Exploring the adoption of mixed-reality sport platforms: A qualitative study on ZWIFT

Daniel Westmattelmann  
*University of Muenster*, daniel.westmattelmann@wiwi.uni-muenster.de

Jan-Gerrit Grotenhermen  
*University of Muenster*, jan-gerrit.grotenhermen@wiwi.uni-muenster.de

Benedikt Stoffers  
*Westfälische Wilhelms-Universität Münster*, benedikt.stoffers@wiwi.uni-muenster.de

Gerhard Schewe  
*University of Muenster*, gerhard.schewe@wiwi.uni-muenster.de

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Recommended Citation
Westmattelmann, Daniel; Grotenhermen, Jan-Gerrit; Stoffers, Benedikt; and Schewe, Gerhard, "Exploring the adoption of mixed-reality sport platforms: A qualitative study on ZWIFT" (2021). *ECIS 2021 Research Papers*. 48.
https://aisel.aisnet.org/ecis2021_rp/48

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EXPLORING THE ADOPTION OF MIXED-REALITY SPORT PLATFORMS: A QUALITATIVE STUDY ON ZWIFT

Research Paper

Daniel Westmattelmann, WWU Münster, Münster, Germany, d.west@wwu.de
Jan-Gerrit Grotenhermen, WWU Münster, Münster, Germany, jan.gerrit@wwu.de
Benedikt Stoffers, WWU Münster, Münster, Germany, benedikt.stoffers@wwu.de
Gerhard Schewe, WWU Münster, Münster, Germany, gerhard.schewe@wiwi.uni-muenster.de

Abstract

A novel type of application is presently advancing the digitalisation of sports by transferring physical performance into a virtual world, enabling users to compete and exercise together online. Nevertheless, mass adoption remains a significant challenge. We focus on the running and cycling application ZWIFT, which has received considerable attention as an exemplary mixed-reality sport (MRS) platform. To illuminate adoption factors, we conducted interviews with 22 (non)users of ZWIFT (including professional cyclists), and apply qualitative content analysis based on the multi-level framework of technology acceptance and use. We refine the UTAUT2 model and define individual-level (e.g., realism, sports identification, task purpose) and higher-level (e.g., weather, values of sport, cheating) context factors and new outcome phenomena (e.g., social network size). Our findings advance the literature on the acceptance of mixed-reality applications in the context of sports, and provide a foundation for further research. Moreover, guidelines for fostering MRS adoption are provided.

Keywords: Technology adoption, Mixed-reality, Virtual interaction, Virtual sports, Content analysis.

1 Introduction

The digitalisation of sports has dramatically accelerated in recent years. Recreational athletes are increasingly adopting applications to track their progress and help motivate themselves. Similarly, at the professional level, performance measurement and analysis are becoming more important to optimise competitive success (Gabbett et al., 2017), and mixed-reality (MR) technologies have been applied to improve training (Neumann et al., 2018; Vignais et al., 2015). As such, this phenomenon affects all levels of athletes and all aspects of sports (Chen, 2009; Tu et al., 2019; Xiao et al., 2017).

The emergence of applications such as the running and cycling platform ZWIFT (Bromley, 2020) is a recent development in the progressive digitalisation of sports. Despite similarities with so-called exercise games, they represent a new approach to physical sports, mediated through a virtual sphere. These novel applications show great promise for digitalising sports, as they provide varying use cases, are suitable for conducting serious competition, and have been shown to attract considerable attention (Westmattelmann et al., 2020). For example, the International Cycling Union (UCI) established virtual races in professional cycling and hosted the first official 'UCI Cycling Esports World Championships' in December 2020 on ZWIFT (UCI, 2020). Beyond that, the boundaries between real and virtual events have progressively blurred since the first stage of the real-world Giro d'Italia 2019, which was simultaneously held on ZWIFT and allowed recreational athletes to compare their performances to those
of professional cyclists in real time (Martin and Maxwell, 2020). Other indoor cycling applications such as Peloton involve less physical interaction and can therefore be classified as MR only to a limited extent. However, MR sports applications have been developed for running, alpine skiing, and golfing, although they may not have yet reached the top level in their respective sports (Golf Digest, 2020; Ko et al., 2020). For each of these applications, sport-specific context factors may prove to be significant (Pelletier et al., 1995, Xiao et al., 2017). Moreover, such applications may attract a variety of potential users with diverse characteristics, athletic backgrounds, and use purposes (James et al., 2019; Parker et al., 2021). As is the case for most novel technologies, adoption of such systems has been shown to build on individuals’ perceptions and motivations (Venkatesh et al., 2003; 2012).

Despite the increasing relevance of virtual sports and related applications, factors influencing their use and adoption have not yet been investigated. Studies at the intersection of MR and sports have thus far been technically or performance-oriented (for an overview see Neumann et al., 2018; Vignais et al., 2015), focused only on users’ perceptions, and have not considered technology adoption. Westmattelmann et al. (2020) focused on the perceptions and performance of competitions enabled by ZWIFT, but not on acceptance of the technology. Their sample comprised only professional cyclists using the application, and thus the generalisability of the identified aspects to recreational users and non-users was limited. Conversely, existing models of technology acceptance (e.g., Venkatesh et al., 2003; 2012) lack contextualisation and applicability concerning such complex systems, especially considering their MR (Muetterlein and Hess, 2017), physical (Speicher et al., 2019), and sports-related (Xiao et al., 2017) components. Through the interplay of these components new aspects of MR sport applications may emerge that have not yet been identified to be relevant in any of the related domains. Consequently, and in accordance with Laumer et al. (2019), we identify a strong need to adapt established theoretical considerations to this novel technology and its specific application context. Against this background, this study addresses the following research question.

What factors could drive or inhibit the adoption of this novel type of mixed-reality application among recreational and professional athletes?

To answer the research question, we first provide literature reviews on MR technologies, sports digitalisation, and antecedents of their acceptance. Based on a taxonomy developed by Speicher et al. (2019), we classify sports platforms such as ZWIFT as MR applications, and more specifically as mixed-reality sports (MRS) platforms. Further, we build on the multi-level framework of technology acceptance and use (Venkatesh et al., 2016) to analyse 22 semi-structured interviews with 11 professional and 11 non-professional cyclists (12 users and 10 non-users) considering the application ZWIFT by performing a qualitative content analysis (Mayring, 2014). Thus, we contribute to the literature on MR applications and technology adoption (in sports) by discovering, defining, and classifying novel antecedents driving the adoption of MRS platforms related to foundations in sports, gaming, or social networks. Moreover, we highlight the approach followed in this study as suitable for systematically identifying context-specific technology adoption determinants. Finally, we derive wide-ranging managerial implications regarding the design of such applications to foster their adoption.

