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Acceptance by athletes of a virtual reality head-mounted display intended to enhance sport performance

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The authors declare no conflict of interest.

Abstract

While a growing number of studies have highlighted the potential of virtual reality (VR) to improve athletes' skills, no research has yet focused on acceptance of a VR head-mounted display (VR-HMD) designed to increase sport performance. However, even if technological devices could potentially lead to performance improvement, athletes may not always accept them. To investigate this issue, the Technology Acceptance Model (TAM) examines if perceived usefulness, perceived ease of use, perceived enjoyment, and subjective norms (i.e., social influence) are positive predictors of intention to use a specific technology. The aims of the present study were to test with competitive athletes the validity of the TAM before a first use of a VR-HMD intended to enhance sport performance and to examine to what extent the level of practice and the type of sport practiced have an influence on the previous variables of the TAM. The study sample comprised 1162 French athletes (472 women, 690 men, M_{age} = 24.50 ± 8.51 years) who usually practiced a sport in competition (from recreational to international level). After reading a short text presenting the VR-HMD and its interests for sport performance, the participants filled out an online questionnaire assessing their acceptance of this technological device before a first use. The results of the structural equation modeling analysis revealed that perceived usefulness, perceived ease of use, perceived enjoyment, and subjective norms were positive predictors of intention to use this VR-HMD, validating the suitability of the TAM for investigating the acceptance by athletes of a VR-HMD designed to increase their sport performance. The results also showed that athletes of all sport levels (a) had a significant intention to use VR, (b) found it quite useful (except for recreational athletes), quite easy to use, and quite pleasant to use, even if their entourage would not encourage them to use it (except for international athletes), and (c) found the VR-HMD easy and pleasant to use whatever the sport practiced. Notably some athletes (e.g., triathletes, swimmers, cyclists) did not find the VR-HMD significantly useful and did not have significant intention to use it to increase their performance. Identifying acceptance by athletes of such a device may increase the likelihood that it will be used by athletes of different levels and from different sports, so that they can benefit from all its advantages related to the improvement of their sport performance. Needs-based targeted interventions may also be conducted toward athletes who might be reluctant to integrate this type of device into their training.

Keywords: Virtual environment; technology acceptance model; training; simulation; competition.

Acceptance by Athletes of a Virtual Reality Head-Mounted Display Intended to Enhance Sport Performance

Introduction

In many domains, technologies designed to increase performance are growing exponentially. Among the different technologies available, virtual reality (VR) is becoming more and more important in fields as diverse as education (Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020), therapy (Cieślik, Mazurek, Rutkowski, Kiper, Turolla, & Szczepańska-Gieracha, 2020), surgery (Moglia, Ferrari, Morelli, Ferrari, Mosca, & Cuschieri, 2016), and rehabilitation (Rose, Nam, & Chen, 2018). In the sport context, athletes' use of technology has constantly developed over many years (for reviews, see Akbaş, Marszałek, Kamieniarz, Polechoński, Słomka, & Juras, 2019; Angosto, García-Fernández, Valantine, & Grimaldi-Puyana, 2020; Neumann et al., 2018), in the pursuit of competitive advantage and/or health benefits through sport innovation. While the first studies on VR technology have existed since the late 1950s, the term "virtual reality" was popularized in the 1980s (Lanier, 1992). The first works on VR in the sport domain were conducted in the 1990s (Carr, 1992). A renewed interest has been observed in recent years for the use of VR in the field of sport, mainly due to the miniaturization of the devices as well as the reduction of the costs associated with their acquisition (Neumann et al., 2018). While the questions related to either the effectiveness of VR for improving sport performance (Faure, Limballe, Bideau, & Kulpa, 2020) or the possibility of transferring a skill from VR to real life (Gray, 2017) have already been investigated, the question of athletes' acceptance of a technology as innovative as VR is also inevitably raised. Surprisingly, studies focusing on the latter question are lacking in the sports literature examining immersive VR intended to enhance sports performance. Therefore, the present study investigated the acceptance of this type of technology by athletes of different levels and from different sports.

VR and Sport Performance

Based on an interactive computer-simulated environment, VR induces a sense of being present in another place, either mentally or physically. According to Heeter (1992) and Sheridan (1992), presence is the sense "of being there" in the virtual environment. Presence is a psychological, perceptual, and cognitive consequence of immersion, the latter being related to the objective level of sensory fidelity a VR system provides thanks to its technological characteristics (Slater, Usoh, & Steed, 1995). Because movement is captured by sensors, the system provides feedbacks to the user who interacts with and/or reacts to the virtual environment. Even online visual feedback for whole body movement may be provided in a computer automatic virtual environment (CAVE), watching one's own performance together with full body superimposition of a skilled performance (Hülsmann et al., 2019). VR may also be used for instructional or observational learning purposes (e.g., Watson & Livingstone, 2018). A SWOT analysis (Düking, Holmberg, & Sperlich, 2018) focusing on the potential usefulness of VR for athletes highlighted many strengths (e.g., training at any time in everyday real-life settings, biofeedback, repetition of actions, reduced risk of injury, manipulation of the visual environment) and opportunities (e.g., improvement of skills and tactics, motor imagery, preparation for competitions). Athletes may compete against or train with virtual avatars, for instance in rowing (Parton & Neumann, 2019) and in running on a treadmill (Nunes, Nedel, & Roesler, 2013). Manipulating an infinite number of scenarios may also contribute to train athletes in an increasingly individualized manner (Hoffmann, Filippeschi, Ruffaldi, & Bardy, 2014). Some reviews (Faure et al., 2020; Frank, 2020; Neumann et al., 2018; Stone, Strafford, North, Toner, & Davids, 2018) have shown that interactive VR applications provide powerful tools to improve athletes' performance and skills, as well as physiological and psychological outcomes. For example, VR practice produced improvements in putting accuracy in novice golfers (Harris et al., 2020), in rowing

performance (Parton & Neumann, 2019), in physical exertion when running on a treadmill (Nunes et al., 2014), in anticipation performance in cricket (Discombe et al., 2022), and in mental training (Frank, 2020). Moreover, sport training in VR may improve real-world performance, especially for closed skills (Gray, 2017; Michalski, Szpak, & Loetscher, 2019).

The most immersive VR systems are the CAVE, a large cube with screens which the user physically enters, and the VR head-mounted display (VR-HMD, e.g., HTC Vive, Oculus Rift), a wearable device with a screen that covers the eyes to view the virtual world in stereovision. Even though the CAVE and the VR-HMD are two immersive systems that share the same key features (Slater, 2009), the present study focused on the VR-HMD because (a) it is becoming increasingly accessible to the public (Cherni, Nicolas, & Métayer, 2021), (b) its cost is much lower than the CAVE, (c) the VR-HMD is also smaller and very much easier to transport than the CAVE, and (d) its positive influence on motor and sport performance has been validated (Bideau, Kulpa, Vignais, Brault, Multon, & Craig, 2010; Michalski , Szpak, Saredakis, Ross, Billinghurst, & Loetscher, 2019; Rolin, Fooken, Spering, & Pai, 2018). Despite all the previous promising advantages, using VR and especially VR-HMD to enhance sport performance can also have several limitations, such as limited field of view, no direct perception of the user's own body, limited haptic feedback, and limited interaction with physical objects (Stone et al., 2018), costs, unsuitability for training some specific sport skills, potential development of unnatural patterns of motion, and even social isolation (Düking et al., 2018). At present, VR use has not yet become widespread as part of the optimization of sport performance (Akbaş et al., 2019). Therefore, it seems relevant to investigate the potential reasons for this observation. Among these, examining the acceptance of VR by athletes could be a promising perspective.

Acceptance of Technology in the Sport Context

Even if technological devices are effective and validated, they may not always be accepted by potential users. The Technology Acceptance Model (TAM, Davis, 1989; Venkatesh & Davis, 2000) is the most widely used model in the literature to explain acceptance of technology, which investigates the psychological determinants that may influence the intention to use a technology, either before or/and after use. The first works conducted with the TAM have highlighted that perceived usefulness of a technology and its perceived ease of use were positive predictors of behavioral intention to use a technology, which is itself a predictor of its actual use (Davis, 1989, Venkatesh & Bala, 2008). Intention to use a technology may also be positively predicted by perceived enjoyment, especially when the technology has a hedonic dimension (van der Heiden, 2004). All the previous variables may also be predicted by subjective norms, which are a particular form of social influence related to the opinions of important others about the individual's potential use of a specific technology (Schepers & Wetzels, 2007). Subjective norms were found to be positive predictors of perceived usefulness and intention to use (Schepers & Wetzels, 2007), but also of perceived ease of use (e.g., Al-Rahmi, Alzahrani, Yahaya, Alalwan, & Kamin, 2020) and perceived enjoyment (e.g., Zhou, & Feng, 2017). The relationships between the previous variables of the TAM are presented in Figure 1. Actual use is not represented in Figure 1 because the present study focused on acceptance by athletes of a VR-HMD intended to enhance sport performance, before a first use of this device.

At first glance, it may be surprising to investigate the acceptance of a technology before its first use. However, this line of research is widely represented in the TAM literature because it may contribute to a better understanding of the first step leading to the actual roll-out of technology (Venkatesh & Bala, 2008). It contributes to identify some of the psychological determinants (i.e., perceived usefulness, perceived ease of use, perceived

enjoyment, social norms) that could initially block or threaten the intention to use a technology whose effectiveness has been objectively proven. Indeed, any potential user may have an opinion about a technology and the desire to adopt it (or not) when this technology is presented to them only through a photo, a text, a verbal discussion, or a video (Li, Ma, Chan, & Man, 2019). For instance, this psychological process is particularly widespread in the field of advertising for technological devices (e.g., Prasetyo et al., 2021). Initially, the TAM has hypothesized that perceived usefulness and perceived ease of use were predictors of attitude towards a technology, the latter then predicting the intention to use it (Davis, 1989). But it is now commonly accepted (for a review, see Turner, Kitchenham, Brereton, Charters, & Budgen, 2010) that the attitude construct is unnecessary in the TAM. Initial opinion before a first use may directly influence intention to use a technology and its actual use, as predicted by the evolution of the TAM's theoretical framework (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000). Of course, this initial opinion may change after use (e.g., perceived usefulness may increase or decrease) or it may be maintained[1].

