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Immotion - Exergame for Warm Up Guidance and Motivation

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von / by

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I agree to make both versions of my thesis (with a passing grade) accessible to the public by having them added to the library of the Computer Science Department.

Saarbrücken, December 2017 Marko Vujić

Abstract

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Chapter 1

The Design and Development of the Immotion Exergame

This chapter outlines the design and development of the Immotion exergame for warm up routine guidance and motivation. We begin this chapter with the description of the design methodology used for the development. For the purpose of this thesis, an iterative and prototype driven, user centered design has been adopted (UCD). After the methodology has been introduced, we continue with the in depth discussion of each individual development phase. Our main focus is placed on the last two stages of the development in which we develop the prototype and the final version of our exergame solution, and evaluate them utilizing various qualitative evaluation methods. During all the development phases presented in the subsequent sections, the particular needs of individuals who engage in some sort of physical (sports) activity and rarely or never warm up prior to those activities have been taken into account and gathered through the adopted UCD process in order to make an adequate exergame for warm up guidance and motivation.

1.1 Overview of User Centered Design

User-Centered Design (UCD) represents *a user interface design process* that puts its focus on usability goals, explicit understanding of users, environment, and tasks to be performed []. Moreover, it is an iterative process, where design and evaluation phases are included from the first stage of the development, that addresses the whole user experience, and is driven and refined by user-centered evaluation. Adopted from [], the following are the general and advised phases of the UCD process:

- Specify the context of use: Identify future users of the solution, the intended purpose of usage, and the conditions under which the solution will be used.

- Specify requirements: Identify user goals that must be met in order for the solution success.

- Create design solutions: Done in stages, building from a rough concept to a complete and final design.

- Evaluate designs: Evaluation should be performed through usability testing with actual users.

Even though being a relatively new field, exergame developers often indicate the relevance of including the players in the design process and point out the benefits of adopting UCD in exergames development. In their study on exergame design for elderly users, Gerling and Masuch recommend and utilize UCD for developing exergames for an elderly audience []. Furthermore, Hernandez *et al.* take advantage of UDC in their year long study whilst developing action-oriented exergames for children with cerebral palsy []. Taking this into account, as showed that UCD can be used for designing effective exergames for specific target demographic, we adopt this approach in the development of our exergame solution for warm up guidance and motivation.

1.2   The Context of Use

There exist solutions designed to encourage physical activity. These solutions are mainly intended to be used for home and in-door workout activities. Many of them offer multitudes of predefined exercise programs and also make it easy to create a fully customized workout plan that are suited for individual's needs and abilities []. However, in our research, we found no available solutions that focus solely on the warm up routine as a preparatory activity before physically more demanding exercise. Taking this into account, as well as the fact that warm up routines are crucial part of any sports activity [] although often avoided by multitude of athletes [], with the Immotion exergame we chose to tackle exactly this issue. We design and develop our exergame to be used as a warm up guidance and motivation tool. That is, our exergame is intended to be used in gyms and fitness centers before any arduous sports activity. Additionally, we target individuals, above all amateur athletes, who do not know how to perform a proper warm up routine before the subsequent sport activity.

1.3   Overview of the Development Phases

The development of the Immotion exergame consisted of three primary phases which are according to the well accepted UCD development phases outlined in the previous section and depicted in Figure 1.1:

