

BOOK OF ABSTRACTS

O-Conference 2026

The First International Conference
on **Orienteering** in Scientific
Research and Higher Education

18–19 July 2026

Chalmers University of Technology
Gothenburg, Sweden

Edited by Marco L. Della Vedova



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<https://o-conference.com>

Book of abstracts of the First International Conference on Orienteering in Scientific Research and Higher Education (O-Conference 2026)

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in partnership with
O-Ringen Göteborg 2026, the Swedish Orienteering Federation, and the International Orienteering
Federation

<https://o-conference.com>

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Preface

It is my pleasure to present the book of abstracts of **O-Conference 2026 – The First International Conference on Orienteering in Scientific Research and Higher Education**, held at Chalmers University of Technology in Gothenburg, Sweden, on 18–19 July 2026, in connection with the opening weekend of O-Ringen 2026.

O-Conference was conceived from a simple observation: **orienteering is an extraordinarily rich environment for research**. It combines physical activity with perception, spatial reasoning, navigation, decision-making under uncertainty, route planning, map understanding, and human interaction with complex environments. These are interesting problems in sports science, of course, but also in artificial intelligence, computer vision, cognitive science, psychology, geography and many other fields. The ambition of O-Conference was therefore to bring researchers from such diverse backgrounds together and provide a dedicated international meeting place for exchanging ideas, methods, results, and educational experiences, where orienteering serves as a unifying theme.

The scientific program was built around three invited talks and an open call for contributions. The **invited talks** were given by **László Zentai** (Eötvös Loránd University, Hungary), who addressed the contribution of cartography to the standardization of orienteering maps; **Jessica Lucchetta** (University of Trento, Italy), who discussed the use of orienteering and challenge-based learning for developing professional skills in STEM higher education; and **Emma Waddington** (McMaster University, Canada), who presented research on the relationship between orienteering, spatial navigation, exercise, and brain health. Together, these talks reflected the interdisciplinary character of the conference, spanning cartography, education, sport, cognition, and health.

Alongside the invited talks, an **open call for contributions** welcomed researchers, academics, and practitioners working on orienteering-related research and educational activities. By the submission deadline of 15 April 2026, the conference had received 23 contributed abstracts covering a remarkably diverse range of topics. Contributions addressed, among other subjects, orienteering performance and physiology, spatial cognition and navigation, cartography, artificial intelligence and robotics, geospatial methods, new technologies for performance analysis, inclusion and well-being, and the use of orienteering within higher education.

Authors were invited to submit self-contained extended abstracts describing the research question or challenge, the methods or pedagogical approach, and the principal findings, insights, or expected contributions. Each submission underwent **single-blind peer review** by at least two reviewers from the Program Committee, whose members represented several countries and disciplines ranging from sport science and medicine to cartography, geoinformatics, artificial intelligence, robotics, bioengineering, and education (see pag. 5). The review process considered the scientific or educational contribution of each submission, the clarity of its objectives and approach, its relevance to the scope of the conference, and its potential interest to the deliberately interdisciplinary O-Conference audience. The reviews also served to provide feedback to contributors and to support the construction of a coherent scientific program. Authors received acceptance notifications along with reviewer feedback on 15 May 2026, and submitted their revised, final extended abstracts by 31 May 2026.

During the conference, the three invited talks were allocated **40 minutes each**, while contributed presentations were allocated **20 minutes**, including questions and discussion. This

format provided sufficient space for the invited speakers to develop broader perspectives while maintaining a dynamic program for the contributed work. The resulting program (see pag. 6) comprised 25 academic presentations organized into nine thematic sessions over two days, complemented by a panel discussion, and an open forum. The presentation of Graham Kemp's contribution was not possible, but the abstract is included here. The sessions reflected the broad scope that O-Conference was intended to encourage: history of orienteering, performance analysis, higher education, the relative age effect, inclusivity, well-being, orienteering-inspired research, new technologies, and experiences from orienteering initiatives and partnerships.

More than 50 participants took part in the conference. For a first edition of an event deliberately spanning several academic disciplines, this level of participation was particularly encouraging. Even more important than the numbers, however, was the interaction between communities that do not normally meet at the same scientific conference. Discussions brought together researchers, educators, practitioners, and members of the international orienteering community, often revealing connections between apparently distant research questions.

The timing and location of the conference were an important part of this idea. O-Conference took place **immediately before O-Ringen**, the world's largest orienteering events. This created an unusual setting in which many participants could combine their scientific interests with direct engagement in the sport itself. For researchers who are also orienteers, the boundary between conference room and forest was therefore particularly short.

This publication collects the extended abstracts presented at O-Conference 2026. It is intended not only as a record of the first conference, but also as a snapshot of a research community that is emerging across disciplinary boundaries. I hope that the ideas presented here will stimulate new collaborations, new research questions, and new ways of using orienteering as both an object of scientific investigation and a tool for teaching and learning.

