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Boosting Motivation in Sports with Data-Driven Visualizations in VR

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ABSTRACT

In recent years, the integration of Artificial Intelligence (AI) has sparked revolutionary progress across diverse domains, with sports applications being no exception. At the same time, using real-world data sources, such as GPS, weather, and traffic data, offers opportunities to improve the overall user engagement and effectiveness of such applications. Despite the substantial advancements, including proven success in mobile applications, there remains an untapped potential in leveraging these technologies to boost motivation and enhance social group dynamics in Virtual Reality (VR) sports solutions. Our innovative approach focuses on harnessing the power of AI and real-world data to facilitate the design of such VR systems. To validate our methodology, we conducted an exploratory study involving 18 participants, evaluating our approach within the context of indoor VR cycling. By incorporating GPX files and omnidirectional video (real-world data), we recreated a lifelike cycling environment in which users can compete with simulated cyclists navigating a chosen (real-world) route. Considering the user's performance and interactions with other cyclists, our system employs AI-driven natural language processing tools to generate encouraging and competitive messages automatically. The outcome of our study reveals a positive impact on motivation, competition dynamics, and the perceived sense of group dynamics when using real performance data alongside automatically generated motivational messages. This underscores the potential of AI-driven enhancements in user interfaces to not only optimize performance but also foster a more engaging and supportive sports environment.

CCS CONCEPTS

• **Human-centered computing → Visualization techniques**; **Interactive systems and tools**.

KEYWORDS

Visualizations, User Interface, Virtual Reality, Sports, Cycling, Asynchronous social interaction, Large Language Models, Real-world data, Artificial Intelligence, eXtended Reality

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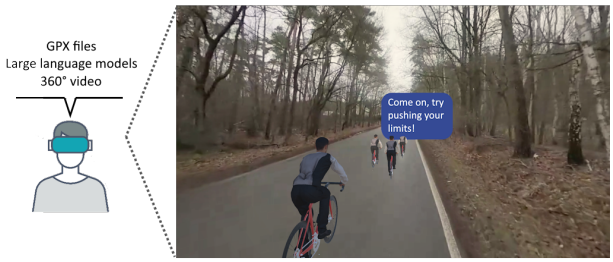

Figure 1: Our conceptual approach using real-world data (GPX files, 360-degree video) and large language models (e.g. ChatGPT) fostering social interaction in VR sports.

1 INTRODUCTION

Technology has come a long way in recent years, enabling users to experience realistic immersive VR environments. Despite the technological progress in VR, its psychological and motivational facets have received less attention [11, 13, 17]. The industry's emphasis on technical specifications often sidelines the motivational drivers that could boost user involvement and satisfaction. Critical motivational components include gamification, personalization, and social interaction, which are essential for the widespread adoption and effectiveness of VR technologies [5, 6, 16]. Integrating these elements not only enhances user experience but also promotes sustained interaction and deeper immersion.

Furthermore, utilizing motivational messaging is a well-known effective persuasion tactic [1, 7]. There is a significant need for research into automated methods for generating such messages, as current techniques are manual and inefficient [8]. As VR evolves, a shift towards valuing motivational elements equally with technical requirements is crucial for creating more engaging, user-centered experiences. In the sports domain, for instance, motivation has proven pivotal, with mobile applications demonstrating its significance [12]. However, VR content generation remains a challenge, particularly in replicating diverse outdoor environments realistically and cost-effectively.

Additionally, the rise of wearable technology offers new dimensions to VR experiences. Wearables provide a continuous stream

of user data, enhancing the realism and interactivity of VR environments. Advances in AI and data utilization could revolutionize how VR supports and extends sports activities, including enabling asynchronous social interactions within VR platforms.

To address the shortcomings of current technology, in this paper, we present an approach that harnesses real-world sports data from wearables such as smartwatches, fitness trackers, and cycling computers. This data, derived from performances of (recreational) cyclists, serves as the foundation for animating avatars. Our approach emulates avatars that mimic real-world cyclists, dynamically generating motivational messages using AI. The contributions of our work are as follows:

- An approach that leverages omnidirectional video recordings to offer a realistic virtual environment that encourages competition and fosters social interaction in VR sports;
- Using generative AI to integrate personalized motivational messages for athletes based on real-world data;
- Studying the effect of this approach on the connectedness of solo athletes with avatars emulating real-world behaviour.

