



**BEYOND THE PHYSICAL
TOWARD MENTAL TRAINING:
*INVESTIGATING A MULTIMODAL
IMMERSIVE TECHNOLOGY
APPROACH IN RUNNING***

Fernando P. Cardenas Hernandez

29 October 2026

BACKGROUND: THE PROJECT & ITS OBJECTIVE

- **MILKI-PSY:** *Multimodal Immersives Lernen mit künstlicher Intelligenz für Psychomotorische Fähigkeiten.*
- **Project's goal:** Supporting psychomotor skill learning with AI and immersive technologies.
- **Study Cases:**
 - Human-robot collaboration
 - *Sports* → *Running*
- **Methodology:** Design-Based Research

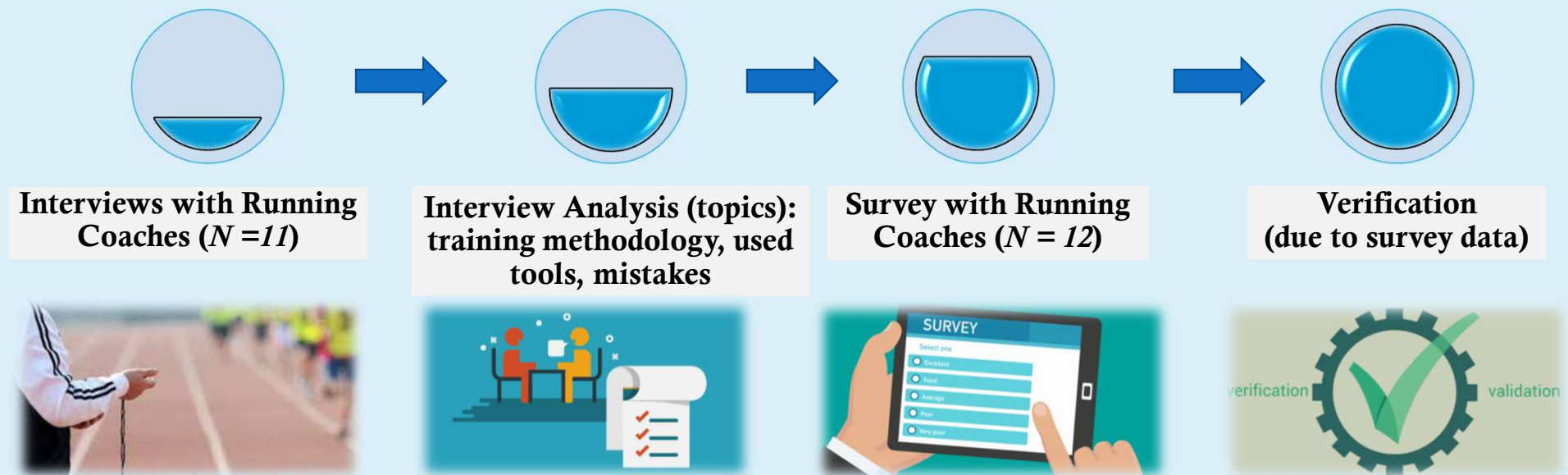


STUDY 1

👉 *Having defined the sport, how did we guide the direction of our research?*

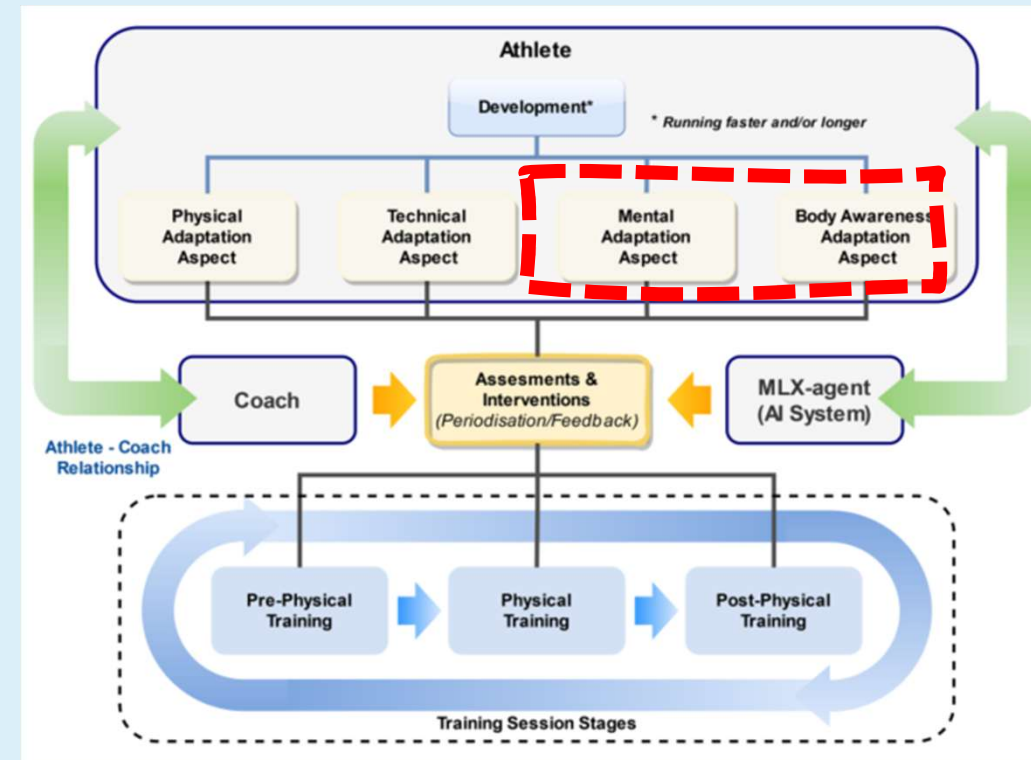
- To start our DBR process, we decided to conduct a *formative study* whose purpose was to *identify the factors that influence running training and the existing needs (gaps)* for improving that training.