In the physical activity domain, Mascret, Delbes, Voron, Temprado, and Montagne (2020) have shown that intention to involve in a VR-based training program may be partly determined by initial opinions towards the technology itself, before a first use. If initial perceived usefulness, perceived ease of use, perceived enjoyment, and social norms are low, the involvement in the VR-based training program is also likely to be low. Therefore, investigating, before a first use, the acceptance by athletes of a VR-HMD intended to increase their sport performance would make it possible to identify certain psychological determinants that could positively or negatively predict their intention to use this technological device that

[1] A reduced number of studies distinguish acceptability (i.e., before a first use) and acceptance (i.e., after use) of a technology. But the general term "acceptance" is by far the highest ranking used in the TAM literature whatever the temporality (before/after). As a result, only the term "acceptance" is used throughout the article (although the present study focused on the perception of a technology before its first use) to be in line with the wording usually found in the literature focusing on technology acceptance before and/or after use.

they have not yet experienced. However, the TAM has not yet been validated with VR-HMD designed to enhance sport performance, neither before a first use of this device, nor after use.

Please insert Figure 1

The TAM is used extensively in many contexts in which technology may have an influence, such as healthcare, finance, gaming, and education (Rivera, Gregory, & Cobos, 2015). This model has also been applied to athletes' acceptance of sport technologies in different domains, for instance running on a social exercise platform (Tsai, Chang, Chang, & Lin, 2021), exergames for older adults (Nawaz, Skjæret, Helbostad, Vereijken, Boulton, & Svanaes, 2016), sports wearable technology (Kim & Chiu, 2019), fitness Apps (Beldad & Hegner, 2018), self-report monitoring (Rönnby et al., 2018), and sport products (Song, Kim, & Cho, 2018). A recent review (Angosto et al., 2020) focusing on acceptance of fitness and physical activity apps showed that the TAM was the most widely used model. But, surprisingly, studies validating the TAM with a VR-HMD designed to increase sport performance had not previously been conducted, while non-acceptance of VR by athletes was considered a threat to the use of this type of device (Düking et al., 2018).

Acceptance of VR-HMD in the Sport Context

The issue of acceptance of the VR-HMD in the sport context has been addressed in a reduced number of studies (e.g., Gradl et al., 2016; for a review in cycling, see Mahalil et al., 2020), mainly through the ad hoc use of some of the TAM variables, notably perceived usefulness and perceived ease of use. However, these variables were used in isolation and the relationships between the different variables of the TAM have never been investigated. Thus, to date, the model itself has not been validated in the context of sport performance. The only studies using an acceptance model of VR-HMD in the sport context have examined the potential role of VR-HMD for enhancing the immersive viewer experience, for instance when

watching a football match (Kunz & Santomier, 2019; Rynarzewska, 2018). However, studies have already been conducted with acceptance models of the VR-HMD in different domains, such as fall prevention for older adults (Mascret et al., 2020), business (Manis & Choi, 2019), and aeronautics (Sagnier, Loup-Escande, Lourdeaux, Thouvenin, & Valléry, 2020). But despite the growing literature investigating the influence of VR on sport performance (Düking et al., 2018; Faure et al., 2020; Neumann et al., 2018; Stone et al., 2018), the issue of acceptance of VR is barely sketched and is often presented as a given: VR is assumed to be necessarily accepted by athletes because it is intended to improve their performance. However, all the research on technology acceptance has shown that the process is not so automatic, whether in studies examining technology acceptance in general (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000) or VR-HMD acceptance more specifically (Manis & Choi, 2019; Mascret et al., 2020). If the VR-HMD intended to increase sport performance is not accepted by athletes, it may simply not be used or at least not be optimally used despite its initial interests related to sport performance. Some athletes may find the VR-HMD of little use because it is too disconnected from the reality and demands of their sport, while others may feel that they would not be able to operate the VR-HMD or that they would not enjoy the device. Others may feel that those around them would not encourage them to use this type of technology, especially their coach, who may find this type of technology useless or who may be unfamiliar with the use of technology in his/her training programs. All these observations may decrease the likelihood that athletes will finally use the VR-HMD and benefit from all the validated advantages of this device. Consequently, understanding acceptance before a first use of a VR-HMD intended to enhance sport performance seems crucial to identify if any initial blockages occur before use and to examine the potential predictive role of perceived usefulness, perceived ease of use, perceived enjoyment, and subjective norms on intention to use the VR-HMD. This is the first aim of the present study.

Research focusing on the role of VR in improving sport performance has been conducted with athletes of different levels of expertise, such as football players from novice to professional levels (Wood, Wright, Harris, Pal, Franklin, & Vine, 2021), players of competitive high-school baseball (Gray, 2017), or beginners in table tennis (Michalski et al., 2019b). These studies allowed the identification of skill-specific perceptual-motor mechanisms. For instance, skilled tennis players and novices have been shown to use different visual cues from the opponent to produce anticipatory judgments (Fukuhara, Ida, Ogata, Ishii, & Higuchi, 2017) and professional rugby players have been shown to outperform low-level players in a decision-making 3 vs. 3 situation (Correia, Araujo, Cummins, & Craig, 2012) and in an uncoupled or coupled perceptual-motor task (Brault, Bideau, Kulpa, & Craig, 2012). Since differences in perceptual-motor skills exist in VR as a function of sport level, it is legitimate to ask whether differences in VR acceptance also exist: While elite athletes and high-level athletes are constantly looking for ways to improve their performance, should we expect that the higher the sport level, the higher the acceptance of the VR-HMD? Moreover, the effectiveness of VR has been validated in sports in which the physiological dimension is preponderant, such as running or cycling (Neumann et al., 2018), in some tasks of team ball sports (for a review, see Faure et al., 2020), in individual sports (e.g., table tennis, Michalski et al., 2019b), and in specific sport tasks (e.g., baseball batting, Gray, 2017). But using a VR-HMD may be considered by some athletes totally inapplicable to their own sport (Neumann et al., 2018). Even if the effectiveness of a technological device has been objectively validated (such as the effectiveness of the VR-HMD to improve sport performance), an athlete who believes that it is not suitable for his or her sport will not necessarily intend to use it. This process of non-acceptance is well known in the literature, for example among teachers who do not want to use a new technology in their courses that is objectively useful while they have not even tried it yet (Scherer, Siddiq, & Tondeur, 2019). The process is similar when elderly

people find, before a first use, a technology too difficult to use while this technology has been specifically designed to be used easily by the elderly (Chen & Chan, 2014). Consequently, the second aim of the present study is to examine if differences in perceived usefulness, perceived ease of use, perceived enjoyment, subjective norms, and intention to use the VR-HMD appeared according to the sport level and the type of sport practiced in competition.

Hypotheses

We first hypothesize that intention to use the VR-HMD designed to increase sport performance would be positively predicted by perceived usefulness (H1), perceived enjoyment (H2), perceived ease of use (H3), and subjective norms (H4). Based on the TAM theoretical framework validated in other domains (e.g., education, Scherer et al., 2019), in VR (e.g., Syed-Abdul et al., 2019), and in sport technologies other than VR-HMD (e.g., Angosto et al., 2020), the higher an athlete would consider the VR-HMD useful, easy to use, and encouraged to be used by those around him/her, the higher his/her intention to use it. We also hypothesize that perceived usefulness would be positively predicted by perceived enjoyment (H5) and perceived ease of use (H6), and that perceived enjoyment would be positively predicted by perceived ease of use (H7), because an athlete may find a technological device more useful if he/she considers it enjoyable and easy to use (Angosto et al., 2020) and because a technological device that is easy to use provides more pleasure and less frustrations (van der Heiden, 2004). Finally, we expect that subjective norms would be a positive predictor of perceived usefulness (H8), perceived enjoyment (H9), and perceived ease of use (H10). Being encouraged by those around you to use a technological device can lead you to find it (a) more useful, because you trust them, (b) easier to use, because you think that those around you will be able to help, and (c) more pleasant, because you think that you will be able to share this experience with them, all of these reasons ultimately increase intention to use technology (Al-Rahmi et al., 2020; Schepers & Wetzels, 2007; Zhou & Feng, 2017). Figure 1

represents the hypothesized model. We also hypothesize that the higher the sport level, the higher the scores on the five variables of the TAM, because elite and high-level athletes are constantly looking for ways to improve their performance. Regarding the influence of the sport practiced on VR-HMD acceptance, we do not provide any specific hypothesis because of the lack of support in the literature and the exploratory nature of this part of the present study.

Methods

Participants and Procedure

The study sample included 1162 French athletes (472 women, 690 men, M_{age} = 24.50 ± 8.51 years) who voluntarily and anonymously participated in the present study. Two inclusion criteria had to be met to participate in the study: to be at least 18 years old (legal age in France) and to usually practice a sport in competition (regardless of type of sport and level of competition). Only competitive athletes participated in the study because the VR-HMD was specifically intended to enhance sport performance. Hours of training per week were collected for all participants and the usual French classification was used to categorize their self-reported levels of competition in usual circumstances (i.e., outside the Covid-19 pandemic period): recreational level (75 participants, 5.85 ± 4.04 hours), departmental level (207 participants, 4.83 ± 2.19 hours), regional level (448 participants, 6.42 ± 2.98 hours), national level (349 participants, 8.80 ± 4.30 hours), and international level (83 participants, 14.42 ± 7.56 hours). Recreational level athletes participated very occasionally in official competitions (e.g., a running race, a football tournament) and they do not follow a regular championship like the participants of another level of expertise. A variety of sports is present among the participants. All the descriptive statistics about sports practiced and sport levels are presented in Supplementary Material 1. Most participants had never used a VR-HMD before (57.49%), many others had used it between one and three times in their entire life (39.41%),

while a small minority have used it more regularly (3.10%), but never with applications designed to improve sport performance.

A nonprobability snowball sampling (Kosinski, Matz, Gosling, Popov, & Stillwell, 2015) was used to disseminate the online questionnaire through social networks (e.g., Facebook, LinkedIn), sport clubs, and University sport departments. Following the procedure usually conducted in the technology acceptance literature (e.g., Li et al., 2019), participants had to read a short text before completing the questionnaire below. The text described what a VR-HMD is, how it could be used in sport, and its interests in improving sport performance (the full text is presented in Supplementary Material 2). This kind of procedure is mandatory in studies investigating acceptance of a technology before a first use. Participation was strictly anonymous, and respondents gave their informed consent electronically. The National Ethics Committee for Research in Sports Sciences (CERSTAPS IRB00012476-2021-16-04-103) approved the study.

