On-Your Marks, Ready? Exploring the User Experience of a VR Application for Runners with Cognitive-Behavioral Influences

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Abstract: Athletes need to train both physical and mental abilities to enhance performance. While technologies such as sensors and actuators have mainly focused on physical training, few solutions support mental training. Virtual reality (VR) technology and cognitive behavioral therapy (CBT) open new possibilities for developing applications targeting this type of training for athletes. We conducted a formative study to investigate the user experience of integrating CBT techniques into VR technology, focusing on two essential mental factors of running: strategy and motivation. To address these factors, we developed a *CBT-influenced* VR application. We tested the user experience of our VR application with 25 runners. The results revealed that runners had a positive and valuable experience with the VR application and its associated CBT elements. The perceived importance of race strategy was a key predictor of user experience assessments. This study suggests that VR solutions influenced by CBT are a plausible approach to developing suitable mental training tools in sports.

1 INTRODUCTION

Running is an accessible and low-cost sport that can be practiced almost anywhere by almost anyone. Nevertheless, running well and efficiently requires comprehensive development of running skills through training the physical, technical, and mental aspects. However, the mental aspect is usually not systematically trained (Cardenas Hernandez et al., 2024). Moreover, most running training programs focus primarily on physical and technical aspects, often neglecting the crucial mental aspect (Boucher et al., 2020; Rupprecht & Matkin, 2012).

One potential method to systematically train the mental aspect could be derived from cognitive behavioral therapy (CBT). CBT is an evidence-based treatment for psychological disorders that can be adapted for sport psychology as a cognitive behavioral *training*. It helps athletes transform dysfunctional performance behaviors and thoughts into functional ones by blending behavior therapy and cognitive therapy approaches (Gustafsson et al., 2017). Some of its interventions include anxiety management, goal-setting, and self-instruction (Whelan et al., 1991). Virtual reality (VR) allows the creation of interactive, immersive environments, both real and imaginary, using graphics, sounds, and other sensory stimuli (Kim et al., 2020; Scurati et al., 2021). VR has been used with CBT in what is denominated as virtual reality exposure-based cognitive behavioral therapy (VRE-CBT) in mental health conditions (van Loenen et al., 2022; Wu et al., 2021).

Drawing on the premise that VR can simulate realistic visual training scenarios that enhance athletic performance (Ahir et al., 2020), unlike verbal, written, or 2D video instructions, we suggest that VRE-CBT can be a useful tool for training optimal behavior in high-intensity situations, such as running races. Visualizing and repeating these *virtual* scenarios could help athletes reduce errors and improve their mental and perceptual skills, giving them a competitive edge (Farley et al., 2019).

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Building on VRE-CBT, we developed a CBT-influenced VR application for head-mounted displays (HMDs) in English. It integrates cognitive behavioral techniques such as *imagery* (by virtually simulating the running race), *behavioral activation* (by visual and auditory emotionally charged stimuli), and *cognitive restructuring* (by effective teaching the race strategy) (Blackwell, 2021; DeSena et al., 2024; Hanton et al., 2008). We aimed to investigate strategy and motivation, which are mental factors that significantly influence running competition outcomes (Hammer & Podlog, 2016; Kilduff, 2014; McCormick et al., 2019; Thiel et al., 2012).

In this work, strategy refers to the cognitive process of making reflective decisions or choices without time constraints (Gréhaigne et al., 1999). It includes plans, principles of play, and guidelines prepared beforehand. Meanwhile, motivation describes the behavioral process influencing the initiation, direction, magnitude, perseverance, continuation, and quality in achieving a goal (Roberts et al., 2018).

To explore how to target these mental factors, we conducted a formative study in which runners of different experience levels tested the VR application and examined their end-user needs and preferences.

2 RELATED WORK

CBT is an evidence-based treatment for different psychological disorders. It follows scientific evidence that shows that thoughts (cognitions) and behaviors (actions, choices) affect the way people feel (emotions) (DeSena et al., 2024). VR has been used as a technological tool for the behavior-cognitive exposure component of CBT that, with the help of virtual environments, facilitates the progressive exposure to aversive-inducing stimuli within a contextually appropriate and controlled scenario (Opriş et al., 2012). In this sense, VRE-CBT can be seen as a useful psychological intervention for different mental challenges.

VR has been applied to train different mental facets of sports performance. We identified that some studies used VR technologies to support the affective and cognitive components of mental training.