STUDY 1 – INFLUENCING FACTORS AND NEEDS IN RUNNING TRAINING: *METHODOLOGICAL SEQUENCE*



STUDY 1 – RESULTS

- Aspects influencing running training: **physical, technical, mental and body awareness**
- Multimodal Learning Experience (MLX) Framework for development of runners:**
 - Involved devices:
Smartphone, smartwatches, VR headsets, IMU's
- Mental aspect & body awareness aspect need supporting tools**



Cardenas Hernandez, F. P., Schneider, J., Di Mitri, D., Jivet, I., & Drachsler, H. (2024). Beyond hard workout: A multimodal framework for personalised running training with immersive technologies. *British Journal of Educational Technology*, 00, 1–32.
<https://doi.org/10.1111/bjet.13445>

STUDY 2

👉 *Having identified existing needs, how should we proceed to develop supporting tools for running training?*

- In the next stage of our DBR process, *after prioritizing mental aspect*, we continued with a *formative study* aimed at *developing and assessing the User Experience (UX)* of a technological tool to support the mental training.

STUDY 2 – USER EXPERIENCE OF A TECHNOLOGICAL TOOL FOR MENTAL TRAINING OF RUNNERS: *FOUNDATIONAL PRINCIPLES*

Type of Technology



Virtual Reality (VR)

Guided by our MLX framework

Implementation



Developing a VR application

Helping athletes transform
dysfunctional performance-related
behaviors and thoughts into more
functional ones

Cognitive Behavioral Training

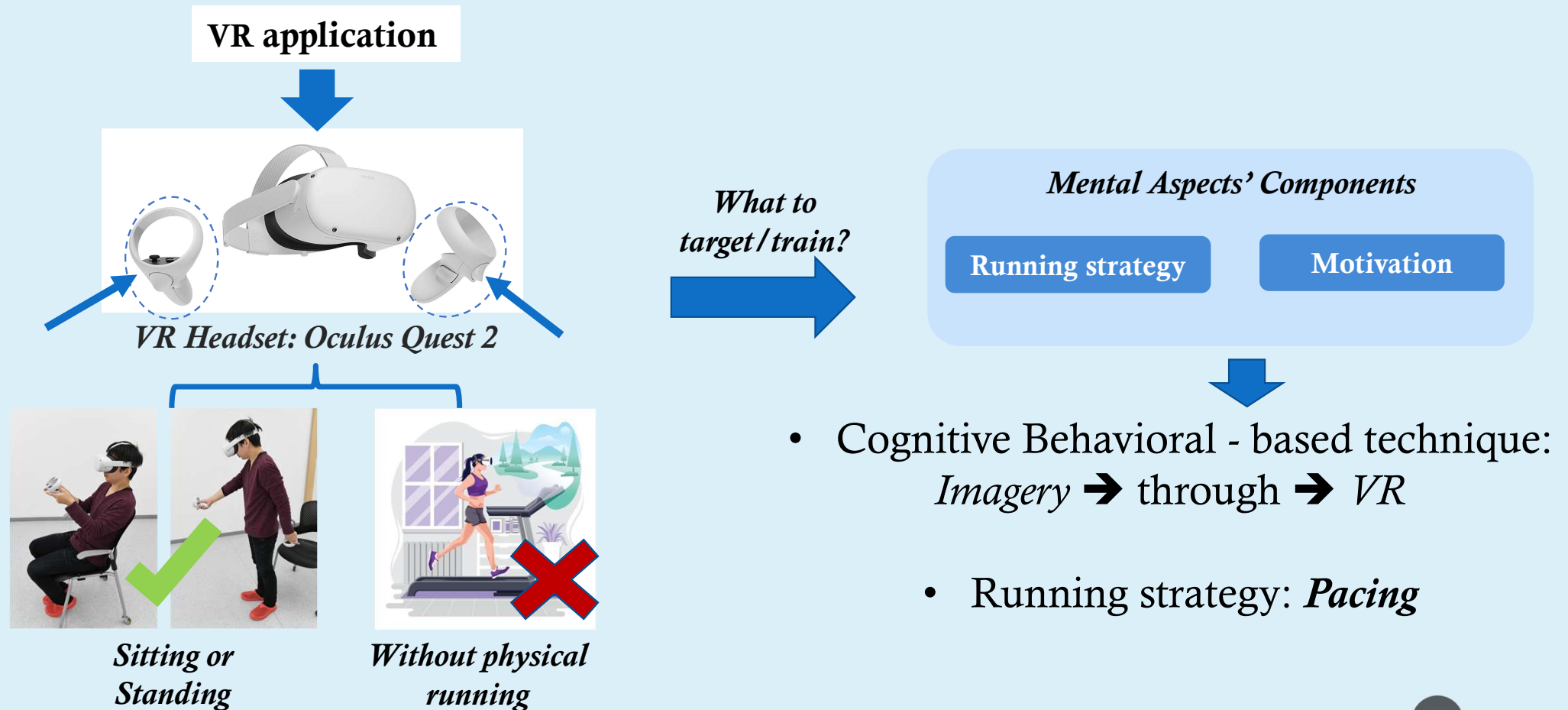
Inspired by *Cognitive Behavioral Therapy (CBT)*