Measures

Participants responded to the four items assessing perceived usefulness (e.g., *"I think this VR-HMD would be useful to improve my sport performance"*), the three items assessing perceived ease of use (e.g., *"I think the use of this VR-HMD would be simple"*), the three items assessing perceived enjoyment (e.g., *"Using this VR-HMD would be fun"*), the three items assessing subjective norms (e.g., *"The people who are important to me would encourage me to use this VR-HMD"*), and the three items assessing intention to use (e.g., *"Assuming I had access to this VR-HMD, I would like to use it."*) on a 1 (*strongly disagree*) to 5 (*strongly agree*) Likert scale. All the items were based on studies assessing acceptance of VR-HMDs in other domains such as business (Manis & Choi, 2019) and health (Mascret et al., 2020), but items assessing perceived usefulness were adapted to the sport domain by replacing the end of each item with *"…to improve my sport performance"*. McDonald's

omegas (Dunn, Baguley, & Brunsden, 2014) were used to measure internal consistency, which was satisfactory for each subscale (.799 < Ω <.949). Descriptive statistics and McDonald's omegas for each variable are provided in Table 1. Demographic variables usually used in the TAM literature were also self-reported: gender, age, and frequency of VR-HMD use (from *never* to *several times a week* on a six-point scale). Frequency of VR-HMD use focused on the participants' prior use of a VR-HMD, but for a purpose other than improving sport performance, such as playing video games. Finally, participants were told to indicate their sport practiced in competition and their sport level (recreational, departmental, regional, national, international).

Please insert Table 1

Data Analyses

Level of significance was defined at $p < .05$ for all the data analyses, which were conducted using the JASP software (version 0.14.1). First, preliminary analyses were conducted: (a) the dataset was screened for missing values, (b) Mahalanobis distance ($\chi^2(9) = 27.88$, $p < .001$) at the multivariate level was used to detect gross outliers (In'nami & Koizumi, 2013), and (c) univariate normality was checked with values ≥ |2| for skewness and ≥ |7| for kurtosis indicating variables non-normal in distribution (Curran, West, & Finch, 1996).

Secondly, the model's fit was evaluated through several indices (Byrne, 2010; Hu & Bentler, 1999): χ^2/df ratio (value ≤ 3), the comparative fit index (CFI, value ≥ .95), the Tucker-Lewis Index (TLI, value ≥ .95), the root mean square error of approximation (RMSEA, value ≤ .05), and the standardized root mean square residual (SRMR, value ≤ .08). A structural equation modeling (SEM) analysis based on the maximum likelihood estimations was then conducted to evaluate the hypothesized model (Figure 1). Control variables (gender,

age, frequency of use, sport level) were first entered in the model to examine their potential predictive role on the main variables of the tested model. If a control variable was not found to be a significant predictor of one of the TAM variables, it was removed from the analysis for the sake of parsimony (Zigarmi, Galloway, & Roberts, 2018).

Thirdly, five one-sample *t*-tests (one per sport level) were used to examine potential differences between the scores of each variable of the TAM and the theoretical mean of the scales (the mean value was 3 because a five-point Likert scale ranging from 1 to 5 was used in the present study). For example, these analyses determined whether participants initially considered the VR-HMD significantly more or less useful than the mean of the scale. Because a high risk of Type I errors needs to be considered in relation to the multiple testing procedure, the Holm-Bonferroni correction was used to judge final significance (Holm 1979). Effect sizes were calculated using Cohen's *d*. Then, five one-way ANOVAs with the factor Sport level (recreational, departmental, regional, national, international) were conducted on the scores of each variable of the TAM to determine whether significant differences occurred according to sport level. If so, differences were examined post-hoc with Tukey tests. Partial eta-squared (η_p^2) was used to calculate effect sizes.

Finally, the same analyses were conducted according to the sport practiced. Only sports that were rated by more than 20 participants were included in these statistical analyses, resulting in the inclusion of seventeen sports.

The final sample size was large ($N = 1162$) for several reasons: (a) SEM analyses usually required large sample sizes, at least 300 participants (Tabachnick & Fidell, 2013), (b) the present study planned to collect responses from participants from different sports and different levels of competition to conduct inter-sport and inter-level comparisons, and (c) the data collection method based on nonprobability snowball sampling led to collecting the

maximum amount of data over a defined period of time, without knowing in advance the final number of participants (Kosinski et al., 2015).

Results

Preliminary Results

No missing values were found because responding to each item was mandatory when completing the online questionnaire. Six participants were initially identified as outliers using the Mahalanobis distance and were excluded from the statistical analyses. The values of skewness (max = |1.054|) and kurtosis (max = |1.111|) indicated that the distribution was approximately normal. The values of skewness and kurtosis for each variable are presented in Table 1.

Validation of the Technology Acceptance Model

Two control variables (gender and age) had no significant relationships with any variables of the tested model; frequency of VR-HMD use had significant relationships with perceived ease of use only; and sport level had significant relationships with subjective norms only. The fit statistics met the criteria for a good fitting model: $\chi^2(7, N = 1162) = 7.56$, $p = .373$, $\chi^2/df = 1.08$, CFI = 1, IFI = .999, SRMR = .016, RMSEA = .008 (90% CI = .000-.038). The results of the SEM analysis highlighted that: (a) intention to use was positively predicted by perceived usefulness (H1 supported), perceived enjoyment (H2 supported), perceived ease of use (H3 supported), and subjective norms (H4 supported); (b) perceived usefulness and perceived enjoyment were the strongest predictors of intention to use the VR-HMD; (c) subjective norms positively predicted perceived usefulness (H8 supported), perceived enjoyment (H9 supported), and perceived ease of use (H10 supported); (d) perceived usefulness was positively predicted by perceived enjoyment (H5 supported), but not by perceived ease of use (H6 not supported), which positively predicted perceived enjoyment only (H7 supported); and (e) among control variables, sport level positively predicted

subjective norms, and frequency of VR-HMD use positively predicted perceived ease of use. All the results were significant at $p < .001$ level. All standardized path coefficients are presented in Figure 2. In sum, the results of the SEM analysis validated the suitability of the TAM for investigating the acceptance by athletes of a VR-HMD designed to increase their sport performance.

Please insert Figure 2

Influence of Sport Level

First, the results of the one-sample *t*-tests showed that (a) perceived usefulness was significantly higher (ps < .001) than the mean of the scale (3) for departmental, regional, national, and international athletes, but not for recreational athletes ($p = .240$); (b) perceived ease of use and perceived enjoyment were significantly higher (ps < .001) than the mean of the scale for all athletes regardless of their sport level: (c) subjective norms were significantly lower (ps < .001) than the mean of the scale for recreational, departmental, regional, and national athletes, but not for international athletes ($p = .974$); and (d) intention to use was significantly higher than the mean of the scale for recreational ($p = .003$), departmental, regional, national, and international athletes (ps < .001). The detailed results of these analyses are presented in Supplementary Material 3.

Secondly, the results of the one-way ANOVAs showed that no significant effect of sport level was found on perceived usefulness, perceived ease of use, perceived enjoyment, and intention to use (ps > .05). However, a significant effect was found for sport level on subjective norms ($F(4, 1157) = 4.298$, $p = .002$, $\eta^2 = 0.015$). Post-hoc Tukey tests showed that (a) subjective norms were significantly higher for international athletes than for recreational ($p < .001$) and departmental ($p = .046$) athletes; and (b) subjective norms were significantly higher for national athletes than for recreational ($p = .047$) athletes. Our hypothesis was

supported for subjective norms only. Means and standard deviations are presented in Supplementary Material 1. The figures for perceived ease of use, perceived enjoyment, subjective norms, and intention to use are presented in Supplementary Material 4. The results for perceived usefulness according to the sport level are presented in Figure 3.

Please insert Figure 3

Influence of Sport

First, the results of the one-sample *t*-tests showed that (a) perceived usefulness was significantly higher than the mean of the scale for the following sports: badminton, basketball, football, handball, rugby, tennis, and volleyball, (b) perceived ease of use and perceived enjoyment were significantly higher than the mean of the scale for all the seventeen tested sports, except perceived ease of use fo judo, (c) subjective norms were significantly lower than the mean of the scale for the following sports: athletics, badminton, basketball, cycling, football, handball, and triathlon, and (d) intention to use was significantly higher than the mean of the scale for all the tested sports, expect for cycling, swimming, riding, table tennis, and triathlon (*p*s >.05). The descriptive statistics and the detailed results of the *t*-tests are provided in Supplementary Material 3.

Secondly, the results of a first one-way ANOVA showed a significant effect of sport on perceived usefulness ($F(16, 991) = 2.946$, $p < .001$, $\eta^2 = 0.045$). Post-hoc Tukey tests revealed that triathletes had significantly lower perceived usefulness than handball ($p = .006$), basketball ($p = .007$), rugby ($p = .013$), football ($p = .020$), and badminton ($p = .032$) players. While significant effects of sport were found on perceived ease of use ($F(16, 991) = 1.711$, $p = .039$, $\eta^2 = 0.027$), on perceived enjoyment ($F(16, 991) = 1.751$, $p = .033$, $\eta^2 = 0.027$), and on intention to use ($F(16, 991) = 2.042$, $p = .009$, $\eta^2 = 0.032$), post-hoc Tukey tests did not show any differences between specific sports. Finally, no significant effect of sport on subjective

norms was identified (p = .067). Figure 4 represents the results for perceived usefulness of the VR-HMD depending on sport. The figures for perceived ease of use, perceived enjoyment, subjective norms, and intention to use are presented in Supplementary Materials 5, 6, 7, and 8, respectively.

Please insert Figure 4

Discussion

The aims of the present study were to investigate the suitability of the TAM to explain acceptance by athletes of a VR-HMD intended to increase sport performance and to examine the potential influence of sport level and the type of sport practiced on each variable of the TAM.

