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Gamified Exergames with Dynamic Difficulty Adjustment: A Framework for Interactive Fitness and Motivation

Aoran Li[1], Ian Chai[2] Kok-Why Ng[3]
[1] *Ph. D candidate, Faculty of Computing and Informatics, Multimedia University, 63100 Cyberjaya, Selangor, Malaysia*
[2] *Principal Lecturer, Faculty of Computing and Informatics, Multimedia University, 63100 Cyberjaya, Selangor, Malaysia*
[3] *Associate Professor, Faculty of Computing and Informatics, Multimedia University, 63100 Cyberjaya, Selangor, Malaysia*
* *Corresponding Author: ianchai@mmu.edu.my*

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ABSTRACT

The aim of this paper is to investigate the potential of interactive fitness by enhancing indoor exercise through the integration of gamified exergames and Dynamic Difficulty Adjustment (DDA). DDA serves as a promising mechanism to promote sustained engagement in video-based exergames by adapting the game's difficulty in real-time based on player performance. This algorithm adjusts the challenge level according to a player's competence, thereby fostering increased participation in physical activity and supporting the development of intrinsic motivation for long-term adherence. Theoretical frameworks such as Self-Determination Theory, Flow Theory, and Operant Conditioning Theory further substantiate the positive role of DDA in gamified exergames, highlighting its capacity to improve user engagement through personalized difficulty settings. The study concludes that the incorporation of DDA is effective in balancing gameplay challenge, thereby encouraging greater participation in indoor fitness activities. Future research is recommended to explore this concept further and assess its broader implications.

Keywords: Dynamic Difficulty Adjustment, exergames, physical activity, intrinsic motivation, interactive fitness

INTRODUCTION

A rise in the popularity of video games has increased in the current society specifically considering the role of promoting physical exercise. Research has been conducted extensively while analysing the importance of Dynamic Difficulty Adjustment (DDA) in the context of video games that refers to the real-time adjustment of difficulty levels in games based on a player's performance (Seyderhelm, & Blackmore, 2021). This concept is known to be effective in engaging more players within the game as a part of the action game concept promoting physical activities (Orozco-Mora, Fuentes-Aguilar, & Hernández-Melgarejo, 2024). The benefit of dynamic difficulty adjustment lies in the fact that the challenges of aligning players' abilities with the game and providing them an optimal gaming experience promoting physical activity is achieved.

Generally, the challenges that a game provides to a player is what makes it interesting for them. Games that are easy to overcome are often uninspiring over the time. However, in the case of older people, these concepts may not prove to be very similar since they do not find physically exhausting games to be highly interesting or encouraging (Vang, 2022). Hence, it becomes necessary for creating a balance between the challenge for a player based on their skills and competence (Zeng, & Sweetser, 2022). The obstacle which is perceived to be highly difficult for one player may be easy for another. Implementing the benefits of DDA allows the video game creators to gauge the skill level of players and then alter the parameters with the aim to provide suitable challenging opportunities to the users based on their skills and competence.

The performance DDA utilises data provided from a specific player on the game in order to adjust the difficulty. This data inclusive number of times that clear has failed to overcome the level or the number of points that they may have received in a specific level compared to others. Additionally, the effective DDA aims for inferring the players emotional state from psychological data through the players current emotional speed including anger or frustration

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and adjusting the game level difficulty for the players to engage better within the games (Nery Bandeira, et al., 2022, June). These features influence the engagement level of the individuals through higher motivation.

DDA contributes significantly in terms of overcoming the challenges of traditional games with static difficult levels that can often reduce the engagement level of a diverse clear base. Players are offered a variety of skin levels while incorporating inclusive experiences through the alignment of gameplay in accordance to the players' competence. This not only is effective in refining the gaming experience but also allows the players to maintain their ideal state of play (Zheng, 2024). The objective of the study is to analyse the benefits of applying dynamic difficulty addresses for Excel games as a method of encouraging physical activity level among individuals. The paper aims to synthesize empirical evidence on the role of DDA in enhancing the motivation towards physical activity levels. Various cognitive and emotional factors that influence the behaviour of individuals towards taking part in excel games for physical activity and the benefits that DDA provides in such situations by adjusting the game level difficulty is also studied.

