



# Effects of user factors on user experience in virtual reality: age, gender, and VR experience as influencing factors for VR exergames

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Received: 20 August 2021 / Published online: 4 May 2023  
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## Abstract

As virtual reality (VR) technology is extensively developing in past years, more and more people are using it in different fields. One of the fast-developing areas in VR is exergaming, a combination of physical exercise and a game. VR exergames that aim to engage people in physical activity should look and feel good for users regardless of their age, gender, or their previous VR experience with similar technologies. However, recent studies showed that those factors are influencing the user experience (UX) with virtual reality. Building on top of the initial study that has reported on the effect of human influencing factors for exergaming, with this work, we investigated the influence of user parameters (such as age, gender, and previous VR experience) on their motivation for sports and VR exergaming. The study was done using a crowdsourcing platform to recruit a diverse set of participants, with the aim to explore how different user factors are connected to sports motivation. Results show significant differences in the user's sports motivation and affinity for technology interaction depending on the age group, gender, previous experience with VR, their weekly exercise routine, and how much money they spend on sports yearly.

**Keywords** Virtual reality · Exergames · User interface · User experience · Motivation · Affinity for technology

## Introduction

Use cases for virtual reality (VR) today are various with the possibilities to create and immerse users in different environments [7]. Those virtual environments (VE) are replicating or even enhancing the real world [59], creating more opportunities and a bigger market for VR. The consumer market for immersive technologies is growing every year. By the end of 2020, it is estimated that VR alone will bring around 2.6 billion dollars in revenue around the world [56]. Predictions and estimations for the near future are that those numbers are just going to grow even larger. Most of its current popularity can be connected to the VR gaming industry. Still, VR technology can be found and used in many other fields such as medicine, architecture, learning, tourism, and sports [9]. In those fields, the VR application's purpose is not the game itself, but instead, it uses the game-design principles in a non-game context [64] and is not aiming only at entertainment. That is why those games are called serious games [15]. One example of such a serious game is VR exergaming. VR exergaming is a combination of playing VR games that require physical exertion, movements, and activities such as strength, balance, and flexibility [41]. VR

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exergaming is gaining much attention lately because it is including opportunities for VR technology and allows individuals to play exergames at home [6].

Exergaming is not only reserved for professional athletes or gamers but can also be used in the health care domain [43]. Exergaming can as well be included in many applications such as rehabilitation, injury treatment, and prevention [4, 21]. With the idea of increasing the motivation of people for exercising, inclusiveness is essential. Therefore the target age group for exergaming is starting from young children [8], over adolescents [2] who are specifically interested in video games to adults. However, that doesn't mean that the elderly are excluded [69], motivating them to perform sports exercises is of high interest.

By the idea of user centered design [22], while creating the application, it should be attempted to provide a solution that is highly responding to the user's needs. Depending on how successfully this methodology is implemented in the application, the user experience will be better [35]. Additionally, to ensure the best user experience, user factors such as age, gender, and prior computing experience must be taken into consideration [12]. Including those factors to understand the better user experience of some technology is not uncommon in research. For example, a recent study has been done investigating the influence of human factors on quality of experience with 360° videos [53], in particular exploring the influence based on the generations. In particular, the research had focus on generation Z, are true digital natives and as they are the generation that could most exploit this type of new media. Research is reporting that participants who were 18 to 26 years old (Generation Z), assess positively enjoyment, quality and degree of realism for the VR set-up. Additionally, this study is also reporting on gender as an influencing factor for VR set-ups, as women are reported to display an increased sensitivity compared to men. Another study also reported how gender affects the perception of multimodal human-machine interfaces. The study [50] has shown that male participants have better user performance with a naturalistic conversational speech interface compared to females. As well, for the same technical set-up, there was a significant effect of age on ratings of how easily the information could be obtained. A group of participants of older age have rated it as not easy, indicating that they might have to put more work into solving tasks than younger participants. Similar effects can be found in other studies as well, for example, for online communication [57]. Based on age differences, users have different preferences for online communication.

Additionally, there has been research done as well about preferences based on the different user age groups and exergaming. In particular, the games that were researched were interested those with the whole body interactivity having elderly people in focus [63]. Results of the study are having

the goal to see if there were differences in how the elderly and younger people perceived the games, and it was found that the actions participants took in exergame changed with their age. Based on the differences found and analysis of the tasks and age of participants this research is defining 10 suggestions on the design of exergames for elderly users. Further on, recently, some similar studies have also been done in VR with a focus on cybersickness and presence. For 3D video content, results have shown a significant effect depending on gender, where female participants have reported feeling more present and less nauseous in the virtual environment [40]. Moreover, for sports-specific content in VR, researchers are proposing different duration of VR exposure based on age and gender [44]. An additional rather understudied influencing fact is the social impact. Meaning how does the presence of other people around a user in a virtual environment changes the experience itself. For example, [60] simulated the amount of people around users playing virtual reality games in public spaces. When it comes to VR exergaming and choosing between gamified and numerical user interface, age, and gender again showed to be important factors for different user preferences [31]. Younger and male participants preferred gamified visualization of the user interface for VR rowing exergames. Additionally, previous VR experience was an essential factor for overall rating as those users who had more VR experience have rated the overall quality of a gamified visualization significantly higher.

However, to our knowledge, no study has been done to investigate user factors for VR exergaming to find relationships and connections with motivation for sports and affinity for technology. Therefore, this paper investigates the influence of user parameters (such as age, gender and previous VR experience) on the motivation for sports and VR exergaming. This was specifically motivated based on the initial study where the VR exergame was rowing, which has shown several different effects on user experience based on the influence of human factors. Such VR exergame research has defined what influence factors are but has not yet investigated their relationship, in particular when it comes to the connection between sports motivation and VR exergaming. Therefore, the motivation of this work is to explore the relationship between users' affinity for technology and sports motivation, so that designing the user experience for VR exergames could be done with respect to such users' profiles.

With this aim, the remainder of this paper is organized as follows. The next section gives an overview of related work and in particular explains the initial study as the basis and motivation for this paper. Section 3 is presenting the methodology for crowdsourced study and details about the test design. The results of the conducted experiment will be summarized in Sect. 4, while Sect. 5 provides a discussion of the findings.

**Fig. 1** Outside view on a setup for VR rowing exergame, where player is rowing with a HMD and VE is seen on the notebook screen



## Related work

Overall, this section presents the important aspects in physiology such as motivation that is also used to create a good user experience, and in particular research that has been done related to the field of exergames. Special focus is put on the initial study that already reported how human factors could be influencing user experience. However, this research aims to further explore connections of user profiles in particular between technology, sports motivation and VR exergames.