2 Background and Theoretical Foundation

2.1 Mixed-reality technologies and their adoption

First, it is important to establish a common understanding of MR applications. According to the reality virtuality continuum (RVC), MR marks the area between two poles representing the Real Environment and a Virtual Environment (Milgram et al., 1995; Milgram and Kishino, 1994). The former represents a purely real world, and is displayed through screens (e.g., video conferencing tools; Park et al., 2014; Waizenegger et al., 2020), while the latter is a completely computer-generated visual environment, also referred to as Virtual Reality (VR; Flavián et al., 2019; e.g., computer games, such as Second Life or World of Warcraft; Billieux et al., 2013; Penfold, 2009). Depending on the extent of computer-generated stimuli, an MR space between these two poles is denoted as Augmented Reality (AR), meaning that the real world is augmented by digital content, or Augmented Virtuality (AV), which is a mainly computer-
generated virtuality augmented by real-world content (Flavián et al., 2019; Milgram and Kishino, 1994). To establish a clearer understanding of MR and take stimuli beyond audio-visual ones into account, Speicher et al. (2019) derived an MR taxonomy of seven dimensions (see Table 1). The authors proposed categorising MR applications into six different types, such as MR as a type of collaboration or MR as an alignment of environments. Accordingly, the understanding of MR depends on the context of an application (Speicher et al., 2019), which highlights the relevance of contextualising research designs.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Environments</td>
<td>The number of required virtual and real environments for a MR application to work</td>
</tr>
<tr>
<td>No. of Users</td>
<td>The necessary number of concurrent users for an MR application to function properly</td>
</tr>
<tr>
<td>Level of Immersion</td>
<td>The user perception of feeling immersed in a virtual world based on its digital content</td>
</tr>
<tr>
<td>Level of Virtuality</td>
<td>The extent of digital content users perceive (corresponds to the RVC)</td>
</tr>
<tr>
<td>Degree of Interaction</td>
<td>The ability to implicitly and explicitly interact with the virtual world (and other users)</td>
</tr>
<tr>
<td>Input</td>
<td>The user input might consider anything sensors can track (e.g., motion or location)</td>
</tr>
<tr>
<td>Output</td>
<td>The system output to the user(s) can consist of audio-visual, haptic and other stimuli</td>
</tr>
</tbody>
</table>

Table 1. The dimensions of MR according to Speicher et al. (2019). No. = Number.

Focusing on the adoption of an MR application, we build on the literature on the acceptance of related technologies exhibiting varying degrees of virtuality. Broadly considering the adoption of VR applications, Muetterlein and Hess (2017) proposed that content quality, distraction, immersion, excitement, interactivity, isolation, and presence might serve as technology-specific antecedents of usage intention. Specifically designed for educational MR applications, Bacca Acosta et al. (2014) summarised 32 studies and identified learning gains, facilitated interaction, collaboration, low costs, an increased experience, and situated learning possibilities as major advantages, and thus, potential drivers of AR learning application usage. For medical AR and VR learning systems, studies have found engagement, imagination, immersion, perceived ease of use, and perceived usefulness to be associated with (intention to) use (Huang et al., 2016; Moro et al., 2017). Focusing on AR and VR gaming (e.g., Pokémon Go), studies identified autonomy, competence, concentration, ease of use, enjoyment, flow, immersion, physical activity, (physical) security risks, socialising, and social norms as factors influencing consumer attitudes and usage intentions (Kosa et al., 2020; Rauschnabel et al., 2017). In e-commerce, anthropomorphism (of systems), confidence, convenience, discomfort, product usage barriers, and potential side effects affected attitudes toward using AR systems (van Esch et al., 2019). Studies emphasising VR or MR hardware devices (e.g., smart glasses) found that age, benefits (hedonic, social, symbolic, and utilitarian), curiosity, enjoyment, past use, perceived ease of use, perceived usefulness, willingness to pay, privacy concerns, and social interactions may serve as antecedents of usage intention (Lee et al., 2019; Manis and Choi, 2019; Rauschnabel, 2018; Rauschnabel et al., 2018). Across domains, these studies have mainly built on established core concepts of technology acceptance research (Venkatesh et al., 2003; 2012) and occasionally enriched them with technology-specific (e.g., immersion) or individual (e.g., competence) factors, which underlines that not only the understanding of MR (Speicher et al., 2019), but also its adoption is context-specific. Thus, no adequately specific adoption framework for MR technologies exists in prior literature, and as yet research in this area has not been organised by a cohesive framework, studies focus on audio-visual stimuli instead.

### 2.2 Sports digitalisation and its adoption

In this section, we discuss current developments in the field of sports digitisation. This complex phenomenon, affects organisational (e.g., stakeholder interactions), technological (e.g. specific equipment), symbolic (e.g. values of sport), and educational (e.g., skill training) aspects (Xiao et al., 2017). Numerous motives for practicing sports might affect the use of related digital applications. In this regard, the Sport Motivation Scale (SMS; Pelletier et al., 1995; 2013) differentiates between intrinsic (e.g., exploration, learning, flow, stimulation) and extrinsic (e.g., rewards, appreciation, external pressure) motivations. Thus, it is necessary to illuminate the effects of this wide-ranging field on the adoption of novel technologies in sports. Currently, technologies are mainly used to broadcast,
track, analyse, or improve the performance of athletes (Davenport, 2014; Xiao et al., 2017). In particular, fitness applications for users of any activity level have attracted considerable attention (James et al., 2019). Users of such applications exercise significantly more than non-users (Chen and Pu 2014; Parker et al., 2021). Studies focusing on why these applications are used have found that social features affected usage and physical activity more strongly than features focusing purely on enjoyment (Tu et al., 2019). Specific intrinsic (e.g., competence, enjoyment), body-focused (e.g., appearance, fitness), and social extrinsic exercise goals (James et al., 2019), as well as community, dependency, self-tracking, and related data (Rivers, 2020) were shown to relate to the usage (of specific features) in accordance with the affordance theory. In this regard, an IS allows a user to perform activities, that is, the features of fitness applications are used according to individual exercise goals (James et al., 2019; Leonardi, 2011). These affordances represent only a subset of potential antecedents of usage intention. More strikingly, these studies either did not examine MR technologies or neglected their peculiarities (e.g., realism, comparability to traditional sports, cheating; Parker et al., 2021).