- Requirements gathering

- First prototype development with user evaluation

- Final exergame development with further user evaluation

In the following sections, each iteration presented in *Development* section of Figure 1.1 will be further detailed.
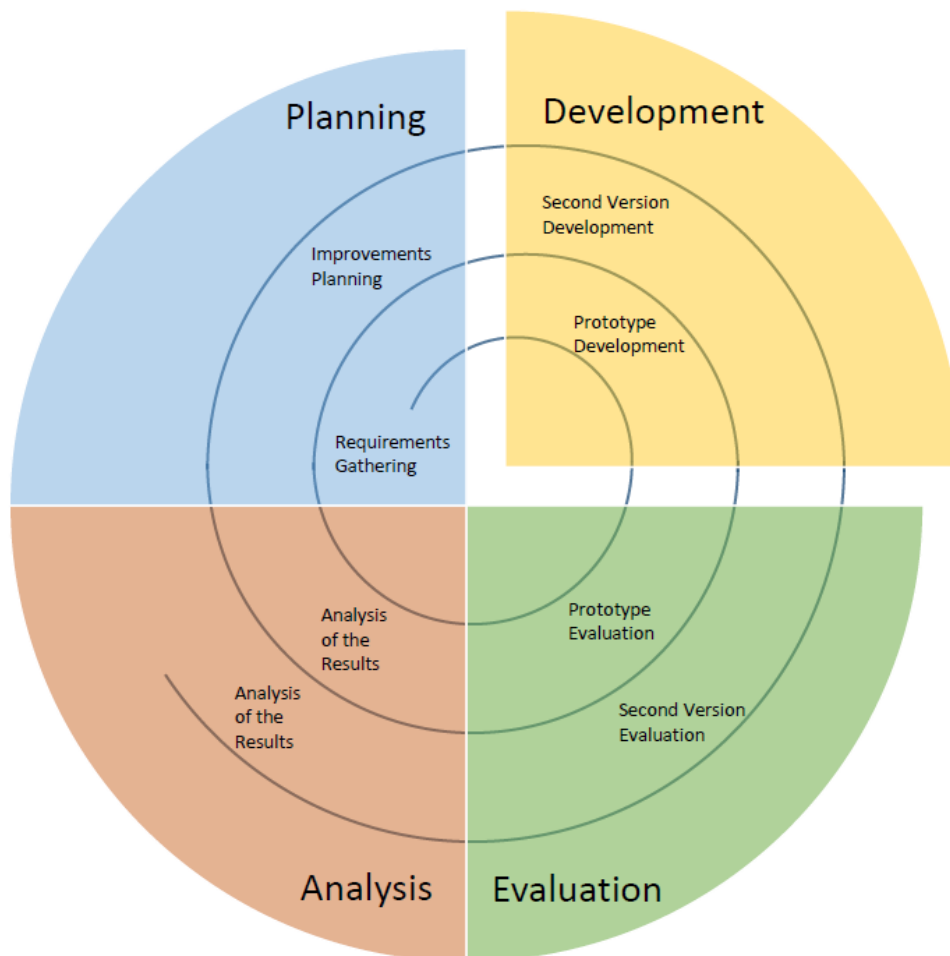

FIGURE 1.1: Overview of the development iterations

1.3.1   Requirements Gathering

This iteration was an exploratory step that justified the development and identified the currently available solutions in the domain of exergames for warm up before sports activities. This was achieved through initial literature review related to exergame, gamification and motivational psychology which identified the most important areas to be addressed when developing gamified solution in the given context. Furthermore, in order to design an enjoyable gaming solution for warm up guidance and motivation, several warm up and sports related requirements needed to be considered too. Having this in mind, sports and fitness related literature have been reviewed as well. Particular attention has been put on those warm up exercises that could hypothetically help in injury prevention, improve performance, and could be included in our solution as one of the required movement.

As previously pointed out, the exergame is meant to be used in a gym or fitness centers before physically demanding sports activities. Hence, these movements should also increase core body temperature, blood flow, and prepare the body for the subsequent exercise. Taking this into consideration, the set of movements to be completed in the game had do be carefully selected based on some initial requirements and constraints. Some of the requirements and constraints based on which the movements were selected were as follows:

- Movements need to be easily detectable by only one Kinect device.

- Movements should be easy enough to be correctly performed without any prior knowledge of the movement.

- Only movements that can be executed without additional equipment should to be considered.

- Only movements recommended for the general warm up routines outlined in sports related literature and suggested by experts should be considered.

- The duration of the exergame guided warm up routine should correspond to the warm up duration suggested by sports literature and experts.

Since no well documented and medically supported warm up programmes for workout routines were found, the required movements were adopted from the *FIFA 11*[] and *FIFA 11+*[] warm up programmes which mostly focus on core and leg strength, balance, and agility. These programmes were shown to have significant impact on injury reduction in football players and can lead to improvements in thigh muscle strength, jump height, and sprint speed []. Based on the mentioned warm up programs review, and the requirements and hardware restrictions previously outlined, the following movements were found to be suitable for the prototype solution:

- jump right,

- jump left,

- jump up, and

- squat.

