The ExerCube: Participatory Design of an Immersive Fitness Game Environment

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Abstract. Exergames have advanced from a trend of the entertainment industry to serious training applications. Nowadays body-centered games can be played at home, as well as in the gym, and provide an effective and motivating workout experience for the player. However, existing solutions often lack a symbiotic and user-centered design approach encompassing the three exergame design levels: the player's body (input movements), the controller (input device) and the game (story, game mechanics, dynamics, aesthetics). Consequently, existing systems exhibit weaknesses like motion sickness or a lack of audio-visual and narrative design of the physical and virtual play space. As such, the player's game experiences remain limited. Our work contributes to the sustainable establishment of fitness games as effective and attractive training tools. In this paper, we introduce the "ExerCube" and the design, evaluation, and subsequent re-design of the early stage prototype. The "ExerCube" is a fitness game setting for adults, which affords immersive gameplay experiences while engaging in a playful motor-cognitive and -coordinative functional workout. Our findings show that the preliminary "ExerCube" prototype was usable and well received by the target audience. We report insights about the target audience's preferences and identify avenues for the implementation of dual flow-based game mechanics, the optimization of the training concept and hardware, as well as for the further development of the game scenario.

Keywords: Exergame fitness training · Participatory design · Flow "ExerCube"

1 Introduction

Virtual Reality (VR) applications and movement-based games – so-called exergames [1] – have advanced from a mere entertainment trend to serious training applications [2]. While a few years ago, exergames for the Nintendo Wii©, Sony Move© or the Microsoft Kinect© turned living rooms into playful training settings, nowadays innovative technologies have been introduced to gyms and convert the training area into virtual sports arenas: virtual training simulations (e.g., Athene Exergaming), gamified fitness training (e.g., Prama Pavigym), immersive and game-based training

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scenarios (e.g. Les Mills, Immersive Fitness) and exergame circuit training (e.g., Exergame Fitness) are no longer fiction, but have become reality.

The combination of trend-based training concepts, innovative input devices and game design is particularly fascination to "digital natives" and opens up new avenues for keeping fit in a motivating and attractive way. Moreover, these motor-cognitive and -coordinative training methods match or even surpass the training effects of traditional training concepts. Several sports scientific studies indicate positive effects on users' cognitive [e.g. 3] and coordinative abilities [e.g. 4].

Although these results suggest that these technologies will become increasingly established in the context of sports and training, a parallel scientific debate reveals weaknesses of the virtual training systems. Interdisciplinary human computer interaction (HCI) research and development (R&D) also deal with the analysis of existing VR and exergame concepts. Thereby, the focus is more on the multi-sensory and -modal experience and perception of specific designs, as well as on the deviation of practice-oriented approaches for the optimization of the training/gameplay experience. Buzzwords like "dual flow" [5], "embodiment" [6], "bodily interplay" [7] und "presence" [8] set a clear direction. A holistic, user-centered and symbiotic design approach on the levels of the moving body, the mediating technology and the virtual game scenario is needed to overcome current weaknesses of existing systems like motion sickness or a lack of audio-visual and narrative design of the physical and virtual play space, to fully exploit the potentials of these parallel training worlds.

The present work's contribution is two-fold: First, it serves to establish fitness games as effective and attractive training tools. Second, it addresses limitations of previous work on exergames which largely fail to consider the player experience, by explicitly putting the user experience at the forefront of the design and evaluation process. In this paper, we introduce the "ExerCube" and the design, evaluation, and subsequent re-design of the early stage prototype. Furthermore, we provide an outlook on future research and development steps towards the final "ExerCube".

2 Related Work

In recent years, researchers from a variety of disciplines and practitioners, such as trainers and therapists, have recognized the training effectiveness and motivational benefits of combining gaming and exercising. Sports science and health-related studies on commercially available and bespoke exergames confirmed the potential of these playful training technologies to increase energy expenditure [e.g. 9], positively affect the learning of sensorimotor skills [e.g. 10], coordinative abilities [e.g. 4], strength and endurance [e.g. 11] and to improve exercise program compliance [e.g. 12]. Concurrently, studies within HCI research provide insights into the effects of all three exergame design levels on players' gameplay experiences:

Body. The bodily exertion greatly influences the player's experiences and there are many ways of movement expressions and interpretations of pre-set motion sequences when playing an exergame [13]. In general, the inclusion of holistic physical activity into gameplay is found to be a positive predictor for the feeling of immersion and

engagement [14]. Moreover, most of the existing, commercially available exergames for consoles lack the implementation of a proper movement scientific approved workout. Even when moving inaccurately, these games allow the player for a successful game performance and do not sufficiently correct movement mistakes. The other way around, existing game-based solutions available on the fitness market often implemented professional fitness workouts as input movements, but lack in a proper user-centered design of the interactive virtual game scenario. Hence, there is a need for better combinations of state-of-the-art designs on the level of fitness concepts, which are used as physical input to control the game and appealing virtual scenarios, which provide accurate movement feedback and instructions for the player.