The success of this first edition depended on many people. I would like to thank all authors and speakers for sharing their work; the members of the Program Committee for contributing their expertise to the review process; the invited speakers for helping shape the scientific program; and all participants for the engaged discussions throughout the two days. I also gratefully acknowledge Chalmers University of Technology for hosting the conference, and O-Ringen, the Swedish Orienteering Federation, and IOF for their partnership and support.

Finally, I hope that O-Conference 2026 represents not an isolated event, but the beginning of a lasting international forum connecting orienteering and academia.

The editor,
Marco L. Della Vedova
O-Conference 2026 Chair
Associate Professor of Applied Artificial Intelligence
Chalmers University of Technology, Gothenburg, Sweden

Gothenburg, August 2026

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O-Conference 2026

The First International Conference on Orienteering in Scientific Research and Higher Education

18-19 July 2026

HA3, Chalmers University of Technology
Hörsalsvägen 4 · Gothenburg



Day 1

Saturday · 18 July

08:30-09:00 WELCOME & REGISTRATION

09:00-09:30 Opening session

09:00 Della Vedova & Hulthén Opening

09:30-10:30 1 • History of orienteering

09:30 Zentai INVITED The contribution of the science of cartography to the successful standardization of the legend for orienteering maps

10:10 Powell The historical geography of orienteering: origins and cultural practices of foot navigation

10:30-11:00 COFFEE BREAK

11:00-12:20 2 • Performance analysis

11:00 Machowska-Krupa Differences in coordination motor abilities between orienteers and athletics runners

11:20 Wang VIDEO Decomposing Orienteering Performance into Speed, Stability, and Mistake Severity Using Split Times

11:40 Tait Exercise intensity distribution across race formats and determinants of sprint performance in orienteering

12:00 Raus Performance analysis of orienteering elite athletes in sprint competitions, a comparative study during EOC 2023

12:20-14:00 LUNCH BREAK

14:00-15:00 3 • Orienteering in higher education

14:00 Lucchetta INVITED Orienteering in Higher Education: developing professional skills for STEM students through challenges

14:40 Della Vedova Orienteering teaching and learning activities at Chalmers

15:00-15:20 4 • Relative age effect

15:00 Esteve-Ibáñez Born to Navigate: Decoding the Relative Age Effect in Talent Development and Elite Selection
Canceled Kemp Using Wikidata to investigate the relative age effect in orienteering and other sports

15:20-15:40 COFFEE BREAK

15:40-16:30 5 • Forum on inclusivity

15:40 Martínez Villanueva Is orienteering an inclusive sport?

16:00 Open discussion Inclusivity in orienteering — contributions from the audience

16:30-17:00 Panel • Opportunities for orienteering in academia

16:30 Della Vedova Panel discussion

Day 2

Sunday · 19 July

08:00-08:30 WELCOME & REGISTRATION

08:30-10:30 6 • Orienteering and well-being

08:30 Waddington INVITED Navigating Towards Better Brain Health with Orienteering

09:10 Palumbo Complex task management in orienteering sustains executive functions beyond physiological decline

09:30 Lin Spatial Strategies under Spatial Reference Frame Incongruence: Effects of Orienteering Experience on Task Performance

09:50 Cych Training processes and characteristics of World Masters Orienteering Championship medalists

10:10 Esteve-Ibáñez Nutrition and Body Composition Profiling in Elite Orienteering Athletes: Dietary Intake, Somatotype, and Methodological Considerations

10:30-11:00 COFFEE BREAK

11:00-12:00 7 • Orienteering-inspired research

11:00 Binsch Virtual Reality Preparation Enhances Navigation Efficiency and Physiological Recovery in Police Officers

11:20 Mannocci Route Estimation from Headcam Video in Orienteering

11:40 Divin Generating complex cost surfaces for the navigation of mobile robots

12:00-13:30 LUNCH BREAK

13:30-14:50 8 • New technologies for orienteering

13:30 Squire Analysis: Uncovering the 'Black Box' of Orienteering Performance with Automated Map Reading Analysis

13:50 Ayao Parfait Performance analysis in orienteering to support the orienteer's autonomy in the Vikazimut app

14:10 Bjørke VIDEO A graph-based framework for analysing and training indoor orienteering

14:30 Hjermstad Semi-Automated Production of ISOM-Compliant Orienteering Maps Using a Modular Human-in-the-Loop Framework Based on Airborne LiDAR and Artificial Intelligence

14:50-15:10 COFFEE BREAK

15:10-15:50 9 • Initiatives and partnerships

15:10 Lucchetta Orienteering 4 Research: Strategic Partnership between Scientific Institutions and Sports Associations

15:30 Rutz-Rothacher Experiences from the O-Challenge Initiative: Promoting Outdoor Participation Through Gamified Digital Orienteering

15:50-16:00 Closing session



Invited talks

Orienteering in Higher Education: developing professional skills for STEM students through challenges

Invited talk

Jessica Lucchetta

University of Trento, Trento, Italy

Keywords: orienteering

The gap between the skills demanded by the job market and the outcomes of traditional university curricula is widening, driven by a global landscape of rapid digital transformation and artificial intelligence. For graduates in STEM disciplines (Science, Technology, Engineering, Mathematics), technical proficiency is no longer a standalone guarantee of success and employers are placing a growing emphasis on transversal competencies, such as resilience, complex problem-solving, strategic communication, and team-based adaptability. Conventional academic curricula struggle to satisfy this need and traditional education models have been argued to be insufficient to simulate the high-pressure, ambiguous, and interpersonal environments of the modern workplace.

