Pilot Training in the Virtual Sky: The Application of Simulators in the Development of Movement Coordination and its Applicability in Rehabilitation

DOI https://doi.org/10.29068/HO.2024.ksz.77-84

Author **2LT Zsolt Lucz,** HDF 86th Helicopter Wing, Ludovika University of Public Service, Doctoral School of Military Engineering, PhD student (ORCID: 0009-0002-9801-8681, MTMT: 10071069)

Keywords simulator, rehabilitation, Mi-17 FTD, DCS, development, coordination

Abstract *In today's fast-paced world, the spread of simulators extends to numerous fields, as their targeted application can lead to significant improvements within a specific sector. The optimal use of simulator-based training in pilot education is indispensable in a modern military Air Force, and their utility in developing and enhancing movement coordination is unquestionable.*

INTRODUCTION

The synchronized operation of body and mind holds paramount importance in our daily lives and activities. Developing movement coordination is essential among aviators as it significantly influences their work efficiency and contributes to maintaining and improving their health. Numerous studies confirm that the use of simulators has resulted in remarkable individual development, aiding in the establishment of proper movement patterns and even supporting rehabilitation.

Movement coordination involves the optimal and purposeful execution of movements in space and time, requiring the fulfillment of multiple factors for coordinated movement to occur. This ability enables us to precisely and efficiently control our body movements (adjusting muscle strength to the power magnitude and direction executing flight control maneuvers) and synchronize them with our environment. It encompasses not only muscular development but also communication between the nervous system and the brain. Simulators can assist in this process by offering several advantages that can improve hand-eye-foot coordination on an individual level.

One of the primary advantages of simulators is the opportunity to practice in a safe environment. In pilot training, novices lack the necessary skills and familiarity with the environment they will encounter. Despite theoretical knowledge, real-world scenarios can differ significantly. Aviation involves numerous risks that pilots must handle professionally and in a calm mental state. Exposing trainees to these potentially hazardous situations in a simulator allows them to develop themselves and form ingrained responses in a risk-free setting. These responses can then be activated reflexively in real-life situations, potentially influencing life-or-death decisions.

It is also worth highlighting the significant variety of functions, situations, and activities that a simulator can generate for trainees. Different difficulty levels can be set, providing continuous feedback to individuals and allowing them to react and improve in real time. When using a simulator for developing movement coordination, we always adhere to the principle of progression. Initially, we focus on establishing basic movement patterns during the first phase, and once proficiency in these fundamental movements is achieved, we gradually introduce more complex tasks into the training program.

APPLIED SIMULATORS

As part of my doctoral research, I have set the goal of optimizing simulator-based training and formulating a new educational methodology, with the development of movement coordination in a safe environment as a cornerstone. The first step towards this goal is creating a module that can be used at home. In this case, trainees can practice using various software tools in the comfort of their home environment. The desired outcome for individuals is to use simulators purely for the experience and enjoyment, free from stress and pressure. Experiences over the past few years confirmed that movement coordination skills have developed unconsciously through the use of the suggested simulators by students. During gameplay, they focused solely on the task at hand without focusing on coordinating their own movements, simply enjoying the simulation experience. Through repeated practice over several days, their executions became more and more accurate and precise, eventually developing the required reflexes.

Digital Combat Simulator

DCS[1] is a combat simulator available for free civilian use, capable of accurately modeling the characteristics of various aircraft. There are numerous aircraft types to choose from; in my case, the Mi-8MTV2 helicopter type was the appropriate choice, as it closely resembles the Mi-17 FTD[2] used in training.

It is important to note that for proper simulation, it is necessary to connect some compatible controller package to the software, as this is the only way to achieve proper eye-hand-foot coordi-

1 Digital Combat Simulator.

2 Flight Training Device.

Figure 1: Digital Combat Simulator Mi-8MTV2 view in VR mode (Source: edited by the author)[3]

nation. During my experiments, I used the Thrustmaster T-16000M FCS flight pack, which includes a joystick, a throttle, and pedals. Additionally, I calibrated a VR headset and a yaw motion chair (a chair that provides rotational movement around 3 axes), but during the experiment, I only used the Thrustmaster package. It is possible, albeit with a significant increase in cost, to replace the throttle with a separate, special collective lever, which is not necessarily required for mastering basic skills.