Controller. During exergame play, the intermediary controller technology ideally assumes the role of mediator between the "physical" and the "virtual" game worlds [15]. However, the decisive factor is always how well an input device integrates itself into the body patterns of the moving player. Kim et al. found that an embodied interface improves user experience, energy expenditure, and intention to repeat the experience within the exergame [6]. The precision of movement recognition [16], as well as the natural integration of this recognition into the game scenario and the related movement feedback are decisive indicators for the "incorporation" of the game controller, and for the immersion into the game world [14]. Furthermore, when it comes to social exertion and bodily interplay [7] while playing an exergame together or against others, existing controller technologies are often criticized to rather limitate than "support", "enable" and "shape social" and bodily interaction between players [17]. Thus, we can identify a need for body-centered controller technologies, which serve as additional, physical playground, easily integrate into the body scheme of the player, provide a balance of guided and free movements and allow for social exertion and social play in cooperative as well as competitive settings.

Game Scenario. Considering the design of immersive, virtual scenarios for fitness game settings, there are various things, which need to be taken into account to achieve the intended effect with the player. The look and feel should appeal to the targeting group of the game and involve specific preferences for game mechanics, levels, visuals, sound and story. Thus, it is important to involve the targeting group into the design process from the very beginning [18]. Furthermore, there are various theoretical concepts and findings from game experience research, which should further serve as inspiration for an appropriate design of the virtual game design. Game experiences that are repeatedly brought up in relation to exergames are the closely related experiences of immersion and several flow variations. Csikszentmihalyi's flow theory [19] can be compared with the feeling of complete and energized focus on a particular activity, combined with a high level of enjoyment and fulfillment. An important precursor to the flow experience is the match between a person's skills and the challenges associated with a task, such as playing a game. Weibel and Wissmath define flow as a result of immersion or involvement in an activity (e.g. playing a game) [20]. Sweetser and Wyeth's "GameFlow" model determines the key elements of player enjoyment [21]. Sinclair et al. applied the flow theory to the task of playing a physically and mentally challenging exergame, calling it "dual flow" [5]. According to the dual flow concept, an optimal training/gameplay experience during exergame play requires a balance

between the game-related challenge and player skills, as well as between the intensity of the required movement input and the player's fitness level. Thus, an exergame must be adjustable to suit the player's individual skill levels.

Current solutions and game experience evaluations often focus on single (e.g. body) or dual design levels (e.g. body and controller) rather than on a symbiotic combination of all dimensions (body, controller and game scenario), which take into account interdependencies and interaction effects of single dimensions on and with one another. Furthermore, they often fail a user-centered and participatory design approach, which – if implemented properly – can increase game attractiveness and effectiveness [18]. Consequently, gameplay experiences while playing existing solutions as well as insights from studies with those remain limited. Our work aims at bridging these gaps with a comprehensive approach in both, development and research, in order to make a sustainable contribution to enhancement of the attractiveness and effectiveness of these playful workout experiences.

3 Participatory Design of the "ExerCube"

In the following, we present the first design cycle of the early stage "ExerCube" prototype. For the creation of the "ExerCube", we were inspired by current workout and design trends on the fitness market, findings from HCI and games user experience research, as well as target group-specific wishes and ideas for the exergame setting which we gained through previous surveys with male and female "digital natives" at the age of around 18 – 40 years. For the design process, we further built upon our previous work with "Plunder Planet" a dynamically adaptive fitness game setting, which was designed with and for children [17, 22–24] involving a participatory and symbiotic three-stage design process at the levels of the player's body, the controller and the game. The early stage "ExerCube" was developed by an interdisciplinary team which consists of experts from the fields of sport science, game design, game research and industrial design.