## Initial study

With the recent improvements and better availability of immersive virtual reality devices on the market, [55], new use cases such as VR exergaming are becoming more popular [33]. As sport [10] or video games [13] are an essential part of the life of many people, the use case of combining both can provide even better motivation and user experience if created and designed in a proper way [18]. In particular, for outside sports that can be depending on weather conditions. In those use cases, VR can bring the feeling and experience of a real environment. At the same time, VR can also add gamification and influence challenges and user motivation. One example of such a sport is rowing. That is why we chose rowing to be the sport for VR exergame in our research. To explore user preferences, motivation, and design for the best user experience for VR rowing, we have previously done several studies to determine the influence of different virtual environments, network parameters and designs of user interfaces. With the following section, it is summarized the most important parts of the research, which are used as the starting point and motivation for further investigation of human influencing factors for VR exergames.

## Set-up of initial study

The main parts used to create the VR rowing exergame are a rowing ergometer, a virtual reality head-mounted display (HMD) or a 360° CAVE environment. The rowing ergometer was the Augletics Eight<sup>1</sup> that has the opportunity to provide the VE system with rowing parameters (for example, stroke force and speed) via an HTTP connection. This input from the ergometer sensor itself has been used directly to model the movement of two oars and a scull in a virtual environment. Besides the tailored REST API, this ergometer also has an improved electronically controlled brake, providing more realistic and quieter exercise. For the VR head-mounted display, the system that has been used is HTC Vive. To fully work, the HMD must be connected to a gaming notebook, together which two HTC base stations. Figure 1 presents how the system was used. Another option for viewing and playing the VR rowing exergame is the CAVE environment. The used one was the Data Arena,<sup>2</sup> and it can be compared with a CAVE2 environment [17]. It contains six projectors that create a 360° panoramic screen with a stereoscopic video that can be seen with 3D glasses. The application for VR rowing itself was made as a Unity project. The virtual environment is visualizing a summer lake and some mountains in the distance. The player is placed in a red scull on the lake and can row using the ergometer handles. It is essential to mention that the cyber sickness induced by the app is minimized as the movement in the virtual scene is aligned with the movements user is performing on the ergometer in the real world. Further on, in the virtual environment, some additional options were added to compare the influence of the user interface's (UI) position

<sup>1</sup> <https://www.augletics.de/en/>.

<sup>2</sup> <http://www.dataarena.net/>.

and complexity. Therefore, in the application, it is possible to choose an option to see metrics (such as rowing speed) in a gamified or numeric visualization. Also, it is possible to choose the location of those metrics as a cockpit or as a coach boat that follows the player.

Additionally, the Unity application has an option to collect the sensor data and to compute the correct timing for breathing in and out. The calculation is done with the lung's current stretch monitored by a breathing sensor and the rowing handlebar position. Therefore, the system can be expanded by adding the breathing sensor the BreathZpot.<sup>3</sup> The sensor has to be attached to the lower part of the participant's breastbone and measure breathing.

As correct breathing rhythm is vital in sports, the virtual environment has also been enhanced with a visualization of lung pictograms. The pictogram is visualizing breathing as a gradually filling and emptying in real-time. The breathing actuator GHOST - feel it<sup>4</sup> provided a haptic impulse whenever athletes should start breathing out.

### Effects on user experience

Several studies with different focuses have been done with the VR rowing system set-up to understand how to improve the user experience for VR exergaming. For example, different virtual environments (HMD and CAVE) [54] were compared. As the HMD setting can create a better feeling of presence, most participants favored it. Also, to investigate multiplayer rowing racing and settings for the VR environment, another study has been done [32]. Furthermore, as breathing is important in sports for achieving better results, a study about breathing UI visualizations [30] and with different haptic feedback [23] have been implemented. Results have shown not only one preferred option but rather that users would use different settings based on their profile. A study about investigating visualization and design options [31] has been done for the user interface in VR when it comes to positioning and complexity of game elements in VR rowing exergame. Results have reported different user experience depending on positioning and complexity of elements, and about having two equal preferences for opposite visualizations. Even though both preferred visualizations have some advantages and disadvantages, it is interesting to notice that preferred settings are dependant on the user groups.

With the aim to design the best user experience for VR rowing, participants were asked about their preferences for visualization of rowing metrics. Metrics that have been visualized include the speed of rowing; time spent rowing, and

distance that the player has covered rowing. Two different visualizations were made for those metrics - a numerical version displaying just numbers and a gamified version displaying speedometers and a progress bar. Besides multiple representations for the metrics were developed, also two different positions for them were designed - a cockpit and a coach boat following the player. However, when asked about the preferred visualization, participants have reported different opinions. Results have shown that participants have rated differently based on their age, gender, and previous VR experience. Younger participants reported feeling better support and clearer gamified visualization of metrics. Furthermore, they have also rated the overall quality of experience better for metrics displayed as the cockpit in front of the player.

In contrast, older participants have rated the overall quality of experience as higher for metrics displayed as coach boat, and stated that the digital visualization is clearer for them. Similar to age, based on gender, different ratings for overall and pragmatic quality of experience were reported. Men have rated higher experience for the gamified version for metrics, while for women, it was higher for digital visualization. At last, the same effect about different user preferences was found as well based on the different previous VR experiences. Participants with previous VR experience preferred gamified visualization, while novice VR users have selected digital visualization as preferred. Therefore at the end of the initial study, it could not be defined what of those two visualizations is, in general, better for user experience, as based on age, gender, and even previous VR experience result in different user preferences. Those parameters affect how significantly different participants rate user experience, clearness of UI, perceived support, and flow perception. Therefore, this study is aiming to look into the connection between age, gender, and VR experience together with sport motivation for VR exergaming in order to explain user preferences.

### Self-determination theory

In psychology, one theory that explains how people control and choose options for their own life is the self-determination theory. This theory also explains the motivation behind people's choices and their emotions regarding the outcome's effect. Self-determination theory (SDT) [51] was developed by psychologists Deci and Ryan, which focused and suggested that people are likely driven by a need to improve and gain fulfillment. SDT is based on three universal psychological needs: competence, connection, and autonomy. It is theorized that if all three of them are fully achieved, people can become self-determined.

With the goal to explain amotivation and motivation, this concept and SDT principles have been used in many

<sup>3</sup> <https://www.sweetzpot.com/breathzpot>.

<sup>4</sup> <https://www.ghost-feel.it/>.



different fields, e.g., education, work, health, parenting, and sports. Also, one of the fields where this concept has been used is gaming. Results from a study show that SDT's theorized needs for autonomy, competence, and relatedness independently predict enjoyment and future game play [52].

