User Experience of Virtual Reality-Based Digital Sports: A Topic Modeling Approach

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Abstract

Digital technologies have been found to transform our society. During and after the COVID-19 pandemic, more and more people have started their usage of digital sports. However, little research has provided a deep understanding of the user experience of digital sports at the individual participant level. To address the research gap, this study explores how virtual reality (VR)-based digital sports satisfy users' innate needs based on the psychological needs of humans and self-determination theory. By conducting a topic modeling with 11,676 tweets generated by VR-based digital golf participation users from Twitter, we identified some elements within VR-based digital golf to explain how VR-based digital golf satisfies participation users' three psychological needs, including the need of autonomy, the need of relatedness, and the need of competence.

Keywords: Virtual reality, digital sports, user experience, topic modeling, VR-based digital golf

1. Introduction

Digital technologies have rapidly transformed our lives and changed various individual behaviors in recent decades. We have witnessed digital transformation in different contexts, such as tourism (Bogicevic et al., 2019), education (Maity et al., 2021), and sports (Ruth et al., 2022). The trend and prevalence of digital transformation have escalated during the COVID-19 pandemic. After the pandemic, individuals become more accustomed to using digital technologies to facilitate their lives, such as remote work, remote education, and digital sports (Kramer et al., 2021).

Different digital technologies, such as smartphones, wearables, the Internet of Things (IoT), and VR, have transformed the digital sports domain by bringing live streaming (Kramer et al., 2021), digital sports participation (Mutz et al., 2021), and sports applications (Naha, 2021). Compared with traditional offline sports outdoors or in stadiums, digital sports provide individuals with convenience, relaxation, and fun without limitations of physical space and weather situations (Mutz et al., 2021).

Digital sports have also attracted the attention of scholars. Some studies have examined the roles and user experience of digital sports in various contexts. For instance, He et al. (2021) examined how to transfer coach experience and guidance into the educational property by analyzing video data via machine learning techniques. Ruth et al. (2022) found that digital sports could encourage individual participation in digital team sports during the pandemic of COVID-19 and lead to an increase in participation in physical sports activities. Prior literature indicated that digital sports based on the 2D background, such as smartphone and PC platforms face challenges due to the low simulation environment, which confuses participants about the workout environment and traps physical exercise of participant (Yulia et al., 2019).

Cutting-edge technologies such as VR based on 3D technologies, to some degree, might address the above challenges. VR has been applied in digital sports to facilitate individual engagement in sports in the virtual world and users in VR-based digital sports have similar sports experiences as in the real world (Neumann & Moffitt, 2018; Chen & Zhu, 2022), such as Walkabout Mini Golf (Golf), Sports Scramble (Baseball), Eleven Table Tennis (Table Tennis) and the Climb (Climbing). VR enables a high-quality presentation of the virtual environment and facilitates user interactions with the environment or with other users based on the multiple sensory stimulations in VR-based digital sports (Kowalczuk et al., 2021). However, VR application in digital sports is still in its initial stage. Prior research has mainly focused on exploring VR-based digital sports from the technology design and sports task content views, little attention has been paid to participant experience, although user experience is vital for understanding user satisfaction with such sports and the success of such sports in the long term.

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To date, huge amounts of user-generated-content (UGC) about VR-based digital sports are available from different social media platforms, such as Twitter, Facebook, and Instagram, little research has applied these data to understand user experience in using VR-based digital sports despite the big data approach could be an alternative approach to supplement the dominant interview and survey methods.

To address the above research gap, this study examines user experience in VR-based digital sports based on human psychological needs and self-determination theory (SDT) with Twitter data. By analyzing 11,676 tweets via topic modeling, this study provides an understanding of how VR-based digital sports meet different psychological needs of users.

2. Research background

2.1. Psychological needs and self-determination theory

According to Maslow (1943), human needs are based on motivation theory, including physical and psychological needs. Human needs refer to how physiological organism drives human endeavors to obtain the goal of maintaining the normal state of their body and psychological desires. Self-determination theory (SDT) identifies latent psychological motivations under human behavior and explains how individuals satisfy their certain needs. The SDT posits that individuals achieve goal pursuit, optimal psychological development, and well-being by satisfying innate psychological needs of autonomy, competence, and relatedness (Deci & Ryan, 2000).