After the requirements were specified and the required movements selected, we start with the prototype development phase.

1.3.2 Prototype Development

This section outlines the development of the prototype version of the exergame for warm up before sports activities. Our primary goal was to develop a working version of the exergame that can process movements in real time in order to guide users through the warm up routine and, presumably, immerses the participants sufficiently so that their focus is shifted from the discomfort and exertion of the exercise towards the enjoyment of the experience. The prototype was developed as a scaled down version of our planned final solution. With the prototype, we aimed to learn more about the problem, possible target groups, and explore the most suitable design and implementation techniques that could be used during the exergame development process.

1.3.2.1 Game Description

The Immotion exergame has been created using the Unity 5.6 game development platform developed by Unity Technologies []. User's movements were captured and processed using Kinect for Xbox One (2.0 2013) motion sensing input devices by Microsoft []. The game engine was run on XX [] and projected on a wall using XX projector. In figure 1.2 we outline the relationship of the game, software, and hardware equipment.

For the prototype version of the exergame, a game scenario that is similar to *Subway Surfers* [] and *Temple Run* [] games has been implemented. In these games, the player controls the character that is on a track and needs to move left, right or jump up in order to avoid obstacles and collect points. In our solution, the player controls the character by doing a set of movements, which are tracked using a Microsoft Kinect device. In-game obstacles (e.i. walls or boxes) and coins were positioned in a way that the user is required to perform a specific movement in order to avoid the obstacle or collect a coin. By collecting coins the overall user score was increased. Contrarily, by hitting an obstacle, the overall user score was decreased. By placing the obstacle and coins in a specific position, our intention was to indirectly promote exercise through the
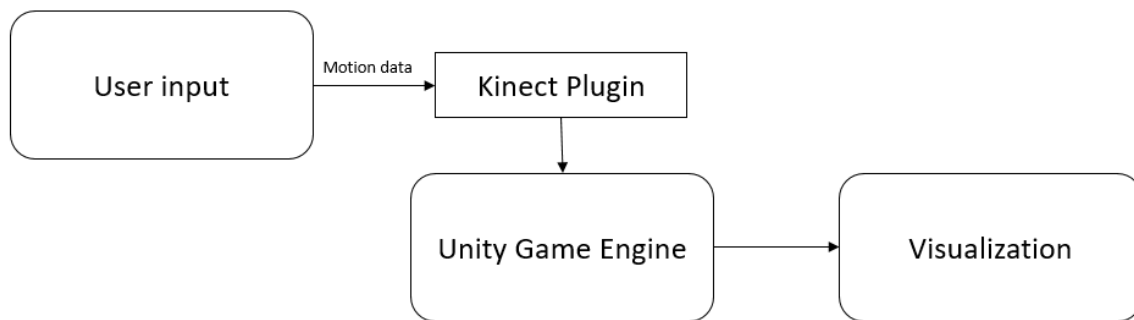
FIGURE 1.2: Hardware and Software supporting the prototype exergame

gameplay of repeatedly performing warm up related movements chosen during the Gathering Requirements phase. Figure 1.3 depicts the usage of the prototype version of the Immotion exergame during one of our final tests.

FIGURE 1.3: Interacting with the prototype version of the Immotion exergame

Next, the main gamification elements that are incorporated into our exergame are further discussed.

1.3.2.2   Gamification Elements

In order to create an immersive game environment that will shift users' focus from the exertion of the exercise, we also employ few game *mechanics*. Werbach and Hunter [] (2012) report that mechanics provide the "*basic processes that drive the action forward and generate player*

engagement". For the prototype version of the Immotion exergame, the most important mechanics was *Feedback*.

1.3.2.3   Feedback

As pointed out in Chapter **??**, feedback have been shown to influence and improve autonomy and, hence, the intrinsic motivation of individuals [Ryan 2006]. Warbach and Hunter argue that giving unanticipated, informal feedback or support about the player's progress can provoke increased intrinsic motivation and autonomy []. They further outline that gamification components represent specific examples and ways for doing the higher level things that gamification mechanics and dynamics represent []. In the prototype version of the exergame, the player receives the feedback using different gamification components that will be further detailed.

