designs for single pilot operations. Bespoke human-machine interactive styles, such as more consultative interactions for higher PD users, can be used to enhance task performance and ensure an appropriate level of automation trust, which in turn can lead to improved user acceptance of new workplaces and workflows. The sharing of socio-demographic information within the operational loop will also benefit crew resource management and cooperation in future, distributed workplaces, but further cultural issues such as individuals' desire for confidentiality may hinder its full potential.

As the present research was centred on the assessment of cultural change as a result of experience, a possibility for further research is to extend the study to investigate how cultural dimensions influence the attribution and acceptance of training needs. This is because changes in cultural characteristics, whether intrinsic or extrinsic, will require the adaptation of training in the first-order, and also in the second-order raise questions regarding the acceptance of these culturally adapted training solutions. Additional sociological research on communicative and behaviours associated with automation trust will assist in capturing necessary changes in cockpit dynamics when operating increasingly autonomous technology. Observational studies of technology usage behaviours will also provide a clearer picture of how cultural dimensions influence real-world practices on the human-machine interface.

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