The need of autonomy refers to individuals' psychological need to be an agent of their own (Karahanna et al., 2018). Such as on social media platforms, people could freely present their own, share content, choose anyone to communicate with, browse others' content, and move or modify freely in the cyber world, etc., to satisfy their need of autonomy (Karahanna et al., 2018). Meanwhile, the need of a place is supposed to be one dimension of the need of autonomy by creating and modifying their place to master the feeling of autonomy. Pierce et al. (2009) stated that owning a dwelling is a motive to have a sense of ownership, referring to "being in a world", for example within or being a part of familiar contexts to obtain security and psychological comfort and to control their own space.

The need of competence means an innate psychological need from which individuals interact with the environment, where people search for challenges to hone their skills or to obtain new skills (Karahanna et al., 2018). Competitive systems also allow users to improve task competence, engagement, and the intention of continuance usage (Liu, 2013).

The need of relatedness drives people to relate to other individuals and feel connected with others. If a person is rendered to interact or communicate with others on platforms, he/she could feel a sense of connectedness in the digital world, because computer-based communication could allow users to make friends as in the real world (Ang et al., 2015).

Prior research has applied SDT to explain how information technologies could satisfy users' psychological needs, such as smartphones and social robots (Nguyen et al., 2020). For example, Nguyen et al. (2020) compared a menu-based interface with a chatbot following the DST theory, they found that user interaction with the chatbot generates high user satisfaction since the chatbot satisfies users' needs of autonomy and competence.

Some studies also applied the SDT to the context of exercise and games, such as dancing and video games (Neys et al., 2014; Staiano et al., 2017). Staiano et al. (2017) found that free choices of exergames options in dancing games cater to individuals' need of autonomy, enhancing users' self-efficacy. Neys et al. (2014) also argued that users could control their actions and gestures in video games, which spur their interest to persist the video games. Drawing on SDT, the study of Li et al. (2021) suggested that challenging degrees of exercise and game tasks and competition could satisfy users' need of competence. According to Zhao et al. (2022), online games could improve elder users' health by enhancing the cohesion in the community and the motivation to exercise and satisfying their need of relatedness as suggested in SDT.

2.2. Digital sports

Rejikumar et al. (2022) defined digital sports as a type of sedentary activity and as an alternative to real sports and sports competition in the physical world. In general, the definition of digital sports could include digital channels of real sports, such as live streaming and digital chess, and virtual sports accessed via digital technology with a combination of the digital and virtual world, such as virtual golf and tennis (Cranmer et al., 2021). Digital sports could surpass physical counterparts to enrich players' lives or experiences without the limitations of space, players, and time when equipped with digital technologies (Filchenko, 2018). Digital sports could transform the roles of athletes (Luo, 2022), coaches (He et al., 2021), and audiences (Na & Rica, 2020).

Various digital technologies have been used in digital sports. For example, in digital sports education,

He et al. (2021) examined how recorded videos of coaches' images and the details of coaches' guidance could improve the movement and step of the coaching demo to broaden the coach's experience. Some scholars have investigated how smartphone-based applications could connect physical sports equipment, provide online sports training programs to users, and promote users' participation in digital sports (Mutz et al., 2021). Live streaming of sports competitions also enriches the traditional and offline tournament watch, which broadens the scope of audiences and offers audiences a comfortable watching experience in comparison to the crowded real environment and the high cost of the offline counterpart (Rejikumar et al., 2022).

Most digital technologies applied in digital sports are static and 2D technologies such as smartphones and PCs, which lack realistic simulation of real sports. There is a call for research on user experience in digital sports based on cutting-edge immersive technologies such as VR (Filchenko, 2018), which could bring insights into the understanding of the potential and the implementation of VR in the field of digital sports.

2.3. VR in digital sports

VR has emerged as an innovative technology that provides users with realistic and interactive 3D environments via technological devices (Guttentag, 2010). VR glasses or headsets could involve users in a wide-view and vivid visual presentation with other audio and interactive experiences and have good task performance (Speicher et al., 2017). VR makes the embodiment of digital sports possible. It transforms users' perception of being involved in the virtual sports world (Rapp, 2023), and generates the physical and mental presence of sporters in an interactive environment (Neumann et al., 2018). The following Figure 1 is an example of VR-based digital sports.

Figure 1. Demo picture of golf+.