1.3.2.4   Gamification Components

Points

According to Zichermann and Cunningham [] (2011) points are "*an absolute requirement for all gamified systems*", because they can serve a wide range of purposes. One of the most obvious is for keeping a score and evaluate progress of the user. However, they can serve as a powerful extrinsic motivator for player types that enjoy collecting points, like *Killers* or *Achievers*. In the prototype version of the exergame, user earn points by collecting coins and lose them by hitting an obstacle. How much points could the player earn or lose by each action is presented in Figure 1.4.
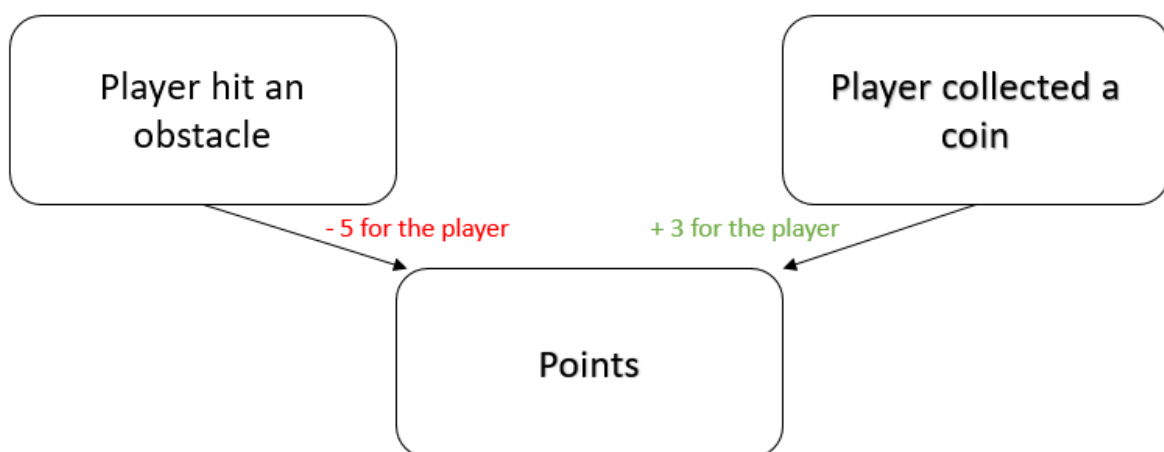

FIGURE 1.4: Earning and loosing point in the prototype version of the exergame

As per Figure 1.4, the player could earn 3 points by collecting a coin. Contrarily, the player could lose 5 points if hit by an obstacle. In order to avoid hitting an obstacle or collect a coin, a movement was required to be performed by the player. Consequentially, the player was guided through the warm up routine without even realizing it. In the course of the game, the player's current score was displayed in the right corner. That way, the player had constant overview of her progress.

Avatar

In the prototype version of the game we use a simplistic avatar which players control by performing the movements in front of the Kinect sensor. The main purpose of our avatar was to correctly replicate player's movements. By doing so, the player gets a real time feedback on how the movements is performed. The avatar that is utilized for the prototype version is presented in Figure 1.5
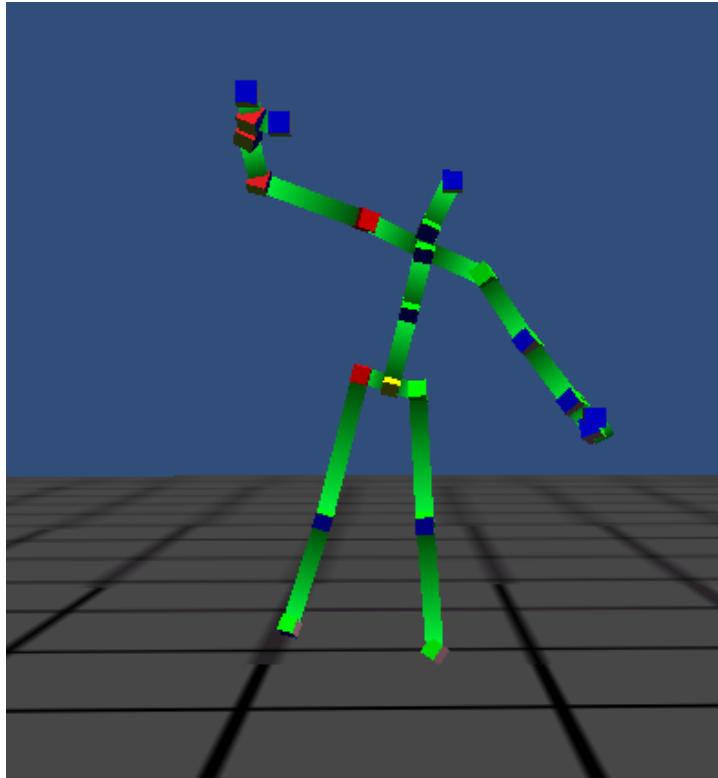