LITERATURE REVIEW

Definition of DDA

(Li, Chai, & Ng, 2023) defined that Dynamic Difficulty Adjustment (DDA) is a technique that, in real-time, dynamically modifies different in-game elements, scenarios, and behaviour based on the player's skill level to prevent game boredom. This is because playing a game that is too easy might make people bored, and playing a game that is too hard can make people lose confidence (Bassano, Chessa, & Solari, 2022). According to a study by (Fisher, 2024), DDA is a crucial tool in video game design that helps with the problems of keeping players interested across a range of different abilities and emotional states (Huber, Mertes, Rangelova, Flutura, & André, 2021). DDA may match game obstacles with a player's skills and mood instantaneously. It guarantees a constant level of engagement and entanglement, unlike static problems that are unable to adjust to the demands of individual participants (Martinez-Millana, 2022). Other studies have explained that DDA not only increases the allure of video games by enabling a more customized experience, but it also provides a way to convert casual players and people who do not have fleeting curiosity into permanent involvement (Mortazavi, Moradi, & Vahabie, 2024).

DDA offers the further advantage of allowing exergames to modify workout difficulty so that players may get effective physical training without becoming overly taxed. On the other hand, affective-based DDA employs present-time physiological data from sensors to modify game difficulty determined by the participant's emotional state (Brons, 2024). Several tools have been used to investigate this approach. DDA can additionally be employed to make e-sports players' training better and more efficient by establishing more difficult settings that constantly test the player's capabilities (Khundam & Nöel, 2021). The content, gameplay, and interface of older adult exergames must be customized to the target demographic while considering their unique traits (Knorr, 2021).

In classic games, the difficulty rises either step-by-step or gradually as the game progresses. Only at the outset of the game, by selecting a difficulty level, can characteristics like frequency, starting stages, or speeds be set (Lobo, 2024). However, if players attempt to map a predetermined learning curve, this may lead to a bad experience. DDA offers a tailored solution for the players to address this issue (Nery Bandeira, et al., 2022, June). Understanding what "difficulty" means is essential before using the DDA. Some of these include design features, resource counts, wins and losses, and so on (Fisher, 2024). However, DDA is more complicated than simply providing an individual with healthier options when they are struggling (Zeng, & Sweetser, 2022). It requires a time estimate and an entrance at the appropriate moment since it is difficult to keep the player interested in an interactive perspective (Huber, Mertes, Rangelova, Flutura, & André, 2021)

Definition of Exergames

Exergaming is the term for technology-enabled physical activities, such as playing video games that need physical activity or exercise to be played. These games demand the player to utilise their entire body to engage in interactive physical activities, communal physical exercises, or virtual sports (Luca Vismara, 2024). The idea behind Exergaming is to transform the love of gaming, which was previously seen to be an inactive habit, into an activity that may be more active and healthful (Bassano, Chessa, & Solari, 2022). Unlike traditional video games, exergaming encourages both video gaming and exercise simultaneously (Schättin, et al., 2022). Numerous intervention studies that looked into the potential health advantages of playing exergames have included them (Shu, Liu, & Yannakakis, 2021). For

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instance, it has been demonstrated that VR exergames encourage players to engage in physical exercise by employing DDA to create levels that are appropriate for the player's skill level, extending playtime.

According to research by (Guimarães, 2021), there was quantifiable proof of success while utilising commercially accessible exercise games. The possibility of exergames to promote PA is supported by the fact that playing them also had an impact on assessments of self-efficacy and intrinsic motivation, two factors that are linked to behaviour change. Although there is confirmation that elder rehabilitation results are improved by exergames, additional high-quality research is needed to draw this conclusion with more confidence (Bermúdez i Badia, , et al., 2023). Regarding an activity to qualify as exercise, it must be purposefully designed to preserve and enhance physical fitness and involve repeated motions carried out in a planned, systematic manner (Brons, 2024). According to this perspective, defining "exercise" to exergames may be hazardous for encouraging physical activity as it excludes many good behaviours that are not intended to maintain or enhance fitness (Fisher, 2024).