### Types of motivation

Based on the SDT, there are five types of motivation: external motivation as a combination of external regulation, introjected regulation, identified regulation, integrated regulation, as well as intrinsic motivation. Those types of motivation are very widely used to explain the human motivation behind choices. Therefore, SDT is commonly used in sport research to explain why people make certain decisions. Usually, questionnaires such as the Motivation for Physical Activity, Exercise questionnaire (RM 4-FM) and the Sport Motivation Scale (SMS) are used to identify users' motivation [37].

The self-determination continuum is starting from amotivation, which is regulated by a lack of control. Next in the continuum is external regulation. External regulation is referring to the influence on motivation coming from an external factor. A person is externally motivated when they are behaving in some way to get the externally provided reward. Suppose the behaviour is driven by feelings such as guilt or shame that is defined as introjected regulation. In this case, a person is doing or not doing something because of a fear of obligation, and it is associated with internal rewards and punishments.

Further on, when the importance of behaviour is accepted as benefiting to accomplish some personal goal, but without necessarily enjoying it, the motivation is defined as identified regulation. Personal importance regulates identified motivation. In the self-determination continuum, just before the intrinsic motivation, there is the integrated regulation.

Finally, intrinsic motivation is defined as entirely driven only by personal interest, enjoyment, and inherent satisfaction, meaning that there is no need for fear, reward, or any external factor. Intrinsically motivated activities are defined as those for which no additional reason is needed besides the activity itself and the resulting emotions.

### Affinity for technology interaction

Affinity for Technology Interaction (ATI) is an important factor when considering user experience and user-center design that asks users for opinion, as it can strongly influence the outcome if users prefer to engage with technology [65]. For example, when it comes to the exergaming inside of a virtual reality environment, users' motivation may be specifically related to the use of technology, especially to learning and exploring new virtual reality technology. Therefore ATI scale contains different questions covering

typical motivations and strategies for the use of the technological system. In the end, it is providing one aggregated score reporting the overall size of the participants' affinity for technology.

The validation research of the ATI scale was conducted, analyzing data from over 1500 participants. The data not only shows that the ATI scale has good to excellent reliability but also reveals interesting structural differences in the sample group: significant gender differences in ATI values were found, with men reporting significantly higher ATI values than women. Regarding age, the data showed a significant weak negative correlation between age and ATI. The older the participants, the less pronounced their ATI, however, this effect is only weak. In samples with educational background information, no statistically significant relationships between educational background and ATI values were found [19].

### User experience and preferences

User experience (UX) has many different definitions, one of them being defined as perception and behavior during the interaction with the technical system [26]. Many factors are influencing the UX, from the functionality of the system, content, aesthetics, up to the human emotions and perception [49]. Another critical factor to consider when talking about user experience in VR is cybersickness [38]. It is defined as a mismatch between the visual and vestibular system. However, when asked about an experience, not all users have the same preferences. Depending on the various user factors, user experience and user preferences are changing. One factor that can also impact the results of a user experience experiment, is the way how the user state is measured. For example, it was investigated which placement of virtual reality questionnaires is most beneficial and showed that rating in virtual reality is similar to rating with pen and paper [48]. It was shown that in general having to perform ratings in virtual environments especially for non-interactive video playback seems to be useful [34]. Emotions can be measured during the experience itself but valence is underestimated in the case of continues rating tasks [61]. A virtual environment can furthermore be used as a controlled way to induce emotions [62].

Research about how easy it is for people to use technology is reporting that age is an important factor. As they are exposed to digital technologies from an early age, young users reported finding technology more useful than the older users [39, 39, 46]. This effect is often referred as digital divide between generation [29, 45]. Further on, not only that older users don't find it always useful to use technology, but also don't find it as easy as younger users [1].

Another user factor that influences user preferences is gender. Research about gender and life preferences is not

limited only to technology but has been in the study for many years and many fields - one of them, as well, being gaming [24] [36]. Studies have reported that women are motivated for gaming by immersion and because of social factors, while for men, motivation in gaming comes from achievements and competitiveness [24]. Still, motivation should also be observed within genders [27].

When it comes to the users' interest in virtual reality and their experience with it a library study was done to learn about user experience, demographics and academic interests amongst their students and staff personnel [20]. The library offers free usage of an HTC Vive system, which was used predominantly by male students (71% male and 29% female users, 61% students and 32% were non-student employees). Most of the users indicated being interested because "it sounded fun" (81%), whereas 9% used the system for personal learning, and only 5% of the users had research interests in mind - although 60% were potentially interested in academic uses. Interestingly, 72% of first-time users stated that they definitely want to use the system in the future again. Furthermore, the study outlined a domain-overarching interest in technology. Although the VR system was physically located next to the science and engineering area, around 40% of its users were affiliated with other study subjects.

## Exergaming

The combination of exercising and gaming creates the term exergaming, defined as playing video games while performing physical movements [41]. This idea is not new but rather started almost at the same time as video games themselves. With the development of VR and video games moving into an immersive virtual world, exergaming has as well been transformed into VR exergaming. One of the first prototypes for research of VR exergaming was PaperDude combining cycling with a VR game. In this game, the player is cycling down the street, intending to deliver newspapers on the bike [11]. One can do sports or activities in VR are many such as rowing, playing tennis, or dancing. Another example of combining sport with VR game is VRun [67], where a player is supposed to run as fast as possible to reach the finish line while avoiding the obstacles. The goal behind exergames is to use the motivation games have while playing video games for exercising [42], among others for the health benefit [47]. Recently some studies for VR exergames have been done exploring users' intrinsic motivation. A study related to high-intensity interval training was investigating how to improve performance by maintaining participants' intrinsic motivation in a VR cycling-based exergame [3]. However, for VR exergaming, there haven't been much research in regards to motivation for physical activity and user preferences.

## Methods

As the aim of this study is to investigate relations between sports motivation and users' demographic parameters for VR exergaming, an online study with several questionnaires about it has been created. In order to investigate the motivation for exercising, doing sports, and measuring affinity for technology, standardized questionnaires were used in this study. Additionally, participants were also asked about their demographic data and their sports and exercise habits (such as how frequently they exercise and how much money they spend on sports). This section will explain how the online questionnaire has been set up and what questionnaires have been used for this crowdsourced study.

## Crowdsourcing

Crowdsourcing is a combination of two words - 'outsourcing' and 'crowd', and describes how the crowd can be engaged to outsource work to solve some problem [25]. Jobs that can be outsourced to a crowd for solving are various, especially with the support of the internet and new technologies.