First, the results showed that the TAM was validated with the VR-HMD in the sport performance context. Before a first use, athletes' intention to use this device was positively predicted by perceived usefulness, perceived ease of use, perceived enjoyment, and subjective norms. These results were in line with the TAM studies focusing on acceptance of technology in general (e.g., Davis, 1989; Venkatesh & Bala, 2008; Venkatesh & Davis, 2000), of VR-HMD (e.g., Manis & Choi, 2019; Mascret et al., 2020), and of other sport technologies (e.g., Angosto et al., 2020; Kim & Chiu, 2019). The fact that perceived ease of use did not predict perceived usefulness (H6 not supported) is quite frequently encountered in studies using the TAM (Hanham, Lee, & Teo, 2021; Sagnier et al., 2020) and therefore does not call into question the validity of the TAM in the present study. The VR-HMD may be considered easy to use by some athletes, but neither useful nor useless to enhance their performance, explaining that easy to use did not predict perceived usefulness in the present study. Furthermore, perceived usefulness and perceived enjoyment were the strongest predictors of intention to use this VR-HMD to enhance sport performance. Perceived usefulness is the

usual strongest predictor of intention to use other sport technologies (Angosto et al., 2020) and the usual strongest predictor in the TAM theoretical framework (Davis, Bagozzi, & Warshaw, 1992) because perceived usefulness is preponderant for explaining acceptance of utilitarian technologies (van der Heiden, 2004). The VR-HMD examined in the present study may be considered by athletes a utilitarian technology since it is intended to improve sport performance. Moreover, perceived enjoyment was a strong predictor of intention to use because technologies using virtual environments are often hedonic technologies (Sun & Cheng, 2009). In some studies focusing specifically on VR-HMD acceptance (e.g., Manis & Choi, 2019; Mascret et al., 2020), perceived enjoyment was even the strongest predictor of intention to use this device. Finally, the results also highlighted that subjective norms were positive predictors of all the other variables of the TAM. The more people around the athletes would encourage them to use the VR-HMD, the more they would find it useful, easy to use, pleasant, and the more they would intend to use it. This was not surprising because athletes may be influenced by their coaches, teammates, family, and peers in the sport context (Donohue, Miller, Crammer, Cross, & Covassin, 2007) and the influence of subjective norms has also been shown in many studies investigating technology acceptance (e.g., Al-Rahmi et al., 2020; Schepers & Wetzels, 2007; Zhou & Feng, 2017).

Secondly, the results of the present study showed that athletes of all levels had a significant intention to use the VR-HMD designed to increase their sport performance. They all initially considered it quite useful (except for recreational athletes), quite easy to use, and quite pleasant to use. Contrary to expectations, no significant differences between sport levels were found for the previous variables. These results may be explained by several reasons: (a) participants were all competitive athletes who want to increase their performances, which is precisely the stated objective of using this VR-HMD, (b) VR is very often considered a hedonic technology (van der Heiden, 2004), and (c) the average age of the participants in the

present study is relatively young, so they may be more accustomed to using technology regularly. Because recreational athletes may be competing for reasons other than performance enhancement (e.g., being with friends, Luiggi, Maïano, & Griffet, 2019), they initially considered the VR-HMD not necessarily useful, although they would still want to use it if they had the opportunity. However, recreational, departmental, regional, and national athletes thought that people around them would not encourage them to use it, which was not the case for international athletes, who think that the people around them will neither support nor oppose their use of this VR-HMD. This result is challenging because it highlights a potential discrepancy between the athletes' intention to use the VR-HMD to enhance their performances and the opinion of those around them who would not necessarily advise them to do so. However, if their coach does not wish to use a VR-HMD in his/her training program, the athletes will certainly not be able to benefit from all its advantages. This could be problematic, especially for elite-level athletes for whom a continuous search for the most innovative ways to improve their performance is fundamental (Nash, Sproule, & Horton, 2011), especially since our results showed that international level athletes were more sensitive to the influence of their entourage than lower-level athletes.

Finally, the results showed that all the participants initially considered the VR-HMD easy and pleasant to use whatever the sport practiced, which was not surprising because ease of use and perceived enjoyment are not directly linked to the specificities of the sport practiced, but rather to the technology itself. More interestingly, the results also showed that participants of some specific sports did not find the VR-HMD significantly useful and did not have significant intention to use it to increase their performance. Some participants (e.g., cyclists, swimmers, and triathletes) may consider the VR-HMD totally inapplicable to their own sport (Neumann et al., 2018), and therefore did not necessarily intend to use it (without rejecting it). Participants from other sports (e.g., athletics, boxing, gymnastics) did not

necessarily find the VR-HMD useful (but not useless), perhaps because the perceived usefulness in the present study focused on improving sport performance in general, and these athletes could not identify precisely in their own sport how useful the VR-HMD could be in improving their performance more specifically.

The present study had some limitations that may be addressed in future research. First, the wording of the items measuring subjective norms did not make it possible to determine to what extent it was the coach or other people around the athletes who had an influence on the acceptance of the VR-HMD. Because we postulate that coaches play a crucial role, conducting a study with an item wording focusing on the influence of the coach could be relevant to (in)validate this hypothesis. Moreover, investigating acceptance of the VR-HMD not by the athletes themselves but by the coaches may also be a promising perspective for a future study (Greenhough, Barrett, Towlson, & Abt, 2021). Secondly, it was impossible in the present study to investigate the interaction between sport level and sport practiced due to insufficient numbers of participants in each of the categories that would have been created. Thirdly, the text that was read before completing the questionnaire described what a VR-HMD is, how it could be used in sport, and its interests in improving sport performance (see Supplementary Material 2). This text was not intended to be exhaustive regarding all possible applications of VR to improve sport performance, but other potential applications could have been mentioned (e.g., helping athletes familiarize themselves with new environments, mental training, maintaining training during an injury). This might have led to greater usefulness / intention to use scores, particularly for athletes from repetitive/motoric sports (e.g., cycling). Fourthly, while the present study has provided interesting results to better understand acceptance of the VR-HMD before first use, the TAM literature showed that acceptance of technology may increase or decrease after first use and/or after regular use (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000). Based on a pre- and post-test design, it would be

interesting to compare acceptance by athletes of the VR-HMD before and after a first use. However, this perspective requires the implementation of virtual environments specific to each sport to develop sports skills that are also specific. Fifthly, the nonprobability snowball sampling used in the present study led to categories of different competitive levels involving different numbers of participants. Future studies may recruit equal numbers of participants for each level. Finally, a recent study (Sagnier et al., 2020) showed that cybersickness was a negative predictor of intention to use a VR-HMD when performing an aeronautical assembly task in VR. It would be relevant to investigate if the pattern would be similar or specific for athletes after a first use of a VR-HMD intended to enhance sport performance.

Conclusion

The present study showed that a VR-HMD intended to improve sport performance is mostly well accepted by athletes of different sport levels before a first use, even if differences appeared in some specific sports. Identifying acceptance by athletes of such a device may contribute to increase the likelihood that it will be used by athletes of different levels and from different sports, through a better understanding of the variables that can affect the intention to use it, namely perceived usefulness, perceived ease of use, perceived enjoyment, and subjective norms. Even if the effectiveness of VR on sport performance has been validated and studies continue to improve it (Düking et al., 2018; Michalski et al., 2019a; Neumann et al., 2018), the question of the acceptance of the VR-HMD deserves to be systematically asked with this type of device to allow athletes to benefit from its full potential, especially high-level athletes whose demands during training are considerable.

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Table 1

Descriptive statistics, skewness, kurtosis, and internal consistency.

	Perceived usefulness	Perceived ease of use	Perceived enjoyment	Subjective norms	Intention to use
Mean	3.395	3.763	4.088	2.658	3.753
Standard deviation	1.063	0.838	0.796	1.057	1.141
Skewness	-0.368	-0.581	-1.054	0.289	-0.789
Kurtosis	-0.560	0.110	1.111	-0.436	-0.284
McDonald's omega	.949	.807	.799	.939	.945

Figure 1

The Technology Acceptance Model (TAM) tested in the present study.

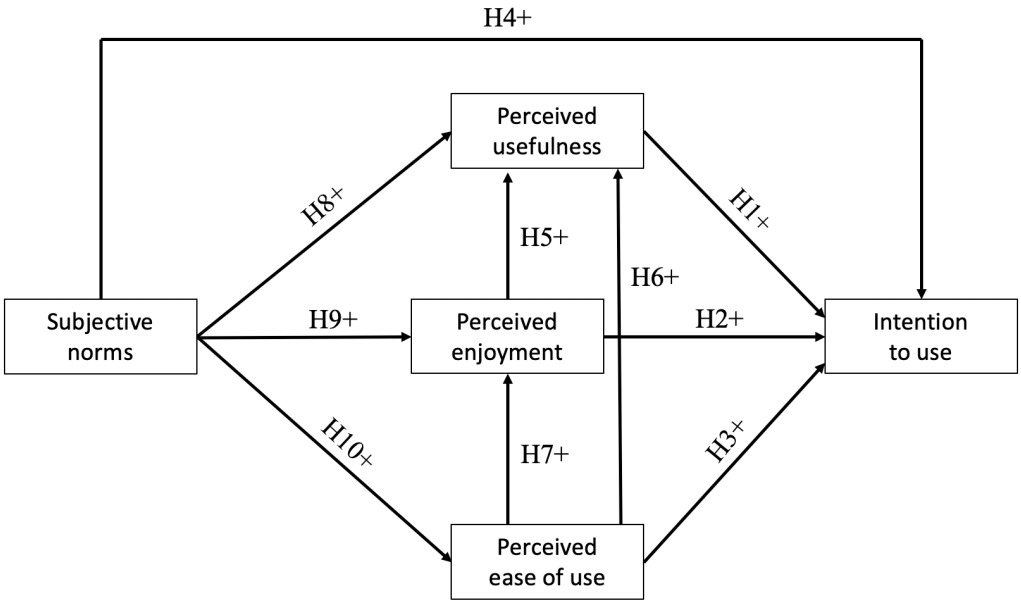
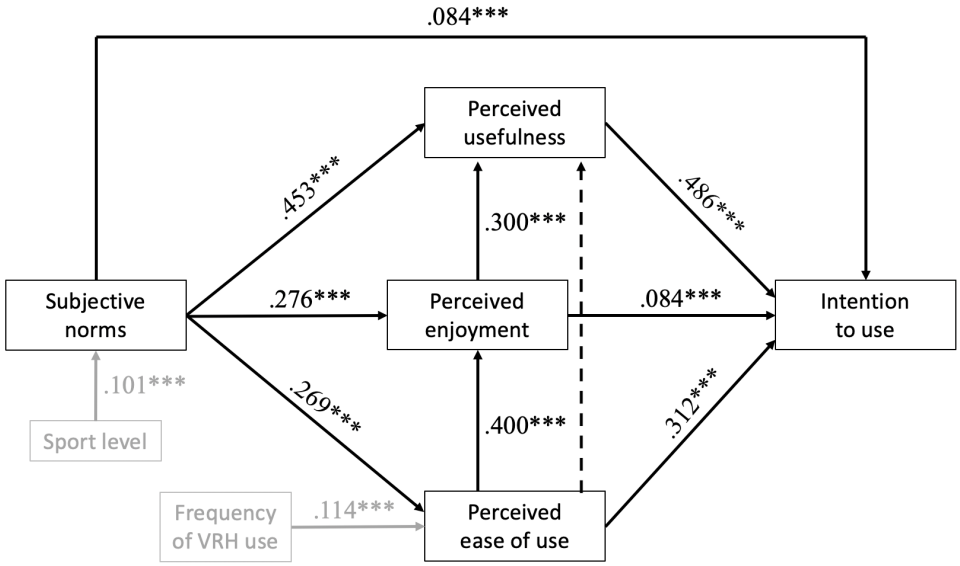