Regarding the application of MR in sports, virtual information overlays augment broadcasts or videos of real-world sports, allowing a more detailed analysis of the action (Fischer et al., 2019). In addition, MR simulations have been applied to train athletes’ reactions by integrating virtual competitors or balls into training environments (Craig et al., 2009; Vignais et al., 2015). Focusing on VR exercising technologies that did not solely rely on audio-visual stimuli, Neumann et al. (2018) reviewed the then-existing literature and identified immersion, focus, feedback, task autonomy, competitiveness, and virtual telepresence (of others) as determinants of users’ physical performance. Because all studies considered in the review were conducted in laboratory settings, none focused on technology adoption. A recent study on ZWIFT evaluated athletes’ perceptions of virtual cycling competitions in accordance with Xiao et al.’s (2017) framework, finding that athletes were mostly satisfied, despite expressing concerns regarding cheating and the degree of gamification (Westmattelmann et al., 2020). However, the sample comprised only professional cyclists who used ZWIFT, and thus the mentioned aspects might not be relevant for casual or non-users. Taken together, studies at the intersection of MR and sports have thus far been technically or performance-oriented and have not focused on technology adoption.

2.3 Multi-level Framework of technology acceptance and use

We refer to the multi-level framework of technology acceptance and use developed by Venkatesh et al. (2016), which extended the broadly applicable but generic Unified Theory of Acceptance and Use of Technology (UTAUT2; Venkatesh et al., 2012) with context-specific attributes from three domains (see Figure 1). Thereby, our approach is inspired by recent work utilising the UTAUT2 as a basis for exploratory interview studies on the acceptance of healthcare chatbots (Laumer et al., 2019; Mesbah and Pumplun, 2020). Using this multi-level framework, we apply established theoretical considerations to a specific application context that goes beyond the UTAUT2. Thus, we extend previous approaches, which is specifically necessary at the intersection of sports and MR applications, considering, for example, that the relevant facets of sports (Xiao et al., 2017), sport-specific goals/affordances (James et al., 2019), or the degree to which applications realistically resemble the associated sport (Westmattelmann et al., 2020) have not yet been included in the existing models, but might be crucial for understanding adoption. Supporting this endeavour, the multi-level framework is considered suitable to explore acceptance factors of VR applications (Muetterlein and Hess, 2017).

The UTAUT2 baseline model serves as the conceptual foundation of the multi-level framework and includes the effects of individual beliefs, facilitating conditions (i.e., “consumers' perceptions of the resources and support available” (Venkatesh et al., 2012, p. 159)), and habits (i.e., automated behaviour because of learning) on behavioural intention. Regarding individual beliefs, performance expectancy represents the expected utilitarian value of a technology, while hedonic motivation considers the enjoyment expected. Effort expectancy considers the ease associated with use, while social influence considers the effects of social pressure. Finally, price value represents an individual’s evaluation of cost-
benefit trade-offs (Venkatesh et al., 2012). In the first of three context domains, the individual-level context factors include events (related to the time dimension: adoption, initial use, and post-adoptive use), task attributes (e.g., task types or autonomy), technology attributes (e.g., functions and features of the technology), and user attributes (e.g., user groups and their specific characteristics). The second domain contains the higher-level context factors, including environmental (related to physical conditions such as temperature), organisational (e.g., institutions or informal social entities such as user communities), and location attributes (e.g., region, culture). Lastly, the third domain considers new outcome phenomena, which refers to new consequences of behavioural intention and technology use added to the original UTAUT2, such as individual performance (Mohammadyari and Singh, 2015).

Figure 1. Multi-level framework of technology acceptance and use. Own depiction based on Venkatesh et al. (2016). Arrows represent potential moderating or direct relations.

3 ZWIFT as a Mixed-Reality Sports Platform

In the following, we introduce ZWIFT as an exemplary application enabling virtual sports and categorise it based on the presented MR taxonomy (Speicher et al., 2019). ZWIFT allows the recording of real-world athletic performances with specific hardware using motion sensors, and to transfer it into a virtual world in real time, simultaneously displaying a visual representation of simulated real-world or fictional landscapes and other users. Thus, the speed and actions of a user’s avatar in the virtual world reflect the athlete's real-world physical activity and actions (for illustrations and further information regarding features of ZWIFT see Borrill, 2020; Delaney and Bromley, 2020). The necessary Number of Environments in ZWIFT is determined to be at least one real world (in which the physical action takes place) and one virtual world (in which the interaction takes place). More specifically, the real environment considers different user locations (e.g., their homes or training venues). This leads to a required Number of Users. A key feature of this application is fostering exchange between users in the form of competitions and socialising via group rides in shared virtual online spaces. In particular, the unique feature of virtually mediated physical interaction with other users requires at least two users. Furthermore, ZWIFT also provides modes in which users only interact with the virtual environment without other users, such as structured training programs.

The mentioned Degree of Interaction as well as the strongly related dimensions of Input and Output appear to be of major relevance in the context of this application. The primary hardware component allowing the abovementioned mechanisms is an interactive so-called smarttrainer, to which a standard outdoor bicycle is attached. The topography of the virtual courses, which resemble locations such as London or New York City, are simulated along with slipstream effects of other users by continuous adjustments of the resistance of the smarttrainer, to allow athletes to interact with the virtual world (Delaney and Bromley, 2020). Therefore, the user Input consists of physical activity, as measured by watts per kilogram of body weight, while the Output comprises a visual representation of a virtual world on a display and haptic feedback provided via the smarttrainer. By these means, a virtually mediated physical interaction with a virtual world (e.g., through power-ups or track gradients) and other users (slipstream riding) is enabled. Gamification elements such as power-ups increase the speed of a user’s avatar or rendering it invisible for a few seconds (Delaney and Bromley, 2020).

