Operational Strategies within Simulated Environments

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SUMMARY

Exploring the range of operational strategies could enhance our understanding of effective regulatory approaches, contributing to the prevention of Musculoskeletal Disorders (MSDs). This study aims to assess whether the use of virtual simulation, integrated into a Serious Game, enables users to establish conditions conducive to efficient regulation of their future professional activities. Additionally, we seek to demonstrate how operational strategies differ when performing similar tasks within the simulated context of a virtual reality Serious Game. The key findings reveal the presence of multiple operational strategies for each simulated task, which appear to establish favorable conditions for better regulation of future activities.

While the Serious Game demonstrated a diversity of strategies, an important question remains regarding whether the game led to improved postural behavior between the beginning and the end of the session, and whether these changes transferred to real work conditions. The analysis showed that certain users progressively adjusted their strategies based on in-game feedback, improving postures related to upper limb and back positioning. However, others maintained their initial approaches despite recommendations. The extent to which this learning translates into long-term workplace adjustments requires further study.

KEYWORDS

Virtual Reality, Operational Strategy, Serious Game, MSD Prevention

Introduction

Numerous automotive industries have attempted to train their operators in standardised best practices for performing assembly tasks, with the aim of mitigating health risks and addressing performance challenges. These efforts, however, have often fallen short of achieving their intended goals, as no universal best practices or standardised operational strategies exist for specific tasks. Instead, each operator tends to develop individualised strategies based on the resources and constraints available to them. Consequently, effective training programs should empower operators to explore and practice a range of diverse operational strategies, enabling them to adapt more effectively to the varied situations encountered in the workplace.

Developing an innovative tool that facilitates the creation of context-specific operational strategies represents a promising approach to this challenge. Simulation-based learning, tailored to industrial applications, holds significant potential for enhancing operators' regulatory capacities. Digital technologies, such as virtual reality and Serious Games, offer a safe and controlled environment where operators can explore, experiment with, and refine their operational strategies.

The primary objective of this article is to propose an innovative approach to the prevention of MSDs through the development of a tool designed to help operators craft operational strategies that are specifically adapted to their work context. We aim to demonstrate how real industrial activities

vary among operators and to explain how a virtual tool, integrating scenarios based on these real-world activities, provides users with the opportunity to develop and adapt their operational strategies in response to challenges encountered during gameplay.

Methods

The game environment was designed to be engaging and relatable to real-world tasks while maintaining originality to avoid a purely industrial feel. A tutorial introduced users to the virtual environment, where a realistic avatar mirrored their movements, enabling direct interaction with virtual objects. Players could choose between immersive environments (beach, forest, snowy mountain) that gradually transitioned into workplace settings. A virtual trainer provided personalised feedback on postural risks and performance after each level. Players accessed their scores and tailored recommendations after each trial for improvement and experimented with various operational strategies. Postural risks were evaluated using a color-coded scoring system for upper limb joints, time spent in risky postures, and task performance metrics (Figure 1).

Figure 1: color-coded scoring system for upper limb joints

Figure 2 illustrates key aspects of the virtual environment and gameplay scenarios, depicting how operators interact with the system and adjust their strategies.

Figure 2: Virtual environment and interaction with the game

Results

We performed quantitative and qualitative analysis of playing serious game scenarios in virtual reality to explore the diverse operational strategies employed by subjects during gameplay. For quantitative analysis A test experiment with 44 operators (28 men, 16 women) from the real industrial sectors revealed significant variability in posture scores (based on exposure duration) and performance scores (completion time) for identical tasks, reflecting distinct strategies. For instance, in the "puzzle assembly" level, one Operator had a posture score of 6.53, indicating risky postures for the back, neck, and elbows, while another Operator, with a lower score of 2.57, adopted less risky postures but took more time to complete the task. Operators adopted varying strategies even for the same task. Serious Games appeared to offer users flexibility to explore different approaches.

Qualitative analysis performed by observing all the activities of seven subjects and interviewing with them using Vézina's activity-centred model indicators (2001) confirmed this diversity. Notably, one user showed minimal strategy regulations, ignoring game feedback and maintaining the same workstation setup throughout. Conversely, another subject adapted strategy by adjusting workstation height and altering task execution based on in-game recommendations.

The game fostered progressive awareness among users regarding their operational strategies. This awareness, blending in-game learning and real-world experience, enabled users to better utilise workplace resources and adopt strategies tailored to health and performance demands. However, technical limitations of the virtual reality system, such as occasional lack of fluidity and restricted hand movement, sometimes hindered optimal strategy regulation.

A key question concerns whether playing the game improved postures and whether these changes transferred to the workplace. Our findings indicate that some players gradually refined their strategies, adjusting their movements and task execution based on feedback. However, technical limitations—such as restricted hand movement in VR—sometimes prevented optimal strategy regulation. Regarding real-world transferability, while the game effectively raised awareness, no direct observation of long-term workplace behavioural change was conducted in this study, necessitating further investigation.

Conclusion

The diversity of strategies observed in the Serious Game can be linked to internal factors like motor control systems, experience, and expertise, as well as external resources provided by the work environment or the game itself. However, further research is needed to understand how these factors influence strategy diversity and motor variability. The findings underscore the importance of tools that enable operators to explore diverse approaches to task execution and develop strategies suited to their characteristics, tasks, and professional demands. The Serious Game used in this study demonstrates its potential as a digital tool to simulate industrial tasks and foster strategies that support both health and performance.

The resistance of some operators to adjusting their strategies, despite game feedback, highlights an important challenge in workplace training. The study revealed that while the game fosters awareness, some operators did not alter their approach, suggesting the need for complementary interventions, such as ergonomic coaching or workplace adjustments, to facilitate real-world application of learned strategies.

Future developments could focus on virtual reality games that allow operators to adjust their work environment and organisation, enhancing the conditions for task execution. Our findings suggest that Serious Games encourage the development of diverse strategies, though this depends on users'

familiarity with the game's features and prior experience. Further research is needed to explore how strategies learned in simulations can effectively translate to real-world applications.

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