FIGURE 1.5: The avatar used in the prototype game.

Visual Feedback

Even though cannot be counted among gamification components, for the purpose of giving players the necessary feedback, we introduce additional visual components. The player is informed when

a game obstacle is hit by the avatar. This is done by adding red overlay to the scene every time event of this kind occurs. This informs the player that last pose was not successful, and deducts points from players overall score.

Audio Feedback

Similarly to previous component, audio cues were introduced to inform the player of success or failure of the performed movement. In case the player managed to collect a coin successfully, a sound comparable to the one heard when collecting a coin in many video games is played. Contrarily, a crashing sound is played on failure when the player hits an obstacle. The volume of the sounds played on success or failure are balanced as much as possible so that they are distinct enough but not disturbing to the player of the exergame.

1.3.3 Game Scenes

Figure 1.6 shows the some of the scenes from the prototype version of the exergame. The prototype has been pilot-tested with few student volunteers. During the pilot testing, the interaction with the exergame has been recorded for further analysis and evaluation [link yt].
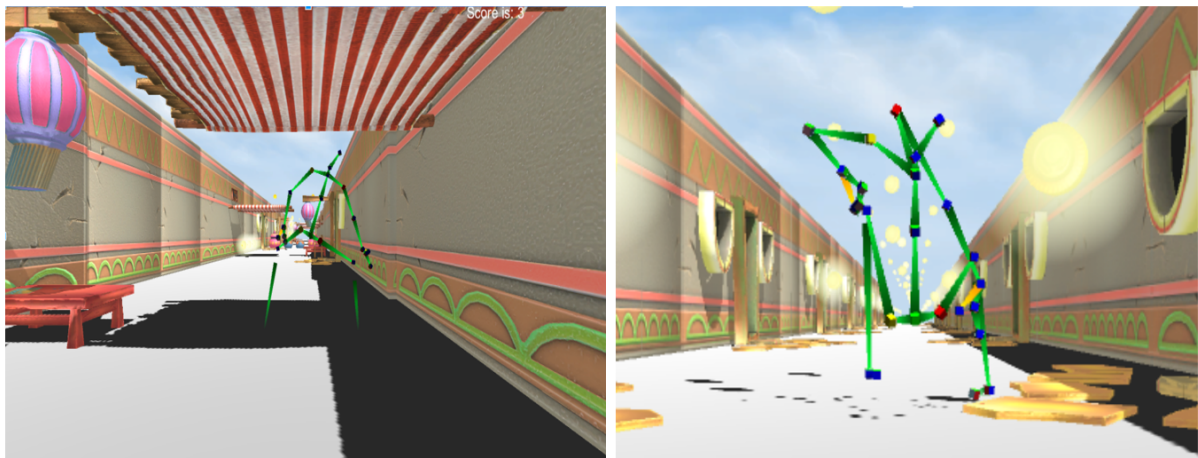

FIGURE 1.6: Game scenes from the prototype version of the exergame

1.4   Evaluation

1.5   Final Exergame Solution

Bibliography

[1] 50 gamification mechanics and elements. `https://www.gamified.uk/user-types/gamification-mechanics-elements/`. Accessed: 2017-03-20.

[2] Amateur vs. professional athletes. `https://education.uslegal.com/amateur-athletics/amateur-vs-professional-athletes/`. Accessed: 2017-07-01.

[3] Bartle's taxonomy of player types. `https://gamedevelopment.tutsplus.com/articles/bartles-taxonomy-of-player-types-and-why-it-doesnt-apply-to-everything--gamedev-4173`. Accessed: 2017-03-10.