Prior research has examined the application of VR in digital sports mainly from three streams. Some scholars have examined the application of VR mainly in education or training for athletes or sports players to transfer learning or motion skills with synchronous interaction (Müller et al., 2022; Pastel et al., 2022). Spectators also experience immersive watching by blocking out the real world with VR technology (Capasa et al., 2022). Some studies have examined users' participation in VR sports and argued that VR-based digital sports could provide users with a mixed experience of sports and entertainment (Yüce et al., 2021). Another research stream has studied the VR system design (Nunes et al., 2014) and sports content design in VR-based digital sports (Oagaz et al., 2022). The third research stream has studied users' motivations to use digital sports at individual user levels. Such as, Westmattelmann et al. (2021) explored the effect of perceived benefits and risks in mixed-reality sports on users' intention to use mixed-reality.

Along with the above research, VR as an immersive technology could transform digital sports context and might satisfy users' psychological needs in the digital sports domain as VR has unique technological advantages such as high presence and timely interaction with people (Neumann et al., 2018), and realistic simulation (Pastel et al., 2022). Thus, we assume that (1) VR could fulfill users' need of autonomy through the ease of use of VR devices, the virtual place as well as the realistic simulation of sports environment with various options in VR-based digital sports platforms. The realistic simulation of movements in VR-based digital sports could improve the precision of the control of movements and actions and enhance users' involvement in VR-based digital sports, further satisfying their need of autonomy. (2) The realistic simulation of movements in VR-based digital sports could also help users develop their sports skills and improve their competence in exercise performance; Then, the design of challenges and competition in VR-based digital sports could satisfy users' need of competence. (3) VR-based digital sports could keep users connected with others in the multiplayer mode without time or space limitations, which could satisfy their need of relatedness.

Since SDT could explain how individuals achieve their goals pursuit by satisfying their psychological needs of autonomy, competence, and relatedness (Deci & Ryan, 2000) and VR-based digital sports could cater to individuals' needs of autonomy, competence, and relatedness, SDT might be an appropriate theory in this study to explain how VR-based digital sports could meet individual participation users' certain needs. Although previous literature has examined user experience and their motivations to use VR-based digital sports at the individual participant level, few studies have attempted to investigate users' VR-based

digital sports experience from the theoretical view of SDT, which could explain how participating in VR-based digital sports could satisfy users' psychological needs. In addition, prior research related to VR-based digital sports mainly applied interviews (Nunes et al., 2014), and mixed research methods with interviews and surveys (Westmattelmann et al., 2021) to understand the user experience of VR-based digital sports, little research has attempted to apply user-generated-content (UGC) on social media to understand the user experience of VR-based digital sports. Thus, this study will examine user experience in VR-based digital sports from the view of users' psychological needs following SDT with UGC. Specifically, this study aims to identify the relevant elements of VR-based digital sports that help explain how VR-based digital sports satisfy users' certain psychological needs.

3. Methodology

3.1. Data collection

Twitter is an online community that allows free conversations on different themes among individuals. It has huge amounts of users. Twitter provides data access for academic research purposes before 2023. Twitter was chosen for data collection in this study due to the convenience of data access. The first author received the academic research access right to the Twitter platform via API with approval from Twitter in 2022 and got access to user-generated content (UGC) data on the Twitter platform.

Digital golf is one of the most popular digital sports. Users could participate in digital golf in different ways, such as single-player and multiple-player. Digital golf provides a unique context for users to explore different activities in golf. Thus, VR-based digital golf (Hereafter VR golf) was chosen as the research context in this study due to its popularity and the possibility of collecting large amounts of reviews generated by VR golf users.

The keywords "VR Golf" were applied in searching data on Twitter on September 29, 2022, and only tweets in the English language were selected in this study. We selected the starting time from the beginning of 2020 which covered COVID-19 since VR-based digital sports used at home has got a boom due to the breakout of COVID-19 at the beginning of 2020 (Westmattelmann et al., 2021) and persistent after the pandemic (Kramer et al., 2021). Finally, we obtained 17,117 pieces of tweets published during the time range of January 1st, 2020, to September 29th, 2022. We further manually filtered and went through all these data to ensure that these tweets were related to the VR golf context. 5441 pieces of tweets were excluded from this study due to the duplication or being written in languages other than English. Only 11,676 pieces of tweet data were valid and applied in data analysis.