To address this problem, active learning methodologies have emerged, and Challenge-Based Learning (CBL) is gaining popularity in higher education. In CBL, students work in teams to tackle complex, multidisciplinary challenges proposed by external actors to develop concrete solutions. Through this process, students foster collaboration, critical thinking, and creativity, connecting theoretical knowledge with practical application while developing transferable skills and professional dispositions. At the same time, the literature highlights the educational value of sport as a learning tool. In this context, the sport of orienteering stimulates competencies like strategic planning, time and resource management, resilience, and self-regulation in uncertain contexts. While previous studies have highlighted that both CBL and orienteering can stimulate skills that align with job profiles, their integration into a single pedagogical framework targeted at STEM students remains a novel and largely unexplored area of research. To leverage the combined potential of these two approaches, our team has explored the integration of CBL with orienteering. Building upon our "Choose Your Own Adventure in CBL" (CYOA-CBL) framework developed over the past years, in 2024, we tested this integration through a pilot activity at the University of Trento, in collaboration with the orienteering club PWT Italia. The four-week program included one week of in-person activities followed by three weeks conducted online with 20 international Master's students from various disciplines. Participants were asked to engage with orienteering and identify social benefits that the sport and the club could generate beyond athletic performance. They were immersed in the world of orienteering, challenging themselves with the sport and putting into practice all the skills necessary to successfully complete orienteering activities (e.g., strategic planning, time management, decision-making under pressure).

This design required students to manage both the CBL challenge and the hands-on, real-world activities of orienteering, creating a powerful environment for navigating project uncertainty. Anonymous individual and group feedback demonstrated the high potential of this intersectoral approach where academia and the sports world co-design educational experiences. This pilot confirmed the model's feasibility and provides a solid foundation for this research: first, it tests whether a novel pedagogical framework can help bridge the gap between academic knowledge and the market's demand for transversal skills; second, it tackles the complex challenge of how to assess these skills, providing an actionable tool for the STEM education community.

Navigating Towards Better Brain Health with Orienteering

Invited talk

Emma Waddington

McMaster University, Hamilton, Canada

Exercise enhances aspects of human cognition, but its benefits may depend on intensity. Recent animal research suggests that vigorous exercise, which releases greater amounts of lactate, activates more brain-derived neurotrophic factor (BDNF) in the hippocampus and, thus, may be optimal for supporting cognitive function. The cognitive benefits of exercise may be further augmented when combined with cognitive training. The sport of orienteering combines exercise with spatial navigation and, therefore, may confer greater cognitive benefits than exercise alone, especially at vigorous intensities. Our past work shows that expert orienteers report greater spatial memory abilities and more frequent use of desirable spatial navigation strategies (both allocentric and egocentric spatial processing) than active, non-orienteering controls. Because orienteering is often described as a “sport for life”, long-term participation in the sport could provide continuous rehearsal of effective navigational strategies. However, acute bouts of vigorous exercise alone have also been shown to increase cognitive function and BDNF in young and older adults. We therefore examined whether an acute bout of vigorous orienteering elicits even greater cognitive and BDNF responses than vigorous exercise without navigation or moderate intensity orienteering. Sixty-three recreationally active, young adults (Mage = 21.10±2.75 years) with no prior orienteering experience completed a 1.3 km intervention course by navigating and exercising at a vigorous (80–85% heart rate reserve (HRR)) or moderate (40–50% HRR) intensity or exercising vigorously without navigation. When comparing pre- to post-exercise measures, both vigorous-intensity exercise and vigorous-intensity orienteering elicited greater peak lactate and greater increases in BDNF than moderate-intensity orienteering, and individuals with higher peak lactate also had greater increases in BDNF. Spatial memory increased only after vigorous-intensity orienteering, suggesting that vigorous-intensity orienteering may particularly benefit spatial cognition. Overall, the results demonstrate the benefits of vigorous exercise and navigation on human cognition and BDNF.

The contribution of the science of cartography to the successful standardization of the legend for orienteering maps

Invited talk

László Zentai

Eötvös Loránd University, Budapest, Hungary

The first civilian orienteering competition was held nearly 130 years ago. In the early decades, the competitions used the existing maps of the respective countries, namely the official topographic maps. Moreover, at that time, these maps were classified in most European countries, but in the Nordic countries, they had been publicly available since the mid-19th century. During the Cold War period following World War II, topographic mapping became even more important, but secrecy remained a constant feature (in the countries of the Eastern Bloc, such maps remained classified until the 1990s). Advances in aerial photography and stereophotogrammetry had by this time made it possible to produce increasingly accurate maps, particularly in terms of contour line representation. The sport was growing in popularity, and the first competition maps specifically designed for the orienteering had already been produced in the Nordic countries. The cost of reproducing colour maps has also decreased, and as the number of participants in orienteering competitions has grown, printing colour maps has become increasingly affordable for larger orienteering events.

