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Ergonomics Considerations in Air Traffic Conflict Detection and Resolution

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Abstract. The latest global air traffic shows a positive sign of a tremendous recovery in worldwide air traffic post-pandemic. This paper aims at providing a systematic literature review on air traffic conflict detection and resolution (CDR) in air traffic control (ATC) from ergonomics perspectives and developing a framework underlying the CDR processes to retort the bounce-back of air traffic density. A preferred reporting item for systematic reviews and meta-analyses (PRISMA) was adopted to conduct the review of prior publications in ATC CDR. Based on the 35 literatures reviewed, a framework of CDR is produced highlighting the key aspects of ATC as a sociotechnical system including humans, environment, interface/system, and task. The present study also sheds light on future research directions covering acceleration of ATC proficiency, design of ATC systems, analysis of global traffic patterns, ATC automation transparency, and task designs to enhance air traffic safety and efficiency. The take-away points from the growing body of literatures on ATC CDR are discussed further in this paper.

Keywords: Air traffic control; Conflict detection; Conflict resolution; Ergonomics; Review

1. Introduction

The unexpected COVID-19 pandemic had hit aviation systems due to travel restrictions and health concerns that have greatly affected air traffic operations. However, the latest investigation of global air traffic shows a positive sign of a vigorous recovery in worldwide air traffic as indicated by the increasing number of passengers by up to 65% as compared to that in 2021 (Aviation, 2022). This upsurge is highly linked to increasing air traffic density after the gloomy period in the aviation domain during the pandemic.

The bounce-back of air traffic density will bring encouragingly positive responses from all aviation stakeholders but it needs to be compensated with greater safety assurance. The assurance process is required to support the pre-post-pandemic adjustment in air traffic, especially on its facilities, operations, and procedures. The recovery process highlights the requirements for innovation and resilience (Aviation, 2022) to enhance the travel experience and ultimately air traffic safety.

The adjustment in air traffic control (ATC) operations is vastly associated with ergonomics issues since safety is an uncompromised feature in this domain. Ergonomics

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issues that may appear more salient due to the extreme dynamic of air traffic include vigilance, out-of-the-loop-of-unfamiliarity (OOTLUF), task demand, and loss of situation awareness (SA), leading to skill loss that affects conflict detection and resolution (CDR) performance.

Research efforts related to CDR in ATC are limited, l*et al*one the focus on the ergonomics aspect of CDR. The majority of the studies concerning CDR in ATC solely highlight its algorithms and models in the short, medium, and long-term CDR problems (Tang, 2019) instead of considering the ergonomics perspective of the ATCOs during CDR. The research and review on CDR have emphasized on the systems whether it is ground-based or airborne-based systems as well as on conflict resolution including pair-wise or global solutions that account for various state variables covering discrete, continuous, or even hybrid (Tang, 2019).

In addition, the few studies covering ergonomics concerns in air traffic CDR merely focus on identifying specified factors influencing the CDR performance within certain contexts and settings. In the current paper, in contrast, a theoretical framework was developed integrating the factors in ATC systems to be considered in enhancing CDR performance in response to the bounce-back of the air traffic density.

The model presented in this study encompasses the main elements of a system including humans, interface, task, and environment. In the following sections, an overview of air traffic control, air traffic conflict, the conforming ergonomics issues, as well as the future research direction are further explained.

2. Air Traffic Control

ATC is a safety-strict domain where ground operators called air traffic controllers (ATCOs) provide support to warrant safe and organized air traffic flow. The key objectives of ATC are to avoid any collisions, ensure aircraft are flying within the specified path for orderly traffic, as well as provide necessary data and assistance to pilots (Svensson, Ohlander, and Lundberg, 2020; Hopkin, 2017). ATC tasks are cognitively demanding and can impose a high mental workload due to their complexity (Pujiartati and Yassierli, 2017).