3.2. Data analysis

Topic modeling is a statistical technique to reveal latent semantic structure in a large number of documents, equipped with classification methods normally as different evolutions of the Latent Dirichlet Allocation model (LDA) (Kherwa & Bansal, 2018). Topic modeling has been widely applied in research on social media data. For instance, Lee et al. (2016) conducted topic modeling with over 380, 000 user data to test the effect of homophily effect on social network formation. Pee et al. (2020) applied topic modeling to identify key participants and key clusters and to examine value co-creation in the social community. Han et al. (2022) applied topic modeling to compare the PC and mobile-based purchase decision process of consumers.

In this study, we applied topic modeling to understand user experience in VR golf based on the collected Twitter data. We first standardized data by removing links, hashtags, punctuation, numbers, stop words, and the theme words (e.g., VR golf, golfing) in the dataset via topic modeling. Second, we combined uppercase and lowercase words of the same meaning, singular and plural words, and words that refer to the same content, such as Oculus and Quest (Jeyaraj & Zadeh, 2020). Third, we conducted a topic modeling and identified 12 topics from the dataset following the steps suggested by Debortoli et al. (2016). Fourth, we selected fifteen representative reviews for each identified topic based on the top frequent words. Fifth, we read the representative reviews of the twelve topics to get a deep understanding of the main content of these tweets and manually coded labels of sub-topics regarding the elements of VR-based digital sports. Finally, we interpreted how these sub-topics in each identified topic reflect users' innate psychological needs following the different needs indicated by SDT.

4. Results

We generate 12 topics using the top eleven words with the highest frequency. All the results of 12 topics are arranged by the quality criteria including coherence and prevalence data (shown in Table 1). The manual coding of labels of sub-topics and a map result of the three psychological needs with these topics based on the most frequent words and examples of tweets are shown in Table 2. The 12 topics identified

various elements related to user experience in using VR golf and linked to users' psychological needs, including the need of competence, the need of autonomy, and the need of relatedness.

Table 1. Coherence and prevalence of topics

Topic	Coherence	Prevalence (%)	Topic	Coherence	Prevalence (%)
T1	0.431	6.235	T7	0.739	7.628
T2	0.655	4.649	T8	0.369	6.576
T3	0.036	6.598	T9	0.492	6.489
T4	0.124	6.407	T10	0.030	6.945
T5	0.056	5.142	T11	0.253	6.957
T6	0.033	29.398	T12	0.066	6.976

Specifically, users expressed their need of competence (T2 and T7) in their VR golf use. The two topics both have high coherence values (Coherence value of T2: 0.655, and Coherence value of T7: 0.739) (See Table 1). T7 (labeled as "Race elements: Competitive content") identified that the competitive content to encourage winning and competition is recognized as a vital element of VR-based digital sports for users to excite their experiences, which might be associated with the need of competence as the competition view. Besides, ubiquitous headsets (e.g., Oculus Quest) with vivid presentation are mentioned in T2 (labeled as "Race elements: Emotion-induced themes and competitive content"). For example, some users reported an emotional experience of horror when encountering a medieval theme in the competitive activity. The mixed horror and competitive content appeal to users and excite sporters to participate in VR-based digital sports which are closely linked to the need for competence.

The words identified in T1 (labeled as "Ease of use: Wireless devices") show users are eager to have a wireless experience in VR golf, which allows users to move freely in the space, revealing that users could control their behaviors and might relate to the need of autonomy. The seamless VR device application to connect Wi-Fi supports assists in great VR participation in digital golf, such as Golf Club and Beat Saber. Thereby, we reasoned that the ease of use of VR technology facilitates users' self-control in the digital sports world, satisfying a sense of autonomy.

In addition, VR technology has transformed digital sports, providing a mixed virtual and real experience. Users would like to compare the virtual sports experience with its real-life counterpart (T9 labeled as "Virtual place: VR platform with a realistic simulation of sports"). The mixed virtual and reality experience originates from the VR platform with high simulation of a sports environment which establishes a realistic but intriguing digital world with audio experience to involve sporters. Moreover, the realistic simulation of movements in VR-based digital sports, which can be like the movements in real-life golf, not only caters to the need of autonomy via precise control of movements for users but also satisfies users' need of competence to horn golf skills such as swing.

