



Holistic thinking and air traffic controllers' decision making in conflict resolution



E Xiaotian ^{a,b}, Zhang Jingyu ^{a,*}

^a CAS Key Laboratory of Behavioral Science, Institute of Psychology, Beijing, China

^b University of Chinese Academy of Sciences, Beijing, China

ARTICLE INFO

Article history:

Received 16 September 2015

Received in revised form 24 September 2016

Accepted 28 November 2016

Available online 2 January 2017

Keywords:

Air traffic control

Conflict resolution

Holistic thinking style

Decision making

Workload management

ABSTRACT

When facing potential conflicts, whether to make interventions is an important decision for air traffic controllers and vital for aviation safety and efficiency. While many task-related factors in influencing such decisions have been identified, the large portion of individual differences has remained insufficiently explained. This paper proposes that controllers with a more holistic thinking style will be more likely to make interventions because they envision more uncertainties in the system which can lead to a higher level of perceived risk and a greater likelihood to take proactive measures. To test these hypotheses, forty-two licensed controllers were invited to complete a questionnaire measuring holistic thinking style and later a conflict detection/resolution task. Multilevel regression analyses showed that (1) when the real risk level (the minimum lateral distance between two converging aircraft) dropped, controllers who think more holistically still tended to maintain a higher risk perception level (perceived likelihood of aircraft collision in the future) which lead to a higher intervention ratio and (2) even when real and perceived risk levels were controlled, those who think more holistically were more likely to make interventions. These findings are discussed with reference to literature in cognitive style, risk perception and workload management. Potential implications for personnel selection and training are also discussed.

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1. Introduction

Ground-based air traffic controllers (ATCos) play a key role in guaranteeing airline efficiency and safety. This is especially the case as airspace saturation and personnel shortage are becoming more salient (ICAO, 2013). In order to increase the maximum capacity of current air traffic management system, understanding how controllers make important decisions is urgently needed as it can help improve current human-computer interface and personnel training and selection procedure.

Making an intervention decision (to change the trajectories of certain aircraft) in cases of potential conflict is vital for ATCos. While unnecessary interventions can cause increases in aircraft fuel consumption and delay rates, failure to intervene may result in dangerous incidents or worse. Previous studies have found controllers' decisions are heavily influenced by the perceived uncertainties embedded in the entire human-in-the-loop system (Bisseret, 1981; Loft, Bolland, Humphreys, & Neal, 2009; Loft, Sanderson, Neal, & Mooij, 2007; Rantanen & Levinthal, 2005; Sperandio, 1971). However, a large individual

* Corresponding author at: Institute of Psychology, Chinese Academy of Sciences, South Building #427, 16A Lincui Road, Chaoyang District, 100101 Beijing, China.

E-mail addresses: ext@psych.ac.cn (X. E), zhangjingyu@psych.ac.cn (J. Zhang).

difference has also been discovered which has still not been fully accounted for (e.g., Stankovic, Loft, Rantanen, & Ponomarenko, 2011). Consequently, if certain measurable, alterable and predictive variables can be found governing controllers' performance, we can achieve a better understanding of controllers' decision processes as well as potentially improving the current practice of personnel selection or training.

In this research, we investigate the influence of one such variable, namely, holistic thinking style on the intervention decision making of professional air traffic controllers. Holistic thinking style can be best described as the tendency to consider the overall context and emphasize relationships and connectedness (Ji, Peng, & Nisbett, 2000). As people who think more holistically are more likely to take the dynamics of the whole system into consideration (Hedden et al., 2000; Ji et al., 2000), it is very possible that controllers who adopt such a thinking style may have different decision making patterns.

1.1. Intervention decision making of ATCos

The highest priority for controllers is to prevent violation of specific minimum separation standards (ICAO, 2005). As prescribed by the International Civil Aviation Organization, the distance between an aircraft and an obstacle cannot be closer than 5 nautical miles horizontally and 1000 feet vertically. In order to guarantee such separation, controllers have to monitor aircraft information on radar screens, assess the minimum possible distance (i.e., the distance between two aircraft at their closest crossing) thus evaluating potential risks of violations (which is the process of conflict detection), and make interventions (to change future trajectories of certain aircraft) if necessary (which is the process of conflict resolution).