CBT: A therapeutic treatment (medical practice) that helps identify and change maladaptive patterns of thoughts, emotions, and behaviors

Improving Athletic Performance



STUDY 2 – USER EXPERIENCE OF A TECHNOLOGICAL TOOL FOR MENTAL TRAINING OF RUNNERS: *DESIGN PRINCIPLES (1)*



STUDY 2 – USER EXPERIENCE OF A TECHNOLOGICAL TOOL FOR MENTAL TRAINING OF RUNNERS: *DESIGN PRINCIPLES* (2)

Scene Sequence of the VR Application



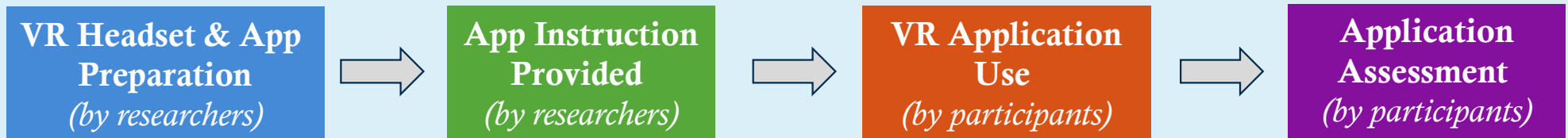
Competition scenes:

- *Start of the race*
- *Finish of the race*



STUDY 2 – USER EXPERIENCE OF A TECHNOLOGICAL TOOL FOR MENTAL TRAINING OF RUNNERS: *METHODOLOGY*

We proceeded to capture the User Experience (UX)



- $n = 25$ participants.
- *Assessment instrument:* A UX questionnaire (adapted from the one developed for the *Multimodal Learning Analytics Grand Challenge* by Worsley et al., 2015):
 - 13 questions on a 10-point Likert scale & seven open-ended questions
 - Analyzed constructs: *Acceptance*, *Immersion – presence*, *Race strategy* & *Motivation*.

STUDY 2 – RESULTS

- *Favorable and satisfactory responses to our VR application in the UX questionnaire.*
- *Perceived importance of race strategy was the only independent variable that significantly predicted (statistically significant relationship) the four analyzed constructs (i.e., dependent variables).*
- *Feasibility of using a Cognitive Behavioral-based VR application to target the mental aspect (specifically the Race strategy and Motivation).*

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	f ^{da}	6.56	2.58
		g ^{da}	6.72	2.30
		h ^{da}	7.44	1.76
Support for mental training	Race strategy	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: I Very awkward – 10 Very natural bm: I Extremely bored – 10 Extremely motivated ul: I Very unlikely – 10 Very likely da: I Strongly disagree – 10 Strongly agree				

STUDY 3

👉 *Based on feedback from users of our previous VR application, our approach demonstrated feasibility.*

So ... "what comes next?"

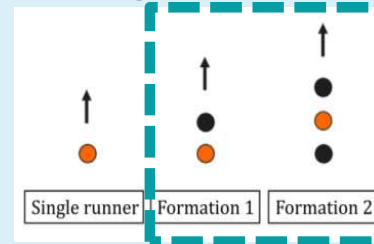
- In the next part of our DBR process, we conducted a study, in which we aimed to test the *potential impact* of our (*revised*) application on real-world running competition preparation.

STUDY 3 – ASSESSING THE POTENTIAL IMPACT OF A (REVISED) VR APPLICATION ON MENTAL TRAINING FOR RUNNERS: *DESIGN PRINCIPLES*

Cognitive Behavioral-based techniques: *Imagery & Self-talk* → through → VR

What to
target/train?

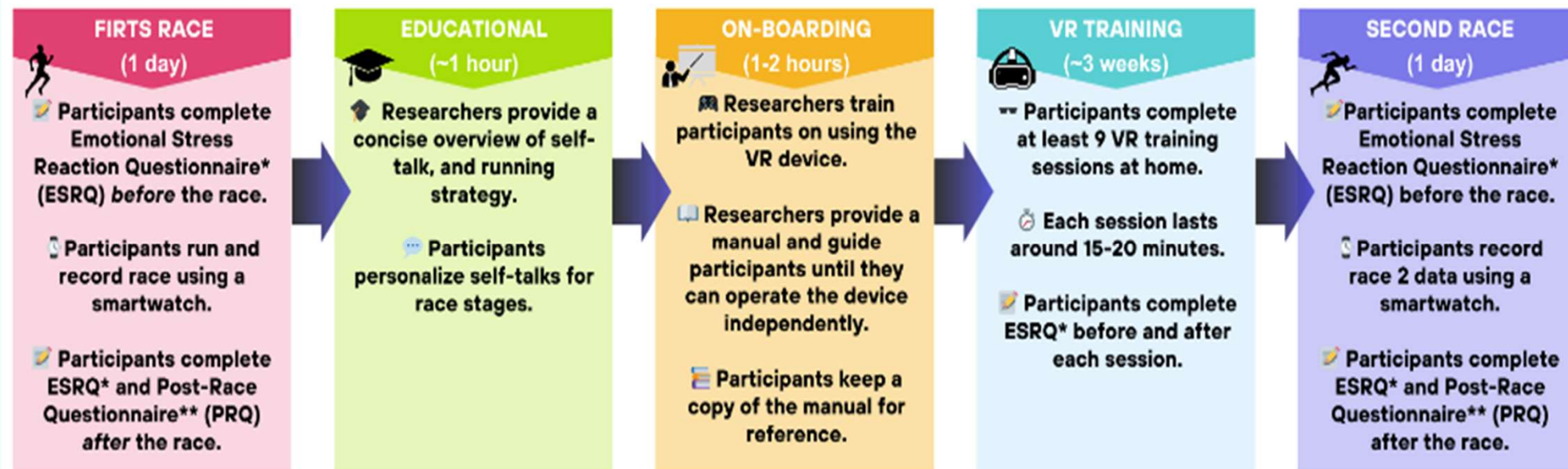
- Motivation → Personalized *self-talk* and *songs/melodies*
- Running strategy → *Pacing & drafting*