The other elements of VR-based digital sports platforms such as PlayStation in T8 (labeled as "Virtual place: VR platform with digital sports lively without time limitation") and T11 (labeled as "Virtual place: VR platform with various digital sports") offer a variety of sports options with Everybody's Golf VR, Real VR Fishing, Eleven Table Tennis, Golf+, and Walkabout Mini Golf and a place in parallel with sports and communities in the real world. Updated versions of VR-based digital sports also enrich the VR platform and are likely to increase the probability for users to stay in the VR sports world (T12 labeled as "Virtual place: VR platform with digital sports updates"). Notably, T4 (labeled as "Virtual place: Customized/private space") provides users with the experience of customized virtual places such as indoor rock-climbing walls and trampoline parks, as well T5 (labeled as "Virtual place: VR platform with various themes in the environment") could enrich the VR-based digital sports space to retain users. From the above topics, we claim that the need of a place drives sporters to stay in the VR-based digital sports world, and options of digital sports, digital sports updates, and customized and realistic simulated virtual places contribute to building up a comfortable VR home to involve and retain sporters. Thus, VR golf could meet users' need of autonomy from the need of a place view.

Furthermore, VR-based digital sports transformed the routine of connecting people no matter with the acquaintance or stranger, specifically through the online and timely interaction element in VR-based digital sports. Two topics (T3 and T6) reported that VR golf users prefer multiplayer and playing with others such as friends. Users express positive social (e.g., great) and emotional experiences (e.g., fun) and even VR golf is an alternative to connect with friends in the real world (T6 labeled as "Social interaction platforms: Friends for fun as real"). Not only acquaintances, but VR golf also keeps users from social problems, for example, some people are afraid of making or having few friends in the real world but, in the VR golf world, users could easily find strangers with similar interests to start sports and socialize with them in the virtual world (T10 labeled as "Social interaction platforms: Online multiplayer").

Table 2. Topics elaboration and constituent words

Topics	Labels of topics	Psychological needs	The most frequent words	Examples of tweets
T1	Ease of use: Wireless devices	Need of autonomy	Club, beat, experience, saber, beat_saber, pack, **wireless**, jet, club_beat, saber_jet, **wires_experience**	Golf clubs beat sabers and jet packs don't have wires, so neither does Quest 2. Experience wireless VR with Quest 2. I used to have a Rift but decided to get a Quest 2 for wireless VR got a Wi-Fi 6 router chilling next to my desk for the best latency.
T2	Race elements: Emotion-induced themes and competitive content	Need of competence	**Racing, fighting, combat, battles**, **blazers**, commentary, **medieval**, **fighting_combat**, **commentary_racing,** combat_medieval, medieval_battles	#Vr #Horror (Commentary and Non), Vr Golf, Racing, Fighting, Combat, Medieval Battles, and more on the way! Get in HERE, we're having Fun! How VR is used by psychologists to profile your personality: Virtual reality (VR) has the power to take us out of our surroundings and transport us to far-off lands. From a quick round of golf to fighting monsters or going for a skydive.
T3	Social interaction platforms: Various types of social interaction with friends for fun	Need of relatedness	Walkabout, **tournament**, join, **stream**, player, **live**, back, ready-player-golf, charity, **friend, fun**	Whether you're a golf fanatic or you've never swung a club, you can test your skills against friends, and celebrity guests in the RPG charity event. Have fun while supporting a good cause. I did a mission accomplished! I've visited and played mini golf with each of my core #VR tournament teammates around the US. I'm thankful for the virtual spaces that have allowed these friendships to happen. Truly awesome.
T4	Virtual place: Customized/private space	Need of autonomy	**Playstation**, registration, **walkabout**, blood, world, truth, bot, blood_truth, **Astro, mega**, **central**	RT @androidcentral: Walkabout Mini Golf's usual twist on the activity adds a tinge of the unusual, thanks to its upcoming Labyrinth DLC. I like walking around Central, there are things like indoor rock-climbing walls, trampoline parks, top golf, and going to plays/musicals. I've heard there's a VR arcade somewhere.
T5	Virtual place: VR platform with various themes in the environment	Need of autonomy	New, great, experience, world, course, **walkabout**, **labyrinth**, center, **provides**, **hotel**, Jim	The amazing team at The Mighty Coconut has joined with Jim Henson Company to bring Jim Henson #Labyrinth# to #Walkabout Mini Golf# coming this Summer! Using Gravity Sketch, the team has been able to build countless environments and experiences for the game directly in VR. I just had the worst work dream I've ever had, My company replaced their driving range on the Vegas strip with a giant 10 stories golf-themed hotel where you could hit a ball with VR in your room, and they sent all the people from our venue to help, and we had No Liquor.
T6	Social interaction platforms: Friends for fun as real	Need of relatedness	**Like, fun,** course**, friend**, walkabout, **good**, **great**, try, **real**, **experience**, new	I love playing golf in real life. With work, wife, kids, friends, etc. I don't get to play as much as I'd like. Playing in VR keeps me closer to the game I love, and I get to play with friends across the country.