3.1 Early Stage Prototype

Body Movements and Controller. On the level of body movements, we decided to design up to five challenge and complexity levels, which are based on traditional functional fitness. Functional fitness is well known for its motor-cognitive and -coordinative, as well as endurance, strength and flexibility training effects [25]. Functional fitness has been defined as emphasizing multiple muscle and joint activities, combining upper body and lower body movements, and utilizing more of the body in each movement [26]. The movement levels gradually build upon one another:

Level 1: Basic jump, squat and lateral shuffle-step with extension or flexion of the body to the upper, middle and lower section of the right and left wall of the cube
Level 2: Level 1 + lateral rotation to the middle of the right and left wall of the cube
Level 3: Level 2 + deep lunge with knee bend to the left and right side

Level 4: Level 3 + lateral rotation to the bottom of the cube
Level 5: Level 4 + burpee

For the first prototype, we implemented only the first level of the training concept. The movements were translated into a game mechanic: In the virtual game space, the player finds themselves on a track, which sets various directions, akin to a racing game track. If the track curves to the right or to the left, the player needs to move to the respective side. Additionally, the player needs to move to the upper (=uphill), middle (=at ground level) or lower (=downhill) right or left side depending on the track's changes in height. The track is looped after a pre-defined number of level sections. Towards the end of the track loop, players have to do one basic jump and squat underneath an obstacle. The player's arm movements and position are tracked with the HTC Vive system. Two cameras are positioned at the cube frame; one in front and one behind the player. While playing the player holds one Vive in each hand, which triggers an in-game feedback (particle effect) on the sidewalls of the "ExerCube", provided the player moves in close enough to the sidewall.

Hardware. We designed an open cube-like trapeze (hereafter referred to as "cube" or "ExerCube"), which serves as part of the game controller (haptic device) and as projection screen (interface). It consists of a solid wooden frame covered with stretchable, semitransparent and bouncy mash fabrics. Each of the three walls of the cube measures 2.40 m width and length, as well as 2.50 m height, whereas the projectable surface of the cube measures 1.80 m. The transition of the front to the sidewalls is slightly curved, to generate a flowing and immersive form similar to commercially available curved TV screens. The bounciness of the fabrics affords an engaging haptic experience, when touching and/or punching into the walls to trigger in-game actions. Additionally, the semitransparency of the "ExerCube" provides a lightly framed non-isolating spatial experience for the player. Three outside beamers project the game scenario onto the walls of the cube.

Game Scenario. Based on our look and feel inspirations, the first game scenario prototype takes the player into a sci-fi inspired world with a racing track, which passes through vast mountain ranges under a sparkling and atmospheric milky way (Fig. 1). For the first prototype, we experimented with very basic elements, perspectives and mechanics.

The player can either play the game in a third- or first-person perspective. The game starts in the third-person perspective and the player sees their mentor from the back. The mentor shows the movements, which the player needs to imitate in order to navigate their movements with the pre-set track in the virtual world. After the player familiarizes themselves with the movements, rules and mechanics, the mentor disappears and the player continues playing without any guidance in the first-person perspective.

Since the first design cycle focused on the basic spatial and flow experiences related to the design of the body movements, the hardware and the game scenario, we chose not to implement any sound and only few in-game events. The only virtual feedback is a visual particle effect, which shows the player whether or not they successfully

performed the movement. The visual feedback would only appear, if the player reached out far enough and was close enough to the wall.

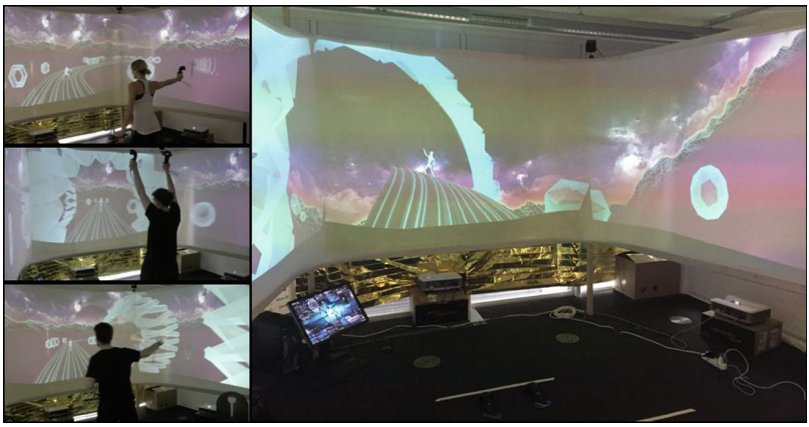

Fig. 1. Early stage "ExerCube" prototype (Source: Sphery Ltd.)