Regarding the affective dimension, VR technologies have been used to lower soccer anxiety levels by exposing users to simulated penalty kicks (Harrison et al., 2021). Additionally, VR interventions in stationary cycling have demonstrated improvement in mood and reduction of tiredness (Plante et al., 2003). Further, athletes feel more motivated and less pressured during their training (IJsselsteijn et al., 2004) and report increased enjoyment (Mestre et al., 2011) using a virtual coach. A positive effect on motivation has also been shown in VR volleyball environments with emotionally expressive virtual characters (Bai et al., 2021).

Elaborating on the cognitive dimension, VR applications have shown potential in promoting decision making in sports like basketball (Tsai et al., 2019) and soccer (Wirth et al., 2021). They can also support sprinters to improve their concentration (Choiri et al., 2017) and help stationary cyclists to ride at the prescribed speed by following the instructions of a virtual coach (Mestre et al., 2011). VR has also been used to analyze basketball tactics (Cannavo et al., 2018) and to help rowers learn race strategies to optimize energy use and enhance performance (Hoffmann et al., 2014).

These research findings show that VR can address both affective and cognitive components of sports, but most studies have focused on either one separately. We propose that a CBT-influenced VR application can simultaneously target both aspects of long-distance running. We also suggest that using a CBT approach can provide an effective and systematic way to initiate the development of VR technology for potential mental training purposes.

3 SCOPE OF THIS STUDY

This article presents a study on the user experience (UX) of a CBT-influenced VR application, exploring its potential to integrate strategic and motivational facets for long-distance races using an HMD without physical running.

The research questions (RQs) of our study are:

- RQ1: How is the user experience characterized within the VR application, as assessed through usability metrics and subjective evaluations?
- RQ2: What are the main strengths and drawbacks of the VR application as articulated by individuals engaged in running activities?
- RQ3: To what extent is the VR application feasible as a cognitive-behavioral tool for potential use in mental preparation for running races?
- RQ4: What user profiles are most likely to benefit from using this VR application?

3.1 VR-Application Description

We aimed to make the application effective by following the conditions for VR exposure therapy that Krijn et al. (Krijn et al., 2004) described: the virtual

Figure 1: VR application flow diagram. Sequence of scenes.

environment should make users feel present, elicit emotions, and induce cognitive changes generalizable to real situations.

The VR application simulates typical racing scenarios, aiming to instruct the *running pace* as the main strategy, while a virtual coach avatar provides strategic guidance, encouraging words, and background audio plays to elicit emotion and immersion for the user. As shown in Figure 1, the CBT-influenced VR application takes the user through six sequential scenes. These scenes are:

Settings: In this scene, the user can choose a preferred initial pace for the competition, which is a crucial strategic factor for any runner to know before starting a race. The chosen pace will also set the speed of other virtual characters in the subsequent scenes. The user can select a pace from a list of values ranging from 2:30 to 6:30 min/km, with 0.10 min/km increments. After selecting a pace, the user must press a virtual button (start button) to proceed to the next scene.

Transition 1: This scene involves CBT techniques such as behavioral activation and cognitive restructuring. Here, the user is in a stadium setting, where a female coach avatar gives a motivational speech with strategic tips and encouragement. After listening to the coach, the user must push a virtual button to continue to the next scene. While the next scene is loading, a sports-related inspirational quote shows up on the screen. The goal of this scene is to positively influence users' motivation beforehand.

Start of the Race: It incorporates CBT techniques such as imagery and cognitive restructuring. It depicts the start of a road race based on a real competition (see Figure 2). It plays the background sound of a cheering crowd at a sporting event. The user is one of the 41 virtual runners lined up at the starting line. The starting gun signals the beginning of the race, and the virtual characters sprint ahead. The user must use the controllers to participate in the race. The thumb stick determines the direction of the user's motion, while the buttons adjust the user's pace. A speedometer in the lower left side of the user view changes its reading based on the user's pace. After completing about 300 m, which is one third of the route, the user listens to the coach avatar giving a voice narration. The coach' voice advises the user to avoid running fast and to focus on keeping a steady pace. This part is envisioned to target the strategy by instructing users to avoid the common mistake of exhausting their energy in the first stage of the race. The scene ends when the user finishes the 1 km route, and the next scene loads automatically.

Figure 2: User's view of the "start of the race" scene.