In its operations, ATC is generally categorized into three different sections: tower, terminal radar, and en-route controls (Svensson, Ohlander, and Lundberg, 2020; Nolan, 2010). Tower controllers are mainly responsible for ground and low-level air movement and provide clearances for both departing and arriving aircraft. After an aircraft reaches a certain level, it is handed off to a Terminal Radar Control (TRACON) for merging and sequencing aircraft around 40 nautical miles (40 NM) from the airport. Afterward, the aircraft is further handed off to Air Route Traffic Control Centre (ARTCC) or also known as en-route controllers who control aircraft that cruise at high speed at high altitudes. After the aircraft arrives at the Flight Information Region (FIR) of the destination, a reverse flow applies where the en-route controllers then hand off the aircraft to the TRACON and subsequently to the tower controllers at the destination airport as shown in Figure 1.

Figure 1 Air traffic control operations

3. Air Traffic Conflict

Avoiding air traffic conflict from happening is probably one of the most vital ATCOs' responsibilities. Air traffic conflict is defined as a situation whereby the minimum separation rules are violated. The International Civil Aviation Authority (ICAO) has determined the minimum separation rules in the air navigation services procedures covering lateral as well as vertical separations. For lateral separation, ICAO (2016) specifies the 5 NM minimum separation distance when controlled aircraft are under surveillance systems. In addition, aircraft must be vertically separated at least by 1000 feet and 2000 feet for Instrument Flight Rules (IFR) flight below and above Flight Level (FL) 290, respectively (ICAO, 2016; Nolan, 2010) as shown in Figure 2.

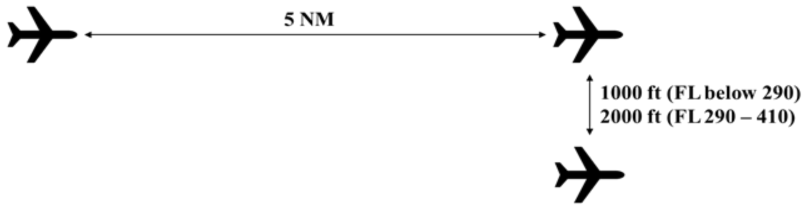

Figure 2 Schematic illustration of separation minima

The separation minima must not be violated at any point to avoid an air traffic conflict from happening, there are several maneuvering options including turning, speed as well as vertical adjustments. Although several prior studies have highlighted the presence of maneuvering preferences in ATC operations, there is no formal standard on the CDR process, leaving ATCOs to be the main actor in the process. Several initiatives to ease and support ATCOs in the CDR process have also been examined in the growing body of literature in the ATC context. Still, a thorough review and analysis of how human factors connect to other aspects and its underlying model, given the bounce-back of air traffic level, is even increasingly critical to ensure air traffic safety.

4. Ergonomics Issues in CDR

4.1. Articles Selection

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page *et al*., 2021) structure which offers an approach to obtaining the evidence-based minimum set of literatures was adopted to conduct the review. The framework consists of three stages including identification, screening that is nested with eligibility checking, and inclusion as shown in Figure 3.

In this study, records from the Scopus database were identified using the combined keywords of "human factors", "conflict detection or resolution", and "air traffic control". There were 71 papers that resulted from the initial search. Moreover, a further search of literatures was performed on other sources and additional 16 papers were identified. Collectively, the combined records of 87 papers published from 1973 to 2022 were obtained in the identification stage.

Subsequently, to acquire a better understanding of particularly more recent developments in CDR, the literatures published from 1973 to 2010 were screened and removed accordingly, leaving 59 papers. The following screening process yielded 52 papers since the other seven papers were not available to retrieve. The remaining papers were screened for eligibility and 17 records were excluded because of several reasons such as the papers solely covered algorithm and model developments (12 articles), focused on the hardware/systems, and did not investigate human-factors issues (2 articles), examined pilots instead of ATCOs (2 articles), and discussed on UAV (1 article). Finally, 35 papers were included in the final review and analysis.