4 Evaluation

Following the first cycle of design, we conducted an early user testing. The evaluation was performed by a team of experts from the fields of sport science, psychology and game research. The aim of this testing was to evaluate our preliminary designs and gain further insights into the early stage prototype's influence on player's immersion and flow experiences, as well as identify opportunities for implementing dual flow-based game mechanics at all design levels. Furthermore, we were interested in participants' interaction and movement strategies and asked for feedback and preferences for the further development of the "ExerCube" setting.

4.1 Method

Participants and Procedure. We recruited 17 participants (8 women, 9 men), aged 15 to 43 years old (mean age = 30.88, *SD = 8.53*). Participants reported diverse game genre preferences, with strategy games (n = 13) having been most commonly mentioned, followed by sports, action and action-adventure games (n = 8 mentions each). All participants engaged in a variety of physical activities to some extent, with swimming (n = 9) and jogging (n = 9) being the most popular. More than half of the participants (n = 9) had previous experience with exergames, mostly with the Microsoft Kinect©. After providing informed consent, participants were first asked to play with the "ExerCube" for 10 min. Play sessions were video-recorded but not further analyzed for the sake of the first evaluation. However, some preliminary observations of the principal investigator have been immediately written down after each play session. After 10 min, participants were asked to complete a questionnaire consisting

of several player experience measures, as well as interviewed with regards to their impressions of the "ExerCube". Interviews lasted from 10–30 min.

Measures. As the eventual aim of the "ExerCube" is to provide players with an optimally challenging experience, both with regards to gameplay and physical exertion, we employed several complementary measures of flow. First, the Flow Short State Scale [27] has already previously been employed to capture flow in sports contexts, and includes a 10-item measure for flow experience, as well as 3 items for assessing worry (7-point Likert scale, from 1 = "I do not agree at all" to 7 = "I fully agree"). Moreover, we assessed "GameFlow" via 7 items developed by Kliem and Wiemeyer [4]. This measure is based on Sweetser and Wyeth's "GameFlow" model, which specifically focuses on flow within the context of (digital) games. Moreover, we asked participants to rate their experience with regards to several other aspects, including how challenging it was to play with the "ExerCube" in terms of physical and cognitive effort, as well as whether they would consider the game fun on repeated playing.

4.2 Results

Descriptive Statistics. Overall, as listed in Table 1, participants rated the "ExerCube" as reasonably engaging and scored it moderately high on flow (M = 4.8, *SD = 0.77*), game flow (M = 3.86, *SD = 1.07*), enjoyment (M = 3.47, *SD = 1.07*) and motivation (M = 4.24, *SD = 1.2*), as well as low on worry (M = 2.37, *SD = 1.45*). Participants noted that while the "ExerCube" was easy to understand (M = 6.29, *SD = 0.85*) and to control (M = 5.41, *SD = 1.58*), gameplay was not sufficiently challenging, both in terms of the required cognitive (M = 3.12, *SD = 0.99*) and physical effort (M = 2.88, *SD = 1.09*).

Table 1. Descriptive statistics for all quantitative measures.

	Flow	Worry	GameFlow	Enjoyment	Control	Movements matched game	Game motivated me to move	Physical effort	Cognitive effort	Optimally challenging	Immersion	Easy to understand	Could concentrate on game without having to focus on body	Visual appeal	Game would still be fun after repeated playing	Would exercise with the game in the future
M	4.8	2.37	3.86	3.47	3.82	4.47	4.24	2.88	3.12	2.76	3.65	5.76	5.59	4.41	3.81	3.82
SD	*0.77*	*1.45*	*0.94*	*1.07*	*1.24*	*0.87*	*1.2*	*1.09*	*0.99*	*1.03*	*1.17*	*1.15*	*1.5*	*1.46*	*2.04*	*1.78*

Qualitative Evaluation. In addition to the questionnaire, we interviewed participants following a guideline and asked them to answer several questions related to their experiences with the input movements, the hardware and controller, the design of the game scenario, their motivation and their flow experience. Furthermore, the notes of the

main observations of the principal investigator are discussed in relation to the results of the interviews and revealed further insights, which underline the results of the quantitative data collection. Following, we shortly summarize the main findings:

Although the first prototype was designed very rudimentary on all design levels (body, controller and game scenario), participants felt immersed and experienced the typical flow indications (e.g. loss of sense of time and space; see also Table 1). Their main memory was the futuristic and abstract look and feel of the prototype, which all of them liked very much. Some testers anticipated existing games (e.g. "Guitar Hero" or "Mario Kart") or movies (e.g. "Tron: Legacy" or "Star Wars") with it. Although all testers enjoyed the general look and feel of the prototype and the fact, that they were surrounded by a cube, they asked for more variety (e.g. story, sound, levels) and challenge (e.g. more obstacles). Participants appreciated the approach of combining fictional and natural elements in the visual design of the game and suggested to further deepen this approach.