That is why crowdsourcing can be found in different industries from marketing [66] over linguistics [68] to research [70], with other goals and contributions such as ideas, knowledge, time, or funds.

For this study, crowdsourcing is selected as a platform for research purposes, and it is important to mention differences compared to a traditional university participants pool. A study has reported that crowdsourcing users were older, more ethnically diverse, and had more work experience compared to university samples and can give reliable results as good as or better than research done in traditional ways [5]. Therefore, crowdsourcing was chosen as a platform for this study to gain knowledge about users' motivation and potential users of VR exergames.

For this purpose, the Crowdee<sup>5</sup> application was used where all questionnaires were presented to participants. Further on, in addition to questionnaires, some trap questions [28] were integrated to ensure that crowd workers are focused on questions and are humans. All those who have not correctly answered trap questions were removed from the study's data set.

## Technology affinity

Affinity for technology interaction (ATI) describes an individual's response to or against of the engagement with technology. To investigate participants' affinity for technology

<sup>5</sup> <https://www.crowdee.com/>.

and understand how it is connected to sports and VR exergaming, the Affinity for technology interaction (ATI scale) questionnaire [19] was included in this study as the full 9-item scale. This scale was also chosen as it is in line with the initial study, so that results could be comparable.

### Motivation for physical activity and exercise

The Motivation for Physical Activity and Exercise questionnaire (RM 4- FM) was particularly designed [14] to determine if the participants are extrinsically or intrinsically motivated to engage in an exercise/physical activity. Altogether, there are 16 + 12 questions separated into four subgroups: external, introjected, identified regulation, and intrinsic motivation. The participants have to rate each question on a Likert scale between 1 (not true at all) to 7 (very true). RM4-FM provides an index (RAI) that is a calculation of all questions multiplied with positive or negative factors to produce one value. The index value can be either positive, which means that motivation is intrinsic, or negative which means that person is extrinsically motivated. Recently, as the questionnaire has been widely used, it has also been further validated [58]. This scale is specifically designed for determining intrinsic and extrinsic factors, and in the study used to get an understanding of those user parameters in regard to VR exergaming.

### Sport motivation

Finally, the sport motivation scale (SMS) has been included in the study as it was developed to measure an athlete's motivation toward sport participation [37]. The questionnaire is using four items each for the aspects identified regulation, integrated regulation, and intrinsic motivation on a 7-point Likert scale ranging from "does not correspond at all" (1) to "corresponds exactly" (7). The SMS was the last questionnaire to be included in the study, as an additional measurement for sport motivation, together with RM 4- FM. One other reason for including the SMS questionnaire in this study is to have comparable results with the initial research where only the SMS questionnaire was used.

### Participants

Participants for the online study were recruited over the Crowdee platform specializing in hosting crowdsourced online research studies. A total of 74 people were recruited for an online study, of which 11 have been rejected from further data analysis as their results were marked as unreliable. In addition to the use of surveys, the inclusion of specific trap questions served the purpose of confirming the humanity of the crowd workers and ensuring that they were attention to the questions being asked. Some questions

provided directions for the participant on what they should answer, such as asking them to select true or false ("because I read this, I will select here very true as my answer"). The study data set was cleaned up by excluding everyone who did not respond correctly to the trap questions. Therefore, for this paper 63 participants (27 female and 36 male) have been included. The average age of participants used for data analysis is 41 years old, the minimum age was 21 and the maximum was 64 years old. Further on, in regards to previous VR experience, 28 participants had never tried VR before. In contrast, 35 had some previous VR experience whereas only 2 of those had a lot of previous VR experience. When it comes to how often do participants exercise, they have reported spending on average 4.5 h a week doing sports (minimum 0 h and maximum 25 h), and on average, they do sports once a week. Also, for doing sports, participants have reported that on average, they spend €308.8 a year (minimum €0 and maximum €1300).

## Results

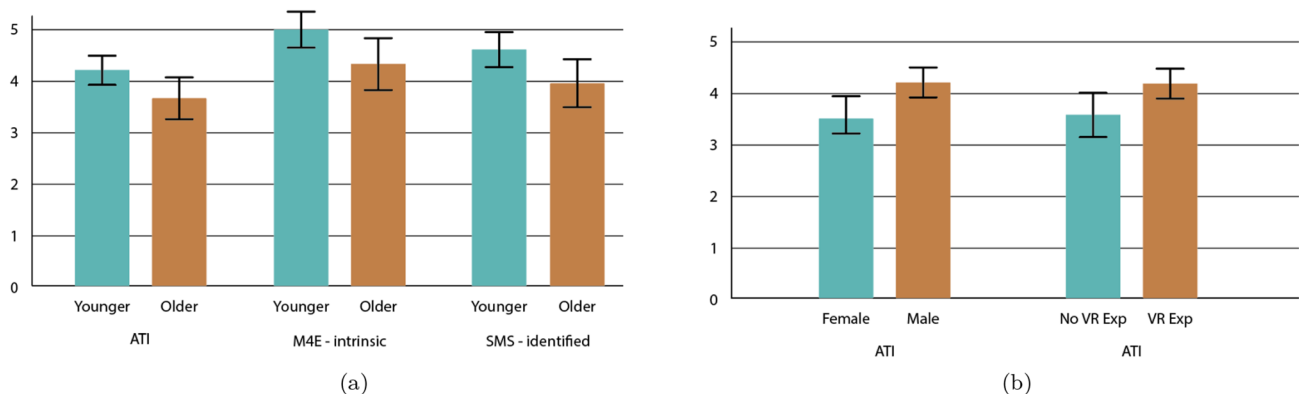
For the analyses of each parameter and effect, a one-way Analysis of Variance (ANOVA) was performed to determine statistically significant differences among the means of two or more groups, where the groups were made with the median split in order to ensure the equal sizing. An overview of all significant effects will be explained in the following sections and is presented in Table 1.

### Age

Two groups were made to analyze the effects that different age has on sports motivation and affinity for technology. Younger age group participants are those with age from 18 to 40 ( $N = 30$ ), while the older age group has consisted of the participants between 40 and 70 years old ( $N=33$ ). Results have shown that older and younger participants have significantly different user preferences for some parameters. One of them is the affinity for technology for which younger participants have reported statistically significantly higher affinity for new technology ( $M = 4.20$ ,  $SE = 0.14$ ) compared to the participants in the older age group ( $M = 3.65$ ,  $SE = 0.19$ ). As well, younger participants have reported significantly higher intrinsic regulations measured in motivation for exercise ( $M = 5.00$ ,  $SE = 0.18$ ) compared to the intrinsic regulation of the older participants ( $M = 4.35$ ,  $SE = 0.24$ ). Similarly, when it comes to identify regulation with sports motivation scale, younger participants as well have a significantly higher value for identify regulation ( $M = 4.63$ ,  $SE = 0.18$ ) compared to the participants in the older age group ( $M = 3.98$ ,  $SE = 0.21$ ). All report results are shown in Fig. 2.