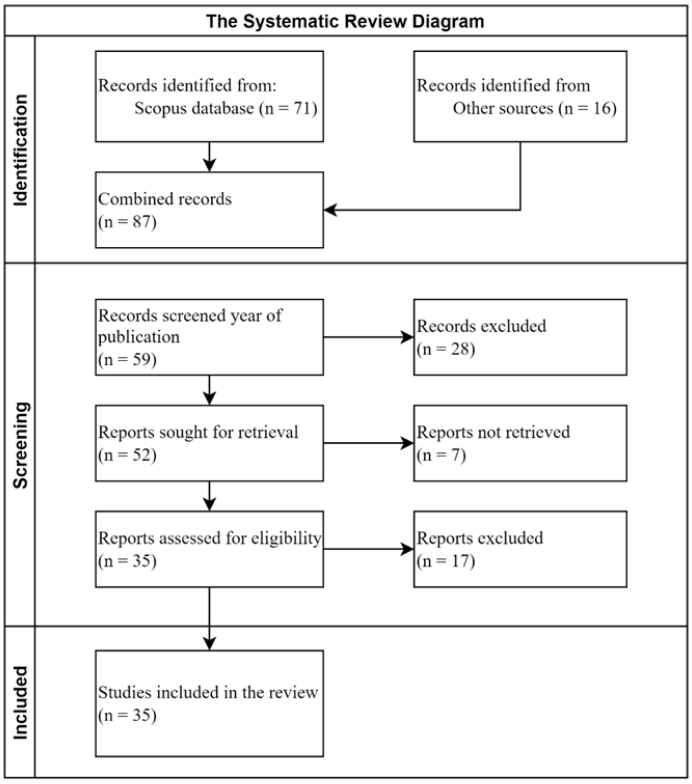

Figure 3 The PRISMA flowchart for the systematic conflict detection and resolution literature selection process

4.2. Ergonomics framework of CDR

Based on the selected literatures, we highlighted the elements of the CDR process in air traffic control with a specific emphasis on the human factors and other associated elements from a system's perspective. The general framework and concept, then the inferences for the four main elements including human, task, interface/system, and environment were discussed accordingly.

We developed a theoretical model outlining the key aspects of the CDR process in ATC as a sociotechnical system as shown in Figure 4. In sociotechnical systems, human performance assessment is a key for its design and evaluation (Salmon *et al*., 2009). In Figure 4, an environment generates information provided through a system and its interface. The environment covers air traffic and airspace factors including crosswind, traffic pattern, conflict geometry, vertical and lateral separation, groundspeed, perturbation, traffic density, and airspace region.

That information is presented to human operators through ATC systems and their interface in the forms of radar display, alerting design, vertical situation, and trajectory displays as well as instrument landing systems for the ground facility. Moreover, automation conditions and transparency have been ever more relevant today to support an accurate mental model of ATCOs in performing their tasks.

The performance of ATC tasks is also influenced by task attributes including task type, working time, working position, shift, instructions, context, and processing load. In order to perform ATC tasks in a way that will support correct understanding, gender, expertise, and trust issues can be further analyzed and strategized. In the following, we present a review of the factors for the four key elements of CDR in ATC that are based on a collective evaluation system.

4.2.1. Human-based issues

Many research studies have been carried out to identify ergonomic issues that affect CDR (CDR) in air traffic control. Concerning human-based issues, there are some research findings in the context of expertise (Wang *et al*., 2021; Sanda, 2018; Kearney, Li, and Lin, 2016; Klomp *et al*., 2015; Kang and Landry, 2014), trust (Mirchi *et al*., 2015), and gender (Trapsilawati *et al*., 2022; Tomic and Liu, 2017).

