International Civil Aviation Organization

Fourteenth Meeting of the Air Traffic Management Sub-Group (ATM/SG/14) of APANPIRG

Bangkok, Thailand, 3 – 7 August 2026

Agenda Item 8: Any Other Business

ANALYSIS OF FATIGUE-RELATED VOICE AND VIDEO CHARACTERISTICS BETWEEN HIGH-ALTITUDE AERODROME AND LOW-ALTITUDE AERODROME AIR TRAFFIC CONTROLLERS

(Presented by China)

SUMMARY

This paper focuses on a comparative analysis of fatigue-related voice and video features of air traffic controllers working at High-Altitude aerodrome vs Low-Altitude aerodrome. To address the issue that the low-pressure and hypoxic environment at high plateaus exacerbates controller fatigue, voice recordings and facial video of controllers from both regions were collected. Analysis of voice data reveals that controllers at high plateaus exhibit acoustic distortions including dispersed high-frequency energy, reduced stability of vocal fold vibration, and elevated turbulent noise. Analysis of video data indicates a marked rise in the frequency of fatigue-related facial manifestations such as eye closure and yawning among High-Altitude aerodrome controllers. Comparative results demonstrate that, High-Altitude aerodrome controllers display greater voice distortion and more severe facial fatigue symptoms.

1. INTRODUCTION

1.1 Air Traffic Controller fatigue is one of the critical factors threatening civil aviation safety. The low-pressure and hypoxic environment at High-Altitude airports may aggravate air traffic controllers' physiological and cognitive workload. Most existing studies focus on a single operating environment, lacking comparisons analysis of fatigue characteristics between controllers at high-altitude and low-altitude areas. Parallel comparative analyses are urgently required to clarify the impact patterns induced by altitude differences.

1.2 Current fatigue management for air traffic controllers mainly adopts normative approaches and Fatigue Risk Management Systems (FRMS). Fatigue detection methods fall into two categories: subjective assessment and objective ones. Subjective assessment tools include various fatigue scales. Objective measurements cover electroencephalogram (EEG) monitoring, eye-tracking technology, heart rate variability (HRV) analysis, and galvanic skin response (GSR) measurement. Among all detection techniques, voice and video are ideal methods for cross-altitude comparative studies due to their real-time performance and non-invasive nature.

2. DISCUSSION

2.1 To compare the differences in fatigue characteristics between high altitude and low-altitude, microphones were installed at controller workstations to fully cover the normal communication range of controllers. The wide-angle cameras were also deployed to capture facial images of controllers.

2.2 The experiment collected voice and video data of tower controllers at Lhasa Gonggar International Airport and Nyingchi Mainling Airport. Meanwhile, voice and video data collected in Urmuqi Tianshan International Airport was set as the low-altitude group. Afterwards, multi-mode based feature extraction method was conducted. Multiple features were extracted from voice signals, including Mel-Frequency Cepstral Coefficients (MFCC) auditory perceptual features, Fast Fourier Transform (FFT) global frequency-domain features, wavelet transform multi-scale transient features, and Ensemble Empirical Mode Decomposition (EEMD) nonlinear dynamic features. The extracted features show obvious dispersed energy and elevated noise in the high-frequency band of voice signals from high-altitude. The energy proportion of the high-frequency component rises abnormally, indicating that the hypoxic environment reduces the stability of vocal fold vibration and intensifies high-frequency turbulent noise. For video data, AI algorithms were applied to extract facial features, with Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR).

2.3 Integrated audio and video analysis results demonstrate that under identical workload conditions, high-altitude airport controllers exhibit significantly severer voice spectrum distortion and higher occurrence rates of facial features than plain controllers, which verifies that the low-pressure hypoxic environment accelerates fatigue accumulation.

2.4 Future research will refine the quantitative analysis framework for behavioural differences between high-altitude and low-altitude air traffic controllers. In addition, a modular physiological signal acquisition platform will be developed. Combined with voice and visual signals, this platform will realize integrated early warning of controller fatigue.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper.

— END —