



AUGMENTED/VIRTUAL/METaverse ENVIRONMENTS AS A SUPPORT IN RECREATION WITH A SPECIFIC FOCUS ON PILATES: ENHANCING PHYSICAL SKILLS AND EMPOWERING MENTAL WELL-BEING

Tamara Ratković,
[0000-0001-9476-5423]

Aleksandar Gadžić,
[0000-0002-1611-6855]

Uroš Jovanov*
[0009-0000-6640-935X]

Singidunum University,
Belgrade, Srebia

Abstract:

Technologically advanced reality is becoming a transformative tool in recreational fitness, providing an immersive environment that goes beyond the limitations of conventional exercise performances and settings. In interlacing visual, auditory, and haptic feedback, it creates an engaging, personalized experience, which influences and has a profound effect on physical skills, cognitive, and motivational aspects of training and exercising. In reviewing relevant scientific literature that presents examples of good practice focusing on the use of augmented (AR), virtual (VR), and metaverse (MR) reality in recreation and sports, several significant positive characteristics stand out in relation to physical skills and psychological well-being, and in particular for the practice of Pilates. In providing user-friendly support and environment, gamification elements, and through individualization of training strategies and movement protocols, these advanced realities introduce low-pressure entry into the physical activity, offer individual preference of a training course and setting, ensure higher exercise engagement, increase enjoyment, and reduce boredom. Apart from obvious physical benefits, it also shows a positive impact on mood, focus, and psychological well-being. Although there are some technical limitations, like cybersickness, high initial costs, and session length restrictions, in the long term, the potential of technologically supported reality in Pilates presents a tempting alternative.

Keywords:

Augmented Reality, Virtual Reality, Metaverse, Pilates.

INTRODUCTION

Technological transformations in the 21st century have altered physical and social reality, introducing augmented (AR), virtual (VR), and metaverse (MR) reality, as well as artificial intelligence (AI), into almost all aspects of daily life, providing immersive experiences that engage both body and mind. Originally developed in the entertainment and gaming industry, these technologies have gradually moved into professional and educational environments, where they serve as a support in the preparation and implementation of complex tasks in a real environment. In other words, entertainment is, relatively speaking, replaced by personalized development.

Correspondence:

Uroš Jovanov

e-mail:

ujovanov@singidunum.ac.rs





The introduction of devices such as Quest, HTC Vive, and PlayStation VR, with improved motion tracking and graphic visualization, ensured a strong penetration of virtualized and technology-assisted environments in health, rehabilitation, sports and recreation, with the aim of improving the psychophysical well-being of users.

The range of technologies that shape this "new reality" depends on the goal and degree of immersion. Based on those criteria, AR, VR, and MR are distinguished: VR replaces the real world and provides the user with full immersion in a virtual environment, while AR works together with the physical world, augmenting it with digital information [1]. Unlike AR/VR as less variable digitally supported environments, MR offers a set of elements and relations that enable a highly personalized space and process, not providing a ready-made solution, but a flexible and adaptable infrastructure for independent construction of programs and environments.

During the last twenty years, there has been a growing interest in the application of these technologies in sports and recreation, as confirmed by international conferences, specialized magazines, and online platforms that follow the development of digital realities in sports (e.g., IACSS, DIVE system, VR rehabilitation games), with a special emphasis on competitive and extreme sports [2] [3] [4] [5]. In the field of Pilates, the literature is still modest: AR and MR mainly appear in the context of rehabilitation [6] [7], while VR is primarily related to the sensory control of muscles and motor skills [8].

The aim of this paper is to, based on the existing corpus on the application of digital realities in sports and recreation, identify indicators significant for Pilates and propose a framework for their implementation, starting from the thesis that guidelines and domains of application

from other sports can be transposed to Pilates and that advanced realities, through support, gamification and individualization of protocols, facilitate entry into physical activity, increase engagement and satisfaction and reduce boredom. Results show that in providing user-friendly support and environment, gamification elements, and through individualization of training strategies and movement protocols, these advanced realities introduce low-pressure entry into the physical activity, offer individual preferability of a training course and setting, ensure higher exercise engagement, increase enjoyment, and reduce boredom.

2. AR, VR, AND MR AS A SUPPORT IN SPORTS AND RECREATION

In sports and recreation, a digitally advanced environment supported by various forms of technologies (AR, VR, MR) provides a wide range of assistance aimed at developing users' active relationship with the environment through immersion and a high degree of interactivity, where they engage both body and mind in order to achieve specific goals [9] (see Figure 1). According to relative scientific literature, immersion provides a rich flow of feedback and a strong connection with the environment, which allows the user to progress towards the desired results at their own pace and in an individualized way [10], while the feeling of mental and physical presence, combined with visual, auditory, and haptic feedback, significantly affects the motor, cognitive, and motivational aspects of training [11] [12]. Therefore, interlacing visual, auditory, and haptic feedback, it creates an engaging, personalized experience, which influences and has a profound effect on physical skills, cognitive, and motivational aspects of training and exercising.