A major challenge in ATC operations is the involvement of ATCOs in a complex set of tasks that require a very high degree of knowledge and proficiency and the practical application of specific skills related to cognitive domains. The ATCOs' expertise largely determined the type of control measures chosen (Sanda, 2018). There appear two different findings on the influence of expertise level. First, experts were found to perform better in CDR, in line with logical wisdom. In Klomp *et al*. (2015), the experts were more proficient in controlling tasks than that of skilled and novice participants. This is because experts deal better with uncertainties in the displayed information considering the constraints and they were more proactively controlling the traffic. Consistently, novices were observed to monitor the airspace more carefully by scanning through each part of it, making the process of critical information-seeking became less efficient (Wang *et al*., 2021). Second, however, according to Kearney, Li, and Lin (2016), the ATCOs' experience did not influence ATCOs' response time during the use of Area Proximity Warning (APW) and Short Term Conflict Alert (STCA).

Although there was a contrast between novice and expert to some extent, studies found that the semantic alert design could help address the expertise gap because it helped the novice as well as experienced ATCOs to provide quicker responses (Kearney, Li, and Lin, 2016). Likewise, the performance of novice ATCOs could also be supported, as indicated by lower false alarms by up to 73%, through training in scan path intervention (Kang and Landry, 2014). These thereby offer solutions for expertise issues, however, another ever more pertinent issue is ATCOs' trust in ATC systems and automation tools.

An inappropriate level of trust can lead to a dichotomy where individuals with high trust will be complacent to the automation thus reducing their SA and those with lower trust will simply ignore the provided automation (Lee and See, 2004). This has already been manifested in a study in the ATC context that ATC interns with higher trust were shown to have reduced SA in high traffic, indicating a sign of complacency on automation (Mirchi *et al*., 2015). Relevant to the finding, the expert ATCOs tended to have lower trust in ATC visualizations and were more skeptical, especially during the implementation of solutions in tight situations (Klomp *et al*., 2015).