I conducted the experiment with the help of students from different study groups, with some joining in the later stages of the testing phase for comparison purposes. The initial goal of the game was to master basic flight techniques, after which tasks gradually became more complex. It took approximately 5 hours to master landings and hovering maneuvers, during which significant improvements in movement coordination were observed in both participants. Over time, the frequency of rough movements decreased, and

Figure 2: DCS calibration using VR and yaw motion chair

3 Virtual Reality.

attention shifted not only to the accuracy of steering but also to understanding helicopter flight characteristics.

In the case of helicopters, where three control surfaces must be coordinated in four dimensions, continuous work on movement coordination was necessary. After five hours of flight, landings were made more difficult by using various platforms such as tight spaces, stationary and moving warships, or moving tankers. These tasks required precise movement coordination, as these landing spots were extremely challenging to approach and required calm steering and gentle movements for successful completion.

Throughout the tasks, students were required to verify successful execution with a video playback. The most complex task, landing on a moving tanker ship, was achieved after approximately 10–12 hours of software use, after which only the length and composition of the tasks changed.

Mi-17 FTD simulator

In the next phase, the trainees continued the experiment with the Mi-17 FTD located at the Hungarian Defence Forces 86th Helicopter Wing. The two cadets who had gained stable motor coordination experience in the DCS transitioned to the real simulator. The rest of the study group joined the experiment here with the goal of measuring differences in piloting skills. Those two students who completed the DCS already possessed comprehensive cockpit familiarity, knowing the positions of controls, levers, and switches, and were thus able to navigate comfortably within the cockpit. They would have been capable of starting and shutting down the aircraft if the task had demanded it, although this was not relevant for the purposes of the experiment. For the other trainees, developing this basic cockpit familiarity resulted in a loss of time.

During simulator training, significant differences in motor coordination were observed among students who had previously familiarized themselves with basic procedures in the DCS. The hypothesis before the study, that modern civilian gaming software is suitable for acquiring fundamental helicopter piloting skills and can lead to outstanding development in motor coordination, was fully confirmed by this experiment. In the Mi-17 FTD simulator, students faced real control forces, weather conditions, and aerodynamic effects, all adjustable by an external operator. From the first hour, the two trainees were able to maintain the helicopter in hover mode and perform basic position changes without difficulty. Essentially, the initial hour served for them to familiarize themselves with and adjust to the simulator's nuances. Subsequently, they had to repeat the tasks with the autopilot turned off. During these repetitions, many aids that had previously assisted the students were removed, forcing them to rely entirely on their own skills. Precise, continuous adjustments of multiple control surfaces became crucial, as rough movements could render the helicopter uncontrollable. Apart from the first hour of the experiment, the two trainees flew without using autopilot. The objective was to measure how quickly they could execute a safe landing on a restricted-size landing pad in simulated conditions and repeat these two more times, eliminating the possibility of luck. Similar to the situation with the tanker ship in the DCS, sophisticated hand-eye-foot coordination was required, necessitating approximately two additional hours of practice, leaving the remaining two hours for various airspace tasks and circuits. The experiment was conducted within a five-hour timeframe to gauge the level of the tasks achieved.

For the other members of the group, the five-hour time limit allocated for the experiment was considered suboptimal. These students encountered the Mi-17 FTD for the first time, starting from the basics. During the five hours, they managed to perform hovering with the autopilot and execute basic positional changes. Initially, the aircraft remained stable without the autopilot but soon became unstable and uncontrollable. Although some muscle memory began to develop, significantly more time was required compared to the allotted simulator usage time for regular practice. One might question why this could pose a problem, as the goal is always for students to start real aircraft operations with solid foundations. The answer lies in the size of the groups. Due to the large number of students, the time spent in the Mi-17 FTD simulator must be limited to ensure every student can use it effectively, hence the critical importance of a student's background upon reaching this stage.

Naturally, virtual reality also serves as a fertile ground for many other experiments. For example, experiments were conducted on fighter pilots, where changes in pulse and stress levels were measured.