Another issue with using this concept of "exercise" to exergames is that it may also refer to passive activities. Physical fitness is divided into two categories: skill-related and related to health (Knorr, 2021). Cardiorespiratory resilience, power from muscle, strength, shape of the body, and adaptability are the various aspects of physical fitness that are linked to health (DeSmet, Baranowski, Thompson, & Lu, 2025). Agility, control, coordination, balance, speed, power, and response time are the elements of physical fitness that are associated with skills (Fisher, 2024). Exergaming, a term derived from the term's "exercise" and "gaming," is a novel kind of exercise that combines play and athletics (Luca Vismara, 2024). This interactive technology is increasingly essential in contemporary indoor playgrounds, jumping parks, and family entertainment centres (FECs) since it combines enjoyment with exercise (McGuirk, 2023). Exergaming is also possible without displays or virtual environments due to the buzzer and target systems, which offer a similarly engaging and dynamic engagement (Schez-Sobrino, Vallejo, Monekosso, Glez-Morcillo, & Remagnino, 2020).

Analysis

Playing video games has grown in popularity as a pastime for many people, and it is also being investigated in increasing numbers as a means of encouraging physical exercise (Fisher, 2024). Dynamic Difficulty Adjustment (DDA), which refers to the immediate modification of the game challenge level depending on the participant's efficiency, has been extensively studied concerning video games (Guimarães, 2021). This guarantees that the difficulties are appropriate for the participant's ability level, offering the best possible gaming experience and encouraging exercise through a gamified strategy. Research by (Lobo, 2024) looked at the possible effects of using Dynamic Difficulty Adjustment (DDA) in exergames. The results showed that in comparison to games without this feature, those with DDA had a noticeably greater impact on the player's experience when playing games.

Exercise-based video games, or "exergames," have promise for treating sensory disorders, pain management, and rehabilitation. However, because it is difficult to create worlds with great authenticity and easy controls, particularly for older persons, technical advancements are low (Huber, Mertes, Rangelova, Flutura, & André, 2021). The lack of cooperation between developers, healthcare professionals, and consumers further exacerbates this lack of development. Patients' sensation of being present and fully involved is thus limited by mostly non-immersive applications for virtual reality (Khundam & Nöel, 2021). The artificial sense of reality that VR interfaces provide is essential to immersion (Schalbetter, 2025). The goal of physical rehabilitation is to help people with physical disabilities or impairments perform better and live better lives. Globally, neurological disorders are the leading cause of disability. There is no treatment for many, although physiotherapy helps control symptoms (Shu, Liu, & Yannakakis, 2021).

Originally created for entertainment purposes, the Kinect gadget has drawn a lot of interest and is currently the most popular choice in technology-assisted rehabilitation. The study looked at how accurate Kinect joint tracking is, which led to the creation of a tool to determine whether the Kinect is appropriate for a certain medical application (Schez-Sobrino, Vallejo, Monekosso, Glez-Morcillo, & Remagnino, 2020). Training methods that are both entertaining and motivating are required to address the public health emergency (Li, Chai, & Ng, 2023). Exergames, or games that require active bodily motions, are useful, appealing, and efficient training aids at home. Sphery Ltd. created the ExerCube, a practical exercise game that is both physically engaging and adaptable (Schättin, et al., 2022). The creation of a home-based ExerCube might make exercise more accessible, lower obstacles to it, and offer a compelling

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way to enhance both mental and physical health.

Procedural Content Generation (PCG) is the term used to describe the algorithmic, independent creation of game material. This is frequently utilised to generate enormous amounts of diverse material without requiring an increasing number of human designers and artists, hence increasing replay value. Exergames can already decrease monotony and boost player interest by employing PCG to generate visually distinct stages that do not adapt to the user (Huber, Mertes, Rangelova, Flutura, & André, 2021). The exergame may be used independently because it was made to operate on a tablet or smartphone. Two suggested methods for monitoring physical activity on an indoor bike were part of the system design. When engaging in activities, people with ID frequently need parental or professional help and direction. It is anticipated that in order to teach the user how to use it, instructors and parents will need to offer help and direction (Martinez-Millana, 2022).