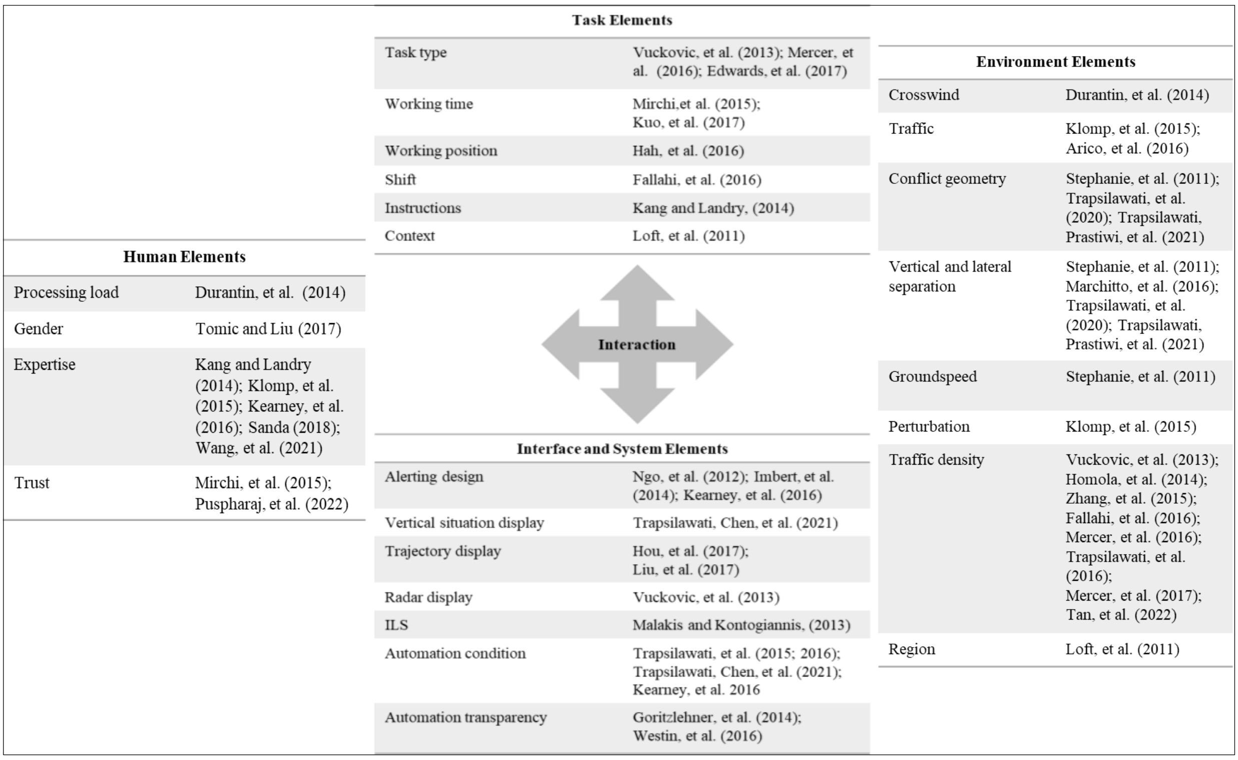

Figure 4 The theoretical model covering the key aspects of the conflict detection and resolution process in ATC as a socio-technical complex system.

To ensure sufficient ATCOs' trust level in ATC systems and automation tools, several assessment methods have been available including subjective, objective, and physiological approaches. The subjective approach such as the human-automation questionnaire (Jian, Bisantz, and Drury, 2000) has so far been perceived as the most appropriate assessment method for trust which lies in the cognitive state. Correspondingly, objective approaches such as numbers of prior warnings and time between events (Kaniarasu *et al*., 2012) were also available. Recently, a physiological approach to assessing trust was proposed using quantum mechanics principles and brain imaging techniques (Pushparaj *et al*., 2021). It is particularly important to provide an ATC system and automation tool that encourages sufficient trust (Lee and See, 2004) through appropriate design and practicable yet accurate assessment of trust.

Next, gender has become a sensitive issue in ATC. The percentage of female ATCOs experiencing work fatigue was higher than male ATCOs, whilst in terms of stress due to shift work, the percentage of male ATCOs was higher (Tomic and Liu, 2017). A promising finding is later brought by Trapsilawati *et al*. (2022) that male and female ATCOs did not show a significant difference in CDR performance, workload, and SA. Nevertheless, they observed a difference in the physiological measures where higher beta activation linked with logical thinking and awareness was more prominent in male ATCOs than in female ATCOs despite the similar CDR performance. This suggests that training programs about attentional resource management should be conducted.

4.2.2. Environment-based issues

In CDR, environmental factors also have a strong impact. Crosswind significantly reduced the aircraft tracking performance and also increased the mental workload of ATCOs (Durantin *et al*., 2014). In a real airspace environment, the difficulty levels were changing over time (Aricò *et al*., 2016). Traffic structure (i.e., the orderliness of traffic) and perturbation (i.e., the number of aircraft that need to be re-routed to prevent air traffic conflict) are the inevitable challenges in the airspace during the control process (Klomp *et al.*, 2015). Large perturbation increased the actions of control and reduce robustness. In unstructured traffic conditions, the high frequency of crossing trajectories was found to lower the space for control actions (Klomp *et al.*, 2015).

There needs to be a thorough review of conflict geometry due to the different fashions in conflict detection. The effects of conflict geometry were prominent that it is more challenging to detect and resolve crossing and converging conflicts than overtaking one as indicated by ATCOs performance, workload, SA, and other physiological measures (Trapsilawati *et al.*, 2020). With regards to ATCO judgments, higher vertical separation induced the perception of lower conflict risks in all conflict geometries (opposite, cross, same headings) (Stankovic *et al.*, 2011). Moreover, the perpendicularly vertical and horizontal routes increased cognitive complexity and thus imposed higher workloads during the conflict scenarios (Marchitto *et al.*, 2016). Given these findings, collectively, the safety of aircraft navigation is clearly facilitated by the availability of the standards for vertical and lateral separations.

