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ISSUES IN THE DEVELOPMENT OF AN ADAPTIVE LEARNING ENVIRONMENT FOR MASTERING TEAMWORK SKILLS OF AIR TRAFFIC CONTROLLERS

The subject matter of the article addresses the development of an adaptive learning environment for the formation and enhancement of air traffic controllers' teamwork skills within the context of contemporary aviation industry challenges. The goal of the article is to research and develop an approach for creating an adaptive learning system for practical training of air traffic controllers, taking into account both individual and group learning needs, which will improve the effectiveness of developing both technical and non-technical skills in air traffic controllers. The tasks of the article: to analyze existing approaches to air traffic controller training and their limitations in the context of teamwork skills development; to identify key cognitive functions necessary for effective teamwork in air traffic management; to develop a concept of a hybrid approach to adaptive learning for air traffic controllers. The methods used are: logical analysis, comparative analysis, and systems approach to studying complex learning environments. The article examines a comprehensive approach that combines personalized adaptive learning with adaptive group training for developing air traffic controllers' team interaction skills. A three-level training methodology has been proposed, encompassing individual preparation, pair training, and full-format group scenarios with gradual complexity increase according to learning progress. Key cognitive functions for implementation in the adaptive training complex have been identified, including team synergy, adaptability, goal-setting, information integration and formation of a holistic air situation picture, predictive modeling, metacognitive and emotional regulation functions. The article presents mechanisms for monitoring both individual and team interaction indicators, enabling the formation of temporary learning groups of air traffic controllers with complementary performance indicators. Attention is given to developing a system for adaptive regulation of complexity levels and focusing on specific aspects of team interaction.

Key words: *air traffic controllers specialists, teamwork skills, group training, simulators, adaptive learning environment.*

Formulation of the problem. According to the Flight Safety Foundation Aviation Safety Network data for 1990-2021, despite an overall decrease in aviation incidents in the early 2000s, 10-20 serious incidents have been recorded annually during the last five years (excluding 2020 due to the pandemic) [1]. Between 2001 and 2022, there were 3,769 aviation accidents resulting in 20,172 fatalities [2]. Research indicates that human-to-human interaction errors in civil aviation contributing to incidents constitute 38.8% of cases. The majority of communication problems (80.6%) were verbal in nature, as opposed to non-verbal (19.4%) [3]. It is established that the most frequent method of internal communication between air traffic control specialists (ATCs) is verbal (70%), while the remainder (30%) comprises a mixture of verbal and non-verbal means. Of particular note is that approximately 82% of aviation incidents related to ATCs operations are attributed to human factors [4]. A comprehensive analysis of human factors in ATCs errors, conducted by the FAA Civil Aerospace Medical Institute (No. DOT/FAA/AM-05/25), revealed that 86% of errors (8,093 cases out of 9,404) were associated with basic skills, while only 14% (1,311 cases) were related to decision-making errors. Of the analyzed basic skill errors, 16% (1,486 cases) were caused by communication problems, 10% (961 cases) occurred due to coordination errors, 6% (583 cases) resulted from data entry errors, and 1% (143 cases) arose during shift handovers between ATCs [5].

Teamwork represents a system of interaction between individuals united by common goals and objectives. Any professional team is characterized by the interdependence of its members, regular collaborative activities including training, clear role distribution for specific periods, and the ability to create synergistic effects from joint work [6].

The study of communicative processes between team members is a key method for understanding cooperative activity mechanisms. Such activity involves coordinating individual participants' actions, forming a shared vision of the work process, and establishing effective communication for information exchange and creating a unified system of mutual understanding and language [7]. In many professional environments, particularly in air traffic control (ATC) systems, information resources are accessible to all team members, regardless of their individual responsibilities. The co-location of operator workstations creates conditions for mutual observation and information exchange through both direct communication channels (verbal messages) and indirect ones (observing colleagues' actions, using shared information systems). The work environment provides contextual cues about current and planned actions, enabling participants to understand their colleagues' intentions and strategies. This is particularly evident in the ATC system where, despite clear distribution of functional responsibilities, work is considered a collective task requiring close cooperation between ATCs. Their interaction aims to integrate various information flows to coordinate actions within the overall mission of ensuring efficient and safe air traffic.