Table 1: Literature matrix

Author	Method	Description	Benefits
(Li, Chai, & Ng, 2023)	Using dynamic difficulty adjustment (DDA) method in video games. This method it also divided into three parts- 1) appraisal of studies 2) prior research and 3) evaluation of theoretical framework	Evaluate the significance of Dynamic Difficulty Adjustments (DDA), whether this tool helps to encourage higher quality and greater amounts form of physical exercise.	The outcome of this study provides a great potential to balance optimal difficulty challenges and DDA algorithms. It also encourages physical activity through enhancing motivation and physical activity levels. It also synthesizes the benefits of DDA on physical exercise as well as in interactive fitness.
(Schez-Sobrino, Vallejo, Monekosso, Glez-Morcillo, & Remagnino, 2020)	Using Dynamic Time Warping (DTW) algorithms and motion curves to engage patients in physical exercise. Furthermore, gamification techniques and methods are also used to evaluate their rehabilitation routines.	Develop a distributed gamified system focusing on automatic assessment of physical exercises to improve the quality of life and functional ability of patients. It also highlights neurological diseases as the largest reason of disability in worldwide.	This work highlights a vision-based system for home that helps to automatically assess patient performance. Moreover, both physiotherapists and patients can engage in a long-term process that transmits the information of the clinic.
(Schättin, et al., 2022)	A total of 15 healthy participants are selected. Furthermore, two laboratory visits are conducted that include an under field visit method. Conducting a quantitative study the	The discussion of this paper highlights the role of engaging and motivating training strategies to deal with public health issues. The significance of ExerCube (by Sphery	The benefits of home-based exergame and on-body feedback systems at an early stage has been revealed throughout this study.

	researcher collected data through an on-body feedback system and semi-structured interview.	Ltd) has been evaluated to adapt and immerse functional fitness games.	
(Bassano, Chessa, & Solari, 2022)	A systematic survey has been conducted in the field of cognitive training and assessment.	In recent years, the concept of virtual and augmented reality techniques have become very common. Hence, the significance of Web based solutions for the continuous evaluation of clinical and patient personnel has been defined in this study.	Using multiple advanced techniques like Machine Learning and Artificial Intelligence algorithms help to improve both clinical and patient personnel. It also adheres to the rehabilitation process and improves the efficacy in healthcare.
(Khundam & Nöel , 2021)	A two motion-based locomotion approach, including ArmSwing and Squat is being implemented using VR technology for studying how physical activities affected players while interacting in the test Scene. An interview and survey was performed on 30 volunteers via social media after the VR experiment.	Virtual running can be implemented as a locomotion technique for VR based exergames. The designs of the games need to be made in a manner that focuses on entertainment while providing physical benefits as well.	The result of the interview suggested that players preferred ArmSwing than Squat for a long period. However, in case of short term exercises, the contrary was prevalent.
(Bermúdez i Badia, , et al., 2023)	A field study approach is adopted on three studies based on PEPE (Portable Exergame Platform for the Elderly) for validating its effectiveness for physical activities, assessing its feasibility and analyse its acceptance	A conception and field validation of PEPE is presented for a gaming platform using mixed reality components. The objective of this approach is to promote physical activity among elders	The custom made games using PEPE can be effective in being used by trainers for long-term purposes and deliver positive results for better exercise among elders and improve the quality of life.
(Huber, Mertes, Rangelova, Flutura, & André, 2021)	A prototype of the VR Exergame is developed, that utilizes Procedural Content Generation for	The VR Exergame prototype is evaluated in an exploratory manner in order to	The approach finetunes specific parameters and creates completely new levels that has the