**Table 1** Effect for different groups of age (AgeG), gender (Gender), VR experience (VRExpG), amount of money spent on sport per year (SportMoneyYG), frequency of doing sport (SportFreqG) hours of doing sports weekly (SportWeeklyHG), and affinity for technology score (ATI\_G) on Relative Autonomy Index (RAI), intrinsic, identified, integrated or external motivation measured for sports motivation (SMS), motivation for exercise (M4E), motivation for physical activity (M4PA) and affinity for technology (ATI)

Parameter	Effect	$df_n$	$df_d$	$F$	$p$	$\eta^2_G$	Power
AgeG	ATI	1	61	4.62	.036	0.07	0.983
AgeG	M4E_intrinsic	1	61	4.21	.044	0.06	0.866
AgeG	SMS_identified	1	61	4.99	.029	0.08	0.833
Gender	ATI	1	61	8.14	.005	0.12	0.890
VRExpG	ATI	1	61	5.76	.020	0.09	0.928
SportFreqG	M4PA_RAI	1	61	6.47	.014	0.10	0.878
SportFreqG	M4PA_identified	1	61	7.76	.007	0.11	0.978
SportFreqG	M4PA_intrinsic	1	61	5.79	.020	0.09	0.929
SportFreqG	SMS_integrated	1	61	20.80	.001	0.25	1.000
SportMoneyYG	M4E_RAI	1	61	4.69	.032	0.07	0.871
SportMoneyYG	M4PA_RAI	1	61	6.76	.011	0.09	0.960
SportMoneyYG	M4PA_identified	1	61	4.27	.042	0.07	0.839
SportMoneyYG	M4PA_intrinsic	1	61	4.45	.038	0.07	0.853
SportMoneyYG	M4E_intrinsic	1	61	5.79	.019	0.09	0.984
SportMoneyYG	SMS_intrinsic	1	61	4.09	.048	0.07	0.940
SportMoneyYG	SMS_integrated	1	61	5.32	.025	0.08	0.968
SportWeeklyHG	M4E_RAI	1	61	7.02	.010	0.10	0.966
SportWeeklyHG	M4E_intrinsic	1	61	5.50	.022	0.08	0.917
SportWeeklyHG	SMS_integrated	1	61	9.91	.003	0.14	0.994
ATI_G	M4PA_RAI	1	61	5.89	.004	0.16	0.999
ATI_G	M4PA_external	1	61	9.08	.001	0.23	1.000



**Fig. 2** **a** Mean values of affinity for technology (ATI), intrinsic motivation (M4E - intrinsic), and identified motivation (SMS - identified) of all participants split by the age group. **b** Mean values of affinity for

technology (ATI) of all participants split by gender (Female, Male) and previous VR experience (VR Exp). Whiskers denote the standard error

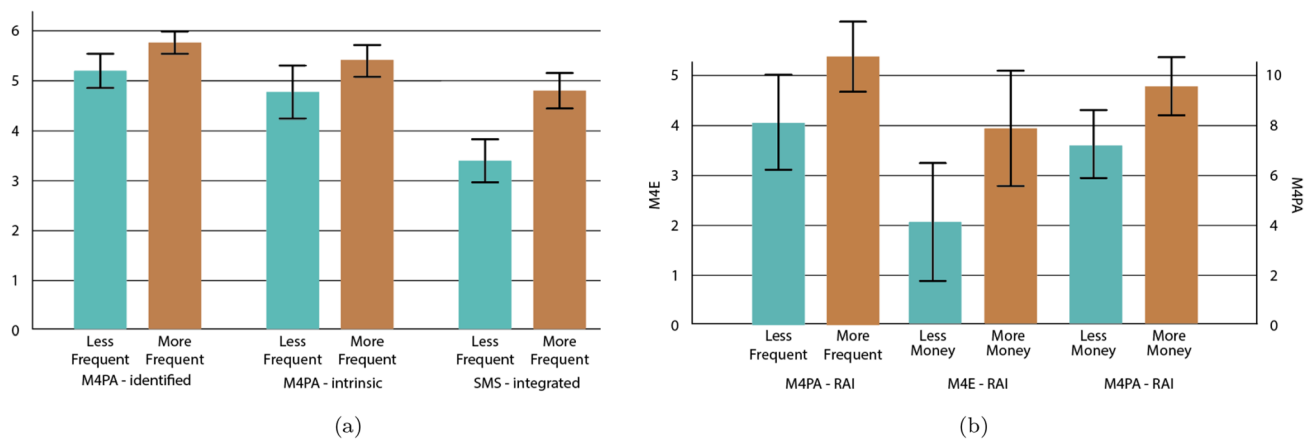
## Gender

When it comes to the effects of different gender, no statistically significant differences were found concerning sports. However, when it comes to affinity for technology, as it can be seen in Fig. 2, male ( $N = 36$ ) participants have reported on average significantly higher interest ( $M = 4.21$ ,  $SE = 0.13$ ) compared to the female ( $N = 27$ ) group ( $M = 3.51$ ,  $SE = 0.21$ ).

## VR experience

For statistical analyses, participants were divided into two groups depending on if they had some or no previous VR experience. The first group was of those participants who had zero prior experience with VR ( $N = 30$ ) and the second group was for those who had played and tried out VR applications and devices before ( $N = 33$ ). Based on those groups, results for effects of previous experience in VR showed no





**Fig. 3** **a** Mean values of identified motivation (M4PA - identified), intrinsic motivation (M4PA intrinsic), and integrated motivation (SMS - integrated) of all participants were split by how frequently weekly they exercise. **b** Mean values of overall index score of motiva-

tion for physical activity (M4PA - RAI) and motivation for exercise (M4E - RAI) of all participants were split by how frequently weekly they exercise and money spent on sports. Whiskers denote the standard error

significant differences in motivation for sports or exercise. But when it comes to the affinity for technology, also shown in Fig. 2, the group with previous VR experience has reported being a significantly affinity for technology ( $M = 4.18$ ,  $SE = 0.14$ ) compared to the group with participants who had no previous experience in VR ( $M = 3.58$ ,  $SE = 0.21$ ).

### Sports and frequency

Two different groups have been made to analyze results about how often do people exercise. One group was of those who exercise one time a week or less ( $N = 19$ ), and the other group was of those who exercise twice a week or more frequently ( $N = 44$ ).