The comparison between take-off and in-flight revealed a statistically significant increase ($p<0.05$) in percentage of consecutive RR intervals that differ by more than 50 ms from each other (pNN50), root mean square of the successive differences (rMSSD), standard deviation 1 and 2 (SD1 and SD2), and a statistically significant decrease ($p<0.000$) in stress score (SS) and in the sympathetic to parasympathetic ratio (S:PS). Between flight and landing, a statistically significant increase ($p<0.05$) in mean HR, minimum HR, maximum HR, SS and S:PS was shown, while experiencing a significant decrease ($p<0.000$) in pNN50, rMSSD and SD2. Finally, between take-off and landing, the variables which showed significant changes ($p<0.05$), with these changes being a significant increase, were mean HR, minimum HR, maximum HR, rMSSD, SD1 and SD2. SS and S:PS ratios showed a statistically significant decrease ($p<0.000$).[4]

An emergency scenario in a flight simulator triggered anticipatory anxiety in pilots, as evidenced by low HRV. This anxiety response heightened during the flight segment and diminished during the landing phase.

SIMULATOR TECHNOLOGY IN REHABILITATION

In today's conflict-ridden world, where the role of soldiers is increasingly valued, I believe there should be a strong emphasis on the rehabilitation of injured

4 Fernández-Morales, Carlos et al.: *Analysis of heart rate variability during emergency flight simulator missions in fighter pilots.*

soldiers. Whether they are injured in actual combat situations or during training, injuries or trauma may necessitate the need to restore their combat capabilities. Virtual reality (VR), augmented reality (AR), and simulators offer endless possibilities for cost-effective and productive rehabilitation.

Neurological injuries often lead to temporary or permanent paralysis of limbs in significant cases. The rehabilitation of such injuries is a lengthy and gradual process, where the individual's motivation and the rehabilitation environment play crucial roles:

- *Intrinsic Motivation:* The individual must have the intrinsic desire to recover. Despite seeming obvious, a constant and monotonous rehabilitation procedure can reduce the effectiveness of recovery due to the lack of motivation.
- *Application of VR Technology:* Utilizing diverse VR environments can activate basic motor functions and sensations that may not necessarily be associated with a normal developmental process. For instance, walking on a balance beam atop a virtual skyscraper activates balance-related functions and the instinct to "survive" more effectively than a similar exercise performed in a room.
- *Mental Rehabilitation:* For soldiers, alongside improving motor coordination, there is also an opportunity for mental rehabilitation. Placing individuals in environments they find difficult or challenging can facilitate mental recovery. This should always be done under the supervision of appropriate professionals.

By integrating these technologies and approaches, rehabilitation can be made more engaging, effective, and tailored to the specific needs and challenges faced by injured soldiers. It not only aids in physical recovery but also addresses the psychological aspects, promoting a holistic approach to rehabilitation in military contexts.

In Europe, the rehabilitation program based on VR technology developed by CUREOSITY is gaining momentum. The company has conducted numerous independent trials, including studies on stroke patients. Participants undergoing treatment based on virtual reality showed significantly greater improve-

Figure 3: Rehabilitation VR goggles used by CUREOSITY (https://www.cureosity.com/ *Downloaded: 04.07.2024.)*

ment compared to patients treated with conventional robotic methods. The company is expanding continuously, and with the increasing popularity of VR, this trend is expected to accelerate further.

SUMMARY

The 21st century is advancing rapidly towards full digitalization. Across all fields of science and industries, modern technology offers solutions and opportunities that were once unimaginable. Optimizing medical procedures, whether in civilian or military contexts, can lead to significant cost savings, remarkable cognitive and motor coordination improvements, and potentially shorten recovery times for patients. Advancements in medical technology also pave the way for studying the physiological effects of VR headsets during military training, both in air and ground operations.

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PILÓTAKÉPZÉS VIRTUÁLIS ÉGEN: SZIMULÁTOROK HASZNÁLATA A MOZGÁSKOORDINÁCIÓ FEJLESZTÉSÉBEN ÉS REHABILITÁCIÓ SORÁN

Szerző Lucz Zsolt hadnagy, MH Kiss József 86. Helikopterdandár, a Nemzeti Közszolgálati Egyetem Katonai Műszaki Doktori Iskola doktorandusza

Kulcsszavak szimulátor, rehabilitáció, Mi-17, DCS, fejlődés, mozgáskoordináció

Absztrakt *Napjaink rohanó világában a szimulátorok térnyerése immár számos területre terjed ki, hiszen célzott alkalmazásuk jelentős fejlődést eredményezhet egy adott szegmensben. A pilótaképzésben használt szimulátoros kiképzés optimális alkalmazása elengedhetetlen egy modern haderőben, továbbá a szimulátorok hasznosíthatósága megkérdőjelezhetetlen a mozgáskoordináció kialakításában és fejlesztésében.*