Figure 2

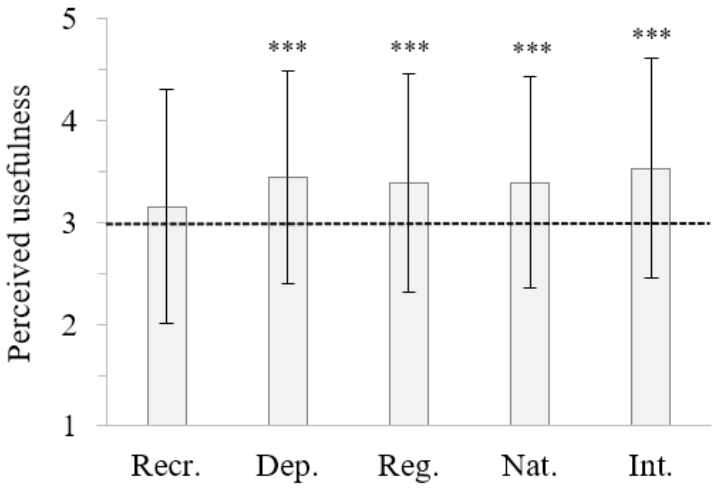
Validated structural model.



Notes. Path coefficients are standardized, and dotted lines indicate nonsignificant paths, ***$p < .001$.

Figure 3

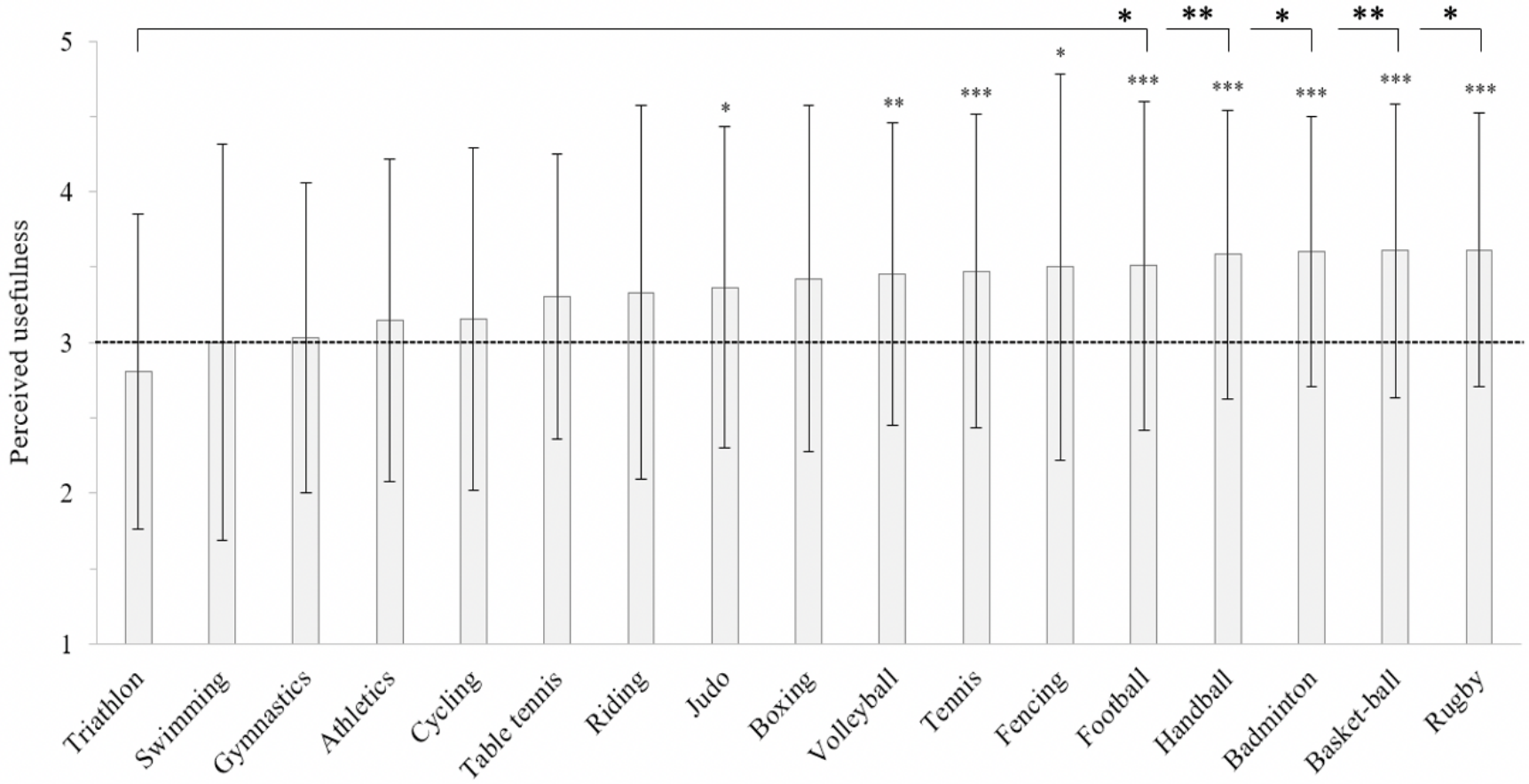
Perceived usefulness according to sport level



Notes. Recr. = Recreational, Dep. = Departmental, Reg. = Regional, Nat. = National, Int. = International. Dotted lines represent the mean of the scale. ***$p < .001$. After applying the Holm-Bonferroni correction, all the results remain statistically significant.

Figure 4

Perceived usefulness according to sport.



Notes. Dotted lines represent the mean of the scale. *$p < .05$. **$p < .01$, ***$p < .001$. After applying the Holm-Bonferroni correction, all the results remain statistically significant, except for Judo and Fencing.

Supplementary Material 1 (Part 1). Descriptive statistics by sport and by sport level.

	Recreational	Departmental	Regional	National	International	Total	PU		PEOU		PE		SN		ITU	
							M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Aerobatics	0	0	0	0	2	**2**	4.63	0.53	4.17	0.71	4.33	0.94	4.00	1.41	4.83	0.24
American football	0	0	1	2	0	**3**	3.67	0.38	4.11	0.51	4.00	0.67	2.22	1.02	3.00	1.76
Archery	0	0	1	0	1	**2**	3.13	2.30	2.83	0.24	3.83	1.18	3.00	0.00	4.83	0.24
Athletics	8	9	74	50	3	**144**	3.14	1.07	3.72	0.84	4.00	0.79	2.52	1.08	3.82	1.08
Badminton	2	20	12	13	4	**51**	3.60	0.90	3.90	0.73	4.12	0.68	2.56	0.88	3.78	0.99
Baseball / Softball	0	0	0	1	0	**1**	1.00	-	2.33	-	3.33	-	1.00	-	1.00	-
Basketball	1	28	48	11	0	**88**	3.61	0.97	3.97	0.79	4.34	0.61	2.61	1.12	3.89	1.13
Beach volley	0	0	1	0	0	**1**	2.00	-	4.00	-	3.67	-	1.00	-	3.00	-
Biathlon	0	0	0	0	1	**1**	3.50	-	3.33	-	4.67	-	3.00	-	2.67	-
Boxing	5	3	6	12	4	**30**	3.43	1.15	3.73	1.09	4.04	0.89	2.62	1.07	3.12	1.34
Canoeing	0	0	0	1	4	**5**	3.30	1.08	3.53	0.45	4.00	1.00	2.33	1.18	4.07	0.72
Climbing	2	3	3	1	2	**11**	2.95	0.98	3.45	1.11	4.00	0.80	2.58	0.73	3.97	0.86
Cross-country skiing	0	0	1	1	0	**2**	2.75	0.00	4.33	0.47	4.50	0.71	2.67	0.94	5.00	0.00
CrossFit	0	1	3	1	0	**5**	3.35	1.54	3.80	1.39	4.67	0.33	3.00	1.22	4.13	1.32
Curling	0	0	0	0	1	**1**	3.75	-	3.00	-	3.00	-	3.00	-	4.00	-
Cycling	1	3	6	9	5	**24**	3.16	1.14	3.90	0.76	4.13	0.91	2.18	0.91	3.72	1.07
Dance	2	1	1	4	2	**10**	3.58	0.95	4.13	0.48	4.43	0.42	3.23	1.03	3.90	0.85
Downhill skiing	1	2	2	0	0	**5**	2.95	1.27	3.27	1.01	2.73	0.64	1.40	0.55	3.53	1.71
Fencing	1	0	2	12	14	**29**	3.50	1.28	3.79	0.88	4.22	0.91	3.20	1.21	3.43	1.00
Figure skating	0	0	0	1	3	**4**	2.38	1.38	2.67	1.56	3.42	1.45	1.92	1.07	3.50	1.73
Fitness	1	0	0	0	0	**1**	2.00	-	2.00	-	2.67	-	1.67	-	5.00	-
Floorball	0	0	0	1	1	**2**	3.88	0.18	4.50	0.71	4.17	0.24	3.67	0.94	3.50	1.18
Football	9	57	54	17	1	**138**	3.51	1.09	3.71	0.75	4.05	0.77	2.71	1.00	3.77	1.10
Freestyle skiing	0	0	0	0	1	**1**	4.50	-	3.67	-	4.67	-	4.00	-	3.33	-
Golf	3	3	3	2	0	**11**	3.95	1.05	4.21	0.70	4.27	0.68	2.94	1.09	3.39	1.48
Grappling	0	0	1	0	0	**1**	4.00	-	5.00	-	4.67	-	4.00	-	5.00	-
Gymnastics	0	1	16	28	0	**45**	3.03	1.03	3.67	0.80	4.07	0.53	2.64	0.99	3.67	1.21
Handball	2	21	45	48	1	**117**	3.58	0.96	3.79	0.70	4.19	0.77	2.66	0.99	3.48	1.25
Hockey	0	0	0	1	0	**1**	3.75	-	3.33	-	3.67	-	3.00	-	4.00	-
Ice hockey	0	0	0	1	0	**1**	3.25	-	3.00	-	3.33	-	3.00	-	3.33	-
Judo	2	2	14	14	7	**39**	3.37	1.06	3.49	0.99	4.07	0.75	2.71	1.08	4.23	0.77
Lifesaving sport	0	0	0	1	0	**1**	3.75	-	2.33	-	4.67	-	3.00	-	3.67	-
Martial Arts	0	1	3	5	6	**15**	4.18	0.83	4.04	0.69	4.24	0.80	3.07	1.16	3.98	1.19
Motorbike	0	0	1	0	0	**1**	3.25	-	3.67	-	5.00	-	5.00	-	3.67	-
Orienteering	0	1	1	4	0	**6**	3.25	1.05	4.22	0.54	4.61	0.65	2.72	0.77	3.67	0.99