	DDA creating game levels with difficulties that matches a player's capability	determine how players traversing to amaze including several exercise rooms can contribute towards the development of their physical activities while matching their capability.	potential of decreasing repetition in games for a longer period of time and allowing simultaneous adaptation of cognitive and physical challenges of the Exergame.
(Shu, Liu, & Yannakakis, 2021)	Experience-Driven Reinforcement Learning framework is being implemented as a novel approach for creating personalised and real-time experience for the users. The Koster principle is also considered that helps in diversifying the gaming elements	The proposed framework aims at developing level based games for Super Mario Bros with variety of enjoyment and playability that are diverse from their levels using Procedural content generation	The implementation of EDRL is effective in generalizing a gaming segment through a sequential process and representing the game content.
Martinez-Millana et al. (2022)	Three steps make up the suggested process, which may be carried out in cycles. The first stage is defining the criteria and conducting a thorough literature review. In phase two, the exergame is developed and its correct operation is confirmed by laboratory testing. Phase 3 testing of the system involves actual users with IDs testing the exergame.	The study concentrated on the implementation of user-centered design concepts to the design, development, and acceptance by users of a sensor-connected mobile health solution that encourages physical activity. The equipment has been mounted on an ergometer bike and an indoor stationary bicycle specifically designed for individuals with intellectual disabilities.	The system may be enjoyable for users with intellectual disabilities, and respondents thought it was a good way to encourage physical exercise among the business's users.
Luca Vismara et al. (2024)	The pilot research suggests utilising an individual RGB-D camera-based visual system (using Microsoft Azure Kinect DK) to promote and sustain upper limb motion through gamified	The MREP is a vision-based device that records 3D body motions in real-time using a single RGB-D camera (the Azure Kinect) as a non-contact instrument.	The study offers a method for suggesting and keeping track of workouts and physical activities utilising gamified tasks that may be used around the

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	activities in a virtual world. This approach can be easily implemented and utilised in domestic settings.		house to encourage upper limb mobility.
Brons et al. (2024)	The Arksey and O'Malley framework and the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines served as the foundation for the scoping examination. The ASReview program was used to screen the papers.	Compared to non-personalized therapies, personalized mHealth interventions are more successful in fostering PA. Personalization in mHealth refers to tailoring intervention tactics to individual traits like gender, illness, coping mechanism, present location, present PA level, or accomplished physical activity.	Interventions in mobile health (mHealth) may be beneficial in a number of ways, including feedback type, content of messages, timing, incentives, and individualized settings.
Guimarães et al. (2021)	The three stages of VITAAL's design were research, development, and testing. The VITAAL exercise game was designed and developed with input from senior citizens.	VITAAL's goal was to provide a technology solution that would support multi-component, individualized therapeutic methods for older people.	The solution helps with cognitive impairment, urine incontinence, and mobility constraints while considering their unique skills and advancements.

METHODOLOGY

The main purpose of this paper is to examine the concept of interactive fitness to enhance indoor exercise through gamified exergames and dynamic difficulty adjustments (DDA). The methodology section of this study is categorized into three parts. The first section includes an appraisal that investigates the significance of DDA in gamified exergames to enhance indoor exercise (Li, Chai, & Ng, 2023). It has been found out from previous studies that exergames have a significant influence on physical activity by increasing interactive fitness. The second phase of the method mainly focuses on prior research. In this stage, the implementation of DDA as a gamified system has been reviewed.

Apart from that, how DDA as a gamified tool positively impacts on both exercising and playing has been scrutinized in this study (Tan, Mahadzir, & Abd Jabbar, 2023). The final process of the method includes some key accurate theoretical frameworks. All of these theories and its related framework should be based on DDA based exercise. Incorporating all these three methods, the objective of this study can be achieved. Moreover, the implementation and application process of DDA to enhance indoor exercise is interpreted as well.

RESULTS

Thematic analysis of the gathered secondary data highlight's important themes related to the impacts of gamification on the improving physical activity through exergames. The review of publications from 2020 to 2024 repeatedly

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identifies benefits, challenges, and user experience tied to gamified physical activities, providing comprehensive insights.

Self-Determination Theory (SDT)

The Self-Determination Theory is considered as a micro theory of motivation well-being and psychological functioning which was introduced by Deci and Ryan. This theory has been constantly implemented and improvised in order to support the concepts of motivation and well-being (Aufheimer, et al., 2023); (Alberts, et al., 2022, November). In accordance with the theory, individuals are considered as active organisms that evolve and develop based on social contexts (Du et al., 2024). This theory can be implemented for closely examining the aspects of motivation and psychological functioning in relation to the implementation of dynamic difficulty adjustments and exhale games for physical activities (Guzmán, Rengifo, Guzmán, & Garcia Cena, 2024). DDA in the context of cognitive rehabilitation addresses diverse cognitive abilities of older adults recognizing the various levels of proficiency individuals may have across cognitive domains.