Transition 2: It applies the behavioral activation technique. In this scene, the user comes back to the stadium. The coach avatar advises to stay calm and confident for the next few kilometers of the race; it also remarks that the user will soon overtake runners who anxiously started too fast and are now exhausted. After the coach's speech, the user must press a virtual button to advance to the following scene. The purpose of this scene is to keep motivating the user by explaining the outcome of applying the strategy at the start of the race. A motivational quote for sports appears on the screen as the subsequent scene loads.

Finish of the race: This scene incorporates CBT techniques such as imagery, behavioral activation and cognitive restructuring. In this scene, the user and three virtual runner characters are nearing the finish line on a street. The background sound consists of the applause and cheers of a crowd, which gets louder as the user approaches the end of the race. As the finish line comes into view, the coach's voice reminds users to swing their arms to increase their speed and encourages them to give their best despite fatigue and soreness. A motivational melody also starts playing in the background. By doing all this, we aim to teach strategy and boost motivation. The scene switches automatically after the user crosses the finish line.

Transition 3: It uses behavioral activation. This is the last scene where the coach avatar acclaims the user for exercising and encourages the user to succeed in running a smart race. A celebratory melody plays in the background to congratulate the user for finishing the race. The user must then press a virtual button to return to the first scene, marking the end of the mental preparation.

With the VR-HMD's controllers, users could interact with the virtual world in a first-person view. Regarding the controllers' buttons, the primary thumb stick on the left controller enabled users to navigate the virtual environment. By tilting their heads, they could also adjust their direction of movement. To adjust their speed, users pressed the B and A buttons on the right controller, which respectively increased or decreased it by 2 min/km each time.

Using the Unity game engine, we developed an immersive VR application in English for the Oculus Quest 2. We used CityGen3D editor to generate the streets of the city for some VR scenes, created the avatar's voice using a text-to-speech voice generator, and applied Unity's built-in rendering pipeline to create our VR-application. This VR application was installed on the Oculus Quest 2 with a resolution of 1832 x 1920 pixels per eye, a refresh rate of 90 Hz, and a field of view of 90 degrees. Participants used the Oculus's built-in headphones for audio.

To conclude this section, we would like to note that we avoided involving the lower extremities in our VR application, to prevent additional physical strain on the runner's legs beyond their regular training before a competition.

4 METHODS

In this section, we explain how we proceeded to identify key determinants of using VR technology influenced by CBT and HMD to train strategy and motivation for runners. All user tests were conducted in accordance with our research project's declaration and obtained the approval of the ethical committee of the authors' institute.

4.1 Participants

This study included 25 participants (8 women, 17 men) who were regular or past runners who had competed in a 3 km or longer race at least once. They ranged in age between 21 and 57 years old (M = 37.1, SD = 10.3) with a mean of 9.61 (SD = 8.45) years of experience and a mean of 12.6 (SD = 18.3) running races from 8 different countries. All participants reported having English proficiency and were voluntarily recruited through personal or third-party verbal invitations, without regard to gender, nationality, education, age, or running experience.

4.2 Procedure

Based on the participants' locations, we conducted our study in indoor and shady outdoor settings with low noise levels to prevent distractions and potential malfunctions with the HMD.

Before testing the CBT-influenced VR-application, a researcher set the HMD's virtual boundaries for each participant. A researcher also gave each participant written and verbal instructions on how to use the VR application properly. The researcher then adjusted the head strap of the HMD to fit the participant's head size, and the participant started using the VR application in a standing-up position. Each single-test session lasted about 6-7 minutes per participant.

Upon testing the VR-application, participants were asked to fill out a printed UX questionnaire. The researcher took notes about the participants' comments and behaviors during the tests. Finally, the researchers thanked people for their participation and gave them more information about the study's purpose.

4.3 Apparatus and Material

We used the Oculus Quest 2 as the primary device for this study. This is an affordable, widely available all-in-one VR device with full motion freedom and a high-resolution display.

To explore the user experience of our VR application from a usability and a CBT-influenced perspective, participants completed a paper UX questionnaire. It was anonymous and consisted of 13 questions on a 10-point Likert scale and seven open-ended questions in English. It was adapted from the one developed for the Multimodal Learning Analytics Grand Challenge (Worsley et al., 2015) and has been validated and proven reliable in previous studies (Romano et al., 2019; Schneider et al., 2019).