Supplementary Material 1 (Part 2). Descriptive statistics by sport and by sport level.

	Recreational	Departmental	Regional	National	International	Total	PU		PEOU		PE		SN		ITU	
Padel	0	0	1	1	0	**2**	3.00	1.41	3.00	1.41	3.83	1.65	3.17	2.12	4.83	0.24
Pétanque	0	0	0	1	0	**1**	5.00	-	4.00	-	5.00	-	4.33	-	3.67	-
Rhythmic gymnastics	0	0	1	1	1	**3**	2.08	1.46	2.44	0.51	3.44	1.68	2.33	0.88	3.44	1.58
Riding	4	4	10	8	1	**27**	3.33	1.24	4.10	0.75	4.19	0.78	2.90	1.36	3.94	0.98
Roller hockey	0	0	0	4	0	**4**	3.81	0.99	4.67	0.67	4.50	0.58	2.75	0.50	2.92	1.73
Rowing	0	0	0	3	2	**5**	3.25	1.26	3.00	0.94	3.73	1.19	2.33	1.22	4.07	0.89
Rugby	4	4	29	27	3	**67**	3.62	0.91	3.74	0.84	4.06	0.86	2.75	1.11	3.84	1.30
Sailboat	0	0	0	1	0	**1**	5.00	-	4.00	-	4.33	-	1.33	-	4.67	-
Sailing	0	0	0	2	6	**8**	3.84	0.78	3.92	0.79	4.42	0.64	3.08	1.14	4.04	0.60
Shooting sports	0	0	0	1	0	**1**	4.00	-	2.00	-	3.33	-	2.67	-	1.67	-
Skipping rope	0	0	0	0	1	**1**	3.75	-	3.33	-	4.00	-	2.00	-	4.00	-
Snowboard	1	0	0	0	0	**1**	3.50	-	2.00	-	3.00	-	2.67	-	4.00	-
Squash	0	0	2	0	0	**2**	3.13	0.18	4.17	0.24	4.17	0.24	1.50	0.71	3.33	2.36
Street workout	1	0	1	0	0	**2**	3.63	0.53	4.50	0.71	4.83	0.24	2.33	0.47	4.33	0.94
Surf	0	1	1	0	0	**2**	2.75	1.06	3.83	1.65	2.50	1.18	2.17	1.65	3.50	2.12
Swimming	1	2	17	10	0	**30**	3.00	1.32	3.59	0.94	3.82	0.99	2.46	1.23	3.82	1.14
Table tennis	0	8	12	6	0	**26**	3.31	0.94	3.85	0.78	3.83	0.76	2.98	0.97	3.64	1.17
Tennis	6	21	34	6	2	**69**	3.47	1.04	3.89	0.83	4.24	0.81	2.71	1.00	3.91	1.04
Trail	3	0	7	1	0	**11**	3.02	1.12	3.64	0.82	3.79	0.85	2.30	0.74	3.48	1.05
Triathlon	11	2	14	10	3	**40**	2.81	1.05	3.47	0.87	3.86	0.83	2.35	0.95	3.77	1.30
Twirling stick	0	0	0	2	0	**2**	2.88	0.18	4.50	0.71	4.67	0.47	2.83	0.71	4.17	1.18
Ultimate	1	0	2	2	0	**5**	2.75	0.90	3.13	1.39	3.80	1.17	2.93	1.59	4.53	0.45
Volleyball	2	8	17	17	0	**44**	3.45	1.01	3.83	0.89	4.03	0.86	2.69	1.07	3.47	1.18
Water polo	0	0	0	2	0	**2**	3.88	0.18	3.83	0.24	4.83	0.24	3.17	0.24	3.00	2.83
Weightlifting	1	1	1	1	0	**4**	3.50	0.89	3.58	0.50	3.75	0.69	2.58	1.20	4.08	1.07
Windsurfing	0	0	0	0	1	**1**	4.25	-	3.00	-	4.00	-	4.00	-	4.33	-
Wrestling	0	0	0	1	1	**2**	4.50	0.71	3.83	1.65	4.33	0.94	3.17	2.59	4.33	0.94
Total	**75**	**207**	**448**	**348**	**84**	**1162**										
PU ***M/SD***	3.16/1.15	3.44/1.04	3.39/1.07	3.39/1.04	3.54/1.09											
PEOU ***M/SD***	3.56/1.04	3.77/0.78	3.78/0.81	3.78/0.84	3.75/0.91											
PE ***M/SD***	4.00/0.80	4.18/0.75	4.08/0.80	4.06/0.80	4.13/0.86											
SN ***M/SD***	2.31/1.11	2.62/0.94	2.65/1.07	2.68/1.06	3.00/1.13											
ITU ***M/SD***	3.45/1.26	3.81/1.07	3.78/1.17	3.71/1.11	3.94/1.11											

Notes. PU = Perceived Usefulness, PEOU = Perceived Ease of Use, PE = Perceived Enjoyment, SN = Subjective Norms, ITU = Intention to Use, *M* = Mean, *SD* = Standard deviation

Supplementary Material 2. Text read by the participants before completing the questionnaire.

The virtual reality headset would allow you to be immersed in a virtual environment (see photos). You could then train in your favorite sport by being exposed to perfectly controlled situations. The virtual reality training modes would be adapted to the specificities of each sport, to the problems encountered, to your needs, and to your performance objectives.

You could for example:
- Carry out tasks that will allow you to improve your performance in specific areas (perception, decision making, action control, reaction time, etc.),
- Compete against a virtual opponent or cooperate with a virtual partner,
- Benefit from real-time or delayed feedback on the relevance of your choices and actions,
- Watch techniques performed by experts, controlling the viewing angle yourself and being totally immersed in the action, to improve your own technique.

Of course, training with the virtual reality headset is not intended to replace real training. In addition to your regular training, each virtual reality protocol would allow you to work on specific aspects to improve your performance in your favorite sport.

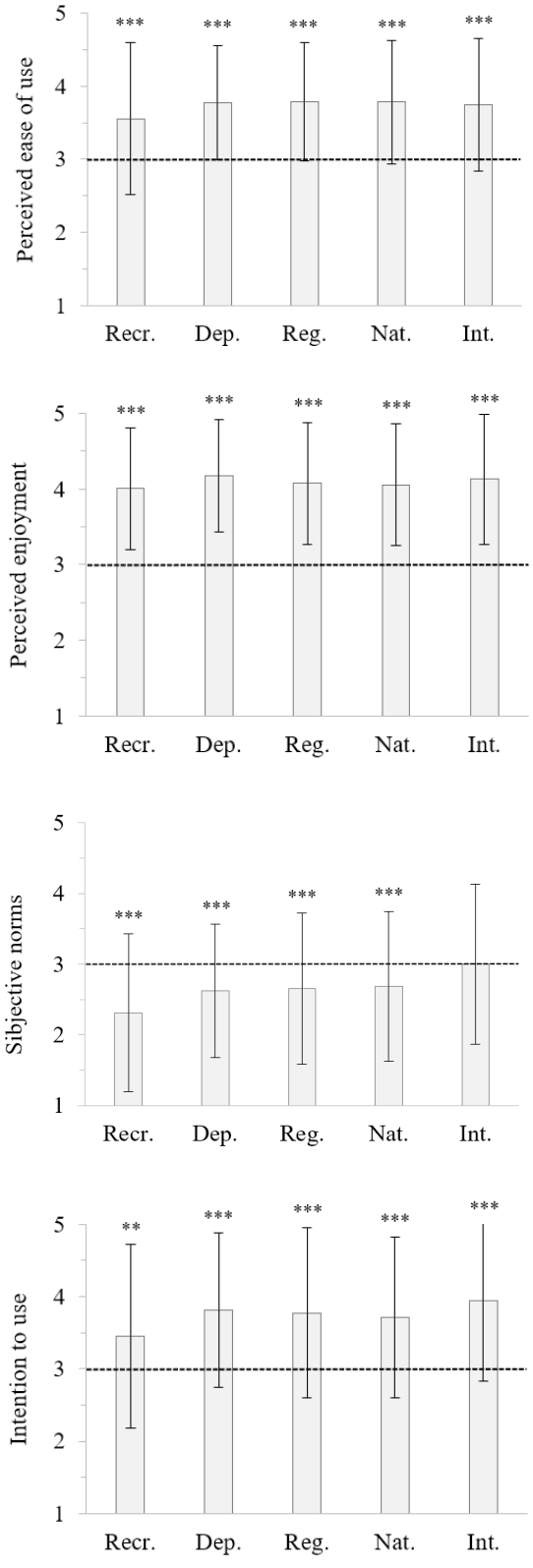
Supplementary Material 3. Results of the one-sample *t* tests comparing scores of TAM variables with the mean of the scales.