When it comes to results about the frequency of doing sports, shown in Fig. 3, the data has reported that there are significant differences on the motivation. When asked about the motivation for physical activity, participants who are doing sports less frequently have reported to have had intrinsic ( $M = 4.80$ ,  $SE = 0.24$ ) and identified ( $M = 5.23$ ,  $SE = 0.16$ ) motivation compared to those who exercise more frequently and have reported significantly higher identified ( $M = 5.81$ ,  $SE = 0.11$ ) and intrinsic ( $M = 5.43$ ,  $SE = 0.13$ ) motivation. Similarly, the sport for motivation scale has also shown that participants with a higher frequency of doing sports have reported significantly higher integrated motivation ( $M = 4.80$ ,  $SE = 0.17$ ) compared to those who go to do sports less frequently ( $M = 3.42$ ,  $SE = 0.23$ ). Another interesting effect was found when comparing the overall index score of motivation for physical activity, Fig. 3. The index is reporting about intrinsic and extrinsic factors in the motivation of participants. A negative value of index reflects that a person is extrinsically motivated by having external factors

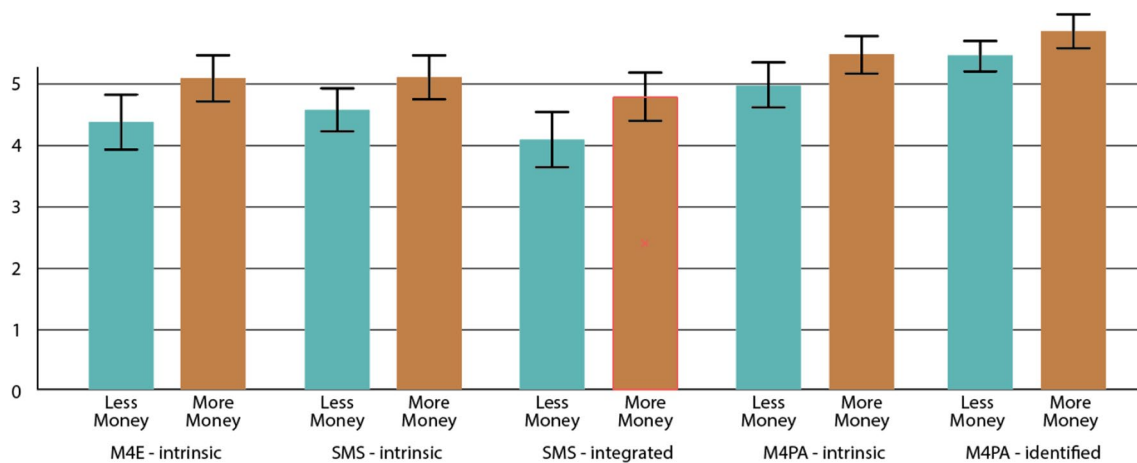
important in behavior, while a positive number reflects that behavior is primarily intrinsically motivated. The index of motivation for physical activity has been reported significantly higher ( $M = 9.01$ ,  $SE = 0.57$ ) for participants doing sports less frequently compared to those who are doing sports more frequently ( $M = 6.76$ ,  $SE = 0.79$ ).

### Sports and money

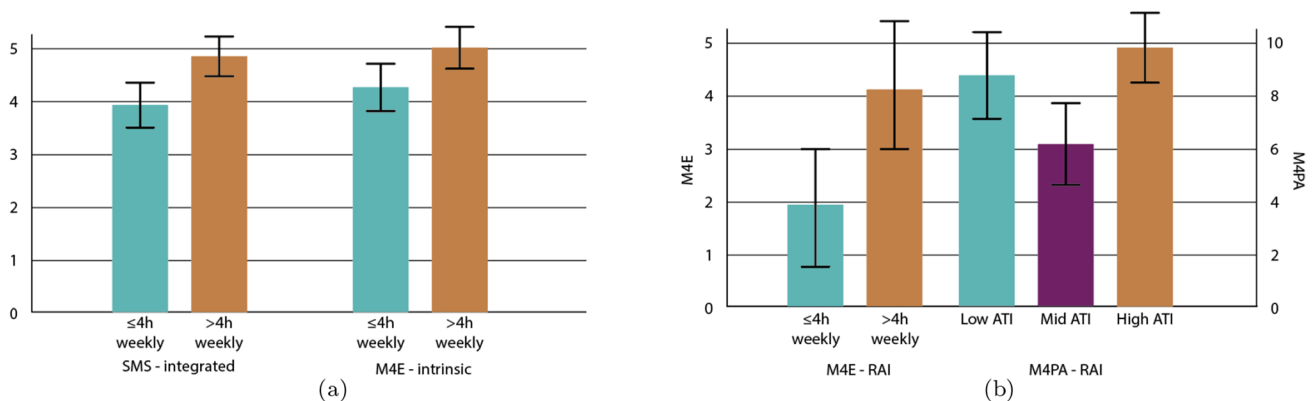
In the study, participants were asked to estimate how much money they spend on doing sports or exercises per year. Based on the entries where the minimum value was 0, and the maximum was 1300 euros, two groups were created for data analyzing. Participants spending between 0 and 250€ per year on doing exercise ( $N = 33$ ) were one group, and in the second group were those participants who spent more than 250€ ( $N = 30$ ).

Interesting differences were found raised on a fact if people are spending less or more money per year on doing sports. Do people spending more money have reported having higher identified ( $M = 5.85$ ,  $SE = 0.14$ ) and intrinsic ( $M = 5.51$ ,  $SE = 0.15$ ) regulation of motivation for physical activity compared to the identified ( $M = 5.44$ ,  $SE = 0.12$ ) and intrinsic ( $M = 5.00$ ,  $SE = 0.18$ ) regulation of people who are spending less money on sports per year. Similarly, while measuring motivation for the exercise once again, results are showing that those participants who are spending more money on doing sports have reported having higher intrinsic motivation ( $M = 5.12$ ,  $SE = 0.18$ ) compared to those who are spending less money on sports ( $M = 4.24$ ,  $SE = 0.23$ ).