For reference in next sections, the questionnaire Likert-scale items are represented as follows:
a) How likely would I be to use this VR application in my free time?, b) How would I rate my experience with this VR application?, c) Would I recommend this VR application to a friend?, d) How motivated would I be to use this VR application again?, e) Is the VR-application fun to use?, f) I really felt like I was in a race while using this VR application, g) I felt very immersed in the VR scenarios while using the

application, h) It is very important to feel immersed in this type of (mental) training, i) A VR application like this has the potential to help me improve my tactic/strategy for a race, j) How important do I perceive the execution of a good tactic/strategy during a running race?, k) A VR application like this has the potential to motivate me to push myself harder to perform great in a race, l) I feel like I have learned something while interacting with the VR application, and m) A VR application like this has the potential to train other elements of the mental aspects in a race.

4.4 Data Analysis

For comparison of all Likert scale ratings, data were reported as means (M) and standard deviations (SD). As an indicator of internal consistency reliability of the items contributing to measure the same construct, the Cronbach's alpha was obtained. Its interpretation followed the approach of George and Mallery (George & Mallery, 2003), which is summarized as: "_ > .9 – Excellent, _ > .8 – Good, _ > .7 – Acceptable, _ > .6 – Questionable, _ > .5 – Poor, and _ < .5 – Unacceptable".

Furthermore, we used Pearson's correlation to examine the strength and direction of the relationships between the features that shape the participants' opinions on the VR application (independent variables) and their Likert-scale responses. For this purpose, we calculated the correlation coefficient (Pearson's r) and the p-value. We reported the strength of the correlation using the interpretation given by Dancey and Reidy (Dancey & Reidy, 2007). For determining statistical significance, we distinguish three cutoffs: p-value < 0.001, p-value < 0.01, and p-value < 0.05.

Multiple linear regression models were used to examine the effects of independent variables, and the estimated marginal means for the categorical predictors were calculated. All reported data was statistically analyzed using Jamovi 2.4.5 software.

We applied a qualitative analysis of open-ended responses by coding the data into emerging categories and selecting the most frequent codes. Two researchers independently performed the analysis and compared their results.

5 RESULTS

Out of the 25 participants, eight reported having some prior experience with VR technology. The results of the Likert-scale questions, grouped by UX questionnaire themes: user experience and support for mental training, and constructs: acceptance, immersion–presence (imagery component), race strategy (cognitive restructuring and behavioral activation component), motivation, and other mental factors, are presented in Table 1. We ordered each item in the groups by its mean in ascending order.

Table 1: Means (M) and Standard Deviations (SD) of the Likert-scale items from the UX questionnaire.

Theme	*Construct*	*Likert-scale item*	*M*	*SD*
User experience	Acceptance	a [ul]	5.40	2.29
		b [an]	6.20	1.73
		c [da]	6.32	2.61
		d [bm]	6.76	2.35
		e [da]	7.52	2.20
	Immersion – presence (Imagery)	f [da]	6.56	2.58
		g [da]	6.72	2.30
		h [da]	7.44	1.76
Support for mental training	Race strategy (Cognitive restructuring & behavioral activation)	i [da]	7.00	1.78
		j [da]	8.92	1.26
	Motivation	k [da]	6.80	1.87
	Other mental factors	l [da]	6.36	1.78
		m [da]	7.28	1.99

[an] 1 Very awkward – 10 Very natural
[bm] 1 Extremely bored – 10 Extremely motivated
[ul] 1 Very unlikely – 10 Very likely
[da] 1 Strongly disagree – 10 Strongly agree

Participants rated the CBT-influenced VR application positively for the acceptance construct (M = 6.44, SD = 0.77 for aggregated values, Av) and the immersion-presence construct (M = 6.9, SD = 0.47 for Av), signifying that they liked the VR application and felt an acceptable degree of immersion (imagery) in the virtual scenarios.

They also agreed that the VR application could help them train the strategy (M = 7.96, SD = 1.36 for Av) and other mental aspects of a running race (M = 6.82, SD = 0.65 for Av), and enhance their motivation (M = 6.80, SD = 1.87). Moreover, they emphasized the high importance of the strategic part during a race (cognitive restructuring and behavioral activation).

We also conducted a correlation statistical analysis to examine the relationship between the Likert-scale responses from the UX questionnaire and the independent variables: participants' age, running experience, and perceived importance of strategy (Likert-scale item j). The analysis revealed some noteworthy findings (see Table 2), which are elaborated in the subsequent paragraphs.