Scene Sequence of the Revised VR Application



STUDY 3 – ASSESSING THE POTENTIAL IMPACT OF A (REVISED) VR APPLICATION ON MENTAL TRAINING FOR RUNNERS: *METHODOLOGY*



* Includes only Likert-scale questions; ** Includes Likert-scale and open-ended questions

- *n* = 6 Participants (1 tech. issue)

• Devices:

Oculus Quest 2 & TicWatch Smartwatches

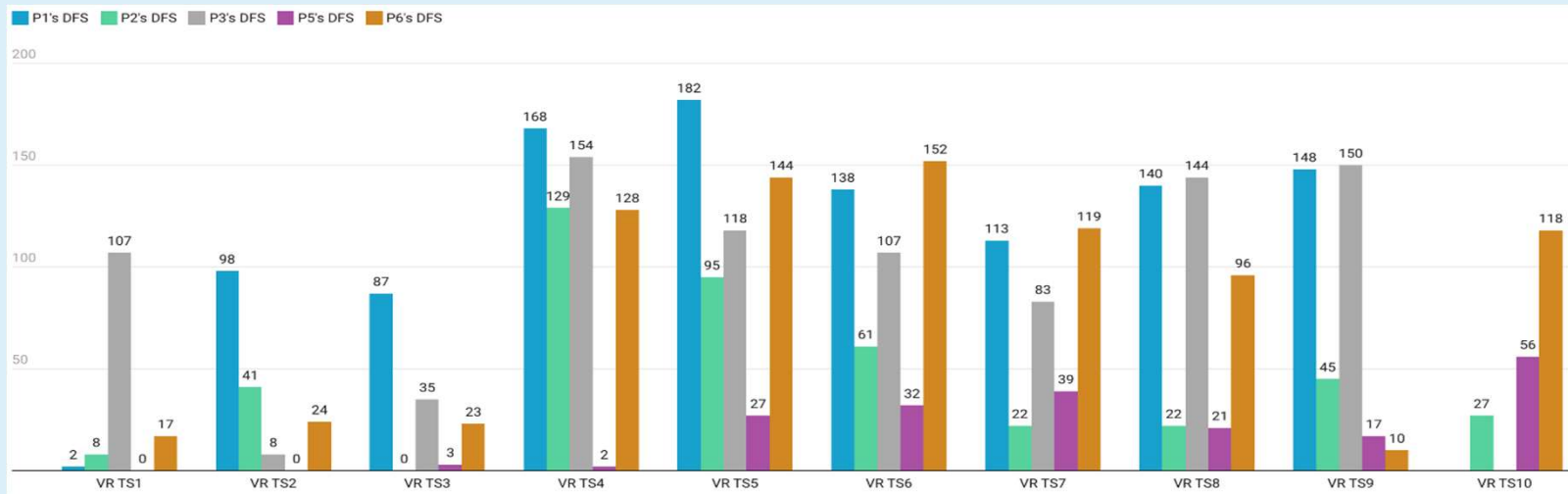
• Self-assessment instruments:

Emotional Stress Reaction Questionnaire (ESRQ) (Larsson, 2011)

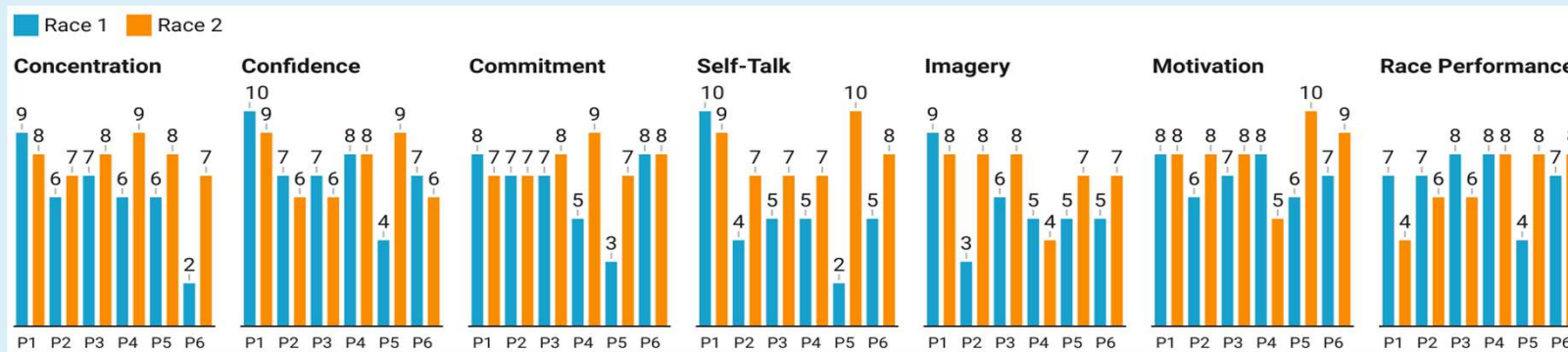
Post-Race Questionnaire (PRQ): Adapted from the Post-Event Reflection Tool (Chow & Luzzi, 2019).