The Level of Virtuality regarding visual stimuli is high, as the simulation displays a purely virtual environment (Milgram and Kishino, 1994). Relatedly, we assume the Level of Immersion to be high.
because athletes were shown to perceive virtual competitions as immersive (Westmattelmann et al., 2020). Using one’s original bike creates a strong sense of realistically riding a bike, while the high degree of physical activity involved requires a clear focus on the task. The application also features virtual representations of real-world equipment, such as bikes or jerseys of renowned brands.

In summary, ZWIFT combines at least two environments, connects users and orchestrates their interactions, provides high levels of immersion, virtualisation, and interaction, and allows physical power input while providing visual and haptic output. According to Speicher et al. (2019), ZWIFT as an MR application can be categorised as a form of collaboration. Because other stakeholders (coaches or sponsors) are also present in the application alongside the physically active (potential) users who are the focus of this study, ZWIFT fulfils the criteria of a multi-sided platform and is referred to as a mixed-reality sport (MRS) platform in accordance with Westmattelmann et al. (2020). In conclusion, the adoption of this novel type of application deserves further emphasis, as it differs significantly from exercise games (applications tracking and fostering physical activity through gamification and social exchange; Chen and Pu, 2014; Hamari and Koivisto, 2015a; Tu et al., 2019), which lack the ability to mediate physical interactions with other users, thereby enabling more serious competition. Compared to eSports (professionalised and institutionalised gaming), the necessary skills for competing in ZWIFT are not limited to operating handheld controllers, and instead require athletic performance comparable to real-world sports (e.g., FIFA series; Funk et al., 2018; Westmattelmann et al., 2020).

4 Methodology

4.1 Interview study design, participant recruiting and sample

We chose an interview-based approach to illuminate perceptions towards ZWIFT, which is well established in the IS domain (Schultze and Avital, 2011) and supports the understanding of individual motives in a socially embedded context (Baumgart et al., 2015; Myers, 2010). Utilising an explorative study design, we applied the multi-level framework of technology acceptance and use (see Figure 1; Venkatesh et al., 2016) to examine whether the UTAUT2 baseline model (Venkatesh et al., 2012) was applicable in the context of MRS platforms and to identify individual- and higher-level contextual factors as well as new outcome phenomena in this novel context. To ensure comparability and the coverage of relevant topics across interviewees, we designed a semi-structured interview guideline derived from the multi-level framework of Venkatesh et al. (2016), incorporating the recommendations of Schultze and Avital (2011). This approach allowed open-ended responses from participants for more in-depth information and encouraged two-way communication. Regarding the time dimension of the multi-level framework, this study covers the stages of adoption, initial use, and post-adoptive use. We invited both users and non-users of ZWIFT to these interviews. This allowed us to obtain a comprehensive understanding, considering that they might substantially differ in their perceptions (Verkasalo et al., 2010). In particular, we considered that non-users might provide insights on motivators of and specifically barriers to adoption, while the factors named by users illuminate antecedents of initial and post-adoptive use, as recommended by Venkatesh et al. (2016). The questions asked of users aimed to investigate why they already were using ZWIFT (e.g., "What is your motivation for using ZWIFT?") and questions for non-users were adjusted to identify what would (de-) motivate them to use ZWIFT (e.g., "What would be necessary for you to do cycling on ZWIFT?").

We directly contacted successful German professional cyclists (defined as regularly competing riders in a professional team registered with the UCI) as well as non-professional athletes, who were recruited by contacting regional cycling clubs. During the initial contact, we ensured that the non-users had basic knowledge of ZWIFT. Finally, we interviewed 22 individuals (6 professional users, 6 non-professional users, 5 professional non-users, 5 non-professional non-users) and recorded these interviews after gaining permission (Myers and Newman, 2007). According to the propositions of Marshall et al. (2013), the number of interviews is satisfactory, specifically as we built on existing theoretical foundations. Among the professional respondents, we find a Tour de France stage winner, Olympic participants and winners of recognised one- and multi-day races. All interviews were completed between October 2019
and January 2020, before the first sporting events were cancelled due to the COVID-19 pandemic, which could have caused biased results. The interviews lasted between 8 and 57 minutes (users: mean (m) = 34 min., standard deviation (sd) = 8 min., non-users: m = 27 min., sd = 14 min.). Several non-users specifically expressed their reasons for future adoption or rejection within a relatively short time span. Furthermore, the age of respondents varied between 19 and 54 years (users: m = 30 years / non-users: m = 32 years). Six participants (27.3%) identified as female, while 16 (72.7%) identified as male. Additionally, the users of ZWIFT rode an average of 1,580 km per year on the platform.

4.2 Interview analysis

We performed a qualitative content analysis on the transcribed interviews (Krippendorff, 2009; Mayring, 2014) using the software MAXQDA. Thereby, we followed a mixed approach combining deductive coding based on categories defined by Venkatesh et al. (2016) and inductive coding, as described by Mayring (2014). This allowed us to incorporate the factors identified from the UTAUT2 baseline model (deductive) as well as to identify concrete novel factors regarding the individual- and higher-level context (inductive). The entire coding process was performed by two of the authors (Coders A and B). First, Coder A deductively coded passages in all interview transcripts, referring to the seven factors of the UTAUT2 as well as task, technology, or user attributes (individual-level context), environmental, organisational, or location attributes (higher-level context), and possible outcomes (Venkatesh et al., 2016). In a second step, Coder A concretised and contextualised the coded text segments by creating new inductive categories at a lower level of abstraction. For illustration, the statement “I have fun with it, I like to play it” was coded deductively as Hedonic Motivation, because it highlights enjoyment and playfulness (see section 2.3 for definition). The passage “Once I rode ZWIFT for more than three hours because I wanted to get the grey jersey as a reward” was coded inductively as Reward System (i.e., a technology attribute), which represents a novel category beyond the UTAUT2 (see Table 2 for definition). Further examples can be found in the results section. In this endeavour, Coder A also derived definitions for each inductive category, which he discussed with Coder B and reformulated when necessary to obtain a shared understanding (Velsberg et al., 2020). To ensure coding objectivity, Coder B then repeated the process using the complete coding scheme (deductive-inductive category system) and category definitions provided by Coder A, without knowing which text segments were identified previously. Finally, both coders jointly refined the category definitions, which are presented in the following section. To determine the reliability on text segment level, we refer to Cohen’s kappa, which accounts for corresponding coding by chance and for different value distributions in different categories (Cohen, 1960). Our coding resulted in a Cohen’s kappa value of 0.85, whereas a value of 0.7 or higher is sufficient for exploratory studies (Brennan and Prediger, 1981; Lombard et al., 2002) and a value of 0.0 would describe agreement by chance (Cohen, 1960; Shrout, 1998).