				Tonight, I want to share a VR game called @WalkaboutMG. This golf game is nice; the environment is great. I can't wait to play the July Verne update! I'm having so much fun these days with a friend living far from my city.
T7	Race elements: Competitive content	Need of competence	Disc, chains, chains_disc, **headset**, dreamnerdygames, **win**, **celebrate**, launch, **competition**, celebrate_launch, launch_chains	Competition time! Win an Oculus Quest 2 headset to celebrate the launch of Off the Chains Disc Golf. You should get one of those VR golf basement setups that you can use with your clubs. You could stream it and have competitions with other streamers who golf but are stuck in areas that have actual winter.
T8	Virtual place: VR platform with digital sports lively without time-limitation	Need of autonomy	Check, **live, playstation, broadcast**, broadcast_playstation, check_broadcast, **playstation_live**, new, walkabout, psvr, wario	Everybody's Golf #VR HEADSET: Clubs? Check. Caddie? PlayStation VR? Step onto the course like never before in the most immersive Everybody's Golf experience yet! Swing for the flag with your PlayStation Move motion. PSVR just said that he will do a 24-hour livestream of Walkabout Mini Golf if it comes to PSVR @WalkaboutMG #psvr #vr #PlayStation
T9	Virtual place: VR platform with realistic simulation of sports	Need of competence Need of autonomy	Domain, sale, domain_sale, domain_domain, **real, life, real_life**, **cool**, frustrating, frustrating_real, kurtisconner	*Playing VR golf* How cool is this? I can play golf AND listen to music. It's like real life. It can be cool. The only way to make good contact in VR is to get your hands in the same position as they need to be in real life. And especially good for training touch around the green.
T10	Social interaction platforms: Online multiplayer	Need of relatedness	Walkabout, new, course, **online**, myst, listen, iamtommacdonald, **tom**, likeyou_listen, **tom_macdonald, iamtommacdonald_online**	Last night I was playing VR Golf online and the guy I was playing was like You listen to Tom MacDonald? Walkabout Mini Golf VR is a fantastically fun game to play, both solo and with friends. Apparently, they're introducing Myst as a playable course. Hope that trends with more games!
T11	Virtual place: VR platform with various digital sports	Need of autonomy	**Walkabout**, Cardano, beat, saber, **beat_saber**, course, **room**, results, **table, fishing, tennis**	I'll have all three ready to go. For more chill-style multiplayer I highly recommend Real VR Fishing, Eleven Table Tennis, Golf+, and Walkabout Mini Golf. And for free multiplayer stuff Rec Room, VRChat, Horizon Worlds, and Gun Raiders. Paper Beast, The Room, Fuji, Real VR Fishing, Walkabout Mini Golf, Virtual Reality, Edge of Nowhere, Fisherman's Tale, Lone Echo, Shadow Point, etc. There are many wonderful formats.
T12	Virtual place: VR platform with digital sports updates	Need of autonomy	Odds, live, **update**, disc, love, check, odds cover, tour, **update_odds**, studio, **sale**	The update for our VR Monday looks beautiful, especially in the hard mode. Well done walkabout mini golf team! The treasure hunt was fun. #MemorialTournament Final Round Betting Odds and Prediction, Collin Morikawa is the favorite at +135 Outright Live.

5. Discussion and conclusion

The present study explores VR-based digital sports experiences based on Twitter data to examine how VR-based digital sports meet individuals' psychological needs from the view of SDT and the psychological needs of humans. Through a topic modeling approach, we identified twelve topics and various elements of VR-based digital sports in each identified topic linked to users' psychological needs.