In the context of aviation industry's historical development, ATCs training traditionally relied on strict adherence to regulatory standards and normative requirements. The prevailing paradigm considered professional competence in emergency situations as a natural outcome of these aviation specialists' technical training. However, detailed analysis of ATC incident statistics demonstrates significant limitations of this approach: purely technical qualification proves insufficient for effective response to critical situations in modern conditions [8].

While most contemporary research focuses on communication problems between ATCs and pilots and optimizing professional training in these aspects [9, 10], issues of erroneous interaction between ATCs and ineffective team decision-making warrant separate attention. Paradoxically, despite high expectations for professional excellence in ATCs teams within their operational environment, many air navigation service providers do not implement systematic team training programs. Considering the fundamental role of coordinated teamwork in ensuring ATC safety and efficiency, there is an urgent need to develop an intelligent adaptive learning environment for teamwork and communication skills acquisition among ATCs.

Analysis of recent research and publications. The professional training of ATCs worldwide employs a differentiated approach to synthetic training tools. According to the European Organization for the Safety of Air Navigation (EUROCONTROL) standards, the practical training system for ATCs is based on four primary equipment categories used as simulators [11]. The first category comprises High-Fidelity Simulators (HI-FI SIM), which provide maximum correspondence to actual working conditions. The second category includes Medium-Fidelity Simulators (SIM), designed for individual and group training. The third category consists of Part-Task Trainers (PTT), developed for mastering specific professional competencies. The fourth category encompasses Other Training Devices (OTD) and software modeling complexes.

The scientific community and practitioners dedicate considerable attention to analyzing the effectiveness of existing training complexes, among which the leading positions are held by Total Airspace and Airport Modeler (Boeing/Jeppesen), Reorganized ATC Mathematical Simulator and ESCAPE by EUROCONTROL, Simmod PRO (FAA), and Air Traffic Optimization (Airtopsoft) [12]. Despite these systems' high technological level, researchers have identified several significant limitations requiring careful consideration and innovative solutions. Foremost, the economic aspect of implementing these training complexes warrants attention. The high cost of these systems creates substantial barriers to their widespread use in educational processes, particularly in training future specialists at institutions with limited financial resources. This issue becomes especially pertinent given the growing demand for qualified ATCs.

An equally important challenge lies in the technical architecture of existing complexes. The closed nature of the software significantly restricts the pedagogical and methodological staff's ability to adapt the learning process to specific student groups' needs and account for regional ATC organization peculiarities. Of particular concern is the limited flexibility of existing systems in modeling various professional interaction scenarios. The most acute problem remains the absence or limitation of specialized tools for developing teamwork skills, which are critical components of ATCs' professional competence. This situation complicates the processes of improving training methodologies for future ATCs, particularly concerning the development of new algorithms for automated generation of group training scenarios adapted to current student models, construction of shared virtual learning environments for remote mastery of team interaction skills, and implementation of other innovative pedagogical approaches. ESCAPE and ESCAPE-Light developed by EUROCONTROL overcome most of the aforementioned limitations, serving as effective and flexible tools for researchers working on artificial intelligence and machine learning projects, and can be used in basic ATC controller training at universities [13]. It is an accessible tool for specialized educational institutions and research centers. The simulator features a modular architecture, providing extensive functionality including CPDLC and high-fidelity flight modeling, allowing users to connect new components and exchange data with other synthetic training tools through appropriate APIs provided by EUROCONTROL. This enables researchers to freely develop and test enhanced algorithms in real-time within a realistic simulated environment, utilizing data and demonstrative events from previous training sessions.

Communication between ATCs results from their interaction with each other and their working environment, considering ATC sector complexity, air traffic intensity, and other factors. When scientists study ATC work in laboratory conditions, they can better understand how various factors influence communication quality between ATCs. Researchers can configure experimental conditions: varying task complexity, adjusting workload, determining training shift duration, and controlling equipment operation. This allows them to thoroughly examine how specific changes in the working environment affect interaction between ATCs.

Theoretical studies on the evolution of complex cognitive skills training methods, conducted by a group of researchers led by Salden, Paas, and van Merriënboer [14], identified key fundamental transformations in educational approaches over the past three decades. Of primary significance is the transition from non-adaptive to adaptive learning methods. While both methods consider prior professional experience when forming ATC training programs, non-adaptive methods are limited to determining the sequence of training tasks exclusively at the preparatory stage. In contrast, adaptive approaches enable dynamic adjustment of task sequences directly during the training process, based on objective indicators of each student's individual progress.