5 Results and Discussion

5.1 UTAUT2 baseline model

Participants mentioned all seven factors from the UTAUT2 model multiple times, validating its relevance in the context of MRS platforms. Nevertheless, the number of mentioning respondents varied across factors. We specifically focused on refining Performance Expectancy and Hedonic Motivation, as they represented utilitarian and hedonic benefit expectations, which are understood to be pivotal for technology usage and have been the focus of related studies (Rauschnabel, 2018; Rauschnabel et al., 2018; Venkatesh et al., 2012). Regarding Performance Expectancy (12/8, i.e., 12 users and 8 non-users mentioned the topic at least once), ZWIFT was seen as a valuable and effective extension of and complement to training on the road, as it was described as "a very good training alternative” (Pro 10). The impact of exercise applications and games on health and training benefits has been examined for fitness apps (Higgins, 2016; Parker et al., 2021; Tu et al., 2019). Respondents mentioned safety-related benefits of using ZWIFT as facets of its perceived usefulness, as using the system keeps its users away from the dangers of road traffic. In line with that, Steffen et al. (2019) emphasised that a reduction of
physical risk was associated with using VR and AR applications, highlighting that they can diminish negative aspects of the real world. Regarding Hedonic Motivation (12|7), statements considered enjoyment, variety, diversion and curiosity as feelings related to using ZWIFT (e.g., “you forget the time and have fun,” Non-Pro 10), which underlines the multifaceted character of hedonic benefits and is in line with research on video games, social networks, and exercise applications (Hamari and Koivisto, 2015b; James et al., 2019; Kwon et al., 2014; Rauniar et al., 2014; Shin and Shin, 2011; Yee, 2006). In parallel, these factors match the intrinsic motivators of the SMS, such as curiosity, flow, or excitement (Pelletier et al., 1995). Moreover, interviewees emphasised Effort Expectancy (11|7) and Facilitating Conditions (10|7). Social Influence (9|8) may be linked to relationships and interactions with significant individuals such as friends, family, and training partners, as well as institutions, such as professional teams and sponsors. Price Value (6|6) was addressed homogeneously, as the majority regards the monthly subscription fee as "Okay, I think 15€ is still acceptable" (Non-Pro 7). Still, we found that non-users explicitly balanced prices and benefits. Habit was mentioned exclusively by users (5|0), who had already adopted ZWIFT (i.e., initial and post-adoptive use stages) and may have been more conscious of their usage habits, whereas non-users were merely using their imaginations. Generally, this pattern of increased consciousness regarding users applied to most categories. These factors were identified and validated by related (exercise) gaming, social networks, and MR literature, while specific emphasis was placed on the topic of social influence (Hamari and Koivisto, 2015b; James et al., 2019; Lee et al., 2019; Muetterlein and Hess, 2017; Ngai et al., 2015; Tu et al., 2019). Social pressure was also emphasised as an extrinsic factor in SMS (Pelletier et al., 1995).

5.2 Individual-level context factors

Beyond the baseline model, we identified individual-level and higher-level context factors and provide examples relating them to associated research, having derived their respective definitions (Tables 2, 3, and 4), which summarise the coded segments in categories and may serve as a starting point for further research. Table 2 depicts the individual-level context factors (task, technology, and user attributes). All respondents mentioned that the platform could be used to pursue specific tasks or use purposes. Competition (10|7); “I find it very appealing that you can participate in different competitions there every day,” Non-Pro 8) and Social Interaction (10|6; “to connect with others and then ride with friends, although everyone is then still at home,” Non-Pro 6) were by far the most frequently mentioned ones. Socially oriented motives, such as socialising and building social capital, have been identified as drivers of IS usage (James et al., 2019; Kaur et al., 2016; Lee et al., 2019; Liu et al., 2017; Yee, 2006). Moreover, especially concerning multiplayer games and eSports, the desire to challenge and overcome other players has been noted as a relevant task type (Funk et al., 2018; Seo and Jung, 2016; Yee, 2006). In contrast to exercise apps, in which competition is limited to comparing tracked performance data and leaderboards (James et al., 2019; Rivers, 2020), MRS platforms enable interactive real-time competition, which is commonly considered to be a major advancement (Westmattelmann et al., 2020). These purposes are followed by Training (7|1) and Gaming (3|2). The task purpose of improving skills through app use is in line with exercise gaming literature (Chen and Pu, 2014; Hamari and Keronen, 2017; Higgins, 2016; Parker et al., 2021). Moreover, the pursuit of gaming-related enjoyment (e.g., chasing achievements) can serve as a task purpose by itself (Hamari and Keronen, 2017; Hamari and Koivisto, 2015b). A novel use purpose or goal considers the opportunity to be scouted by professional teams (2|0). MRS platforms allow users to publish their performance data not only for social motives (Rivers, 2020), but also to catch the attention of teams and engage with them: "[Athlete] just won this ZWIFT competition and therefore got a professional contract with [team]" (Pro 4).