Besides, the sports motivation scale has as well shown that spending more money is connected with intrinsic motivation and integrated regulation. People who are



**Fig. 4** Mean values of intrinsic motivation (M4E - intrinsic, SMS - intrinsic, M4PA - intrinsic), integrated motivation (SMS - integrated), and identified motivation (M4PA - identified) of all participants split by money spent on sports. Whiskers denote the standard error



**Fig. 5** **a** Mean values of integrated motivation (SMS - integrated) and intrinsic motivation (M4E - intrinsic) of all participants were split by how many hours they exercise weekly. **b** Mean values of overall index score of motivation for physical activity (M4PA - RAI) and motiva-

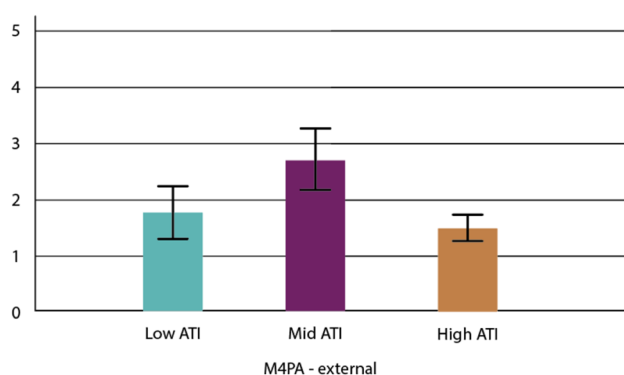
tion for exercise (M4E - RAI) of all participants split by the weekly hours of exercise and level of affinity for technology (ATI). Whiskers denote the standard error

spending more money on sports have reported feeling significantly more intrinsic motivation ( $M = 5.12$ ,  $SE = 0.19$ ) and integrated regulation ( $M = 4.81$ ,  $SE = 0.20$ ) compared to the participants who are spending less money yearly on doing sports. In comparison, those spending less money have reported lower intrinsic motivation ( $M = 4.42$ ,  $SE = 0.20$ ) and lower integrated regulation ( $M = 4.00$ ,  $SE = 0.22$ ). When looking at the index of motivation for physical activity and exercise, both groups have index values positive, which means that both groups are intrinsically motivated. However, those participants who are spending more money have reported a significantly higher index of motivation for physical activity ( $M = 9.60$ ,  $SE = 0.59$ ) and exercise ( $M = 3.96$ ,  $SE = 0.62$ ) compared to the group with spending less money and has reported lower index after motivation for physical activity ( $M = 7.18$ ,  $SE = 0.70$ ) and exercise ( $M = 2.08$ ,  $SE = 0.60$ ).

Effects influenced by the money spend on sports are visualized in Fig. 4.

### Sports and duration

Another parameter that was analyzed when it comes to sports is how many hours a week does a person exercise, and based on the answers, two groups were created. A group with a lower duration of exercising was formed with exercising time including up to 4 h a week ( $N = 33$ ), and a longer duration was defined as exercising more than 4 h a week ( $N=30$ ). Depending on that results (Fig. 5) have shown that people who exercise more hours a week have significantly higher intrinsic ( $M = 5.04$ ,  $SE = 0.20$ ) and integrated ( $M = 4.88$ ,  $SE = 0.20$ ) motivation compared to the intrinsic ( $M = 4.31$ ,  $SE = 0.23$ ) and integrated ( $M = 3.93$ ,  $SE = 0.21$ ) motivation of those who exercise less intensely. Further on,



**Fig. 6** Mean values of external motivation (M4PA - external) and all participants split by their affinity level for technology (ATI). Whiskers denote the standard error

Fig. 5 shows when it comes to the index for describing the motivation for exercise, both groups have positive values as an index, which means they are intrinsically motivated. However, the group who is exercising more often in a week has a significantly higher motivation index ( $M = 4.16$ ,  $SE = 0.63$ ) compared to the group who exercises less intensively ( $M = 1.89$ ,  $SE = 0.57$ ).

### Sports and ATI

Three groups depending on different technology interests were created to analyze the effects between sport motivation and technology affinity - low ( $N = 19$ ), medium ( $N = 21$ ), and high ( $N = 23$ ) affinity for technology. Low affinity is defined as an ATI score below 3.5, the medium is defined as a score between 3.5 and 4.5, while high affinity was defined as an ATI score higher than 4.5. Data analyses, as presented in Fig. 6, has shown that group with a medium affinity for technology have reported having significantly lower external motivation ( $M = 2.71$ ,  $SE = 0.27$ ) compared to the group with low ( $M = 1.76$ ,  $SE = 0.23$ ) or high ( $M = 1.50$ ,  $SE = 0.11$ ) affinity for technology. Similarly, the index of motivation for physical activity, even though in all cases indicating that for all groups is mainly intrinsic, for the medium group is significantly lower ( $M = 6.21$ ,  $SE = 0.80$ ) compared to the index of the group with lower affinity for technology ( $M = 8.86$ ,  $SE = 0.87$ ) or the group with higher affinity for technology ( $M = 9.82$ ,  $SE = 0.68$ ).

### Discussion

To explore how different user factors and different affinity for technology are connected to sports motivation, an online crowdsourced study has been done using standardized physiological questionnaires. Overall, results have shown that use factors such as age, gender, and previous VR experience

result in significantly different affinity for technology (ATI) score. Furthermore, based on the ATI score, results have shown that participants also have reported having significantly different overall index value (RAI) of motivation for physical activity. However, in order to understand links between the factors and influences on user preferences in VR exergaming, each user factor, and potential effects are discussed separately.

### Age

Age is a user factor that showed effects on both, motivation for sports and affinity for technology. When it comes to how likely people are to interact with technology, younger participants actively had, as expected [19], a higher affinity for technology. Therefore, this effect is also noticeable when asking about user preference for UI in VR exergaming. As results from our initial study showed, younger participants found gamified visualization (such as including a speedometer instead of the numerical value of speed) more supportive and clear. In comparison, older participants preferred typical numerical visualization. It seems natural that younger humans tend to be more easily active and, therefore, also more motivated to perform a sport.

### Gender

The results from our crowdsourced study reported differences based on subjectively stated gender (binary category) were significant for the affinity for technology. As expected, based on the validation of the ATI scale [19], in our study, male participants had a higher affinity for technology.

Interestingly, a similar trend was as well reported in the initial study having VR exergame in focus. Correspondingly the results from the initial study can be observed as men have rated the gamified version as better overall and pragmatic quality, while women have preferred digital numerical visualization. This can be explained similarly, like with effect with age, with the different affinity for technology. As men are more likely to enjoy new technology, their preferred user settings for visualizing the parameters are the gamified version, while women prefer more traditional and less technical numerical visualization.

### VR experience

Reporting on the connection between ATI score and previous VR experience participants with previous experience with VR devices had a significantly higher affinity for technology. This can be explained as those people who are more interested in technology will be the first ones to try new technology available on the market, such as virtual reality. Once again, the initial study's effect connected with the user

factor of previous experience, can be explained in relation to the ATI score.

For the VR rowing, exergame participants with more VR experience have rated the overall quality of user experience better for gamified visualization. Meaning that user groups with higher ATI scores have been rated as preferred visualization of the gamified user interface.