Controlling traffic in the airspace is inseparable from its density. Prior research on traffic density has come toward a conclusive direction that a greater mental workload would be imposed on ATCOs as the traffic density increased (Mercer *et al.*, 2017; Fallahi *et al.*, 2016; Trapsilawati *et al.*, 2016) except that in Homola *et al.* (2014) who found no difference in workload rating despite the increasing traffic. A more recent study by Zhang, Yang, and Wu (2015) confirmed this finding that investigating airspace merely from its density information for both linear aircraft and dyad levels is not enough. Instead, examining its global pattern is more useful. Furthermore, consecutive evaluations on targeted aircraft could well represent conflict detection performance (Tan, Chen, and Lye, 2021).

During the CDR in denser traffic conditions, the highest ATCOs concentration to resolve a conflict was observed only within 30 seconds of its detection (Mercer *et al.*, 2016). The utilization of Multi-Conflict Display (MCD) plus radar allowed ATCOs to detect conflicts faster in the searching task under the dynamic multi-pair scenarios in unfamiliar and busy airspace (Vuckovic *et al.*, 2013). On the other hand, the main and interaction effects of upper and lower region variables were absent (Loft, Finnerty, and Remington, 2011). Particularly, ATCOs in the context group accepted approaching aircraft from irrelevant regions faster than those from relevant regions. The examination of airspace factors must receive greater attention for the development of future and safer ATC systems by considering the state of the global system.

4.2.3. Interface/Systems-based issues

ATC systems will evolve and bring across-the-board implications for ATCOs' roles and responsibilities that will be immensely changed from those of today (Langan-Fox, Sankey, and Canty, 2009). In ATC systems, a radar display is probably the most important item allowing ATCOs to continuously monitor aircraft position. To support conflict detection, Vuckovic, *et al.* (2013) examined a plan-view radar display and a multi-conflict display (MCD) and found that radar display was useful for the static environment. Thus, MCD plus radar display is suitable for better conflict detection in heavy air traffic.

In ATC operations, a radar system is typically equipped with an alerting system to warn ATCOs of an imminent air traffic conflict. For the sake of updating ATCOs' mental picture during the CDR process, prior studies (Kearney, Li, and Lin, 2016; Imbert *et al.*, 2014; Ngo, Pierce, and Spence, 2012) examined various alerting designs for the radar display ranging from visual to vibrotactile alerts. Ngo, Pierce, and Spence (2012) and Kearney, Li, and Lin (2016) both investigated auditory alerts but contrasted them with different alert types.

Ngo, Pierce, and Spence (2012) found that auditory and audio-tactile alerts offer the potential for reducing conflict detection time. Kearney, Li, and Lin (2016) observed a better performance with the semantic alert. While Imbert, *et al*. (2014) focused on different types of visual alerts and found that the box-animated type led to the highest performance accuracy during the conflict detection process. Collectively, a better alerting design may be in the form of combined features of these studies where it should incorporate auditory-semantic, vibrotactile, and box-animation. However, it is suggested that alerts for critical or emergencies must be designed to be more salient and rarely activated. Therefore, further study is needed to validate the proposal to support the CDR process.

The most important factors in handling traffic are aircraft position and performance data. These elements contain the "knowledge variables" with the highest "rate of change", and are very useful for traffic processing (Malakis and Kontogiannis, 2013). On top of radar displays, ATCOs are often armed with other displays such as trajectory prediction and vertical situation displays. Unexpectedly, ATCOs with trajectory prediction display showed a higher workload than those without it, perhaps due to the display complexity and clutter (Hou *et al*., 2017; Liu *et al*., 2017). Moreover, vertical situation display (VSD) has been extensively used on onboard aircraft however it has just been introduced for the ATC context providing a vertical profile of aircraft in a controlled sector. VSD was found to lower ATCOs' workload and increase their SA (Trapsilawati, *et al*., 2021). In sum, it is necessary to carefully design and examine the provision of additional displays for ATCOs to ensure their effectiveness.