All but two interviewees highlighted that their perceptions of specific technological attributes or features that might foster or hinder their intention to use the application. The perceived degree of Realism (9|5) and technical features enabling this perception, such as the simulation of the course gradient and slipstream riding, were the most frequently mentioned. A Tour de France stage winner elaborated on the realistic replication of routes from real-world bike races: "Alpe d'Huez was completely replicated. Well, I have ridden it a few times in real life and then this Alpe du ZWIFT, it is really one to one." (Pro 10). This quote highlights the simulational realism of ZWIFT, which is driven by the MR
technology and allows the virtual recreation of aspects of the real world (Ribbens et al., 2016; Steffen et al., 2019). Furthermore, the present work supports the understanding of realism as a multidimensional concept, including for example audio-visual, active, simulational and social realism (Lin and Peng, 2015; Ribbens et al., 2016). Moreover, it strengthens the perceived active realism and interactivity by redesigning interactions and blurring the lines between the real and virtual worlds (Bastos et al., 2018; Muetterlein and Hess, 2017; Xiao et al., 2017). The results support the high relevance of perceived realism as a distinctive feature of MRS platforms in comparison to existing fitness apps (e.g., James et al., 2019). The Reward System and virtual items were incentives for seven users and three non-users: "I like this gaming character. [...] I'm someone who tortures himself for a virtual jersey" (Non-Pro 10). This example illustrates that reward systems – as a facet of gamification – can serve as an external mechanism to keep players excited, to nudge them to perform certain tasks, as well as to continue using the application (Hamari and Koivisto, 2015b; Pelletier et al., 1995; Wang and Sun, 2011). Because large amounts of data are recorded, Performance Measurement (4/4) enables analysing performances and comparisons between athletes: "I am motivated [...] above all by statistics. But also regarding data of other riders" (Non-Pro 5). Relatedly, ZWIFT offers Training Management (3/1) by providing structured workouts. Both factors are specific to the context of sports. For example, the digitalisation of training and competitions opens up broader tracking and analysis possibilities, which might relate to usage intention (James et al., 2019; Rivers, 2020; Xiao et al., 2017). In line with research that underlines the suitability of virtual solutions to create tailored training situations (Vignais et al., 2015; Xiao et al., 2017), MRS platforms enable advanced training management because they allow to depict the real world (Steffen et al., 2019). Nevertheless, athletes complained that the Reliability (4/0) of the recorded data was not always ensured due to measurement errors in the smatrtrainer, which might hinder use intention. The reliability of IS has commonly been considered as one of the three facets constituting trust in technology (Lankton et al., 2015; McKnight et al., 2011). Notably, the remaining two facets (functionality and helpfulness; McKnight et al., 2011) have not been mentioned in the context of MRS platforms. Due to the recording of personal data, Data Security (3/1) was also mentioned. Privacy issues are commonly regarded as antecedents of IS use (Bansal et al., 2015; Malhotra et al., 2004) and have been proven to be determinants of social network adoption (Kwon et al., 2014; Shin and Shin, 2011).

**User-specific attributes** were mentioned 13 times (10/3). Nine respondents (all users) emphasised the necessary Computer Skills regarding the virtual (e.g., registration of an account) and physical (e.g., linking the smatrtrainer to the bike and the Internet) setup of ZWIFT. This is a concretisation of existing research on the general relevance of skills and knowledge for operating novel applications (Kaur et al., 2016; Kosa et al., 2020; Park et al., 2014; van Esch et al., 2019; Wang and Wang, 2008). Kim and Ross (2006) stated that Identification with the original sport is one of the most significant drivers of using video games related to a given discipline. Accordingly, four users and three non-users mentioned this topic, stating for example, “I can't imagine doing any other sport than cycling as a virtual sport, because [...] for me virtual sport would only be a stopgap if I can't do the real sport” (Pro 7).

<table>
<thead>
<tr>
<th>(Sub-) category</th>
<th>Definition</th>
<th>Conceptualisation</th>
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</thead>
<tbody>
<tr>
<td><strong>Task attributes (12/10)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competition (10/7)</td>
<td>The chance of participating in competitions and comparing skills with other users</td>
<td></td>
</tr>
<tr>
<td>Social Interaction (10/6)</td>
<td>Interaction possibilities with other users during the use of ZWIFT</td>
<td></td>
</tr>
<tr>
<td>Training (7/1)</td>
<td>The perceived suitability of ZWIFT (as a supplement/substitute) for training</td>
<td></td>
</tr>
<tr>
<td>Gaming (3/2)</td>
<td>Fun and enjoyment through interaction in the virtual world (e.g., with Power-ups)</td>
<td></td>
</tr>
<tr>
<td>Data-driven scouting (2/0)</td>
<td>The opportunity of catching the attention of profession teams</td>
<td></td>
</tr>
<tr>
<td><strong>Technology attributes (12/8)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Realism (9/5)</td>
<td>The perception of stimuli (audio-visual and physical/haptic) generated by the application as realistically</td>
<td></td>
</tr>
<tr>
<td>Reward System (7/3)</td>
<td>Availability of virtual rewards (e.g., rankings, experience points, achievements)</td>
<td></td>
</tr>
<tr>
<td>Performance Measurement (4/4)</td>
<td>Recording, processing and analysis possibilities of performance data (own or by other users)</td>
<td></td>
</tr>
<tr>
<td>Data Security (3/1)</td>
<td>The perceived data security (e.g., secrecy of personal data, privacy policy)</td>
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</tr>
</tbody>
</table>
5.3 Higher-level contextual factors

Regarding higher-level contextual factors (Table 3), all respondents underlined the relevance of environmental factors. Thereby, all respondents mentioned Weather conditions (“indoor sport allows me to pursue my hobby in all weathers,” Non-Pro 10) and the Season (“Especially in winter […] when it rains or when it's simply already dark,” Pro 10) as an antecedent of usage. Three users mentioned that in areas with a high degree of Urbanisation, the use of ZWIFT might be preferred over cycling in a city with a large amount of traffic. In addition, the Topography (1|1) of a residential area was linked to an increased use of ZWIFT: “[my teammate] lives in Andorra. And there […] it is difficult to train because of the altitude.” (Pro 7). Taken together, under circumstances that make outdoor cycling in the real world less favourable, using ZWIFT was shown to be a suitable alternative. This also applies to the COVID-19 pandemic, which created a situation in which group rides and races could not take place in the real world. In this regard, Westmattelmann et al. (2020) emphasised participants’ positive attitudes toward virtual modes of mutual training and competition. More generally, under unfavourable environmental conditions, MR applications might be preferably used to virtually simulate the physical world, while excluding unfavourable aspects (Steffen et al., 2019).