The Dynamic Difficulty Adjustment aspect is implemented in video games to meet the standard of Self-Determination Theory regarding encouragement of successful involvement autonomous behaviour and a feeling of competency (Schwarz, et al., 2021); (Li, Chai, & Ng, Dynamic Difficulty Adjustment in Video Games for Encouraging Physical Exercise: A Review and Theoretical Framework., 2023). Difficulty level of a game is adjusted based on a player's performance through the dynamic difficulty adjustment feature. Gamers are allowed to feel autonomous and experience control in their activities for the aligning the game demand and skill competence requirement resulting in development of intrinsic motivation (Sanchez, et al., 2022). In accordance with the self-determination theory for motivation it is considered that players would engage in a repeated gaming behaviour when they perceive that the game is highly intrinsically motivating. Hence implementation of the DDA feature is beneficial that allows adjusting the difficult level of the game influencing intrinsic motivation and engagement.

It is evident from the recent research that Self-Determination Theory is often implemented in serious gaming designs. The emphasis of motivational aspects of behaviour through this theory specifically regarding intrinsic or autonomous motivation is reflected through give me activities as it is personally interesting or satisfying which allows achieving goals (DeSmet, Baranowski, Thompson, & Lu, 2025). Satisfactory gaming promotes feelings of mastery and related best that facilitated development of autonomous motivation for further engagement behaviour. Development of expertise in a field that holds significance to one individual can contribute towards improving their feeling or self-determination (Li, Chai, & Ng, Dynamic Difficulty Adjustment in Video Games for Encouraging Physical Exercise: A Review and Theoretical Framework., 2023); (GomezRomero-Borquez, Del-Valle-Soto, Del-Puerto-Flores, Briseño, & Varela-Aldás, 2024). Hence focusing on whether a person has a specific hobby for a sport or physical activity can contribute towards enhancing their skills through physical exercise and exclave interventions.

Flow Theory

The concept of Flow Theory proposed by Mihaly Csikszentmihalyi defined a state of enjoyment and intense engagement in an activity. Moreover, it is also characterized by maintaining a balance between skill and challenge (Kim, 2022). Apart from that, it also leads to a sense of control, focus, and intrinsic motivation. The key concept of flow theory is divided into-intense focus, challenge-skill balance, intrinsic motivation, sense of control, and autotelic experience. Heightening the concentrating and focus toward a specific subject, it helps to achieve goals through a sense of satisfaction and enjoyment (Goddard, Stevens, Jackman, & Swann, 2023). Similarly, here in this study flow theory is underpinned to examine the role of DDA and interactive fitness to enhance indoor exercise. Flow can help in enhancing creativity and productivity. Hence, people become motivated to implement DDA as a gamified tool, and other exergames to enhance their physical activity level through indoor exercise. In this way, the engagement of people in physical exercise is also enhanced to ensure interactive fitness.

Apart from that, the application of flow theory often utilised as a therapy to help individuals to overcome challenges. As in this study, application of flow theory can help people to deal with their physical crisis by engaging in indoor exercise (Mckoy & Diamond, 2022). Along with this, by involving in various gamified tools by exergames, people can also keep track of their daily physical activity levels and performance. Therefore, it has become understood that flow state theory helps individuals

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to experience deep focus immersion, and intrinsic motivation in their indoor exercise. Additionally, it also helps to define the state of engagement and concentration that people can achieve by completing a target in indoor exercise (Lobo, 2024). Hence, the concept of Flow theory assists individuals to overcome their physical challenge by motivation and engagement, as well as adapting gamified exergames and DDA.