Following the founding of the IOF in 1961, international competition began with the 1962 European Championships (although such competitions were already a regular occurrence in the Nordic countries by that time), and it became increasingly clear that standardizing the map specification for orienteering maps was the most urgent task. In 1965, the IOF Map Committee was established, comprising experienced experts delegated by the countries with the most experience in the sport, who, based on their cartographic knowledge, articulated the following principles:

- The orienteering maps must show the actual situation.
- They must show all visible features that are easily identifiable and useful for the competitors.
- It is very important to show all details that effect the route choice.
- The legibility is most important: leave out all unnecessary features.
- The maps of the international events have to use the same legend in all countries.

Thanks to digital technology, cartography has advanced significantly since then, and orienteering has become a globally practiced sport. However, the principles regarding orienteering maps formulated by the IOF Map Committee established a set of general cartographic guidelines that remain valid to this day.

Contributed abstracts

Virtual Reality Preparation Enhances Navigation Efficiency and Physiological Recovery in Police Officers

Olaf Binsch

The Netherlands Organisation for Applied Scientific Research (TNO), Soesterberg, The Netherlands

Keywords: Virtual reality training, Spatial navigation, Operational resilience, Autonomic regulation, Stress recovery

Introduction Police officers increasingly operate in complex, crowded, and dynamic environments where efficient navigation and sustained cognitive performance are critical. Traditional preparation methods rely primarily on 2D maps, requiring officers to mentally translate flat representations into three-dimensional spatial models. This transformation demands working memory resources and attentional effort, which may compete with operational decision-making once on site. Virtual reality offers immersive, first-person exploration of operational terrain and may allow faster integration of egocentric route knowledge and allocentric spatial understanding. While VR has shown effectiveness in medical and military training contexts, evidence for its operational impact in real-world policing remains limited. This study examined whether brief pre-mission VR familiarization enhances navigation performance, influences physiological workload, and improves recovery following a demanding surveillance task.

Method Forty-six Dutch police officers were assigned to either a VR preparation condition or a control condition using a 2D paper map. The VR group explored a highly realistic, 1:1 scaled 3D simulation of a concert venue for 15 minutes using a head-mounted display and interactive controls. The control group studied a standard operational map of the same venue for the same duration. All participants subsequently conducted an individual surveillance task during a live open-air concert attended by tens of thousands of visitors. The task required navigation between specified targets under evolving instructions delivered via phone messaging. Performance was assessed using GPS tracking to calculate distance traveled, time to reach the final target, and the number of direction changes greater than 90 degrees as an indicator of searching behavior. Physiological workload was measured through heart rate and heart rate variability using ECG recordings. Salivary cortisol was collected at baseline, immediately after the task, and approximately ten hours later to evaluate stress response and recovery. Participants also reported perceived stress levels.

Results The primary performance difference between groups was found in navigation efficiency. Officers prepared with VR made approximately half as many directional changes compared to the control group, indicating reduced searching behavior and more direct route selection. However, total time and distance traveled did not significantly differ between groups. This suggests that while both groups reached the destination within comparable durations, VR-prepared officers navigated with greater spatial confidence and fewer corrective movements. Heart rate did not differ significantly between groups during the task. Heart rate variability was significantly lower in the VR group. Lower HRV is typically associated with increased autonomic activation. Given the absence of elevated subjective stress and the improved navigation efficiency, this reduction likely reflects heightened cognitive engagement rather than distress. The VR group may have reallocated attentional resources from orientation to surveillance execution, leading to focused task involvement. Cortisol levels immediately after the task did not differ significantly between groups. However, the VR group demonstrated significantly lower cortisol levels during the recovery phase measured the following morning. This indicates faster physiological recovery from the operational stressor. Perceived stress ratings did not differ significantly between groups.

Discussion The findings demonstrate that brief immersive familiarization alters behavioral navigation patterns in real-world settings. Reduced directional changes reflect stronger spatial encoding and less orientation-related cognitive friction. Although speed did not improve, efficiency in route selection suggests that VR preparation allowed officers to reallocate attentional resources toward operational monitoring rather than basic wayfinding. Lower HRV in the VR group likely reflects adaptive engagement. Importantly, improved cortisol recovery suggests that immersive preparation reduces prolonged physiological strain. Recovery capacity is a key component of resilience in professions exposed to repeated stress. The implications extend beyond policing. Navigation skills might influence stress responses in everyday contexts such as commuting, traveling, evacuations, and crowded events. When individuals feel disoriented, physiological arousal may increase, decision-making might degrade, and perceived stress possibly rises. Training spatial awareness and environmental familiarity might reduce this cognitive load. For normal citizens, improving navigation skills through deliberate exposure to new environments, spatial memory exercises, or VR-based simulations may enhance confidence and reduce stress in unfamiliar settings. Practicing route planning without constant GPS dependence should strengthen allocentric mapping abilities, which can improve adaptability during emergencies when digital tools fail. Developing flexible navigation strategies might therefore contribute to psychological resilience and autonomy.