The study, with 18 participants, has shown that asynchronous social interaction increases motivation and reduces loneliness when practising indoor VR sports. These findings confirm the feasibility of combining real-world data to generate encouraging messages to improve the solo indoor cycling experience.

2 CONCEPTUAL DESIGN

By integrating real-world data such as GPX files and 360-degree videos with large language models like ChatGPT [1], our aim is to create a VR sports environments that fosters social interaction and provides motivation. As an illustrative use-case, we focus on an indoor VR cycling experience in which we strive to enhance motivation through asynchronous social interaction. We chose indoor cycling given its exponential growth in the last years [15] and its suitability for older individuals [3]. The subsections below describe the building blocks of our approach and how we applied them. These blocks let us, and any future user (or developer), include other scenarios (e.g., more cycling routes), import sports data from GPX files, and personalize the interaction cues (the messages from virtual cyclists) according to the user's actual performance. Figure 2 offers an overview of the system architecture of our proof-of-concept.

2.1 Real-world data collection

360-degree video recordings offer a realistic and immersive experience of known places for the user [14]. The continuous improvement of affordable 360-degree cameras like GoPro[2] and Insta360 X3[3], the generation of 360-degree videos is becoming even easier over time. ***GPX data*** files serve as a standardized XML format encapsulating location-based data (i.e., waypoints, routes, and tracks). Beyond spatial coordinates, a GPX file may contain additional information such as timestamps, elevation, heart rate, and speed. Prominent services like Strava and dedicated devices like Garmin bike computers adeptly capture GPX data. From these files, we harness GPX coordinates and heart rate data to personalize user motivation, aligning it with their exertion levels. Using speed alone is limited due to variations in perceived effort among individuals. Employing this data asynchronously empowers users to ride at their convenience, requiring only a 360-degree video recording and existing ride data. In our proof-of-concept, we used the Unity game engine to develop an application that maps GPS coordinates onto the virtual track and 360-degree video leveraging the Haversine formula to transform points on a sphere to 3D points. With our approach, users can opt for a leisurely ride, challenge professional athletes, or exclusively compete against their own past performances, as long as the activity data is available. ***Outdoor physical measures*** are used to synchronize the video playback to the actual speed of the recorded path. Utilizing a Garmin bike GPS coupled with a hub-mounted speed sensor, we accurately captured the bike's trajectory, enabling us to precisely align the video playback speed within the application. Furthermore, the GPX file serves the dual purpose of determining the cycling direction. This information will represent the ground truth of the cycling route when designing the VR environment later on.

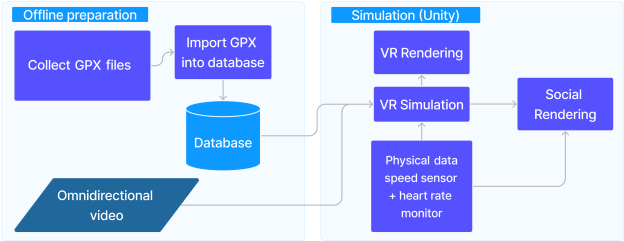

Figure 2: A technical representation of our proof-of-concept

2.2 Social group dynamics simulation

Virtual avatars help us simulating group dynamics in the virtual environment (see Figure 1). The virtual cyclists are animated using inverse kinematics, and their performance is based on the GPX data collected from the given track. Our approach simulates their performance based on speed and heart rate, which can help users to compare themselves with their virtual peers. ***AI-based message generation*** is exploited to simulate the social interaction of peer cyclists with the user of our application. We exploit ChatGPT to generate messages that could motivate people during cycling. We performed the following search query to enable this: 'Write a short motivational message that a passing cyclist would say to you to encourage you. Base the message on the fact that the passerby has a heart rate of X beats per minute.'. These messages will be displayed in a chat box above the passersby cyclist's head (see Figure 1). The prompt used to generate the messages contains the heart rate of the passerby (based on the collected GPX data). We did not include the heart rate of the actual cyclist/user for the message generation, since passers-by cannot estimate this either in a realistic setting outdoors. ***Indoor physical measures***, in our case using a Garmin sensor is used to measure the user's speed when cycling indoors. To enhance the feeling of speed and immersion, the video speed

[1]https://chat.openai.com
[2]https://gopro.com/
[3]https://www.insta360.com/product/insta360-x3

Figure 3: The physical setup of our concept during the study

in the virtual environment will change dynamically based on the speed reported by the sensor.