Obviously, the physical minimum distance serves as an important basis for such judgment. For example, in an experiment, when the manipulated minimum lateral distance between two aircraft increases, controllers' intervention rate drops correspondingly (Loft et al., 2009; Neal & Kwantes, 2009). However, even when the minimum lateral distance is almost double the required separation standard (i.e. 10 nm), a certain portion of controllers still decided to make interventions. These findings suggest that controller's intervention decision is not solely determined by the physical relationship among aircraft (the objective risk), rather, it is the perception of risk that played a major role (Loft et al., 2009; Neal & Kwantes, 2009).

It is suggested that in real operations, controllers need to consider many uncertainty factors which are helpful to forge their perception of risk (Loft et al., 2007). Firstly, the trajectory uncertainty must be considered (Loft et al., 2009). Considering such uncertainty means controllers do anticipate the bearing, altitude and velocity of aircraft to be changing in the future rather than fixed. The causes can be manifold, including weather turmoil, pilot operation errors, aircraft technical failure and flight mode. In this way, controllers will perceive the future aircraft positions to be variant rather than determined. As a result, they will perceive a shorter minimum distance (and a larger risk of violation). In Fig. 1, we show an illustration how considering trajectory uncertainty can alter their perceived minimum distance (and risk perception). In this scenario, two converging aircraft (P1 and P2) will reach the point of minimum lateral distance (when P1 flew to point A and P2 to point B) if they keep on using current bearing, altitude and velocity. In Fig. 1a, trajectory uncertainty is not considered, so the perceived minimum lateral distance equals the length of line AB. However, if controllers presume that the trajectories of these two aircraft can vary, then the future positions of these aircraft will not be at fixed points (A and B). Rather, they can appear at some other positions around A and B (as shown in the circles around A and B in Fig. 1b). As a result, the perceived minimum lateral distance is less than the length of line AB. It is quite obvious that when more uncertainties are taken into consideration (Fig. 1c), the perceived minimum distance will correspondingly decrease. In perceiving such a shorter minimum distance, controllers will perceive a higher likelihood of trajectory conflict. In this way, they will be more likely to make interventions.

Apart from uncertainty in future trajectories, another issue a controller needs to ponder is the uncertainty of future work demand (Averty, Guittet, & Lezard, 2008; Loft et al., 2007, 2009; Remington, Johnston, Ruthruff, Gold, & Romera, 2000). It has been found since long that controllers are workload managers tending to maintain a workload homeostasis (Sperandio, 1971). This is because they need to keep themselves in a good state of mind by reserving mental resources so that they can cope with any incoming events (e.g. a sudden anomaly). As making an accurate assessment of conflict likelihood can be time-consuming, they sometimes choose to make an intervention decision without fully assessing the conflict potential. In this way, both safety and lower workload can be guaranteed, though at the sacrifice of accuracy which can undermine airline efficiency. This accuracy-workload tradeoff is a common form of the workload management in air traffic control. In our study, we consider this process coexists with the trajectory evaluation process but they are separate concerns controllers need to consider.

Uncertainties of future trajectories as well as of future work demands are always perceived by controllers (Averty et al., 2008; Loft et al., 2007, 2009; Remington et al., 2000). Some situational or individual factors may have effects on how many uncertainties controllers perceived. Loft et al. (2009) have identified several situational factors that can influence these uncertainties. In their experiments, participants were asked to perform a conflict resolution task. In each scenario, a single pair of converging aircraft were presented within a sector on the radar screen and controllers were asked to make interventions when necessary. The first finding was that controllers tended to make fewer interventions when the minimum distance between two aircraft increased. They also found controllers were more likely to make interventions when there were potential vertical conflicts as compared to potential horizontal conflict. This is because when aircraft are changing altitude, their future trajectories are more difficult to predict compared to when they are at level flight. In addition, the researchers found that when instructed to expect high workload, controllers were more likely to intervene compared to those who were

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