For safety professionals such as police officers, soldiers, firefighters, and emergency responders, immersive terrain familiarization before deployment may serve as a cognitive inoculation mechanism. By reducing uncertainty-related cognitive demands, professionals can preserve attentional capacity for threat detection, communication, and decision-making. More importantly, improved post-event physiological recovery suggests that spatial competence may indirectly protect long-term health and reduce cumulative stress burden. Resilience should therefore be conceptualized not only as emotional toughness but as cognitive efficiency under uncertainty. Navigation training, whether via VR, scenario rehearsal, or structured environmental learning, might be viewed as a preventive resilience intervention.

Recommendation For scientists in navigation research, future studies should examine how immersive environments facilitate integration of egocentric and allocentric spatial representations and how physiological markers such as HRV distinguish adaptive engagement from overload. For security and safety professionals, VR should be implemented as a short, mission-specific reconnaissance tool to reduce orientation-related cognitive load before deployment. For resilience of police officers, soldiers, and emergency responders, operational preparation should incorporate not only performance metrics but also recovery markers such as cortisol normalization. Enhancing recovery capacity may be as important as improving immediate performance. Future research should further examine how immersive spatial learning modifies autonomic regulation and recovery dynamics across populations. Next, civilian resilience programs may benefit from including spatial competence training to enhance adaptability during crises. Strengthening navigation skills appears to improve not only performance efficiency but also recovery capacity, making it a promising avenue for enhancing resilience across both professional and civilian domains.

Reference

This abstract is based on the paper:

Binsch, O., Oudejans, N., van der Kuil, M. N. A., Landman, A., Smeets, M. M. J., Leers, M. P. G., & Smit, A. S. (2022). The Effect of Virtual Reality Simulation on Police Officers' Performance and Recovery from a Real-Life Surveillance Task. *Multimedia Tools and Applications* 82, 17471–17492. DOI: [10.1007/s11042-022-14110-5](https://doi.org/10.1007/s11042-022-14110-5).

A graph-based framework for analysing and training indoor orienteering

Øystein Bjørke

Independent Researcher, Norway

Keywords: indoor orienteering, graph theory, maze-solving problem, shortest path problem, deliberate practice

Indoor orienteering has grown steadily in recent years, yet it still is challenged by lack of methods for objectively assessing course difficulty. Course setters rely on experience and intuition when designing courses, and it is hard to evaluate if the courses meet the expected level of difficulty. This research presents a graph-based framework that addresses this. It provides an objective, quantitative model for analysing indoor orienteering courses. In addition it enables the athletes to deliberate practice the cognitive skills the sport demands. The work represents first steps toward graph-based difficulty estimation, quantification of cognitive challenges, and structured training methods. These are foundational building blocks that the community can refine and extend.

An indoor orienteering map defines a finite set of possible routes through a building. These routes can be represented as a directed weighted graph, where nodes correspond to decision points and controls, edges represent corridors and passages, and edge weights capture real-world distances. Level changes (stairwells) are encoded through simple letter conventions that also serve as a compact notation for describing and comparing routes.

Once such a graph of the building is available, several types of analysis become possible. Along the path between two consecutive controls, the framework applies graph algorithms to quantify navigational difficulty. In its first basic implementation, the analysis considers the number of decision points along the optimal route and outputs a numeric difficulty score for each leg of a course. Graph algorithms can identify all possible route choices, estimate overall course difficulty, repetitiveness of route choices on legs, total climb and location of the most difficult route between nodes in the graph. At the event level, aggregating paths across all courses shows traffic patterns within the building, including where competitors from different courses are likely to run in opposite directions, a practical concern for event safety and flow.

The framework also opens for more advanced analysis based on graph theory. The research includes proposed extensions to the IOF XML format allowing other software to import and export graph data, enabling course analyses to be shared and contributing to a larger dataset for future research on difficulty norms.

The framework has been applied to more than 100 recent indoor orienteering courses. For each course, difficulty metrics were computed automatically from the graph model and compared with the target difficulty level of the course. The preliminary findings show a reasonable correlation between graph-derived difficulty scores and target course difficulty (figure 1), as well as variations supporting human subjective evaluation of difficulty.

A separate but related contribution is a method for deliberate practice of the cognitive part of indoor orienteering. Using the graph model and the analysis it provides, competitors can train the specific skills that indoor orienteering demands, reading the map, identifying route choices, and making decisions under pressure, in a structured way simulating the competition situation.

Both the route analysis and training solutions has been implemented as proof-of-concept web applications.