Like displays, ATCOs are also equipped with various automation tools such as conflict resolution aid (CRA) (Trapsilawati *et al*., 2016; 2015) minimum safe altitude warning (MSAW), short-term conflict alert (STCA), and area proximity warning (APW) (Kearney, Li, and Lin, 2016) across different levels of automation. However, automation also brings problems since it is hardly perfectly reliable. Trapsilawati, *et al*. (2016) confirmed that degradation of overall performance was present during a conflict resolution task, however, its level remained above the manual performance, suggesting that automation in ATC is necessary. Moreover, to implement the Air Traffic Management (ATM) system successfully, human-automation should be effectively coordinated.

Human-automation coordination brings up an emergent issue of automation transparency that can be realized through better techniques for communication and visualization (Westin, Borst, and Hilburn, 2016). Surprisingly, the conformance of human and automation strategies as well as solution transparency did not significantly increase human acceptance of automation (Westin, Borst, and Hilburn, 2016; Göritzlehner *et al*., 2014). However, the interaction between transparency and conflict geometry was present and the effects of VSD were significant on performance, suggesting that automation transparency could help diminish the cost of automation imperfection in performance when the situation is difficult or the automation erred (Trapsilawati, *et al*., 2021; Göritzlehner *et al*., 2014). Further research is demanded for addressing the issue of automation transparency that involves greater participation of professional ATCOs to increase the robustness of insights supporting the design and operational processes that are often overlooked.

4.2.4. Task-based issues

In ATC systems, the tasks are cognitively demanding and require ATCOs to be very precise in performing them to ensure safety. Vuckovic, *et al*. (2013) investigated search tasks given static and dynamic targets and found that ATCOs performed well in the dynamic multipair search task despite the longer response time required. However, the average time required to respond was significantly higher in decision-making tasks (Edwards *et al*., 2017), indicating a higher workload. In sum, decision-making tasks were objectively more demanding for ATCOs whereas doing routine tasks in a dynamic fashion was generally acceptable due to the conformance with the task nature.

Various means are offered and examined to support ATCOs in performing their tasks including providing scan path, and instruction, as well as considering task processing load. The provision of the scan path of expert ATCOs to novice ATCOs were found to marginally lower the false alarms than solely providing instruction to the ATCOs (Kang and Landry, 2014). The processing load associated with ATCOs' memory also needs to be carefully considered as a high processing load led to lower aircraft tracking performance and higher ATCOs' mental workload (Durantin *et al*., 2014).

Working shifts and time are also essential for ATCOs. During the night working shift and high traffic, operators experience higher mental stress, which could, over a prolonged period, induce mental disorders (Fallahi *et al*., 2016). Performing ATC tasks on the night shift would influence physiological indices and it will take a long time to recover. However, longer working time mostly induced higher trust in ATC automation systems (Mirchi, *et al*. 2015) and fatigue (Zuraida, Wijayanto, and Iridiastadi, 2022; Zuraida and Abbas, 2020) which may lead to automation complacency. To avoid so, preventive actions including real-time workload monitoring are deemed essential. The result of Kuo *et al*. (2017) over real-time monitoring of ATC tasks for 31 hours of normal shift, showed that an increase in subjective workload could be assessed through the decrease in gaze standard deviation.

ATC tasks are related to the working position, either at Resolve (R) or Detect (D) side which is responsible for tactical and strategic actions, respectively. Hah, *et al*. (2016) found that ATCOs relied more on automation rather than manually performing their tasks on the D side. Prominently, ATCOs prefer to conduct tactical tasks on their own and depend on automation more for planning tasks. On top of the working position, Loft, Finnerty, and Remington (2011) further considered providing context to examine the reduction of memory error and response cost. The ATCOs provided with contextual information accepted aircraft faster in the irrelevant region than in the relevant region and faster hand-off compared to the standard group. The study also highlighted that the provision of spatial context eliminates the need for ATCO to examine future memory states of selected aircraft for entry into unrelated regions.