Figure 1. VR in sports [13]



A critical analysis of research from the fields of sports, recreation, and computer sciences, which deal with simulated environments and active user engagement [14] [15] [10], shows that AR, VR, and MR assistance can be grouped into four key fields. First, the improvement of physical skills, which is achieved through sensory integration and precise movement correction, where "serious games" and visual, sensory, and haptic biofeedback systems surpass traditional forms of instruction [6] [7] [1]. AR enables body correction in real space, VR adapts training protocols to the current state of the user, and MR stimulates anticipation and decision-making by simulating motor behavior [16] [17]. Second, these technologies facilitate motor learning and the mastery of complex movement techniques in sports that require specific conditions, encourage coordination, fluidity of movement, and the development of neuroplasticity, even in the elderly population [18] [19] [10]. Third, the presence of virtual partners and team scenarios in VR/MR environments increases performance, persistence, and effort threshold without additional psychological burden, while enhancing competitiveness and competitive spirit [2] [3] [10] [20]. Fourth, precise control of the environment through immersion in personalized virtual ambient experiences (e.g., simulated nature) contributes to stress reduction, the development of psychological well-being, and the experience of "flow", whereby immersion can reduce the perception of pain and increase endurance [21] [10].

2.1. IMPROVEMENT OF PHYSICAL SKILLS

The improvement of physical skills in sport and recreation has increasingly drawn on principles developed in rehabilitation, especially those related to graded practice, motor control, and individualized feedback [6] [7]. The proper execution of exercises, that is, the development of self-awareness, motor control, and reflexive regulation of self-awareness, is supported through sensory integration. Serious games such as VR-MMA employ muscle activity and motion sensors to dictate movement quality and muscle engagement, while also encouraging accurate and precise task performance [1]. Feedback, whether visual, sensory, or haptic, can enhance and accelerate motor learning more effectively than traditional methods such as video demonstration, verbal correction, or photos [1].

While AR enables more precise exercise execution and supports movement correction within real space [1], VR allows precise control of the training by adapting it to the user's abilities and current condition, thereby

enabling flexible adjustment of standardized situations to the user's status [16]. MR, on the other hand, provides a simulation that, through the study of the user's motor behavior, simultaneously supports behavior correction and guides the user toward more appropriate decision-making through their anticipation [17].

2.2. MOTOR LEARNING AND COMPLEX MOVEMENT TECHNIQUES

Movement techniques and learning motor skills, as well as practicing them, are serious obstacles to regular sports activities. Let's just think of sports that require special conditions both spatially and temporally, e.g., skiing, triathlons, or swimming. Work on the complex structure of game elements, their interrelationship, movement techniques, movement fluency, synchronization, and the transfer of movement in team and paired sports- that is, [18] the development of cooperation and coordination skills in relation to the environment, teammates, opponents, or coaches [19] can be effectively supported through assisted reality in everyday life conditions. Even in the elderly population, interactive VR walking tours can significantly improve brain functions and neuroplasticity, which reduces the risk of cognitive decline [10], or in athletes who require a higher level of cognitive perception and a higher level of movement sensitivity, such technologies may foster the development of these capacities even in the absence of sport- specific physical engagement, thus contributing to a more balanced integration of physical and mental readiness for complex performance demands.

While AR provides, as in the previous case, body correction but also the improvement of cognitive abilities, i.e., it not only trains the automation of physical movement, i.e., physical behavior, but also affects the broader framework of body cognition, VR enables deeper immersion and a higher degree of adaptation to changing environmental conditions, whether physical or social [16].

2.3. SOCIAL ACCESSIBILITY AND COLLECTIVE EXPERIENCE

A large number of studies indicates that the presence of a virtual partner in team-based exercise contexts, including competitive settings, can significantly influence performance during exercise, increase perseverance, and increase effort tolerance without negative psychological exhaustion [2] [3] [10]. Competitiveness can also be developed through the same system. In addition, collective



user experience has been examined by Pallot et al. [22], while Kim and Kim further emphasize that effective MR training in this domain can produce tangible performance outcomes through the development of tactics and strategies, thereby reinforcing users' competitive spirit [20].

2.4. PERSONALIZED ENVIRONMENT

The precise control or selection of the environment contributes to the development of the relationship between physical and mental well-being through immersion in a specific environment in which exercises or gameplay takes place. In such contexts, users may prepare for the real-world environment or engage in recreation and sport within environments aligned with their personal performances. This is particularly important for mental recovery from stress and for the psychological well-being of users, especially those living in stressful urban environments. Stress reduction and relaxation through "flow" psychology that enables immersion in a virtual experience of a natural environment enhances enjoyment through colors, scenery, and sounds, increases concentration and focus on exercise, and develops motivation in the user [21]. The sense of space and time is lost, and the user completely surrenders to the experience. Some authors, such as Neuman, emphasize that immersion produces a dissociation that enhances focus and distraction from pain, allowing users a greater degree of endurance [10].