We found that participants easily became familiar with the navigation mechanisms of the game (see also Table 1) and could effortlessly control the game without the guiding mentor. The guideline-based interviews as well as the participatory observation revealed, that the majority felt even more immersed, when the mentor disappeared. However, participants found the mentor helpful in the beginning and suggested, that the mentor should move more accurately and provide better movement instructions. Concerning the visual appearance of the mentor, participants could imagine both, a fictional and human-like avatar, as long as the locomotor system looks like a human one.

Generally, participants reported that the required input movements felt natural and intuitive. This finding could be further supported by participants' statements, which revealed that the majority oriented towards the virtual setting to coordinate their movements. There was no mismatch between the physical and virtual movements and the hardware and controller technology were implemented discreet enough. Consequently, nobody experienced motion sickness. A wish for an additional input movement was boxing.

At the end of the interview, we gave participants a quick outlook on future development plans for the "ExerCube" and asked for feedback on these ideas. Participants liked the idea of being able to play together or against others while being challenged on an individual physical and cognitive level. They also liked the idea of a racing game including a clear goal, more variations and a matching adaptive sound design.

5 Re-design of the "ExerCube" and Discussion

Based on the results of the first user testing, we re-designed the "ExerCube" prototype (Fig. 2). We further developed single design elements on the levels of body movements, hardware, controller and game scenario in order to provide all facilities for the future implementation of the dual flow.

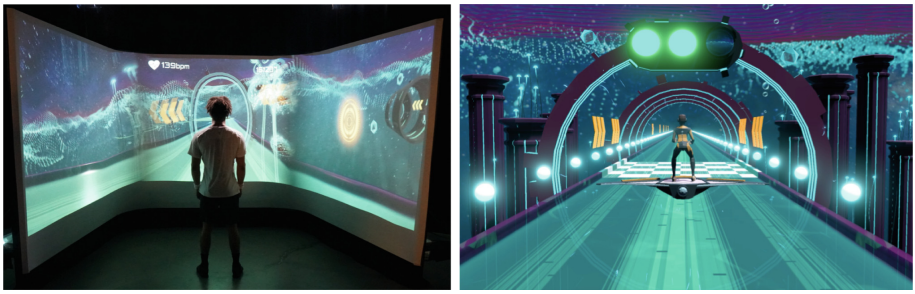

Fig. 2. First re-design of the "ExerCube" setting (Source: Sphery Ltd.)

5.1 Second Draft Prototype

Body Movements and Controller. To increase the interaction of the player with the walls of the cube, we decided to extend our existing movement levels with some boxing elements and came up with the following:

Level 1: Basic jump, squat and lateral shuffle-step with extension or flexion of the body to the upper, middle and lower section of the right and left wall of the cube
Level 2: Level 1 + lateral rotation to the middle of the right and left wall of the cube with and without punch
Level 3: Level 2 + deep lunge with knee bend to the left and right side
Level 4: Level 3 + left and right punch
Level 5: Level 4 + squad jump with punch into the front wall of the cube
Level 6: Level 5 + burpee

With the first user testing we could prove the general feasibility of the basic movements. However, participants reported that it was quite easy to control the game and the physical and cognitive challenge were experienced rather low (see also Table 1). Hence, to sustainably increase the challenge and to allow for a comprehensive and holistic workout experience, we implemented all movement levels into the redesign. Generally, the idea is that every player can work out in their best suiting motor-cognitive and coordinative challenge level. The movement sequence of every level follows a random and thus not foreseeable, but movement scientific meaningful approach (including warmup, guidance to the individual peak and balancing of motor-cognitive and -coordinative stimuli).

During the testings we could observe that participants interacted rather tentative with the cube hardware. This might have been triggered by the fact that players had to hold HTC Vives in their hands while playing. Therefore, for the second stage prototype, we replaced the HTC Vives with two HTC trackers, which are attached to the player's wrists. Again, the cameras track the position of the player's arms and legs in the cube and the player is able to freely use their hands.