[4] Codeacademy- gamafication. `http://www.enterprise-gamification.com/mediawiki/index.php?title=Codecademy`. Accessed: 2017-01-20.

[5] Codeacademy- gamafication. `https://badgeville.com/`. Accessed: 2017-01-20.

[6] Deloitte leadership academy. `https://badgeville.com/wiki/case_studies#Deloitte`. Accessed: 2017-01-27.

[7] Fifa 11+. `http://f-marc.com/11plus/home/`. Accessed: 2017-02-21.

[8] Game design elements definition. `https://en.wikipedia.org/wiki/Game_design#Design_elements`. Accessed: 2017-01-20.

[9] Gamification - applications. `https://en.wikipedia.org/wiki/Gamification#Applications`. Accessed: 2017-01-20.

[10] Gamification 101, the psychology of motivation. `https://community.lithium.com/t5/Science-of-Social-blog/Gamification-101-The-Psychology-of-Motivation/ba-p/21864`. Accessed: 2017-02-27.

[11] Gamification course by prof. kevin werbach, coursera.org. `https://www.coursera.org/learn/gamification/lecture/JPQNK/4-2-the-pyramid-of-elements`. Accessed: 2017-02-20.

[12] Gamification examples. `https://badgeville.com/wiki/Gamification_Examples`. Accessed: 2017-01-25.

[13] Gamification examples. `http://www.enterprise-gamification.com/mediawiki/index.php?title=Gamification_Examples`. Accessed: 2017-01-27.

[14] Gamify. `https://badgeville.com/wiki/Gamify`. Accessed: 2017-01-20.

[15] Intrinsic and extrinsic motivation in gamification. `http://gamification-research.org/2014/08/flow/`. Accessed: 2017-02-20.

[16] Intrinsic and extrinsic motivation in gamification. `http://www.gamification.co/2011/10/27/intrinsic-and-extrinsic-motivation-in-gamification/`. Accessed: 2017-02-12.

[17] Marketing gamification: Toyota turns charging your iphone into an epic game. `http://yukaichou.com/marketing-gamification/marketing-gamification-toyota-turns-charging-iphone-epic-game/`. Accessed: 2017-01-27.

[18] My coke rewards. `https://www.mycokerewards.com/content/home.html`. Accessed: 2017-01-27.

[19] My starbucks rewards. `https://badgeville.com/wiki/mystarbucksrewards`. Accessed: 2017-01-27.

[20] Nike +. `https://badgeville.com/wiki/Nike`. Accessed: 2017-01-27.

[21] Reem Altamimi and Geoff Skinner. A survey of active video game literature. *Journal of Computer and Information Technology*, 1(1):20–35, 2012.

[22] Noël C Barengo, José Francisco Meneses-Echávez, Robinson Ramírez-Vélez, Daniel Dylan Cohen, Gustavo Tovar, and Jorge Enrique Correa Bautista. The impact of the fifa 11+ training program on injury prevention in football players: a systematic review. *International journal of environmental research and public health*, 11(11):11986–12000, 2014.

[23] Richard Bartle. Hearts, clubs, diamonds, spades: Players who suit muds. *Journal of MUD research*, 1(1):19, 1996.

[24] David Bishop. Warm up i. *Sports medicine*, 33(6):439–454, 2003.

[25] David Bishop. Warm up ii. *Sports Medicine*, 33(7):483–498, 2003.

[26] Anja Broeck, Maarten Vansteenkiste, Hans Witte, Bart Soenens, and Willy Lens. Capturing autonomy, competence, and relatedness at work: Construction and initial validation of the work-related basic need satisfaction scale. *Journal of Occupational and Organizational Psychology*, 83(4):981–1002, 2010.

[27] Mihaly Csikszentmihalyi. Flow and the psychology of discovery and invention. *New Yprk: Harper Collins*, 1996.

[28] Mihaly Csikszentmihalyi. Finding flow, 1997.

[29] Mihaly Csikszentmihalyi, Sami Abuhamdeh, and Jeanne Nakamura. Flow. In *Flow and the foundations of positive psychology*, pages 227–238. Springer, 2014.

[30] Edward L Deci and Richard M Ryan. Promoting self-determined education. *Scandinavian journal of educational research*, 38(1):3–14, 1994.