3 EXPERIMENTAL EVALUATION & RESULTS

We conducted a user study to evaluate both technical feasibility and user experience, especially in terms of social interaction. We recruited 18 participants, consisting of 4 women (22.2%) and 14 men (77.8%), with ages between 18 and 53 years (average 28 years, SD = 12.28). The largest share of the participants cycle weekly (61.1%), 22.2% cycle daily, 5.6% cycle monthly and 11.1% never cycle. The predominant motivation to cycle is transportation (83.3% of all the participants). The rest, 16.7%, is a group that cycles as a sport. The majority (77.8%) mostly cycle alone, while the rest mostly cycle in a group. Only one participant had experience with Zwift. Almost all participants had previous experience with VR (88.9%), varying from occasionally using VR applications (most participants) to developing VR solutions themselves.

3.1 Experimental setup

The proof-of-concept was built in Unity. A race bike and bike trainer act as the stationary bike. We used a Valve Index VR headset. During the simulation, the wind is emulated using a fan in front of the user (see Figure 3). The video recordings were performed using horizon levelling with a GoPro Hero Max at 5.6K, 30 fps. The camera was mounted on a helmet during a cycling activity to obtain the desired perspective for the video. Cycling activities from the same track were collected with a Garmin bike computer (connected to a Garmin heart rate chest strap).

Study Design. The study received approval from the Ethical Committee at our university. Participants had time to adjust the bike (e.g., adjusting the seat's height) and test the VR headset while riding the bike. For the study, participants were instructed to cycle at a comfortable speed, as we were interested in assessing the direct impact of social interaction without influencing their effort level. The study, using a counterbalanced within-subject design, investigated our approach's effects on the feasibility, perceived social presence, motivation, and physical exertion during indoor cycling. Participants completed two five-minute cycling sessions with different conditions: a simulated social interaction condition and a control condition. In the social condition, participants could cycle with other **virtual** individuals (five in total) based on collected GPX data. Sessions were kept short to ensure that the experiment was not influenced by the participant's physical condition rather than their perception of the system and its features. In the social condition, the virtual cyclists shared motivating AI-generated text messages based on the virtual passerby's heart rate every 20 seconds (e.g., "Come on, try pushing your limits!" or "What a pace! My heart rate is starting to get a little high"). Messages were generated upfront and dynamically selected based on different heart rates to avoid unexpected situations (e.g., LLM service unavailable) and ensure consistency with the message generation for all participants. We generated ten messages for each heart rate (100-180 bpm, blocks of 10 bpm). To maintain consistency, virtual cyclists remained near the participant's virtual representation, preventing situations where the user's cycling speed could hinder staying near the avatars. In the control condition, participants had one virtual cycling companion without simulated social interaction.

Data gathering and analysis. Participant data included demographics (age, gender), cycling habits, and Zwift/VR experience. Speed, recorded with a Garmin sensor, was collected during the sessions. Post-session, participants completed questionnaires covering VR and cycling experience, including immersion, competition, perceived effort, social interaction, loneliness, dizziness, and nausea, using a 5-point Likert scale (1-Fully disagree, 5-Fully agree). A semi-structured interview provided further insights into the overall experience. We performed ANOVA tests to investigate the significance for both conditions' results.

3.2 Results

The results (see Table 1) showed a significant effect of social interactions (social condition) on the perception of not feeling alone during cycling. This statement was rated higher on the Likert scale when encouraging and motivating messages from the avatars were received. The analysis of the interaction detected in the question about social competition reveals that the order that starts with the control condition has a significant difference in scores between the conditions ($F(1, 32) = 29.45$, $p = 5.589e\text{-}05$), while the other order does not ($F(1, 32) = 0.0331$, $p = 0.858$). Those who started with the control condition rated the competition feeling higher when having the social interaction.

AI-generated messages. Two questions were shown about the messages; "The messages of the other cyclists were appropriate" (Q1), "The messages of the other cyclists were motivating" (Q2). On average, the scores were high (Q1: M=3.94, SD=0.73; Q2: M=3.89, SD=0.96), indicating that the messages were well received. The findings of our evaluation suggest that both conditions show promising results to improve the cycling experience. The social interaction condition showed an improved motivation, competition, and perception of not being alone. However, there was no significant difference in the perception of social interaction. It is hardly unexpected that we did not detect a substantial effect on social interaction, given our investigation into a one-way communication format. The (perceived) physical exertion did not differ between the conditions. Also, it is not surprising, given the rather short cycling effort and the presence of real-world data in both conditions.