The rapid development of educational technologies has created prerequisites for implementing adaptive learning through automated training courses and learning management systems. These systems function as quasi-subjects of the educational process, providing a personalized approach to each student and helping to fill gaps in their knowledge and skills. Domestic researcher Demianenko V. M. emphasizes the necessity of developing adaptive learning systems using artificial intelligence to ensure open and accessible education [15]. Such systems can overcome language barriers, accommodate special student needs, and eliminate disparities between different educational institutions. However, it remains critically important to maintain the teacher's leading role in the educational process and implement new technologies in a pedagogically balanced manner to prevent the emergence of student «infantilization» effects. In his view, successful integration of adaptive learning should enhance, rather than replace, the educator's role as a key figure in education.

Task statement. The research purposes of the articles are to discover individual-cooperative adaptive learning approach and the key issues in the development of an adaptive team learning environment for ATCs.

Outline of the main material of the study. We propose a hybrid approach that combines personalized adaptive learning with adaptive group training for the ATCs to develop team interaction skills. The methodology is based on the complexity of team scenarios: The 1st stage of training (*initial level*) comprises individual adaptive training to develop basic communication and coordination skills through interaction with a «reference controller» in the learning module of the Adaptive System for Team Practical Training of Air Traffic Controllers (ASTPT-ATC); the 2nd stage (*intermediate level*) encompasses pair training; the 3rd stage (*target level*) involves transition to full group scenarios at higher levels of team skill development. The system will monitor both individual and team performance indicators of team interaction. Applying a *dynamic adaptive team formation approach*, ASTPT-ATC will facilitate the formation of temporary learning groups of ATCs with complementary performance indicators, additionally enabling more effective students to support those with lower indicators in developing specific components of team competence. In subsequent training stages, team composition rotation will occur based on analysis of current performance results, considering the progress dynamics of each participant with emphasis on weak points. The ASTPT-ATC's prognostic module, based on each student's dynamic profile, will evaluate the potential for further development of the learning team and its members, determining the optimal moment for changing the composition of pairs or groups of future ATCs. In the context of modernizing educational methodologies, particular relevance is attached not only to the implementation of *automated task selection by adaptive learning systems* but also to the integration of mechanisms for independent task selection by students. This comprehensive approach opens additional opportunities for individualization and adaptivity of the learning process, creating prerequisites for productive self-regulated and self-directed learning of ATCs [16]. The fundamental differences between the considered training approaches are presented in Table 1.

The development of ASTPT-ATC must meet a complex of interrelated requirements. The structural-organizational requirement entails creating an expandable modular architecture that supports simultaneous operation of multiple teams with varying numbers of participants and their pairwise interaction with flexible configuration of training scenarios on

Table 1

Comparative Characteristics of Traditional, Classical Adaptive, and Individual-Cooperative Adaptive Learning Approaches to Training ATCs

CRITERION	Traditional Training	Classical Personalized Adaptive Learning	Individual-Cooperative Adaptive Learning with Self-Regulation Elements
Learning Process Focus	Teacher-centered, who serves as the main source of knowledge and control	Student-oriented process, focused on individual needs and learning pace	Balanced approach focused on the student, emphasizing individual development within the context of group interaction
Curriculum Formation Approach	Fixed training program, defined at course beginning. Changes are rare and difficult to implement	Program adapts to each student based on their performance and learning absorption rate. Involves forming individual learning trajectories	Flexible program considering both individual student style characteristics and current learning performance, as well as teamwork needs. Learning trajectory dynamically modifies depending on pair/group learning activity progress
Teacher's (Instructor's) Role	Unified role as sole expert and controller of the learning process	Acts more as a facilitator supporting individual learning	Differentiated role that change depending on training stage, mode, individual and team needs
Learning Format	Predominantly group work with fixed composition. Limited opportunities for individual approach	Individual work with the system. Pace and task complexity are personally tailored	Mixed format: individual sessions alternate with pair and group work. Team composition is adaptively selected and periodically changed
Learning Accessibility	Mandatory physical presence at fixed times with clearly defined learning periods	Flexible schedule adapting to individual training pace. Open learning environment with remote access possibility using information and telecommunication technologies	Combined approach balancing individual preparation pace in personalized learning format with group synchronization when practicing interaction skills. Hybrid environment combining face-to-face interaction with digital learning tools and possible learning environment virtualization. Based on adaptive model considering both individual dynamics and team synchronization needs
Development of Communication and Team Skills	Develops naturally through joint learning	Limited team skills development due to focus on individual work	Purposeful formation of team competence through group composition rotation and special interaction scenarios
Assessment	Current periodic and final assessment according to predetermined schedule	Continuous progress monitoring with dynamic complexity adaptation	Constant performance monitoring with multi-level assessment system considering both individual and team learning activity indicators
Metacognitive Development	Develops primarily through independent reflection and experience exchange	Systematic development of individual metacognitive skills through special tasks	Comprehensive development of both individual and team metacognitive abilities through joint reflection and experience analysis