Organisational attributes found 20 mentions (12|8). Generally, organisational attributes are mainly emphasised in sports and eSports research, as the institutionalisation and government of competitions are relevant issues in these contexts (Funk et al., 2018; Seo and Jung, 2016). Similar to social networks, a Critical Mass (8|5) of users is understood to be crucial for MRS platforms: “everyone around me is on [ZWIFT], which is very, very important to me, […] if nobody would ride there, I wouldn't use it either” (Non-Pro 8). Critical Mass has been mainly applied in social media research to describe the number of users of an application – often known ones from the real world – who are users of an application (Ellison et al., 2007; Kwon et al., 2014; Rauniar et al., 2014). For competition-oriented riders in particular, the use of ZWIFT depended on the time of the Sporting Season (7|3) and the application was mainly used in the off-season when no competitions were taking place. Thus, mainly for competitive users, usage patterns could be related to seasonal breaks. Over time, many sports have developed their own set of Values of Sport (4|6), which might impact the use of MRS platforms that bring traditional sports into the virtual world. Regarding ZWIFT, some claims were made in the interviews we conducted that the character of cycling would be lost: “My only concern on this subject is actually that cycling itself […] is moving into this virtual world. […] Cycling is simply a sport that is lived outside” (Pro 3). In particular, non-users mentioned this factor as a pivotal reason for their unwillingness to use ZWIFT. Athletes also observed that the virtualisation of cycling increased their apprehension of Cheating Issues (6|4), which involve setting a user’s body weight too low or manipulating the smarttrainer hardware. In the context of ZWIFT, the relevance of cheating concerns and suspiciously deviating weight data have been identified (Westmattelmann et al., 2020). Cheating or other forms of manipulation need to be addressed through organisational and institutional measures, as discussed in eSports and sports literature (Aabarbanel and Johnson, 2019; Houlihan, 2014; Lee et al., 2007). Otherwise, fair and serious competitions cannot be held: "If […] competitive ZWIFT riding is going to find its way into modern cycling after all, then something [about cheating prevention] needs to be changed.” (Pro 5). To increase the intention to use, Real-life Events (5|0; e.g., in sports bars) were mentioned, whereby the participants
were fascinated by the events and the “[...] pretty awesome atmosphere,” (Pro 3). In these events, smarttrainers were set up in a given location, and the (mostly competitive) use was projected on a large screen, in a combination of real sports and an eSports event. These events contributed to blurring the lines between virtual and real-world cycling from an organisational perspective (Xiao et al., 2017).

<table>
<thead>
<tr>
<th>(Sub-) category</th>
<th>Definition / Conceptualisation</th>
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<tbody>
<tr>
<td>**Environmental attributes (12</td>
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</tr>
<tr>
<td>Urbanisation (3</td>
<td>0)</td>
</tr>
<tr>
<td>Topography (1</td>
<td>1)</td>
</tr>
<tr>
<td>**Organisational attributes (12</td>
<td>8)**</td>
</tr>
<tr>
<td>Critical Mass (8</td>
<td>5)</td>
</tr>
<tr>
<td>Sporting Season (7</td>
<td>3)</td>
</tr>
<tr>
<td>Values of Sport (4</td>
<td>6)</td>
</tr>
<tr>
<td>Cheating Issues (6</td>
<td>4)</td>
</tr>
<tr>
<td>Real-life Events (5</td>
<td>0)</td>
</tr>
</tbody>
</table>

Note: Numbers in brackets represent the total number of users (n = 12) | non-users (n = 10), who mentioned a (sub-) category at least one time in an interview transcript (total n = 22).

Table 3. Definitions and mentions of higher-level context factors.

5.4 Outcomes

Regarding the conception of acceptance and use (Table 4), four users and one non-user mentioned Specific Mode Use (e.g., conducting tailored workouts). Research on social networks has emphasised that usage satisfies multiple needs, such as networking or information retrieval (Clavio and Walsh, 2014; Liu et al., 2017). Thus, we propose that usage (intention) in the context of MRS platforms should not to be measured as a generalised construct, but on multiple use dimensions representing specific modes of a multi-purpose system (van der Heijden, 2004). Arguing in terms of affordance theory, we propose that the interplay of task purpose, technological characteristics, and potential further contingency factors determines adoption and usage patterns for such systems (James et al., 2019; Leonardi, 2011).

<table>
<thead>
<tr>
<th>(Sub-) category</th>
<th>Definition / Conceptualisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>**New conception of acceptance and use (4</td>
<td>1)**</td>
</tr>
<tr>
<td>Specific Mode Use (4</td>
<td>1)</td>
</tr>
<tr>
<td>**New outcome phenomena (8</td>
<td>2)**</td>
</tr>
<tr>
<td>Performance Output (7</td>
<td>2)</td>
</tr>
<tr>
<td>Social Network Size (2</td>
<td>0)</td>
</tr>
</tbody>
</table>

Note: Numbers in brackets represent the total number of users (n = 12) | non-users (n = 10), who mentioned a (sub-) category at least one time in an interview transcript (total n = 22).

Table 4. Definitions and mentions of outcome measures.

Finally, we also identified novel outcome phenomena (8|2). Mostly users (7|2) mentioned that the platform allowed them to increase their relative Performance Output (wattage per kg body weight) over various periods. This is a specific outcome related to the key performance indicator in cycling sports, which is commonly utilised in sports sciences (Padilla et al., 2000; Sanders et al., 2019). Nevertheless, MRS platforms are so realistic that outcomes of using these IS are comparable to performances in the traditional sports discipline (Westmattelmann et al., 2020). Physical outcomes have been considered in experimental settings and physiology-orientated IS studies (Neumann et al., 2018; Parker et al., 2021), but not in technology acceptance research. Therefore, we propose a novel link here. Using ZWIFT can also lead a user to extend their Social Network Size (2|0) on- and offline: “[...] you have met a lot of people via ZWIFT, with whom you have made contact in the real world and with whom you ride. That’s
very cool,” (Non-Pro 3). Accordingly, Social Network Size could serve as an outcome corresponding to the task purpose of socialising (Ellison et al., 2007; Kwon et al., 2014; Rauniar et al., 2014).

6 Contribution and Implications

6.1 Theoretical contributions

This study explores and (re-)defines adoption factors of ZWIFT, as an example of MRS platforms, which represent a novel type of application utilising MR technology to enable virtually mediated sports and add a novel facet to sports digitalisation. Building on the multi-level framework proposed by Venkatesh et al. (2016), we discover and define various individual- and higher-level contextual factors, which are crucial for understanding adoption intentions, as well as new outcome phenomena. Moreover, we validate the UTAUT2 factors, thereby refining utilitarian and hedonic motivators. Our findings illustrate how the institutional characteristics of sports (Xiao et al., 2017), sports-specific goals (James et al., 2019), and motivations (Pelletier et al., 1995), as well as technological characteristics (especially virtually mediated physical interaction possibilities; Westmattelmann et al., 2020) of MRS platforms shape a unique context for their adoption. Accordingly, this study contributes to the literature, which as yet has neglected either the peculiarities of MR technology for exercising and sports (e.g., James et al., 2019; Parker et al., 2021), or adoption and its potential drivers regarding advanced and potentially haptic IS (e.g., Neumann et al., 2018). Specifically, we propose that MRS platforms are not limited to training and tracking purposes (e.g., Rivers, 2020; Vignais et al., 2015), but that they allow for competitive usage (e.g., purpose of competing, cheating issues), which differentiates them from exercise apps and extends existing research on associated goals and application scenarios (James et al., 2019; Rivers, 2020).