STUDY 3 – RESULTS (1)

Drafting scores increased in middle VR training sessions



Self-talk and Motivation scores of the PRQ increased in Race 2 compared to Race 1



STUDY 3 – RESULTS (2)

Instructional self-talk increased in Race 2

Participants' Self-Talk Application Across Race Stages					
P	Race	Start	1 st half	2 nd half	End
1	1	Run slowly	Keep it up	Keep it up	You did it
	2	Don't stop, you are a machine	Don't stop, you are a machine	Go to the end	You did it
2	1	Here it goes	No self-talk	Focus on breathing	Almost there
	2	Focus on breathing	Focus on breathing	Focus on breathing	Almost there
3	1	No self-talk	Keep pacing	Keep going through fatigue and heat	Keep pushing, you are in a good rhythm
	2	Keep calm, keep pacing	Run smart, keep it up	It will be over soon!	Finish strong
4	1	No self-talk	Overtake or lose	Almost done, keep the pace	Overtake this person! final stretch
	2	Take it easy	Take it easy, stay behind	You can do it!	Overtake this person!
5	1	I can do it	Less than when I started	Almost there! You can do it	Almost there!
	2	Slowly, on my rhythm	Slowly, on my rhythm	Less than when I started, let's go	Overtake the person in front!
6	1	Keep pacing and breathing	Slow down a bit	Jesus, help me	Get through it
	2	Keep calm, keep the pacing	Slow down a bit	Focus on yourself, keep a good technique	Almost there, give your best

Color-Coding: *Blue* = Instructional self-talk, *Green* = Motivational self-talk

Drafting occurred more often in Race 2

Participants' Use of Drafting Across Races Stages					
P	Race	Start	1 st half	2 nd half	End
1	1	No drafting			
	2	Used	Used	Used	Attempted
2	1	No drafting			
	2	Used	Used	Attempted	Used
3	1	Not drafting			
	2	Used	Used	Attempted	No drafting
4	1	No drafting			
	2	Used	Used	No drafting	No drafting
5	1	No drafting			
	2	Used	Used	Attempted	Used
6	1	No drafting			
	2	No drafting	Used	Used	Attempted

Cardenas Hernandez, F. P., Schneider, J., Nagler T., Parada-Cabaleiro E., Schiffner, D., Dengel A. & Drachsler, H. (2025). Miles with Mind: An Exploratory Study of Cognitive-Behavioral-Based VR Training for Strategy and Motivation in Long-Distance Running. *Frontiers in Sports and Active Living*, 7. <https://doi.org/10.3389/fspor.2025.1722120>

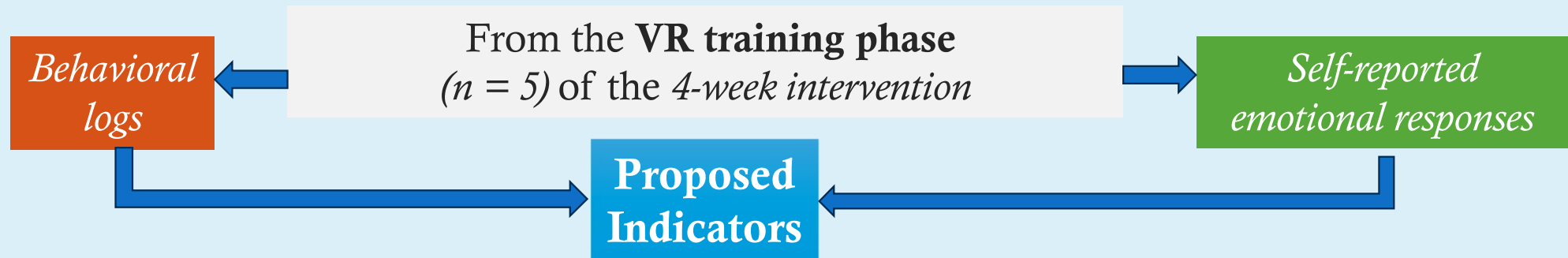
STUDY 4

👉 *Our VR application was tested and showed interesting insights, so ...*

is there anything else we can find?