It is worth being clear about the limitations. The graph model is a simplification of reality. It does not capture visual complexity, or the physical experience of running through a building. The correlation with human difficulty ratings, while encouraging, is based on a simplified model. These are areas where further research is needed. The framework provides a foundation: a

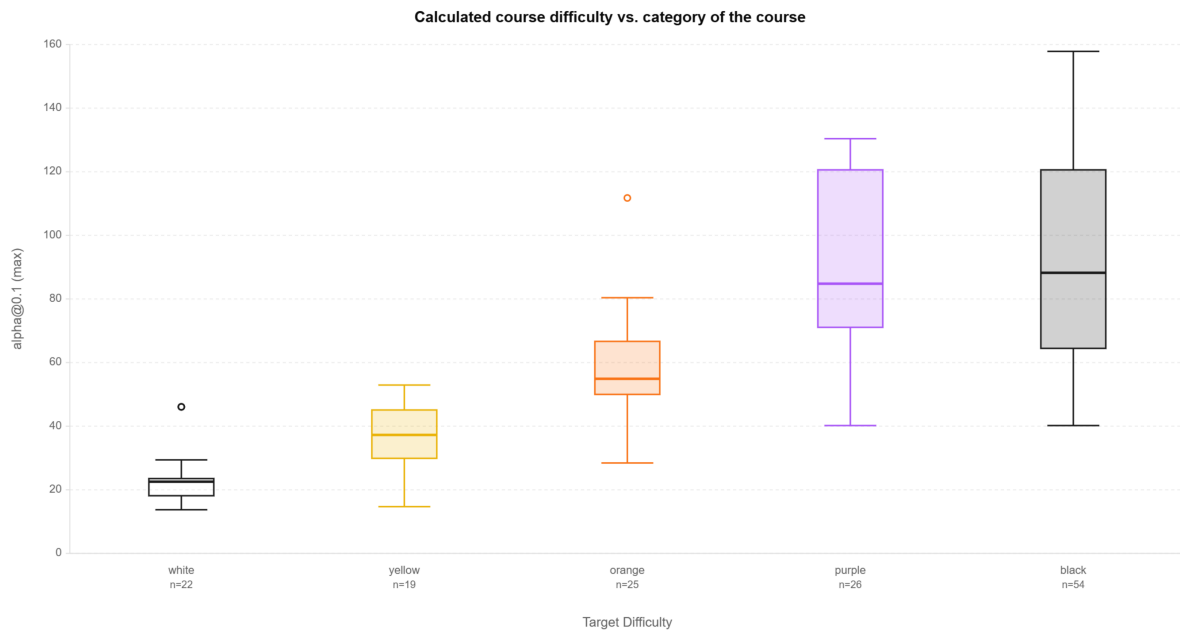


Figure 1: Correlation between graph-derived difficulty scores and target course difficulty

common language and data model for discussing indoor orienteering course difficulty, a basis for reproducible analysis across events, and a starting point for data-driven course design and structured cognitive training.

Differences in Coordination Motor Abilities between Orienteers and Athletics Runners

Piotr Cych and Weronika Machowska-Krupa*

University of Health and Sport Sciences, Wrocław, Poland

Keywords: motor coordination abilities, testing, balance, athletics runners

This study aimed to examine the differences in coordination motor abilities between athletics runners and foot orienteers (Foot O). Another purpose of this study was to analyse gender differences in terms of coordination motor abilities.

Methods or pedagogical approach Coordination skills tests were undertaken by 11 Foot-O and 11 athletics runners. Each group consisted of five women and six men who lived in the Lower Silesia region of Poland. The Foot-O group consisted of 11 orienteers aged 24.09 (± 4.78) years, with a minimum 10 years of experience, while the athletic group consisted of 11 long-distance runners aged 24.91 (± 4.04) years and with a performance level at distances of 5 km and 10 km equivalent to that for orienteering. Some of the participants represented world-class level (e.g., foot orienteering world junior medallists), and most of them were of national elite level. Coordination tests of motor abilities were chosen for their reliability and repeatability and included tests of spatial orientation, rhythmisation of movements, balance and kinaesthetic differentiation.

Key findings, insights, or expected contributions The Foot-O group performed significantly better than the athletics group in terms of some coordination abilities. Differences were observed between the Foot-O and athletics runners in balance ability measured during the “Walk on the bench” test. No differences were observed between males and females. Further research on larger population should be carried out in this area in order to confirm these findings.

Reference

This abstract is based on the paper:

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Training processes and characteristics of World Masters Orienteering Championship medalists

Piotr Cych* and Weronika Machowska-Krupa

University of Health and Sport Sciences, Wrocław, Poland

Keywords: orienteering, training process, masters athletes

The study aimed to capture the relationships between sports performance and workouts of different age groups medalists at the World Masters Orienteering Championships (WMOC). The second aim was to investigate morphological parameters (body mass, height, BMI) of the WMOC medalists and their achievements. The information may be of interest to athletes in the MW35+ classes, as well as to scientists and coaches interested in the relationship between aging, training, and its effects.