the simulator. The environment's functionality must meet three main requirements: 1) realistic modeling of various problem situations integrated into group/pair scenarios, with the possibility of introducing complications in the team interaction process; 2) provision of different formats for communication and coordination between students; 3) implementation of adaptive learning management to adjust task complexity and form individual learning trajectories based on intelligent analysis results of individual and team indicators of group learning activity [17]. Considering the above, team adaptive simulator training of ATCs should be built on the cognitive functions discussed below.

Modern ATC training methodology should encompass complex processes of coordination, control transfer and communication, shift handover, and team debriefing through implementing structured protocols, practicing multi-sector scenarios and resolving inter-sector problem situations, developing interaction skills with automated systems and decision support systems, and improving communicative strategies for safety-critical information transfer. Thus, the basic **team synergy function** involves developing mechanisms for achieving emergent effects and results during training exercises. An important element is developing skills to utilize each team member's strengths and compensate for individual limitations.

Developing adaptability as a professionally important quality of ATCs should be ensured through modeling abnormal and emergency situations, practicing flexible response strategies to changing operational conditions, training stress resistance when performing professional tasks under increased workload, and mastering team resource management techniques in the dynamic ATC environment.

The functional aspect of goal-setting and management in the learning process should focus on developing future ATCs' systemic vision of professional task hierarchy and developing skills in balanced decision-making under multiple objectives. **The resource balancing function** aims to develop ATCs' ability to optimally distribute attention and cognitive resources between parallel ATC tasks. Developing ATCs' ability to dynamically redistribute resources according to changing task priorities is important. Special attention during group training should be paid to mastering techniques for modifying target settings according to air situation dynamics and ensuring effective communication regarding changes in target priorities between ATC team members, particularly under severe time constraints.

The integration function focuses on developing the ability for comprehensive analysis of heterogeneous information and forming a holistic picture of the air traffic situation. Research development in situational awareness has progressed parallel to technological advancement and expanded scientific understanding of human interaction. While initial research stages primarily focused on individual situational awareness, the scientific community gradually recognized the necessity of studying collective situational awareness, particularly in complex environments involving multiple process participants. The contemporary understanding of team situational awareness encompasses two interrelated aspects. First, it is a dynamic process of perception and comprehension of multiple information elements by several individuals working toward a common goal. Second, it is the team members' shared understanding of past, present, and future states of task elements being performed [18]. In this context, it is important for ATCs to practice skills in synthesizing data from various sources and their coordinated interpretation. Developing team sub-competency in forming a shared situation image should be facilitated through a system of team exercises aimed at practicing coordination mechanisms between ATC sectors, improving professional communication, and utilizing tools for shared situational awareness among ATCs. Another important element is developing the ability to identify and resolve discrepancies in situation perception among different ATC process participants. We find it methodologically justified to include practical elements in future ATCs' training programs that require interpretation of incomplete data, verification of air situation development hypotheses, and recognition of the need to correct shared mental models.

Given current aviation industry development trends, including to ATC training scenarios for interaction with AI-based automated support tools becomes particularly important, aimed at forming a balanced understanding of automated systems' capabilities and limitations while maintaining readiness for independent decision-making regarding control actions, when necessary. The methodological foundation for such training is multi-level structuring of learning scenarios, involving gradual increase in complexity of interaction models with automated DSS.

In the context of modern digital transformation, ATCs team training undergoes fundamental qualitative changes – the learning environment evolves into a multidimensional space of professional interaction, synergistically combining two key aspects: communication in the air traffic service system and their integration with intelligent autonomous systems. An example of such a system is the modern development of «digital ATCs» [19].