Table 2: Pearson's correlation coefficients between the Likert-scale ratings from the UX questionnaire and the independent variables: participants' age, running experience, and perceived importance of strategy.

Theme	*Construct*	*Likert – scale item*	*Age*	*Running experience*	*Perceived importance of strategy*
User experience	Acceptance	a	-0.101	-0.124	0.374
		b	-0.157	-0.178	0.353
		c	-0.303	-0.226	0.568*
		d	-0.162	-0.183	0.502*
		e	-0.358	-0.174	0.483*
	Immersion–presence (Imagery)	f	-0.198	-0.279	0.477*
		g	-0.211	-0.121	0.352
		h	-0.466*	-0.205	0.621***
Support for mental training	Race strategy (Cognitive restructuring & behavioral activation)	i	-0.406*	-0.239	0.709***
	Motivation	k	-0.559**	-0.465*	0.667***
	Other mental factors	l	-0.250	-0.170	0.536**
		m	-0.520**	-0.458*	0.560**

*** p-value < 0.001, ** p-value < 0.01, * p-value < 0.05

Concerning the user experience theme and its:

• *acceptance* construct, the correlation analysis indicated that participants who rated their strategy as more important also had more positive attitudes and experiences with the VR application. They were more likely to use it again, recommend it to others, and enjoy it.

• *immersion-presence* construct, the correlation analysis showed that older runners tend to rate feeling immersed for mental training as less important than younger runners. In the same way, it was found that the runners who rated their strategy as more important also had higher ratings for the feeling in the race and the importance of feeling immersed, and vice versa.

Speaking of the support for mental training theme and its:

• *race strategy* construct, the correlation analysis indicated that older runners tend to give lower scores than younger runners on how much they think a VR application can help them improve their race strategy. Additionally, the analysis suggested that the participants who rated the VR application higher in terms of its usefulness for their race strategy also valued their race strategy more.

• *motivation* construct, the correlation analysis revealed that older and more experienced runners were less convinced that a VR application could help them improve their motivation for race preparation than younger and less experienced runners. The correlation analysis also indicated that the runners who valued their strategy more also rated the VR application higher in terms of its motivational effect, and vice versa.

• *other mental factors* construct, the correlation analysis showed that older and more experienced runners were less convinced that a VR application could help them improve other mental aspects of their race preparation than younger and less experienced runners.

On the other hand, the correlation analysis revealed that the runners who valued their strategy more also rated the VR application higher in terms of its usefulness for other mental elements, and vice versa. Likewise, the correlation analysis indicated that the runners who felt that they learned something from the VR application also rated strategy higher in terms of its importance, and vice versa.

We assessed the reliability of the acceptance and immersion-presence constructs by calculating the Cronbach's alpha coefficient for each construct based on the mean of the items that composed it. The acceptance construct had excellent internal consistency (Cronbach's $\alpha = 0.925$), and the immersion-presence construct had good internal consistency (Cronbach's $\alpha = 0.827$).

Subsequently, we examined how the independent variables (participants' age, running experience, and perceived importance of strategy) influence participants' assessments of our four constructs (acceptance, immersion-presence, race strategy, and motivation). We applied multiple linear regression models to analyze the effects of the independent variables on each construct and estimated the marginal means for the categorical predictors. The R2 values for each construct were: acceptance = 0.319, immersion-presence = 0.322, race strategy = 0.524, and motivation = 0.549.

Table 3: Model coefficients of the constructs: acceptance, immersion-presence, race strategy, and motivation.

Theme	*Construct*	*Predictor*	*Estimate*	*Standard error*	*t*	*p-value*	*Standard estimate*
User experience	Acceptance	Intercept	-4.508	4.721	-0.955	0.350	-
		Age	0.056	0.053	1.054	0.304	0.295
		Running experience	-0.050	0.051	-0.973	0.342	-0.216
		Perceived importance of strategy	1.046	0.376	2.782	0.011	0.665
	Immersion–presence (Imagery)	Intercept	-2.503	4.599	-0.544	0.592	-
		Age	0.036	0.052	0.699	0.492	0.196
		Running experience	-0.046	0.050	-0.919	0.368	-0.203
		Perceived importance of strategy	0.952	0.366	2.600	0.017	0.620
Support for mental training	Race strategy (Cognitive restructuring & behavioral activation)	Intercept	-3.967	3.549	-1.118	0.276	-
		Age	0.033	0.040	0.836	0.413	-0.168
		Running experience	-0.035	0.039	-0.907	0.375	0.795
		Perceived importance of strategy	1.127	0.282	3.985	< .001	0.196
	Motivation	Intercept	-0.461	3.636	-0.127	0.900	-
		Age	0.001	0.041	0.033	0.974	0.007
		Running experience	-0.073	0.039	-1.852	0.078	-0.334
		Perceived importance of strategy	0.888	0.289	3.064	0.006	-

Our results (see Table 3) showed that only perceived importance of strategy significantly predicted the four constructs, while age and experience did not significantly predict any.