Methods The preparation process of 49 World Masters Orienteering Championship (WMOC) medalists (aged 35–75) was surveyed using a questionnaire. The respondents were asked about the number of training sessions, time devoted to training and competitions, and the characteristics of the training measures used (including the number of specialized training sessions and competitions) during the preparation and competition periods. The data underwent non-parametric statistical analysis, with the Mann-Whitney U test used to assess differences between two structural indicators.

Key findings, insights, or expected contributions The obtained results largely align with observations made for other endurance sports, but differ significantly in detail due to the specific nature of orienteering as a sport with a significant impact on the final result of muscular strength, cognitive processes, and visual engagement. Men trained more frequently than women and younger subgroups (WM35–WM55) trained more often than older ones (WM60–WM75). During preparation, men trained longer than women, while younger masters trained more hours than older ones. No significant gender differences were found in training volume during the competition period. Sixty-two percent of medalists used over 10 specialized training sessions within six months of WMOC, with younger male veterans (M35–M55) reporting the highest number. More men (92.9%) than women (54.5%) competed over 10 times in the six months preceding WMOC. WMOC medalists trained optimally, considering age-related decline, and frequently prepared by participating in orienteering competitions. Some training work-out differences were observed among medalists based on age and sex. The study observations provide the first insight into the preparation of master category orienteering competitors for international competition. Indeed, most are very professional in their preparation and devote much time to training and participating in competitions, especially younger masters (WM35–WM55). The average height was 179 cm for men and 165 cm for women, with average weights of 70 kg for men and 54 kg for women. BMI was 21.5 (SD = 1.43) for men and 20.4 (SD = 1.74) for women, with significantly lower BMI values in women. Men's BMI decreased with age ($R = -0.534$). The BMI value of masters foot orienteers is typical for middle-distance runners. Women are closer to the somatotype of 1500 m athletes and men to 800 m athletes. Lack of earlier elite success does not preclude being on the podium at the WMOC (only 3 of the 50 medalists surveyed had won a medal in elite in WOC in the past).

Reference

This abstract is based on the papers:

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Generating complex cost surfaces for the navigation of mobile robots

Zsófia Divin*, Gáspár Albert, and Zoltán Istenes

ELTE Eötvös Loránd University, Budapest, Hungary

Keywords: mobile ground robots, routeplanning, off-road navigation

During a course, an orienteer repeatedly faces the task of route planning in the terrain, which they solve based on a map and their prior knowledge. Following this process of this decision, it is possible to examine the factors influencing route planning and navigation in areas with sparse road networks, and then model the optimal route according to different criteria. The focus of my research so far has been on navigating on foot, during which an algorithm was developed that can plan the optimal route in the terrain and its travel time for running between any two points. This algorithm basically models the decision making on route choices of an orienteer during a course. However, this route planning can be applied not only to navigation on foot but also to various vehicles, including robots.

As off-road robots continue to develop, there is a growing need for improvements in related technologies; thus, a key step forward in robot mobility is to pre-plan routes optimized for them. In the presented research, the terrain features that affect the movement of off-road robots were identified and, consequently, the optimal routes for them were selected. The optimal route can be defined in several ways; therefore, in the case of robots, it is necessary to distinguish between the fastest routes and those with the lowest energy consumption. Field tests were carried out with two 4WD field robots, AgileX Scout Mini and AgileX Scout 2.0. The robots followed the same path around the faculty, which was designed to include different slope angles and various surface types, such as asphalt, grass and gravel path. However, since the robots used are 4WD robots, it was only possible to test on relatively bare surfaces, not in forested areas. During the field tests, the robots' inertial measurement unit (IMU), odometry, GNSS, and robot status data were measured. By analyzing the data, among the terrain characteristics it was found that the slope and the terrain roughness calculated from the robot's acceleration change were the main influencing factors on both the robots' speed and their energy consumption, while speed also affects the latter. Terrain roughness, which influences the vertical acceleration of the robot's IMU, generates a decrease in the battery voltage, -0,187 V per 1 m/s² acceleration. By applying different weightings to these parameters and conducting multiple-round testing, the cost of traversing specific points within a selected test area were modelled. Two different cost surfaces were created based on the most appropriate weightings for both speed and energy efficiency. Then, on the resulting cost surfaces, the lowest-cost routes were designed between two freely chosen points, which routes can be optimized for short travel time or low energy consumption by varying the weighting of the influencing parameters.

The idea of the route-planning method presented here comes from the route-planning needed during an orienteering course. It could be used in the future to facilitate the autonomous movement of robots in the field, as, with the right data, the robot itself may be able to plan its own route. The robot would be able to plan a route based on data it measures itself or even plan the optimal route in unknown terrain if it has access to high-precision topographic data by generating a cost surface optimized for speed or low energy consumption.