[31] Edward L Deci and Richard M Ryan. The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological inquiry*, 11(4):227–268, 2000.

[32] Carlos Delgado-Mata, Ricardo Ruvalcaba-Manzano, Oscar Quezada-Patino, Daniel Gomez-Pimentel, and Jesus Ibanez-Martinez. Low cost video game technology to measure and improve motor skills in children. In *AFRICON, 2009. AFRICON'09.*, pages 1–6. IEEE, 2009.

[33] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. From game design elements to gamefulness: defining gamification. In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments*, pages 9–15. ACM, 2011.

[34] Pascal Edouard, Nina Feddermann-Demont, Juan Manuel Alonso, Pedro Branco, and Astrid Junge. Sex differences in injury during top-level international athletics championships: surveillance data from 14 championships between 2007 and 2014. *British journal of sports medicine*, 49(7):472–477, 2015.

[35] Karl B Fields, Craig M Burnworth, and Martha Delaney. Should athletes stretch before exercise? *Chinese Journal of Sports Medicine*, 26(5):626, 2007.

[36] Felix Fischer, Jacques Menetrey, Mirco Herbort, Peter Gföller, Caroline Hepperger, and Christian Fink. Causes of overuse in sports. In *Prevention of Injuries and Overuse in Sports*, pages 27–38. Springer, 2016.

[37] Csikszentmihalyi Flow. The psychology of optimal experience. *Harper&Row, New York*, 1990.

[38] Andrea J Fradkin, Belinda J Gabbe, and Peter A Cameron. Does warming up prevent injury in sport?: The evidence from randomised controlled trials? *Journal of Science and Medicine in Sport*, 9(3):214–220, 2006.

[39] Andrea J Fradkin, Tsharni R Zazryn, and James M Smoliga. Effects of warming-up on physical performance: a systematic review with meta-analysis. *The Journal of Strength & Conditioning Research*, 24(1):140–148, 2010.

[40] Juho Hamari and Jonna Koivisto. Measuring flow in gamification: Dispositional flow scale-2. *Computers in Human Behavior*, 40:133–143, 2014.

[41] Juho Hamari, Jonna Koivisto, and Harri Sarsa. Does gamification work?–a literature review of empirical studies on gamification. In *System Sciences (HICSS), 2014 47th Hawaii International Conference on*, pages 3025–3034. IEEE, 2014.

[42] Allen Hedrick. Exercise physiology: Physiological responses to warm-up. *Strength & Conditioning Journal*, 14(5):25–27, 1992.

[43] Robin Hunicke, Marc LeBlanc, and Robert Zubek. Mda: A formal approach to game design and game research. In *Proceedings of the AAAI Workshop on Challenges in Game AI*, volume 4, 2004.

[44] Susan A Jackson and Robert C Eklund. Assessing flow in physical activity: The flow state scale–2 and dispositional flow scale–2. *Journal of Sport and Exercise Psychology*, 24(2):133–150, 2002.

[45] Jesper Juul. *Half-real: Video games between real rules and fictional worlds*. MIT press, 2011.

[46] Karl M Kapp. *The gamification of learning and instruction: game-based methods and strategies for training and education*. John Wiley & Sons, 2012.

[47] Juha Karvonen. Importance of warm-up and cool down on exercise performance. In *Medicine in Sports Training and Coaching*, pages 189–214. Karger Publishers, 1992.

[48] Anthony D Kay and Anthony J Blazevich. Effect of acute static stretch on maximal muscle performance: a systematic review. *Medicine & Science in Sports & Exercise*, 44(1):154–164, 2012.

[49] Kristian Kiili. Evaluations of an experiential gaming model. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, 2006.

[50] Kristian Kiili and Sari Merilampi. Developing engaging exergames with simple motion detection. In *Proceedings of the 14th International Academic MindTrek Conference: Envisioning Future Media Environments*, pages 103–110. ACM, 2010.

[51] DUANE V Knudson. Warm-up and flexibility. *Chandler TJ, Brown LE. Conditioning for Strength and Human Performance. Philadelphia, PA: Lippincott-Williams & Wilkins*, 2008.