		Perceived usefulness			Perceived ease of use			Perceived enjoyment			Subjective norms			Intention to use		
	df	**t**	***p***	**Cohen's *d***	**t**	***p***	**Cohen's *d***	**t**	***p***	**Cohen's *d***	**t**	***p***	**Cohen's *d***	**t**	***p***	**Cohen's *d***
Sports																
Athletics	143	1.616	.108	2.939	10.313	< .001	4.418	15.152	< .001	5.042	-5.393	< .001	5.957	5.957	< .001	3.101
Badminton	50	4.798	< .001	4.015	8.883	< .001	5.381	11.754	< .001	6.038	-3.623	< .001	2.917	6.747	< .001	3.936
Basketball	87	5.858	< .001	3.706	11.484	< .001	5.012	20.460	< .001	7.061	-3.227	.002	2.327	8.595	< .001	3.604
Boxing	29	2.023	.052	2.977	3.681	< .001	3.421	6.448	< .001	4.558	-1.932	.063	2.448	3.058	.005	2.913
Cycling	23	.673	.507	2.776	5.834	< .001	5.148	6.088	< .001	4.557	-4.405	< .001	2.392	1.370	.184	2.797
Fencing	28	2.098	.045	2.727	4.833	< .001	4.292	7.212	< .001	4.637	.870	.392	2.641	5.845	< .001	3.947
Football	137	5.494	< .001	3.224	11.075	< .001	4.939	16.059	< .001	5.279	-3.362	.001	2.726	8.438	< .001	3.455
Gymnastics	44	.218	.829	2.952	5.657	< .001	4.597	13.562	< .001	7.668	-2.461	.018	2.665	4.047	< .001	3.444
Handball	116	6.585	< .001	3.740	12.210	< .001	5.389	16.776	< .001	5.449	-3.703	< .001	2.687	9.795	< .001	3.849
Judo	38	2.146	.038	3.164	3.071	.004	3.520	8.943	< .001	5.453	-1.686	.100	2.517	4.057	< .001	3.332
Riding	26	1.399	.174	2.692	7.612	< .001	5.465	7.887	< .001	5.360	-.378	.709	2.136	2.456	.021	2.681
Rugby	66	5.525	< .001	3.964	7.254	< .001	4.473	10.080	< .001	4.718	-1.866	.067	2.467	5.412	< .001	3.284
Swimming	29	.000	1.000	2.279	3.426	.002	3.812	4.570	< .001	3.879	-2.424	.022	1.996	1.231	.228	2.473
Table tennis	25	1.493	.148	3.444	5.847	< .001	5.036	5.330	< .001	4.928	- .132	.896	3.009	2.857	.008	3.292
Tennis	68	3.795	< .001	3.345	8.930	< .001	4.684	12.610	< .001	5.200	-2.370	.021	2.718	8.285	< .001	4.094
Triathlon	39	-1.170	.249	2.678	3.406	.002	4.000	6.568	< .001	4.668	-4.306	< .001	2.462	1.948	.059	2.667
Volleyball	43	2.997	.005	3.433	5.784	< .001	4.225	7.955	< .001	4.691	-1.922	.061	2.509	4.254	< .001	3.083
Sport level																
Recreational	74	1.184	.240	2.754	4.625	< .001	3.418	10.839	< .001	4.990	-5.355	< .001	2.074	3.104	.003	2.731
Departmental	206	6.098	< .001	3.300	14.199	< .001	4.825	22.673	< .001	5.598	-5.832	< .001	2.781	10.959	< .001	3.577
Regional	447	7.674	< .001	3.163	20.398	< .001	4.668	28.372	< .001	5.076	-6.856	< .001	2.485	13.973	< .001	3.215
National	348	7.061	< .001	3.267	17.397	< .001	4.498	24.701	< .001	5.070	-5.647	< .001	2.532	11.922	< .001	3.340
International	82	4.499	< .001	3.257	7.515	< .001	4.138	10.001	< .001	4.819	- .032	.974	2.650	7.728	< .001	3.544

Notes. For the Student t-test, effect size is given by Cohen's *d* and the alternative hypothesis specifies that the mean is different from 3 (i.e., mean of the scale).

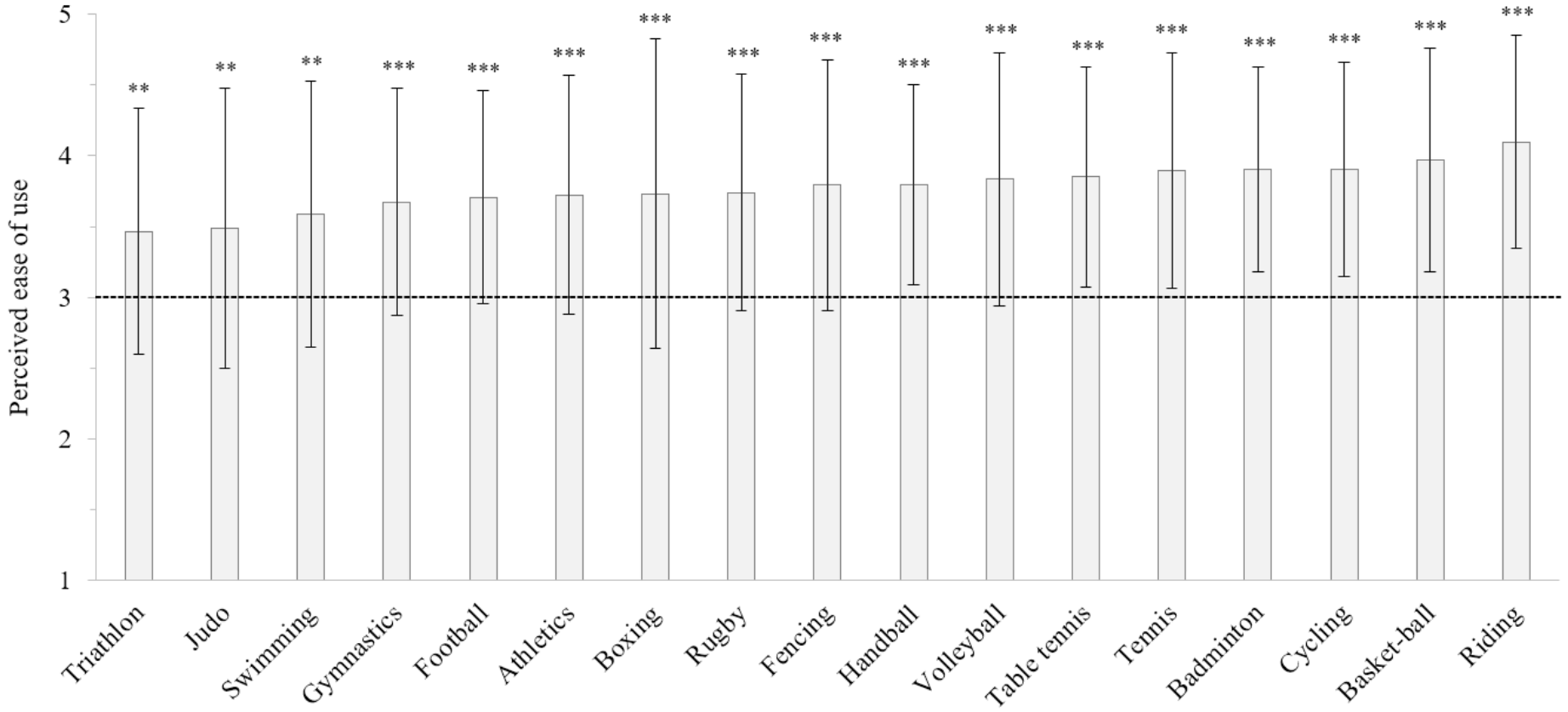
Supplementary Material 4. Perceived ease of use, perceived enjoyment, subjective norms, and intention to use according to sport level.

Note. Recr. = Recreational, Dep. = Departmental, Reg. = Regional, Nat. = National, Int. = International. Dotted lines represent the mean of the scale. **$p < .01$, ***$p < .001$. After applying the Holm-Bonferroni correction, all the results remain statistically significant.