The open-ended questions helped us identify the upsides and downsides of the VR application and suggested potential improvements. Participants gave positive feedback on diverse aspects of the VR application. 11 participants commented that they learned to apply running pace during different stages of a race. Two participants mentioned that they learned something new about the running technique, such as swinging their arms.

The background audio was another feature that received high satisfaction from six participants, who appreciated its motivational effects. The selection of the virtual stages in a race was also approved by 11 participants, who enjoyed the diversity and realism of the scenarios. Finally, seven participants found the guidance and instructions helpful, and supportive.

Participants also reported some downsides to the VR application. Three participants experienced cybersickness symptoms like dizziness and eye strain, but none felt the need to stop using the application. Two participants who wore glasses expressed their displeasure to wear them along with the HMD as it made them feel uncomfortable. Some scenarios, especially the "finish of the race" scene, were too short for three participants, who complained about its time duration. Three participants also reported initial difficulties with the VR technology, needing more time and instructions to adjust to the VR environment and controls.

Additionally, participants also provided some suggestions to enhance the VR application. 12 participants reported that to get a higher immersion, it is necessary to incorporate physical movements that mimic the running gait, such as swinging the arms or lifting the knees. They believed that this would make the VR experience more realistic and engaging. Six participants recommended adding additional race strategy scenarios, stages, and effects, such as different terrains or weather conditions. Three participants suggested finding alternatives to control the speed in the VR application. They found the current method of using a controller to be unnatural.

Seven participants suggested improving the graphics, indicating they were blurry.

More than half of the participants struggled to use their VR hands to interact with the virtual elements at the start of the test. For instance, one lady in her sixties, who was excluded from the results, spent about 15 minutes trying unsuccessfully. Six participants exhibited boredom and asked the researchers how long it would take to complete the "start of the race" scene.

Other six participants disregarded the avatar's speech and kept pushing the button to augment their speed. Approximately five participants looked up at the sky or turned their heads to explore their surroundings while virtually moving. Six participants whose mother tongue was not English paid no attention to the motivational quotes and the avatar's speech during the test.

6 DISCUSSIONS

Regarding the user experience of our CBT-influenced VR application (RQ1), overall, it received positive ratings from the participants in terms of acceptance and immersion. The mean scores of the items used to evaluate these aspects were higher than six (on a 10-point scale) for more than 80% of the time, indicating that the participants had acceptable user experience.

Based on our results, we identified the main perceived strengths and drawbacks of using our VR application (RQ2). As distinguishable positive facets, we found that participants enjoyed, engaged, recognized and appreciated the virtual scenarios and their background audio that simulated race stages. This suggests that these scenarios contain relevant and valuable features that can facilitate meaningful learning experiences in virtual environments, as supported by previous work (Dengel et al., 2022; Vergara et al., 2019). Likewise, the presence of the avatar coach and its guidance had a positive effect on most participants' perception (19 out of 25 participants), confirming its beneficial influence as reported by prior studies (Eyck et al., 2006; IJsselsteijn et al., 2006). Specifically, runners stated learning to adjust their running pace according to the coach avatar's feedback, aligning with the research findings on cycling (Mestre et al., 2011). Moreover, the participants experienced relatively low levels of cybersickness symptoms from the VR-application.

As visible drawbacks, we distinguished that some participants faced challenges in getting accustomed to and interacting with the VR application at the beginning of the test. They claimed they needed more time and guidance to adapt to the virtual environment and its controls. These challenges could affect their motivation and cause frustration. However, the use of general user models based on people's experience, gender, or age could represent a viable alternative to ease adaptation in virtual environments (Octavia et al., 2011). On the other hand, although standing up and using buttons or a joystick to control the VR application have evoked some feelings and perceptions related to running a race, participants expected a more natural and intuitive way to mimic real running gait for controlling speed and direction in VR. Walking-based locomotion techniques (Martinez et al., 2022) such as arm swinging, may be adequate solutions for our application, as some participants performed this movement involuntarily. Furthermore, using a second language instead of the native one may have caused some participants to ignore the motivational quotes and the avatar's speech in English, possibly due to the lack of language switching skills. The incorporation of more languages could mitigate this challenge.