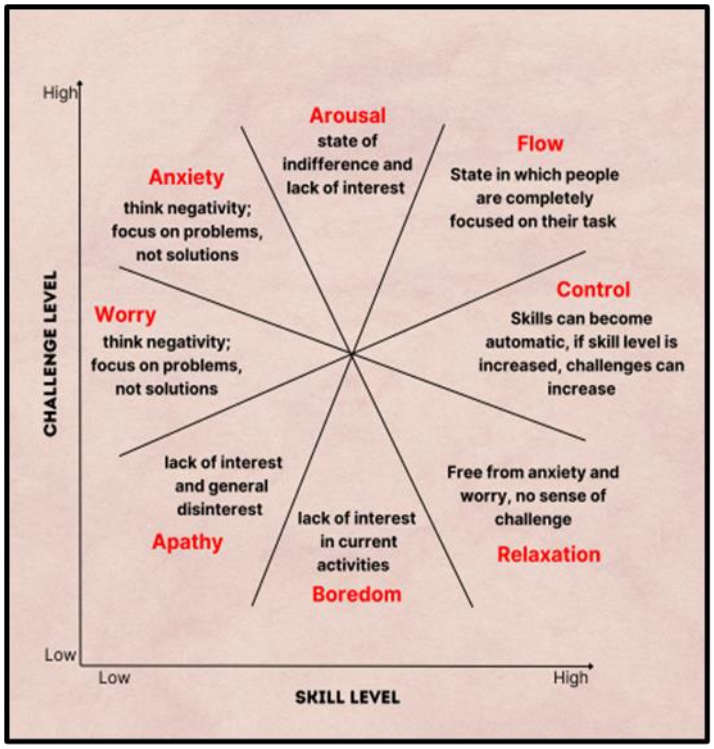

Figure 1. Flow Theory

The flow model is also considered as a psychological adaptive concept that emphasizes a fitness game environment for individuals. As per the flow concept, it is also defined that an optimal gameplay or training experience during exergame play helps to maintain balance between player skills and game related challenges (Mortazavi, Moradi, & Vahabie, 2024). An individual's fitness level and the intensity of required movement input is also measured by the motivation level. Based on previous sports and gaming experience, the concept of flow model allows individuals to use user-centered design approaches like exergames to improve their indoor exercise level.

Operant Conditioning Theory

The Operant Conditioning theory was founded by behavioral psychologist B.F. Skinner. It is one kind of learning theory that utilizes the concert of punishment and rewards to change behavior (Ma, 2022). It is also known as Skinnerian conditioning or instrumental conditioning. Two main key principles for this theory are- intermittent reinforcement and schedules of reinforcement. Both of these are one kind of tactic that helps in operant response that is maintained and learned by individuals. On the other hand, positive reinforcement also helps to increase probability of a behavior. Here, in this study by underpinning operant conditioning theory, the behavior of individuals toward gamified exergames and DDA to enhance indoor exercise can be understood (Alqadhi, et al., 2022). Along with this, negative reinforcement also helps to eliminate negative consequences that motivate and encourage individuals toward indoor exercise level. It is one kind of learning method that employs punishment and rewards for behavior.

Rewarded behaviors in operant conditioning theory are more developed or repealed. It encourages individuals to engage in indoor exercise activities (McGuirk, 2023). Furthermore, their motivation to adapt new approaches like gamified exergames and DDA is also enhanced. Therefore, it has become understood that instead of punished behaviors, rewarded behaviors are often used. The behaviors in indoor exercise are modified and learned through consequences. It is also known as Response-Stimulus (R-S) theory that helps individuals to provide random responses and activate it based on stimuli (Sinnemäki, et al., 2025). It has been found out that gamification also acts

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as a behaviour that transforms rehabilitation exercise into multiple interactive virtual activities. In these interactive virtual activities- gamified exergames and DDA are also included. It helps to enhance an individual's behavioral movement toward fitness as well as indoor exercise.

The model of operant conditioning also pointed out interactive virtual reality (VR) into DDA to deal with difficulties in indoor exercise. Hence, it proposed that exergaming should be employed as an effective exercise behavior change strategy (Zhang, Yu, & Ji, 2024). It has a positive and long-term impact on an individual's fitness level as well as their engagement in indoor exercise. In order to maintain individual motivational level in DDA, the concept of behavior is also very crucial. It helps to train cognitive and physical functions that enhance levels of fitness.