- *We sought opportunities to improve our CB-based VR application by enhancing the monitoring of emotional reactivity and by reinforcing the adoption of race strategies.*

STUDY 4 – IDENTIFYING IMPROVEMENT STRATEGIES OF A VR APPLICATION ON MENTAL TRAINING FOR RUNNERS: *FOUNDATIONAL PRINCIPLE*



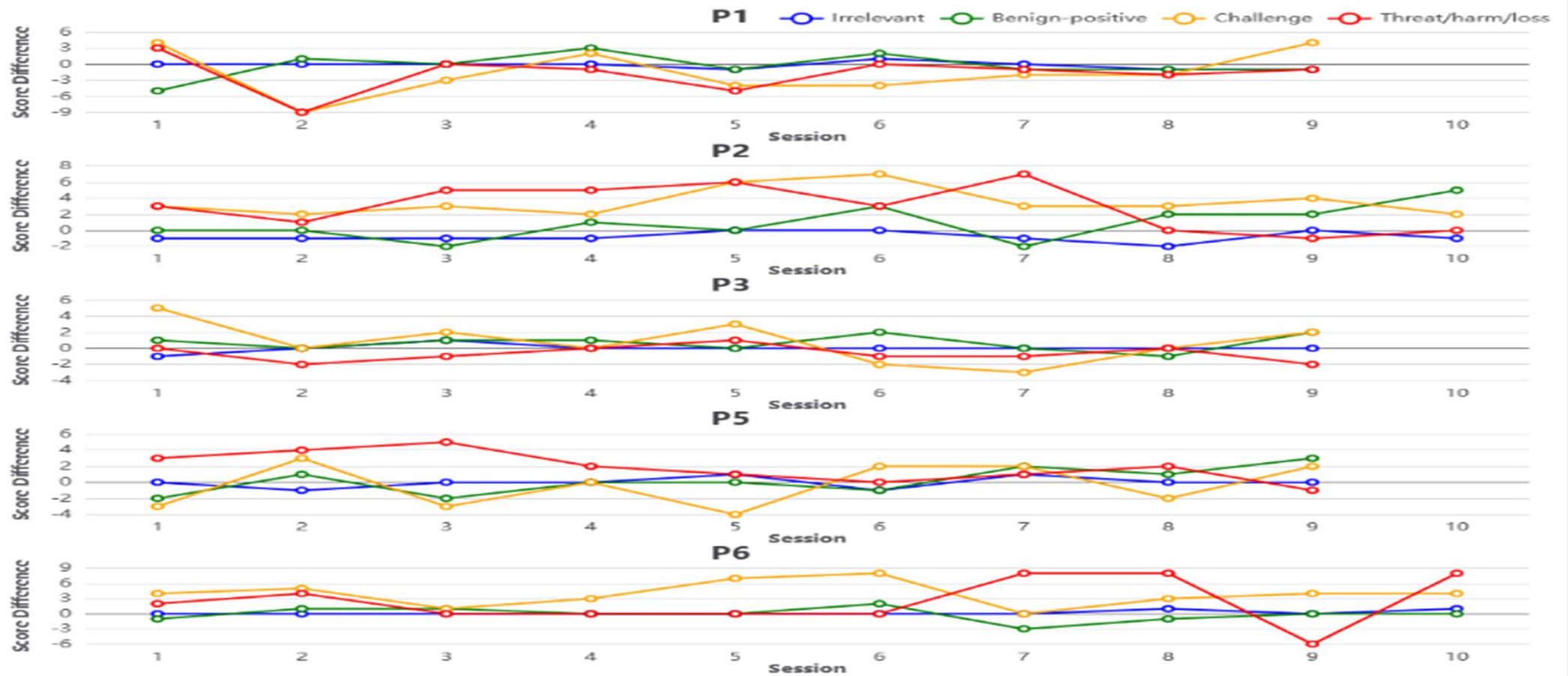
- *Emotional Response Indicator:*
 - ❖ *Irrelevant appraisal metric ; Benign-positive appraisal metric ; Challenge appraisal metric ; Threat, harm or loss appraisal metric*
- *Pacing Performance Indicator:*
 - ❖ *Pacing profile metric ; Average pacing metric*
- *Drafting Performance Indicator:*
 - ❖ *Points with / without hints metric ; Formation repetition count metric*
- *Session Duration Indicator*

} *Derived from the Emotional Stress Reaction Questionnaire, ESRQ (Larsson, 2011)*

STUDY 4 – RESULTS (1)