Moreover, we add to the literature on MR adoption by identifying higher-level contextual acceptance factors, which might be specifically relevant in research on the adoption of applications applying high degrees of virtuality (Muetterlein and Hess, 2017). Concretising this proposition, we emphasise that, particularly for IS that exhibit MR as a type of collaboration (i.e., individuals interacting virtually mediated via a virtual world; Speicher et al., 2019), the overarching frame governing this interaction (i.e., higher-level context factors) should be considered. Additionally, our study illustrates the adoption of a concrete example utilising MR to overcome space-time boundaries, enable collaboration, and physical interaction, which has as yet been a theoretical concept (Speicher et al., 2019; Steffen et al., 2019) or studied in laboratory settings without considering adoption issues (Neumann et al., 2018). Given the trend of further convergence of virtuality and reality in diverse areas, we encourage scholars to increasingly apply multidimensional MR taxonomies (e.g., Flavián et al., 2019; Speicher et al., 2019).

Emphasising the lack of a coherent framework for examining MR technology adoption beyond “traditional” factors (e.g., Venkatesh et al., 2003; 2012), we propose a structured approach to organise knowledge on a technology’s peculiarities. Therefore, we further develop the approaches of Laumer et al. (2019) and Mesbah and Pumplun (2020), who built solely on the UTAUT2 baseline model, because we not only identified and defined acceptance factors but also classified them accurately into specific context domains by building on the structure of the multi-level framework (see Figure 1; Venkatesh et al., 2016). This approach emphasises an interdisciplinary perspective on technology adoption, because antecedents from the fields of sports, video games, social networks, and subcategories such as exercise gaming or eSports were considered. Therefore, our definitions may serve as a starting point for further studies, as the identified factors could affect existing UTAUT2 concepts (e.g., technical features towards performance expectancy; Shin and Shin, 2011), directly relate to usage intention (e.g., use purposes; James et al., 2019) or moderate relations (e.g., environmental attributes; Venkatesh et al., 2016). To underpin these relationships, we propose to build on affordance theory (Leonardi, 2011), as we highlight that MRS platforms serve different purposes and afford specific mode use (potentially depending on the higher-level context). Thus, we link the UTAUT2 with affordance theory via the multi-level framework’s context domains. Finally, emphasising the often neglected time dimension of adoption (adaptation, initial use, and post-adoptive use), we identified factors that might be specifically relevant at different stages by including users’ and non-users’ perceptions.
6.2 Practical implications

This study also provides design guidelines to support the adoption of MRS platforms. The implementation of features appealing to various user groups with differing purposes and goals should be considered. For example, training- and health-oriented individuals could be appealed to through performance tracking, training management, and analysis features, while gamification aspects might reach younger and playful users, possibly with less interest in serious sportive competition. In contrast, reliable performance measurement and cooperation with real-world race organisers might attract competitive users. Therefore, high adoption rates can be considered a key success factor for MRS platforms, as social media research suggests that only a few providers will remain in the market in the long term (Haucap and Heimeshoff, 2014; Katz and Shapiro, 1994). Accordingly, to target the related factors Critical Mass and Social Influence, we recommend implementing displays showing how many people, specifically friends, are using the app at any given time, and the establishment of referral programs. Moreover, by attracting well-known elite athletes as promoters, and joint real-life events with organisers of real-world competitions, rejection of MRS platforms due to potentially changing Values of Sports could be reduced. Specifically, focusing on the adoption of new users, we recommend considering low subscription fees (Price Value) and leasing models for necessary hardware to reduce entry barriers. To compensate, providers can generate revenue via in-game purchases (Hamari, 2015) or advertising (Terlutter and Capella, 2013). More broadly, virtually mediated physical interaction and haptic feedback might increase realism and immersion associated with the use of MR applications across domains. Therefore, specifically to maintain existing users’ engagement, well-designed and technically mature hardware is required to ensure a reliable transfer of stimuli between the real and virtual worlds. Accordingly, beyond the well-researched head-mounted devices or fitness trackers, further and more elaborate hardware and features for their integration need to be developed (Flavián et al., 2019).

Regarding the degree of virtualisation of the environment, various tradeoffs may be expected between resembling the traditional world (sport) as realistically as possible or focusing on virtuality and its manipulation possibilities (Steffen et al., 2019). For example, gamification aspects such as powerups or items increasing a users’ performance might create enjoyment and a distinctive virtual experience, but could also cause the application and potential competition to seem less realistic. In general, developers must decide whether users may manipulate physical input/output parameters.

6.3 Limitations and further research

We also need to acknowledge some limitations. Our study focuses on MRS platforms for carrying out endurance sports, namely the running and cycling platform ZWIFT. For sports requiring more body contact or involving movable objects, virtualisation is more difficult to operationalise, and acceptance factors might differ. Nevertheless, endurance disciplines make up a substantial share of individual and recreational sports, and the presented application might prove to be a hallmark for further applications of MR technologies in sports, as comparable applications are already emerging in disciplines such as alpine sports and golfing (Golf Digest, 2020; Ko et al., 2020). Another issue concerns the subjective notions of the respondents and the two coders due to the methodological approach adopted. Nevertheless, validity measures of our analyses supported consistent coding. Moreover, we conducted interviews with German cyclists only. Consequently, the validity of our results might be limited by cultural differences. Although our sample was relatively large and included users as well as non-users from recreational to world-class levels, the generalisability might still be limited. Further studies should aim to validate our results and identify further contextual factors, e.g., by focusing on (potential) users of triathlon or skiing applications from different regions. As various stakeholder groups beyond active athletes are engaged in these platforms, further research should also emphasise organisational-level adoption in sports communities. In line with Muetterlein and Hess (2017) and Kosa et al. (2020), the present work supports further empirical research on the adoption of MR applications. Quantitative studies need to be conducted because this study focused on identifying antecedents but does not provide deep insights on the magnitude of their relations. Moreover, group-specific barriers to use need to be identified; for example, cheating and data manipulation might specifically concern competitive users.
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