Implementation of group learning scenarios integrating interaction with digital assistants will simultaneously develop joint decision-making skills when working with intelligent management systems and interpersonal communication skills. Systematic exchange of professional experience regarding autonomous systems' operational features will promote expert knowledge formation and deeper understanding of teamwork principles under technological transformation. Developing the metacognitive component of professional training, in this context, should focus on developing the team's ability for critical analysis of automated recommendations, understanding algorithmic solution limitations, reflective assessment of interaction effectiveness with support systems, and collective learning based on accumulated experience. Initial training stages should focus on mastering basic algorithms of joint activities under normal system operation conditions, while advanced levels should include elements of uncertainty and necessity for non-standard decision-making. Special attention should be paid to practicing function distribution mechanisms among controller shift members, action coordination during control method changes, and technical/software failures in automation functions. Development of ATCs' communicative sub-competency of team competency can be realized through forming effective information exchange skills regarding flight safety element functioning within automated systems and coordinating shared situational awareness, particularly during support tool failures (e.g., MTCD used for detecting potential medium-term conflicts) or forced limited use within specific ATC sectors.

The **predictive modeling function** involves developing ATCs' ability for anticipatory analysis of air situation development and potential impact of various limitations on processes related to air traffic flow management and airspace use. It appears methodologically justified to include elements of potential conflict situation prediction and proactive action planning for their prevention in the training program. The **uncertainty management function** aims to develop tolerance for uncertainty and decision-making competence under conditions of incomplete or contradictory information about the operational environment's state within own and adjacent sectors.

Given the above, the **metacognitive regulation function** is designed to ensure the development of reflexive self-control and self-regulation mechanisms not only for ATCs' own learning and professional activities but also for mutual control and cross-verification skills when interacting with colleagues. Implementation of this function creates a foundation for developing: 1) skills of conscious monitoring of one's cognitive processes and their correction, when necessary, 2) ability for attentive conscious awareness of potential cognitive problems in colleagues of ATC shift and their support, when needed. The implementation of the «planning-execution-control» cycle in air ATC simulator training should include systematic practice of structured planning skills, execution monitoring, results evaluation, and action correction based on feedback.

The **emotional regulation function** involves developing professional stress management competency among ATCs at the team level during training. An important element is implementing conditions in group scenarios that provide for team members to offer mutual support during training sessions. Primarily, applying this approach, with predetermined and agreed-upon verbal and non-verbal markers, is designed to teach ATCs to timely and accurately recognize stress signs in their colleagues. The adaptive environment should enable analysis of team participants' emotional reactions, for example, through changes in behavior, voice tone, and speech rate during task performance. Observing cascading stress reactions among team members, the system should identify cases of desynchronization in team interaction related to elevated stress levels, indicate the need to review communication and mutual support strategies, and provide recommendations for optimizing group dynamics. Results of intelligent analysis of accumulated data (found significant correlations between various indicators) can be used to modify training scenarios in aspects of task complexity and integration of specialized exercises aimed at developing identified weaknesses in team stress resistance development.

The group of parameters most significantly influencing decision-making accuracy, ability to operate under high workload conditions, and interaction between adjacent ATC sectors comprises the ATCs' cognitive workload and emotional states. Unfortunately, these parameters are also the most challenging to measure directly. In such cases, only indirect assessment is possible, based on event response time, pupil movements, and speech clarity. The complexity of measuring such parameters likely necessitates extensive training of the intelligent system with each specific air traffic controller, essentially requiring adaptation to individual behavioral patterns and responses. However, following such system training, it becomes possible to modify simulator task parameters very precisely and flexibly for each operator while accounting for how situations in one area of responsibility influence adjacent sectors. Since the system, after being trained for each specific controller, can determine their psychophysical and cognitive state with reasonable accuracy, it enables monitoring of controller-to-controller interactions, allowing for maximally adaptive influence on team skill formation. ATCs predisposed to operating under high traffic intensity conditions may experience a loss of concentration and attention when this parameter drops below a certain threshold. Conversely, ATCs, who perform their functions well and accurately under medium and low-intensity conditions have a high likelihood of losing situational awareness in their ATC sector due to elevated stress levels, when traffic intensity increases significantly. The methods for optimizing workload can vary considerably. For example, consider the interaction between Tower Controller and Approach Controller. The system has determined, that when air traffic intensity in the TMA reaches a certain threshold, further workload increase for the controller operating in this area leads to delayed reactions, command confusion, increased nervousness in inter-position communication, and decreased accuracy and timeliness of information transfer. In such situations, the ASTPT-ATC will reduce departure traffic intensity from the airport in the direction served by this sector and change the number of aircraft proceeding for landing through this sector. Through such «waves» of intensity, it becomes possible to identify the optimal workload level for each controller to reduce occupational stress or vice versa. This dual-focused approach enables both the customization of workload for individual ATCOs, creating optimal conditions for the development of procedural and team-oriented skills, while simultaneously generating individually tailored challenges to enhance controllers' capacity for efficient performance under varying air traffic intensity and its dynamic fluctuations. This facilitates the development of stress resilience and optimization of both personal workload and that of colleagues in adjacent ATC sectors as part of the teamwork within the collaborative operations.