3. APPLICATION OF TECHNOLOGY-ASSISTED REALITY IN PILATES

The application of AR, VR, and MR technologies in Pilates opens possibilities for more precise control of movements, individualization of exercise, and strengthening of motivation in a pleasant, low-stress environment, with special effects on muscle activation, posture stability, fluidity of movement, and persistence in exercise. In relating a diverse pool of research, previously introduced, results comparing the potentials and obstacles of introducing digitally advanced reality in sports and recreation, we have concluded that in Pilates, a variety of implementations could occur.

3.1. SUPPORTED REALITY - AR

AR in the Pilates studio would provide support directly during the execution of exercises: wireless surface sensors placed on key muscle groups (core, gluteus, paraspinal musculature, etc.) could register muscle activity in real time, offer corrective feedback and connect the level of effort with gamified elements (points, levels, unlock new tasks), thus the client moves from "raw power" to finer control, isolation of target muscles and core stability.

AR is therefore particularly important for the improvement of physical skills, movement techniques, and motor learning, i.e., for the behavioral aspects of exercise (see Figure 2). [23]



Figure 2. Pilates AR reformer machines [23]



3.2. VIRTUAL REALITY – VR

VR, on the other hand, would enable independent exercise with the support of AI applications through VR glasses (e.g., Club Pilates VR), which could offer personalized sessions, monitor individual progress, and adjust goals (mindfulness, flexibility, core strength, etc.) (see Figure 3) [24]. In the VR studio, the client sees the avatar of their own body in proper alignment, movement path, and cortical activation indicators, which increases awareness of posture, rhythm, duration, and speed of movement, where breathing and endurance parameters can also be monitored. The movement and posture consciousness is present, aligned with its rhythm and speed, with a specific focus on breathing and sequencing indicators which follow the value of longer repetition stamina.

In this way, VR simultaneously supports the improvement of physical skills, movement techniques, as well as the development of cognitive and social skills and psychological well-being.

3.3. METAVERSE - MR

MR, as a highly sophisticated environment, could offer an augmented personalized ambient and a socially rich Pilates experience within a "metaverse ecosystem" (e.g., SimWin), in which the client physically exercises on a mat or reformer, but subjectively participates in virtual classes with real or virtual participants in a desired environment (see Figure 4) [25].

The instructor still leads the class, but, relying on the control panel with objective sensor parameters, individually adjusts the content and intensity of the exercises, which does not replace but strengthens his professional role, and further strengthens the client's trust through transparent, quantified indicators of progress. MR is particularly relevant in the conditions of a developed partnership relationship between client and instructor, where long-term development is jointly planned without clearly set boundaries in advance.



Figure 3. Immersing in VR [24]



Figure 4 Recreation in Metaverse [25]



4. CONCLUSION

The application of AR, VR, and MR technologies in sports and recreation is far-reaching, and the combination of wearable sensors, digital avatars, personalization of exercises, and an immersive, socially mediated environment significantly expands the possibilities of designing and realizing physical activity [18]. Research shows that VR games can significantly increase the level of physical activity and motivation in sedentary work tasks, which opens up space for the concept of a "virtual Pilates zone" in the form of short pop-up sessions during the working day, in a standing, sitting or lying position, making the Pilates studio constantly available - at the workplace, at home, on vacation or traveling [18].

In the field of Pilates, AR, VR and MR can be positioned in three categories today: (1) sensory monitoring of muscle activity (sEMG) as visual feedback for posture, balance and control, which achieves physical benefits through behavioral ones; (2) the flexibility and fluidity of standardized exercise patterns, with an individualized relationship between muscle effort and feedback, which encourages reflective cognition and cognitive development; (3) immersive spaces - from the intimacy of the home to virtual landscapes - that provide a framework for psychological and social well-being through inclusive experiential formats. In this way, it increases client motivation, provides objective monitoring of progress, and offers a personalized environment, while AR, VR, and MR allow Pilates to go beyond the physical boundaries of the studio and become part of a wider virtual ecosystem.

In this way, client motivation increases through the process of exercise realization. Personal development is monitored, and the follow-up or the whole process is objectivized. Above all, an individualized environment is offered to the client, enabling a higher level of personal satisfaction. Therefore, AR, VR, and MR offer a unique Pilates framework which can break the rules of physical and enter the world of a wider virtual ecosystem without negative effects on physical and mental health and with a positive impact on social well-being. The model of Pilates VR gamified studio shows how the problems of spatial constraints can be overpowered and how routines can be transformed through playing.

VR studio models show how spatial limitations can be overcome, how routines can be transformed through play without negative effects on psychological well-being, and how social randomness can be replaced by an intentionally structured social experience. Motivation

based on objective measurement of achievement, anticipation, individualized approach, and flexible location makes exercise continuously applicable and accessible in a familiar, pleasant, and socially acceptable environment, whereby the Pilates studio becomes a node in the digital sports ecosystem where motivation and self-reflection encourage inclusion. In addition to the obvious physical benefits, previous studies also indicate the positive impact of these technologies on mood, focus, and psychological well-being, while technical limitations such as cybersickness, high initial costs, and session length remain challenges, but do not diminish the long-term potential of VR and related systems as attractive options in fitness and recreation.

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