Question/Statement	ANOVA results				
		Sum Sq	Df	F value	Pr (>F)
I did not feel alone while cycling	Intercept	441.00	1	394.44	0.000
	Social interaction	7.11	1	6.36	0.017
	Order	4.00	1	3.58	0.068
	Social Interaction : Order	0.11	1	0.099	0.755
The presence of other cyclists caused more competition	Intercept	318.03	1	277.55	2.2e-16
	Social interaction	10.03	1	8.75	0.005
	Order	0.25	1	0.22	0.64
	Social Interaction : Order	8.03	1	7.00	0.012
I have the feeling social interaction was present	Intercept	245.44	1	231.00	3.43e-16
	Social interaction	2.78	1	2.61	0.12
	Order	2.78	1	2.61	0.12
	Social Interaction : Order	1.00	1	0.94	0.34

Table 1: Results of two-way ANOVA measures on social interaction and cycling statements

4 DISCUSSION

Enhancing VR sports realism with real-world data. We incorporated GPX data and 360-degree video to enhance realism in VR indoor cycling. While we did not utilize actual cycling speed from GPX files, we propose using data based on the user's performance, such as from fellow cycling club members, for a personalized and competitive experience. For avatar representation, exploring real-world data is recommended. Cyclists in our concept simulate crank movement without lateral motion, but full-body tracking could be explored for more realistic cycling behavior [4]. Virtual avatars could also resemble familiar individuals like athletes, family, or friends.

Asynchronous interaction in VR sports. In the experiment, participants felt less alone while cycling in VR with a group compared to just one companion, experiencing increased competitiveness and motivation. These findings support integrating asynchronous interactions in XR for sports solutions [2, 10]. However, perceived social interaction did not significantly change. Our use of LLMs was limited to one-way interaction based on heart rate, but future research could explore two-way interactions incorporating user speech input for more engaging conversations. Different roles like a virtual coach or passer-by cyclists interacting with the user could be investigated. A limitation was the lack of personal connection with virtual riders; future studies could include GPX data from personal networks or past real rides performed together.

Motivational message generation. While textual messages provide dynamic motivational support based on virtual cyclist performance, future research could explore alternative modalities such as voice messages, suggested by participants for a more immersive experience. Visual enhancements like athletic avatars reflecting performance could impact physical output and perceived exertion [9], enhancing realism. Currently, message generation relies on GPX data, but considering both cyclists' heart rates may enhance motivation and personalization. Pre-collecting messages prevented server downtime during the experiment, but investigating real-time message generation is worth exploring.

Sample size and public feedback. Despite the significant findings, our study's smaller sample size is a limitation. However, we showcased the application at a science festival, where over 700 individuals tested our proof-of-concept, garnering significant popularity and positive reactions. Notably, no VR sickness was observed. Although these festival results are not included due to protocol deviations, they underscore interest in commercial availability and potential integration with platforms like Zwift. Additionally, the short ride times in our experiment aimed to mitigate physical condition effects, emphasizing the need for longer-term studies.

Future-proofing technological integration. Having successfully applied our approach to indoor cycling, we aim to extend it to other sports benefiting from peer motivation. The primary research challenge lies in developing equipment for real-world data collection and indoor performance while wearing VR glasses. Additionally, leveraging advancements in 360-degree cameras can enable users to record new tracks, ensuring scalability across popular routes. Previous findings suggest that tracks with turns induce natural bending reactions despite being discouraged for indoor cycling due to immersion levels reported.

5 CONCLUSION

This paper introduces our approach to harnessing real-world data and AI-generated motivational messages for VR sports solutions. To assess the feasibility and the impact on social interaction and motivation, a user evaluation was conducted with 18 participants, focusing on an indoor cycling context. The study revealed that enhancing realism in VR sports applications is a feasible strategy. Additionally, our findings indicate that the suggested features and asynchronous social interaction hold promise in boosting motivation and alleviating feelings of loneliness during indoor solo cycling. Furthermore, we suggest avenues for future research to advance the utilization of AI-based content generation and real-world data in VR sports solutions.

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