VR-based digital sports could meet users' need of competence. The contexts of VR sports include the competitive elements (e.g., Medieval Battles), which highlight racing and combat, along with the updated launching versions and commentary to increase the quality of competition appealing to users in related VR-based digital sports. In addition, emotion-induced elements such as horror themes of VR sports verified the evidence that competition content with emotional experience assists in exerting users' interest to participate in VR-based digital sports by satisfying their need for competence. According to Karahanna et al. (2018), collaboration and competition with peers are two important dimensions satisfying users' need of autonomy. The finding in this study is partly consistent with the findings of Karahanna et al. (2018). The difference could result from the different research contexts. Our study focuses on the digital sports context and competition is a focused theme in sports, whereas Karahanna et al. (2018) researched social media and collaboration is highlighted in social media use. Moreover, the realistic simulation of movements in VR-based digital sports enhances users' task performance and hone their sports skills without the limitations of time and space. It is an easier and more convenient alternative option for users to satisfy their need of competence.

In the current research, VR-based digital sports could satisfy users' need of autonomy. The need of autonomy could drive users to use new technology and experience it (Lau & Ki, 2021). The current research identified that ease of VR use, the wireless of VR devices such as Oculus Quest II, facilitate the application of VR in a digital sports context. Then, free and precise control on movements similar to real sports movements, which are provided by the wireless VR headsets and realistic simulation of VR technology, are unique technological elements of VR-based digital sports, satisfying users' need of autonomy. In this vein, other technologies such as smartphones could not provide such a realistic digital sports experience even though smartphones also have the convenience of being used at anytime and anywhere (Neys et al., 2014; Chen & Pai, 2018).

The need of autonomy also stems from the need of a place to be controlled and retained in VR-based digital sports. Consistent with some prior technology usage research, the need for place engages users in certain virtual worlds (Partala, 2011). The current study identified various choices and updated versions of VR-based digital sports applications are available on VR platforms for users to set up their virtual space in digital sports. In addition, realistic simulation of the environment in VR-based digital sports also provides users with an immersive sports environment in a virtual place via multiple stimulated senses such as visual and audio cues and facilitates the regulation of their gestures and exercise (Speicher et al., 2017). Then, the various themes and customized virtual environments of VR-based digital sports enhance the quality of autonomy in the virtual place, encouraging users to stay in the virtual sports world. The finding is also consistent with the prior research finding of Schneider et al. (2021), who found that the customization of the virtual background of remote work via PC would satisfy users' need of place and retain them in the virtual space.

VR-based digital sports could satisfy users' need of relatedness by transforming the social norm in the real world (e.g., a VR platform is becoming an online alternative to a real place to contact friends), which aligns with similar elements in a stream of prior social media literature (Ang et al., 2015; Zhao et al., 2022). VR-based digital sports broaden the social scope of users from offline to online environments. During the COVID-19 pandemic, individuals need to relate to others due to the constrained physical distance (Uhm et al., 2022). Playing digital sports with others gives users a sense of being social with others in a VR-based environment even if they stay in different physical places (Neumann et al., 2018). Such as users in VR-based digital sports can play sports, talk with each other, and see the avatars of other players, similar to social interaction in playing real sports. Meanwhile, VR-based digital sports provide various types of social interaction such as online tournaments and charity activities which are rarely experienced in real life.

This study contributes to digital sports research by exploring how VR-based digital sports could meet users' psychological needs based on the SDT. Specifically, this study enriches the understanding of user experience in VR-based digital sports by identifying the topics related to users' psychological needs and various relevant elements in each identified topic to explain how VR-based digital sports satisfy users' psychological needs. In addition, this study applied social media data to examine the user experience of VR-based digital sports. It also offers a methodological contribution to the field of VR-based

digital sports research by using a large number of social media data generated by users of VR-based digital sports to understand their user experience.

In practice, managers of VR-based digital sports designers could consider how to make VR-based digital sports satisfy users' psychological needs from the views of artifacts closely related to the themes of competence, autonomy, and relatedness in VR-based digital sports design.

6. Limitations and future work

Last but not least, our study is not without limitations. First, the data in this study was only collected from the Twitter platform. Future research could consider using social media data from multiple social media platforms to examine VR-based digital sports among users. Second, caution should be taken when generalizing the findings in this study to other VR-based digital sports contexts if the sports context is quite different from the sports context in this study, such as VR shooting. Third, this study only investigated users' psychological needs based on topic modeling. To get further deeper understanding of how VR-based digital sports could meet users' psychological needs, future research could apply surveys or experiments to examine the different roles of VR technological features in meeting users' different needs. Fourth, this study focuses on understanding the user experience of VR-based digital sports from their psychological needs view, future research could consider examining user experience in VR-based digital sports from another theoretical lens, such as user emotion via sentiment analysis.

7. References

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