Emotional Response Indicator

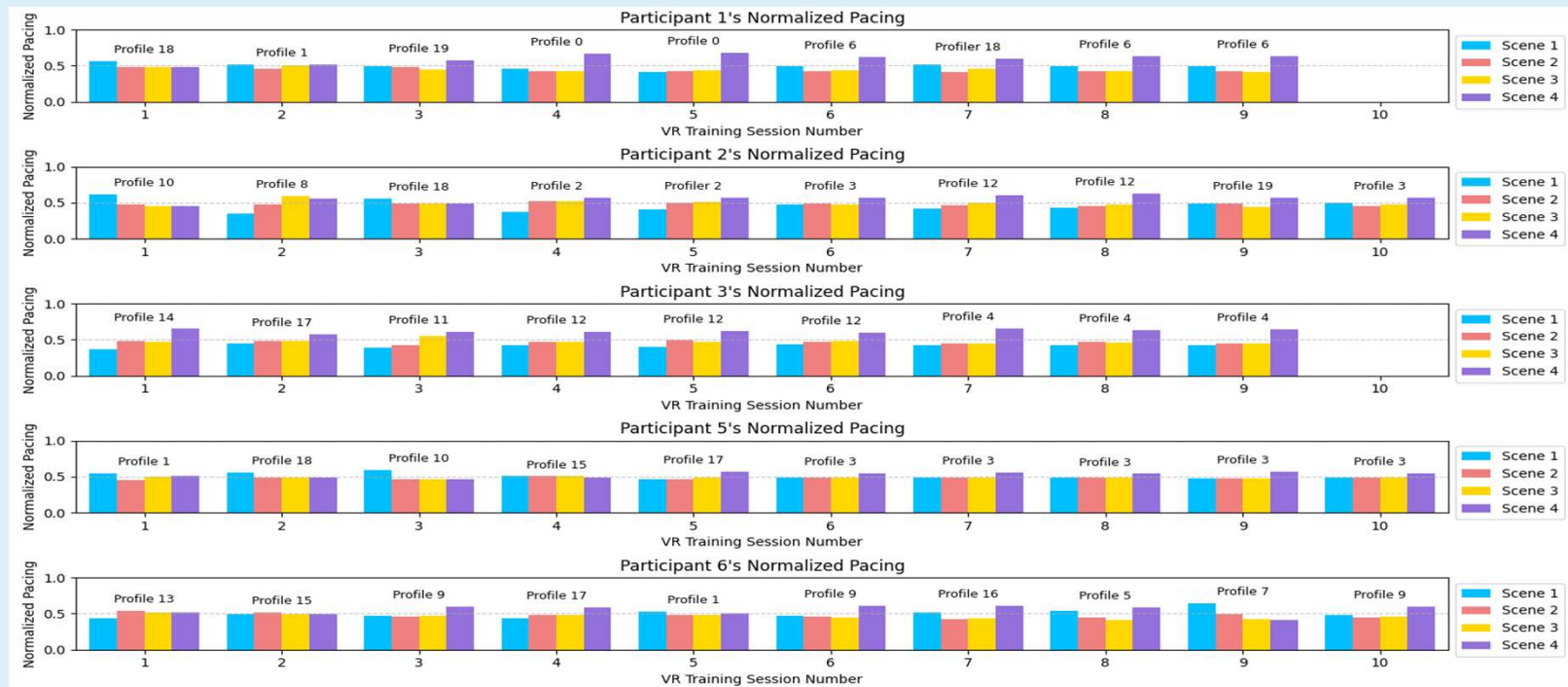
Challenge & Threat/Harm/Loss Appraisal: They were more sensitive to changes across sessions



STUDY 4 – RESULTS (2)

Pacing Performance Indicator

Pacing Profile*: *Some participants stabilized their pacing, while others varied*

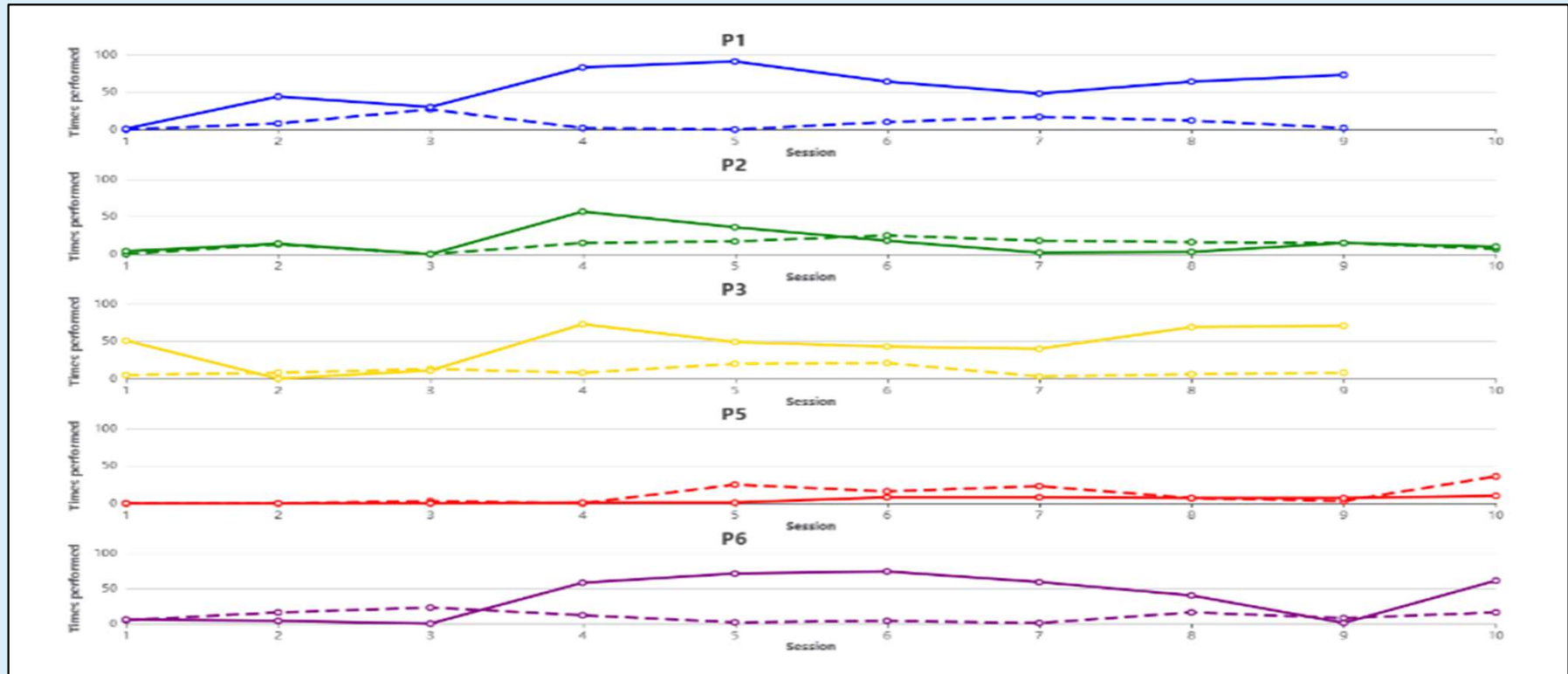


[*dimensionless]