Moreover, the application was perceived as a promising VR-cognitive behavioral intervention that can support mental preparation for running races (RQ3). Our findings suggest that the VR application has the potential to support elements such as race strategy and motivation simultaneously. Additionally, the runners gave a slightly higher rating for strategy training than for motivation training. This result is reflected in the open-ended questions, where some runners mentioned: "I learned again to keep the pace, mostly at the beginning of the race…", "There were good suggestions about pacing yourself …" and "Slowing down in the beginning even if others overtake you…". However, other runners also expressed boredom and commented: "I felt bored in few minutes" and "It was realistic, but at same points of the race, it was a bit boring". To maintain participants' engagement, it would be advisable to provide strategic instructions or motivational speeches more frequently, as well as to monitor user performance and give appropriate feedback regularly. In addition, some participants orally expressed their desire to interact with the virtual runners of the application in an expressive manner. This finding is consistent with the results of Bai et al (Bai et al., 2021), who stated that virtual characters with emotion expression in VR volleyball games can increase the user's emotional experience and engagement.

In terms of the type of users who have the potential to benefit most from the VR application (RQ4), results showed that the perceived importance of the race strategy plays a key role in shaping the user's attitude, experience, motivation, learning outcome, immersion, and usefulness of our CBT-influenced VR application, regardless of their running experience. Therefore, to get the most value out of our VR-application, we recommend explaining to users the relevance of a good race strategy, as pointed out by Abbis and Laursen (Abbiss & Laursen, 2008).

The runners' age variable can also modify the user's importance of immersion and the usefulness of the VR-application. Our results suggest that older runners are less likely to value immersion for mental training in VR than younger runners. This may be due to different preferences or lower levels of experience with VR. This finding aligns with previous research (Syed-Abdul et al., 2019), which indicated that older adults may face barriers or challenges in using VR, such as lack of access, skills, or confidence, affecting their perception of VR experiences.

This study has some limitations that should be acknowledged. As a first limitation, we consulted participants to explore whether our CBT-influenced VR application could work, but we did not measure its actual effectiveness. Nevertheless, studies like this are good enough to provide a rough idea about the functionality and impact on real users. Second, our relatively small sample size (25 participants) may affect the statistical reliability of our results. Although a larger and more diverse sample would be desirable to confirm and extend our findings, for exploratory studies like ours, the number of participants does not require many participants (Nielsen & Landauer, 1993). Third, our study focused only on strategy and motivation as the target mental elements, but there are other cognitive (e.g., attention and memory) and behavioral factors (e.g., confidence and happiness) that may also affect an athlete's performance. Finally, we used generic virtual scenarios in our study that were suitable for any runner, but they did not cater to or adapt to the specific needs of each runner.

7 CONCLUSIONS

We presented a formative study on the user experience of a VR application that targets mental factors in endurance sports such as running. Results from our study show the feasibility of using such an application for targeting mental elements such as race strategy and motivation simultaneously from the perspective of runners with race experience. The results and methods in this study may serve as a guideline for researchers and developers to create CBT-influenced VR tools for potential mental training in the field of sports psychology, aimed at enhancing athletes' performance.

The CBT-influenced VR application appeals more to the participants who have a high interest in strategy as a key factor in their mental preparation. The application may not be as attractive for participants who do not value strategy as much or have other preferences or goals. The user experience in CBT-influenced VR applications may vary by participants' age, as different age groups have different perspectives and expectations on the VR technology.

For future work, we suggest exploring the incorporation of meaningful or recognizable music in the design of an CBT-influenced VR application, as it has been demonstrated to improve athletes' performance by increasing their motivation and enjoyment (Ballmann et al., 2021). Similarly, we recommend the integration of multisensory sources (visual, audio, and tactile), as they may regulate the cognitive load and enhance the user experience by increasing immersion and presence with vibrotactile stimuli (Marucci et al., 2021). In that sense, runners can get mentally prepared through VR-cognitive-behavioral training, which complements the physical and technical aspects, and run their best possible race with confidence.

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