The effectiveness of ASTPT-ATC implementation for forming and developing team interaction skills largely depends on creating realistic scenarios that integrate various cognitive functions, as well as adaptive formation of the learning group itself, with gradual complexity increase according to learning progress. The training system should provide adaptive regulation of complexity level and focus on specific aspects of team interaction, considering both individual results and pace of group training exercise completion, as well as integral team effectiveness indicators. The application of learning adaptation algorithms in ASTPT-ATC is based on objectivity and consistent application of the criteria base for evaluating team work effectiveness in ATC training, where each cognitive function defines specific performance parameters.

Conclusions. The analysis of existing learning approaches has revealed several limitations to develop ATCs' team competency and adapt to their individual and group learning needs. According to the authors, the proposed approach to development an adaptive learning platform for team practice in ATC shows promising potential to resolve the challenges. The integration of cognitive functions essential for teamwork, combined with emotional and metacognitive regulatory mechanisms, creates a comprehensive learning environment that more accurately reflects the complexity of real ATC operations. Monitoring of the described ATCs' state parameter groups and various response combinations from the intelligent adaptive learning environment to changes in these parameters will enable the construction of highly flexible and individually tailored simulator training scenarios. This capability is particularly crucial for developing teamwork competence, allowing ATCs to enhance both their direct ATC skills within their sector and their coordination capabilities with adjacent sector.

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Пальоний А.С., Зєнов Д.О. ПИТАННЯ РОЗРОБКИ АДАПТИВНОГО НАВЧАЛЬНОГО СЕРЕДОВИЩА ДЛЯ ОПАНУВАННЯ АВІАДИСПЕТЧЕРАМИ НАВИЧОК КОМАНДНОЇ РОБОТИ

Предметом статті є питання розробки адаптивного навчального середовища для формування і розвитку в авіадиспетчерів навичок командної роботи в контексті сучасних викликів авіаційної галузі. Метою статті є дослідження та розробка підходу до створення адаптивної системи навчання для практичної підготовки авіадиспетчерів з урахуванням як індивідуальних, так і групових потреб у навчанні, що дозволить підвищити ефективність формування в авіадиспетчерів як технічних, так і нетехнічних навичок. Завдання статті: проаналізувати існуючі підходи до навчання авіадиспетчерів та їх обмеження в контексті розвитку навичок командної роботи; визначити ключові когнітивні функції, необхідні для ефективної командної роботи в системі управління повітряним рухом; розробити концепцію гібридного підходу до адаптивного навчання авіадиспетчерів. Методи дослідження: логічний аналіз, порівняльний аналіз, системний підхід до вивчення складних навчальних середовищ. У статті розглянуто комплексний підхід, що поєднує персоналізоване адаптивне навчання з адаптивним груповим тренінгом для розвитку навичок командної взаємодії авіадиспетчерів. Запропоновано трирівневу методологію навчання, що включає індивідуальну підготовку, парні тренування та повноформатні групові сценарії з поступовим підвищенням складності відповідно до прогресу навчання. Визначено *основні когнітивні функції для реалізації в адаптивному тренажерному комплексі, включаючи функції командної синергії, адаптивності, цілепокладання, інтегрування інформації та формування цілісної картини повітряної обстановки, прогностичного моделювання, метакогнітивної та емоційної регуляції. Запропоновано механізми моніторингу як індивідуальних, так і командних показників взаємодії, що дозволяють формувати тимчасові навчальні групи авіадиспетчерів з комплементарними показниками успішності. Увагу приділено розробці системи адаптивного регулювання рівня складності та фокусування на конкретних аспектах командної взаємодії.*

Ключові слова: *авіадиспетчери, навички командної роботи, групове навчання, тренажери, адаптивне навчальне середовище.*