STUDY 4 – RESULTS (3)

Drafting Performance Indicator

Drafting Formation Repetition Count: *Formation-2 dominated drafting use*



Solid line = Formation-2, dashed line = Formation-1

Cardenas Hernandez, F. P., Schneider, J., Schiffner, D., Dengel A. & Drachsler, H. (2026).
Using Emotional and Behavioral Indicators to Assess Cognitive Behavioral-Based VR
Training for Runners. *Accepted and Presented at 12th Immersive Learning Research Network
(iLRN2026) Conference.*

LIMITATIONS & TAKEAWAYS

Limitations

Technological Limitations



Sample-related Limitations



Methodological Limitations



Takeaways

Foundation for holistic training



Integrating physical, technical, mental & body awareness aspects

Immersive technology



Supporting performance & enhancing training

Future research

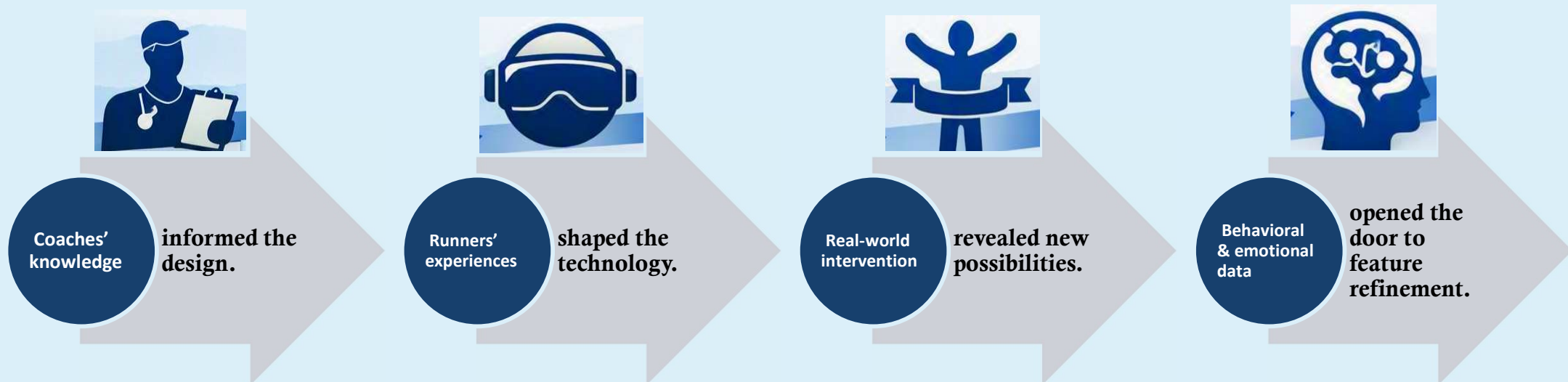
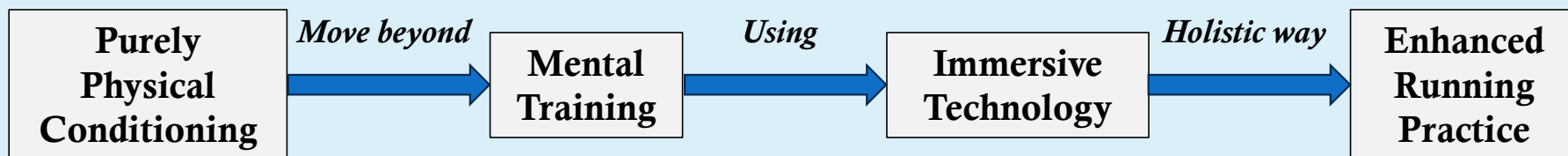


Refining & testing through iterations

CLOSING

- What we found was not a final solution, but a **pathway**.

The Pathway





*Thank you for
your attention!*

RESEARCH OVERVIEW

Recap of the Studies

• *Study 1 – Expert Study (Running Coaches)*

Established *key influencing factors* and *needs* in running training through interviews and surveys.

Key findings:

- **Key Training Aspects:** Physical, technical, mental, and body awareness. Mental and body awareness lacked systematic tools.
- **MLX Framework Development:** Proposed integrating AI agents and immersive technologies (e.g., VR) to support coaches across all four aspects.

• *Study 2 – User Experience (UX) Study (Runners)*

Evaluated the *design* and *feasibility* of the first CB-based VR application for mental training, informed by the MLX framework.

Key findings:

- **Positive Reception:** Favorable acceptance.
- **Strengths & Limitations:** Identified both effective features and areas needing refinement.

• *Study 3 – Four-Week Intervention (Runners)*

Assessed the *potential impact* of the refined VR application in a real-world competition.

Key findings:

- **Motivation & Self-Talk:** Increased self-reported scores in the second race.
- **Drafting Strategy Use:** Greater application of drafting strategies based on self-reports.

• *Study 4 – Indicator Analysis (VR Training Phase)*

Analyzed *behavioral and emotional indicators* to inform future refinements of the application.

Key findings:

- **Challenge & Threat/Harm/Loss Metrics:** Identified as useful for monitoring emotional reactivity.
- **Drafting Formation Repetition Count:** Identified Formation 2 as the dominant one.