Hardware. The observation and feedback of participants on the rather tentative interaction with the cube hardware was also related to the missing orientation points in

the lower section of the cube, which was not covered with fabrics. Thus, we re-designed the height of the walls' covered surface, which is now reaching from the cube's top to nearby the floor (Fig. 2). Furthermore, we are also experimenting with different materials (bouncy fabrics and foamed materials) to further enhance the interactive and haptic experience with the hardware. The aim is to create both, a virtual and a physical play space, which are symbiotically interconnected with each other.

Game Scenario. Based on the feedback and wishes of the participants, we also further developed the game graphics and the scenario. We came up with a virtual underwater sci-fi racing scenario (Fig. 2). The player's avatar/mentor is positioned on a hover-board, which needs to be navigated by the player following the track layout. The player and their avatar must overcome and target at obstacles, which appear in front or on the sides and try to be as fast and successful as possible to win the race. If the player is to slow, others and their avatars will overtake them. In the end, there is a leaderboard, where the high scores and winners are listed.

Again, the track layout provides information about which movement the player needs to perform next. For a maximum realistic and accurate movements of the mentor, we captured the movements of a real functional fitness trainer with the professional motion capturing system OptiTrack and implemented them into the game. Thus, the virtual mentor performs all movements accurately.

In summary, we can state the following things: Despite the rare implementation of interactive elements in the first "ExerCube" prototype, the scenario provided the illusion of being more interactive due to its immersive structure, graphics and perspectives. It appealed that the majority of participants felt like they were actually controlling everything in the game for at least the first couple of minutes of the test session. Only some testers realized earlier that the actual interaction possibilities with the scenario (dependency of in-game actions on input movements) were very limited. However, they still were involved in the gameplay and experienced flow. This could also be confirmed by the results of the questionnaire, which prove that participants felt immersed throughout the game session.

Despite the fact that we tested the first prototype with a very heterogeneous group of participants (gender and age), the futuristic and technological seeming game scenario was generally very well valued.

6 Future Work and Conclusion

We could show that the basic "ExerCube" setup including body movements, hardware and virtual game scenario is usable and has been well received by the targeting group. We gained insights into targeting group specific preferences and wishes in terms of the look and feel, the game mechanics and dynamics. We could identify new avenues for the implementation of dual flow-based game mechanics, for the optimization of the training concept and hardware as well as for the further development of the game scenario.

Based on the R&D steps we conducted so far, we will further evaluate and develop the "ExerCube". For the next testing, the "ExerCube" will feature dual flow-based

game mechanics related to the player's motor-coordinative and -cognitive abilities as well as emotions. Based on the player's heart rate (measured with a heart rate sensor) and in-game performance, the game difficulty and complexity will be automatically and manually adjustable via a specifically developed trainer UI. We further implement three gradually adjustable sub-levels (low, medium, high) of each movement level to challenge the player's physical abilities and experiment with different cognitive challenge levels as well as sounds and atmospheres. The player's avatar/mentor will provide more or less feedback and instruction, depending on the player's in-game performance: If the player performs well, the mentor will automatically disappear and if the player performs poorly, the mentor will reappear and support the player with real-time instructions and visual movement feedback and corrections.

Beside the adaptive single player version, we will also offer a collaborative and a competitive multiplayer version of the "ExerCube". With the collaborative version, two players can play together in one cube or against each other in different cubes. To ensure equal opportunities for all player and athlete types to win the exergame battle, the "ExerCube" will also feature dynamic multiplayer balancing mechanics [28]. Last but not least, we are also developing a specific sound design featuring adaptive sounds, which will have an additional impact on the player's dual flow experience.

In the near future, the "ExerCube" by Sphery Ltd. will be commercially available as gym application. Beside cooperative play sessions, players can then join multiplayer battles within the same gym and across gyms in the same region or across the world. There will be further "ExerCube" game scenarios providing different training concepts (e.g. high intensity training or yoga) and specific hardware extensions.

To sum up, our work contributes towards the current trend of fitness games and exergame research in a number of ways: First, we developed a prototype, whose design and concept extend existing solutions by combining innovative approaches from related R&D fields like sport science, game experience and HCI research. Second, we present a user study and provide insights into our user-centered, iterative R&D work. We describe the re-design of the first "ExerCube" prototype and provide an outlook on future work, which shows how we further implement the user's feedback into the design and work on better, holistic game experiences. Thus, we contribute towards filling gaps in exergame design and research.

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