[52] Matthew A Ladwig. The psychological effects of a pre-workout warm-up: An exploratory study. *Journal of Multidisciplinary Research*, 5(3):79, 2013.

[53] Andrzej Marczewski. *Gamification: a simple introduction*. Andrzej Marczewski, 2013.

[54] Amir Matallaoui, Jonna Koivisto, Juho Hamari, and Ruediger Zarnekow. How effective is exergamification? a systematic review on the effectiveness of gamification features in exergames. In *Proceedings of the 50th Hawaii International Conference on System Sciences*, 2017.

[55] Hermann O Mayr, Stefano Zaffagnini, et al. *Prevention of Injuries and Overuse in Sports*. Springer, 2015.

[56] Elisa D Mekler, Florian Brühlmann, Klaus Opwis, and Alexandre N Tuch. Do points, levels and leaderboards harm intrinsic motivation?: an empirical analysis of common gamification elements. In *Proceedings of the First International Conference on gameful design, research, and applications*, pages 66–73. ACM, 2013.

[57] Jeanne Nakamura and Mihaly Csikszentmihalyi. The concept of flow. In *Flow and the foundations of positive psychology*, pages 239–263. Springer, 2014.

[58] Yoonsin Oh and Stephen Yang. Defining exergames and exergaming. *Proceedings of Meaningful Play*, pages 1–17, 2010.

[59] Ronald L Pardee. Motivation theories of maslow, herzberg, mcgregor & mcclelland. a literature review of selected theories dealing with job satisfaction and motivation. 1990.

[60] Marko Pećina and Ivan Bojanić. *Overuse injuries of the musculoskeletal system*. CRC Press, 1993.

[61] Daniel Pereles, Alan Roth, and Darby Thompson. A large, randomized, prospective study of the impact of a pre-run stretch on the risk of injury on teenage and older runners, 2012.

[62] Richard M Ryan and Edward L Deci. Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary educational psychology*, 25(1):54–67, 2000.

[63] Richard M Ryan and Edward L Deci. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, 55(1):68, 2000.

[64] Marc R Safran, Mr Anthony V Seaber, and William E Garrett Jr. Warm-up and muscular injury prevention an update. *Sports Medicine*, 8(4):239–249, 1989.

[65] Katie Salen and Eric Zimmerman. *Rules of play: Game design fundamentals*. MIT press, 2004.

[66] Frank G Shellock and William E Prentice. Warming-up and stretching for improved physical performance and prevention of sports-related injuries. *Sports Medicine*, 2(4):267–278, 1985.

[67] Martin Sillaots. Achieving flow through gamification: A study on re-designing research methods courses. In *European Conference on Games Based Learning*, volume 2, page 538. Academic Conferences International Limited, 2014.

[68] Gustavo F Tondello, Rina R Wehbe, Lisa Diamond, Marc Busch, Andrzej Marczewski, and Lennart E Nacke. The gamification user types hexad scale. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play*, pages 229–243. ACM, 2016.

[69] Robert J Vallerand. Intrinsic and extrinsic motivation in sport and physical activity. *Handbook of sport psychology*, 3:59–83, 2007.

[70] Willem van Mechelen. The severity of sports injuries. *Sports medicine*, 24(3):176–180, 1997.

[71] Elizabeth A Vandewater, Mi-suk Shim, and Allison G Caplovitz. Linking obesity and activity level with children's television and video game use. *Journal of adolescence*, 27(1):71–85, 2004.

[72] Darren ER Warburton, Crystal Whitney Nicol, and Shannon SD Bredin. Health benefits of physical activity: the evidence. *Canadian medical association journal*, 174(6):801–809, 2006.

[73] Kevin Werbach and Dan Hunter. *For the win: How game thinking can revolutionize your business.* Wharton Digital Press, 2012.

[74] Krista Woods, Phillip Bishop, and Eric Jones. Warm-up and stretching in the prevention of muscular injury. *Sports Medicine*, 37(12):1089–1099, 2007.

[75] Nick Yee. Motivations for play in online games. *CyberPsychology & behavior*, 9(6):772–775, 2006.

[76] Gabe Zichermann and Christopher Cunningham. *Gamification by design: Implementing game mechanics in web and mobile apps.* " O'Reilly Media, Inc.", 2011.