DISCUSSION

This study investigated the application of Dynamic Difficulty Adjustment (DDA) within gamified exergames and its potential to promote interactive indoor fitness. The integration of DDA demonstrates promising results in maintaining user engagement by tailoring game difficulty to the player's real-time performance, effectively addressing the common challenge of static game design, which often leads to disengagement due to misalignment between challenge and skill level.

The findings support previous research suggesting that personalization in digital games can significantly improve physical activity adherence (Li, Chai, & Ng, 2023; Guimarães, 2021). This personalization is crucial in fostering intrinsic motivation, a key concept in Self-Determination Theory, which asserts that autonomy, competence, and relatedness are core to sustained behavioral engagement. By dynamically adjusting difficulty, DDA helps users experience a sense of competence and flow, encouraging prolonged participation in physical activity through exergames.

Furthermore, the implementation of theoretical frameworks such as Flow Theory and Operant Conditioning Theory reinforces the psychological validity of DDA mechanisms. Flow Theory, in particular, emphasizes the balance between challenge and skill, and DDA operationalizes this concept by continuously calibrating game parameters to match user ability. This dynamic alignment prevents frustration from overly difficult tasks and boredom from tasks that are too easy, thereby preserving optimal engagement.

Despite these promising outcomes, the study also acknowledges limitations. One notable challenge is the lack of standardized algorithms capable of accurately mapping user capability with in-game difficulty, especially for diverse user groups such as elderly individuals or those with cognitive impairments. The current implementations of DDA vary widely in sophistication, from rule-based systems to more complex machine learning algorithms, but consistent effectiveness across populations remains underexplored.

Moreover, the study identifies a need for further empirical validation in real-world settings. While many prototypes and small-scale implementations have shown success, larger-scale longitudinal studies are required to determine the long-term effects of DDA on user behavior, fitness outcomes, and dropout rates. As pointed out in related literature (Mortazavi, Moradi, & Vahabie, 2024), the development of emotion-aware and biofeedback-integrated DDA systems could be a valuable direction for enhancing engagement and personalization.

In conclusion, DDA offers a compelling method to adapt exergames for individualized experiences, promoting physical activity and motivation through intelligent game design. Its integration into interactive fitness platforms holds significant potential, but realizing this fully will require continued interdisciplinary collaboration among game designers, psychologists, and health professionals.

CONCLUSION

The empirical findings of this study have highlighted that Dynamic Difficulty Adjustment (DDA) acts as a technique in real-time that helps in gamified exergames and fitness. It has been also found out that DDA also acts as a crucial tool that enhances the advantage of exergames. This study also reviewed many previous studies that help to summaries the significance of gamified exergames and DDA to enhance indoor exercise. All of these previous studies employed different methods that help to scrutinize how DDA helps to deal with new physical activity approaches in a significant way.

This study also underpinned self-determination theory, flow theory and operant conditioning theory. The findings of all these theoretical frameworks allows individuals to improve their behavior to keep engaged and motivated during indoor exercise. Furthermore, it also can be concluded that through the concept of flow model different difficulties and gamified exergames related challenges can be overcome. In this way, the ultimate outcome of this study helps to summarize the significance of different approaches in gamified exergames to deal with dynamic difficulties in indoor exercise and interactive fitness.

FUTURE RESEARCH

Certain key limitations have been identified after conducting in study on determining how DDA and gamified exergames has an influence over the interactive fitness of individuals through indoor games. The limitation is that while the incorporation of Dynamic Difficulty Adjustment in video games has a positive impact over engagement there remains challenges in analysing the long-term effectiveness of this strategy. Future scope for research remains on how this technology can be optimised based on developing user experience through enhancing for the engagement and motivation of the players while also decreasing the amount of dropout race while being in mid challenge of the game levels.

It has been observed that DDA has the potential of personalizing the workout intensity of individuals while ensuring that difficulty levels remain engaging, without making it extensively difficult. Adjustment of the difficulty levels makes individual participation more convincing which leads to attraction towards such exercise routines. It is necessary that proper standardized algorithms are implemented to match the difficulty level of a user with their capabilities. With the lack of proper precision, users may be unable to have access to words adjusted difficulty levels, which has a direct impact over there engagement with the games. Further scope for study remains as to how the algorithm of DDA can be developed for retaining clear engagement.

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