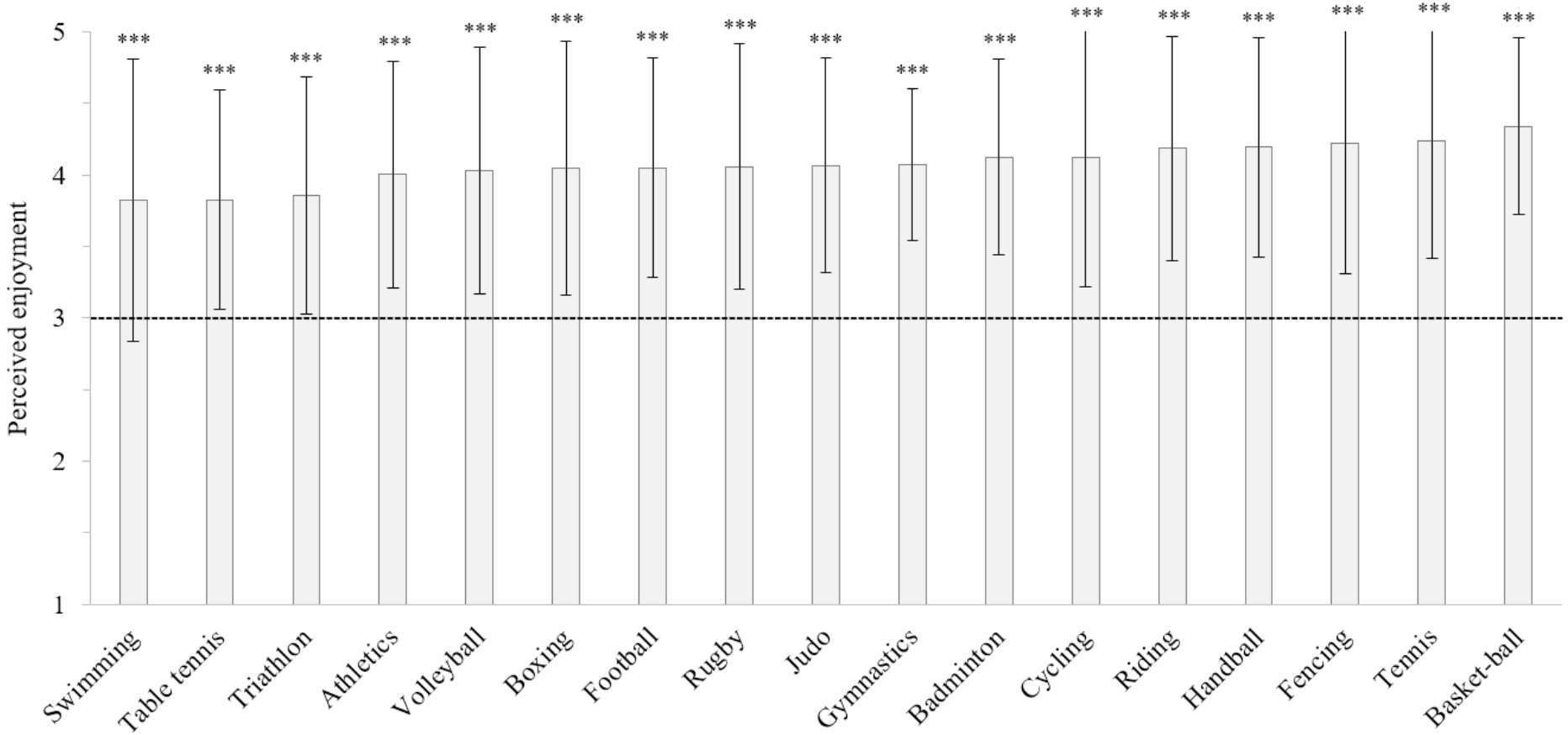
Supplementary Material 5. Perceived ease of use according to sport.

Note. *$p < .05$, **$p < .01$, ***$p < .001$. After applying the Holm-Bonferroni correction, all the results remain statistically significant, except for Judo.



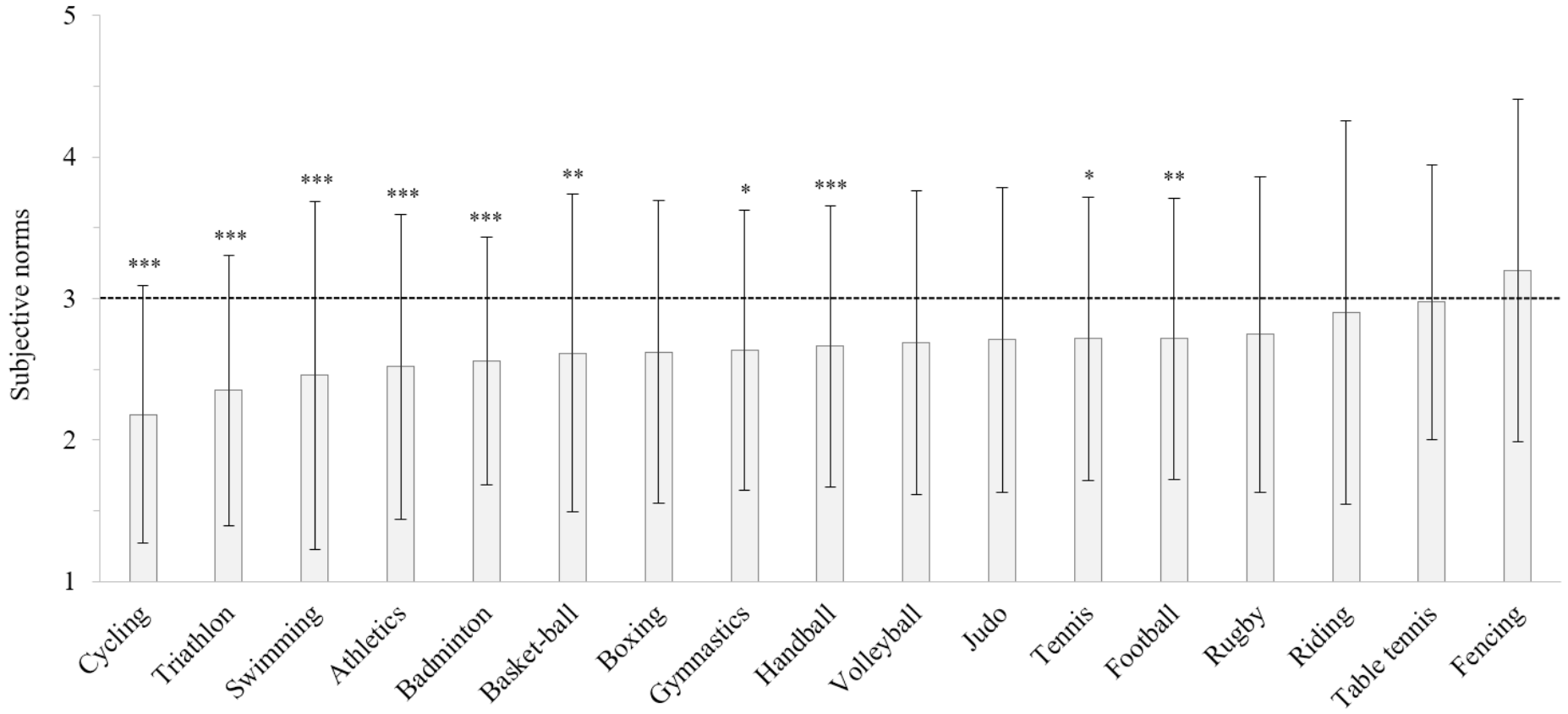
Supplementary Material 6. Perceived enjoyment according to sport.

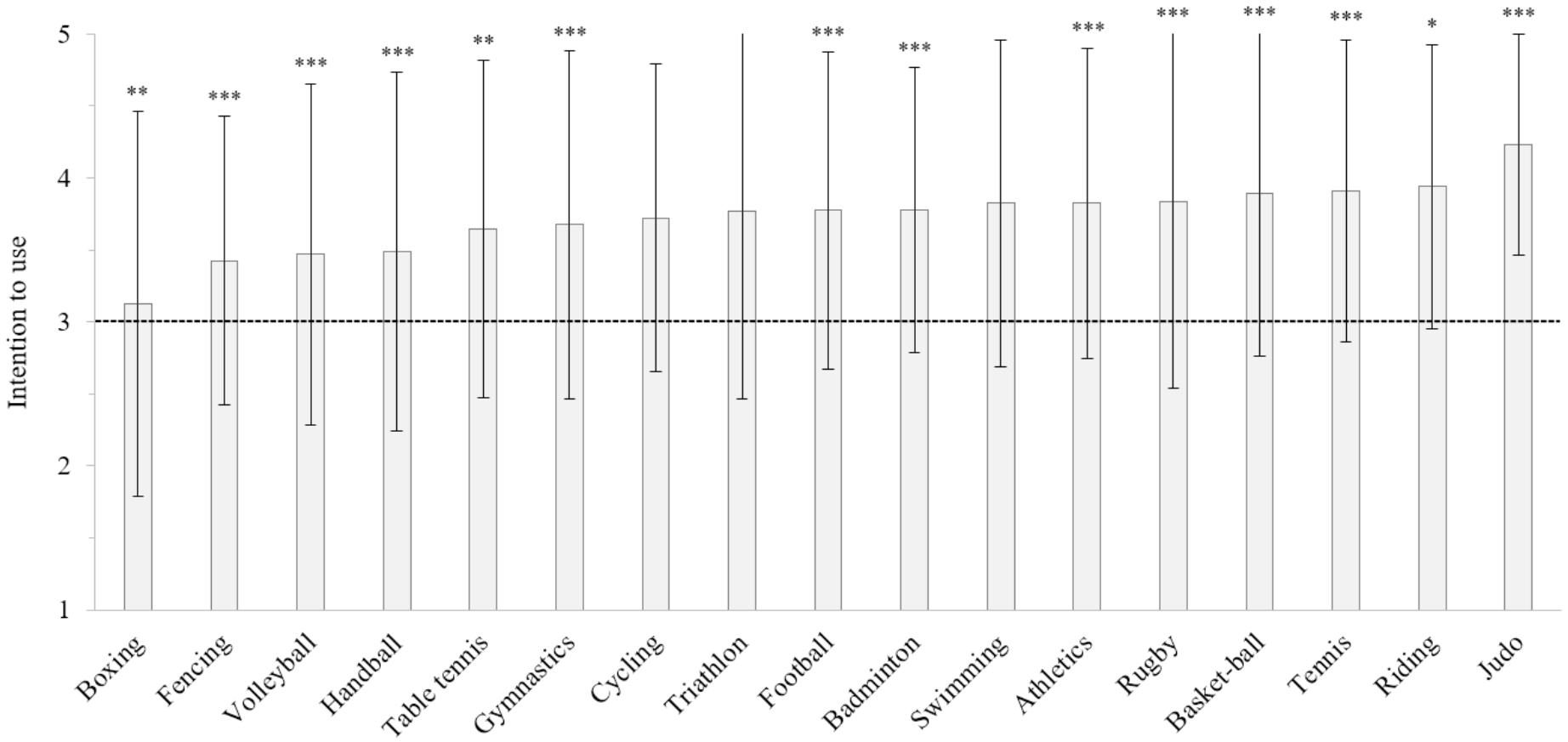
Note. *$p < .05$, **$p < .01$, ***$p < .001$. After applying the Holm-Bonferroni correction, all the results remain statistically significant.



Supplementary Material 7. Subjective norms according to sport.

Note. *$p < .05$, **$p < .01$, ***$p < .001$. After applying the Holm-Bonferroni correction, all the results remain statistically significant, except for Swimming, Tennis, and Gymnastics.



Supplementary Material 8. Intention to use according to sport.

Note. *$p < .05$, **$p < .01$, ***$p < .001$. After applying the Holm-Bonferroni correction, all the results remain statistically significant, except for Riding and Table tennis.