### Sports and motivation

Results reporting about the motivation for exercise and physical activity done as part of our research for VR exergaming are as expected, following general sports motivation characteristics. However, the goal of reported effects was to investigate if by knowing user characteristics (such as how frequently they exercise, how much money they spend on doing sports), one can learn about the type of user motivation and adjust the user preferences.

At the same time, when it comes to motivational factors in sports, younger participants had higher intrinsic motivation and higher identified regulation. This means that compared to the older group, younger participants find more interest and enjoyment in exercising and find sports essential for themselves. This effect seems to be explainable by the fact that younger humans seem to be more open toward newer things in general. Therefore, the initial study results where older participants preferred the visualization of metrics as a coach boat could be explained based on that their motivation for sports is not as internally motivating. This means that they could prefer to have even in a virtual environment a replication of external motivation, such as a coach boat, rather than having metrics close to themselves.

### Sports and frequency

Identified and integrated regulations are important when it comes to how frequently people exercise. Still, results have reported that a higher frequency of doing sports brings higher values on the intrinsic scale, the identified scale, and the overall scale for physical activity motivation. Additionally, the values on the integrated motivation of the sport motivation scale were higher for participants doing sport with higher frequency. When it comes to VR exergaming and improving the user experience for it, an important factor is intrinsic motivation as this motivation is connected with the feeling of enjoyment. However, when it comes to observing the frequency of doing exercises, results suggest not only to focus on intrinsic motivation.

### Sports and money

Depending on the amount of money spent on physical activity and exercise, results have reported effects on

different types of motivation. A higher amount of money spent on sports results in higher values on the intrinsic scale, the identified scale, and the overall scale for physical activity motivation. Additionally, the values on the integrated motivation scale and the sport motivation scale's integrated motivation scale were higher for participants spending more money. The values on the intrinsic and overall motivation scales of the motivation for exercise were higher for participants spending more money on sports activities.

Further more, even though user motivation for sports was reported to have an effect on money spent, it would be interesting to observe if the same pattern occurs as well for VR exergames, in particular, those focusing on sports.

### Sports and duration

Integrated regulation plays an important role in determining exercise duration [16]. The values on the integrated motivation scale of the sport motivation scale were higher for participants spending more time in the gym. Additionally, the intrinsic scale values and the overall motivation scale of the motivation for exercise were higher for participants spending more time in the gym every week. However, when it comes to VR exergaming, the exercise duration could be as well limited not only by the player's motivation but also by the effect of cybersickness. Therefore, the factor of duration for the exergame should not be observed alone.

### Sports and ATI

Lastly, to explore the motivation for VR exergaming that is a combination of technology and sports, the level of affinity for technology was analyzed in relation to sports motivation. Results showed that medium affinity for technology resulted in a reduced overall motivation on the overall scale and an increased external motivation scale on the motivation for physical activity scale. However, for all ATI levels the overall score of motivation (RAI) is a positive index number, indicating that participants are more or less intrinsically motivated for sports. Still, that intrinsic motivation is significantly lower for participants with a middle ATI score. The same effect is described when looking only at the dimension of external motivation. For those having the middle ATI score, external motivation for sports is significantly higher than the other two groups. Looking in particular at the group of participants with middle ATI scores is important because their user preferences can't be explained based on the ATI score, so it is interesting to notice that their motivation for VR exergames would be externally driven.



## Limitations and future work

Perhaps, the most important limitation of this study is that as it was done as an online study, there was no possibility to confirm participants' statements. Even though this effect was eliminated by using trap questions to confirm that participants are concentrated while reading. Still, when it comes to reporting about their sports habits, there was no additional validation if they reported the correct information. However, as the study was done via crowdsourcing, participants have been financially rewarded for their work and most probably motivated to finish their crowd-work correctly.

Even though this study is not using further categorisation of exergames, e.g., those focusing on rehabilitation or sports, it would be interesting to classify the influence of motivation based on the purpose of VR exergaming itself. However, this study is proposing the first step with a broader concept connecting users' motivation for sports and VR exergames in general. So, in the future, it would be interesting to explore how in particular those users involved in sports might be predisposed for playing as well more sport-based VR games. Further on, motivation and user experience are important not only for VR exergaming, but the study could be as well expanded to the other VR serious games. Finally, based on this study's results, a structural model could be built to improve the user experience of the VR exergames.

## Conclusion

In general, it was shown that there are important factors influencing the motivation for sports and affinity for technology, which are needed for understanding user preferences and experience in VR exergaming. The idea was to explain user experience in VR exergaming based on the influence of user factors. Based on the example of user preferences in the initial study using VR UI visualization showing that age, gender and previous experience with VR systems result in different perception of clearness of UI, perceived support as well as the perception of flow, this paper we have further on discussed the role of user factors.

On the other hand, the participants' age influenced the affinity for technology and motivation for exercising on the intrinsic motivation scale and the sports motivation scale. Furthermore, gender and previous experience with VR also affect the affinity for technology. Therefore, an affinity for technology is an essential factor, and while designing a VR exergame should be considered. Based on different ages, gender, and previous VR experience, users had diverging preferences, and they also reported diverging affinity for technology. For all of those three user factors (age, gender and previous VR experience), their preferences were affected by their ATI score.

Moreover, as VR exergames are many times aimed to be played frequently, the fulfilment of user preferences is important to ensure entertainment and enjoyment. In the development of VR exergames, it is not always easy due to the limited time or resources, to include measures of motivations. Designers and developers of VR exergames should be aware of the links between parameters such as the frequency of playing VR exergames and constructs such as users' motivation. Based on the effect of previous experience and user factors e.g. motivational effects, the latter can be estimated by measuring the first ones. The results of this study have shown that there are effects between frequency, intensity, and money spent on exercising and user motivation. As could have been expected with the increased effort, the more time and money participants invest in the activity, the higher the motivation to perform the corresponding activity gets. At the same time, age is negatively related to an affinity for technology and motivation for exercising. In the long run, user experience ratings for VR exergaming can potentially be explained or at least estimated based on user demographics and technology usage. This enables an efficient and effective tool, during development and product evaluation, to have more knowledge on a potential variance of user experience.

**Funding** Open Access funding enabled and organized by Projekt DEAL.

## Declarations

**Conflict of interest** The authors declare that there are no conflict of interest. On behalf of all authors, the corresponding authors state that there is no conflict of interest.

**Consent for publication** All human participants involved in the studies described in this publication provided explicit written consent to allow publication of the analysed study data.

**Consent to participate** All human participants involved in the studies described in this publication provided explicit written consent to participate in the studies of their free will.

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