5. Takeaway Points and Future Research Directions

The above review provides important takeaway points concerning research in ATC. It also offers several research directions to support CDR from ergonomics perspectives. In the following, the takeaway points and recommendations for future research are highlighted following the four elements described in the framework covering human, environment, interface/system, and task.

The review of human-based elements in CDR in ATC underlined that expertise matters but there are things that can be offered to address the gap in expertise, for instance, semantic design alert to promote faster response time (Kearney, Li, and Lin, 2016) and scan path training to improve novice performance (Kang and Landry, 2014). Furthermore, trust is an increasingly important notion in complex socio-technical systems including ATC. It is particularly important to provide an ATC system and automation tool that encourages sufficient trust (Lee and See, 2004) through appropriate design and practicable yet accurate assessment of trust. Given these points, future research is needed to explore more means to fulfill the expertise gap and expedite proficiency in ATC. In addition, more research on assessing trust in ATC automation as well as designing ATC systems that can induce sufficient trust is also urgently required given the air traffic bounce-back.

In the airspace environment, many factors influence control difficulty. Its levels vary depending on traffic structure, perturbation, crosswind, etc. Traffic density and aircraft velocity alone are not sufficient to reflect ATCOs' mental demands. Instead, several conflicts and global traffic patterns including regional coverage should be carefully considered in future research to support the development of safe and efficient ATC systems.

Next, interface/system issues require increasing attention due to the evolution of ATC systems that shift the paradigm of ATCOs' roles. Automation across levels, various displays, as well as different alerting designs have been addressed in the growing body of literature on ATC. However, an emergent topic in the ATC domain is the human-automation collaboration that raises the automation transparency issue on which system designers should center their attention for the sake of sustainable, effective, and safe collaboration between ATCOs and ATC automation. Further research is deemed necessary to address the human-automation collaboration in ATC.

Regarding ATC tasks, it varies from judgmental to action-based tasks. Decision-making appears to be the most cognitively demanding task for ATCOs despite their familiarity with the dynamic nature of ATC. In addition, various means are proposed to support ATC tasks including the provision of scan paths and instruction. Several crucial aspects of ATC tasks are working shifts, time, position, and regional context. This sheds light on future research that should address the continuous monitoring of ATC task performance to avoid human errors and automation complacency. Moreover, more attempts to propose suitable task designs are required through the investigation and proper adjustment of working parameters including its context.

This study provides an overview of ergonomics issues in CDR based on the prior ATC literatures through PRISMA guidelines. However, there are several possible limitations to this review. First, the literatures were mainly obtained from Scopus electronic database, thus leaving the potential of missing additional relevant literature from other databases. Second, the review outline adopted a system's perspective and only covered the main elements including humans, task, interface/system, and environment.

6. Conclusions

The latest investigation of global air traffic shows a positive sign of a vigorous recovery in worldwide air traffic after the pandemic. In the current paper, a theoretical framework is developed, integrating the factors in ATC systems to be considered to enhance CDR performance in response to the bounce-back of the air traffic density. The model highlights the key aspects of the CDR process in ATC as a sociotechnical system including humans, environment, interface/system, and task. ATCOs are the key to the design and evaluation of an ATC system as a socio-technical system. The air traffic environment generates information provided through a system and its interface to support the accurate mental model of ATCOs in performing their tasks.

The present study provides a thorough review of CDR in ATC from ergonomic perspectives and sheds light on future research agendas. Collectively, further research on the acceleration of ATC proficiency, design of ATC systems inducing sufficient trust, consideration of global traffic patterns, ATC automation transparency as well as ATC task designs provoking more sustainable and interchangeable human-automation collaboration is ever more important to enhance air traffic safety and efficiency.

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