Born to Navigate: Decoding the Relative Age Effect in Talent Development and Elite Selection

Héctor Esteve-Ibáñez*, Alberto Ferriz-Valero, and Javier Montiel-Bonmatí

Universidad Católica de Valencia, Valencia, Spain

Universidad de Alicante, Alicante, Spain

Keywords: relative age effect, orienteering, talent selection, youth sport, performance

Background Orienteering is a cognitively and physically demanding endurance sport where chronological age grouping is utilized to balance competition. This system can trigger the Relative Age Effect (RAE), a phenomenon where athletes born early in the selection year may gain developmental advantages over their younger peers.

Purpose This research program investigated the prevalence and potential impact of RAE on sports participation, international talent selection, and competitive performance across different age categories and sexes within the Spanish context.

Methods A multi-methodological approach was employed, analyzing three distinct datasets aligned with the main research aims: (1) birth distributions of 34,718 federated athletes to examine participation patterns; (2) 384 international selection records from 1987 to 2023 to assess talent selection bias; and (3) performance indicators from 7,731 competitive entries to explore age-related differences in competitive outcomes. Data were segmented by birth quartiles and semesters and analyzed using chi-square tests, odds ratios (OR), and ANOVA.

Results Findings confirm a significant RAE in Spanish orienteering, primarily favoring athletes born in the first semester. In general the overall federated populations, RAE was small but persistent in youth categories and among male elite athletes, while it was not observed in female elite categories. Talent selection analysis revealed a marked bias among males, particularly in Junior World Championships (OR = 3.77 for Q1 vs. Q3), whereas no comparable selection bias was found in females. Performance analysis further showed that relatively older orienteers achieved significantly higher scores in formative categories, from U-10 to M-16, although these differences were no longer evident in older junior stages.

Conclusions RAE structurally influences appears to influence the athletic trajectory of male orienteers, with associations observed in participation, selection, and performance from early developmental stages into adulthood. However, given the observational nature of the data and the limited methodological detail available within this abstract, these findings should be interpreted cautiously. The results suggest a potential systemic bias in talent identification that may contribute to the exclusion of later-born athletes with long-term potential. Implementing corrective measures, such as biological age assessment or adjusted selection criteria, and illustrating these patterns with clear visual summaries in the final presentation, may help promote more equitable talent development in orienteering.

Nutrition and Body Composition Profiling in Elite Orienteering Athletes: Dietary Intake, Somatotype, and Methodological Considerations

Héctor Esteve-Ibáñez*, Vladimir Schuindt da Silva, and Eraci Drehmer-Rieger

Universidad Católica de Valencia, Valencia, Spain

Federal Institute of Paraná, Curitiba, Brazil

Keywords: orienteering, sports nutrition, body composition, somatotype, elite athletes, bioelectrical impedance

Background Orienteering is a high-demand endurance sport that requires prolonged aerobic effort, complex terrain running, and sustained cognitive engagement. In this context, body composition and nutritional status play a critical role in performance, recovery, and long-term athlete health. However, discrepancies between assessment methods, sex-specific differences, and suboptimal dietary practices may compromise the interpretation of physiological profiles and the effectiveness of training and nutritional interventions in elite orienteering athletes.

Purpose This research program aimed to (1) characterize dietary intake and nutritional adequacy in elite orienteering athletes, (2) examine body composition and somatotype profiles in elite and non-elite competitors in relation to physical activity level and nutrition knowledge, and (3) compare the agreement and sex-specific responses of different body composition assessment methods used in elite foot-orienteers.

Methods Three complementary cross-sectional studies were conducted. Dietary intake was assessed in 20 elite orienteering athletes using four-day weighed food records and analyzed against dietary reference intakes. Anthropometric characteristics, somatotype, body composition, physical activity level, and nutrition knowledge (A-NSKQ) were evaluated in 58 elite and non-elite orienteers from seven countries using ISAK protocols and validated questionnaires. Additionally, body composition was assessed in 27 elite foot-orienteers using anthropometry and two multi-frequency bioelectrical impedance devices, examining main effects of sex and method, and their interaction, through repeated-measures analyses ($p \leq 0.05$).

Results Elite orienteering athletes showed insufficient total energy and carbohydrate intake relative to recommendations, alongside excessive protein and fat consumption, with frequent inadequacies in calcium, zinc, and vitamin D. Elite competitors exhibited lower body fat percentages than non-elite athletes (males: $8.4 \pm 2.2\%$ vs. $11.3 \pm 4.8\%$; females: $17.6 \pm 6.2\%$ vs. $17.9 \pm 3.9\%$), with a large effect size ($\eta^2 p \approx 0.27$), and more performance-oriented somatotype profiles. Higher nutrition knowledge scores were observed in elite athletes, particularly among males. Comparisons between body composition assessment methods revealed significant main effects of both method and sex ($p < 0.05$), as well as significant method $\times$ sex interactions for variables such as fat-free mass, fat mass percentage, and lean mass, indicating that assessment techniques yield different results depending on sex.

Conclusions The combined findings highlight the multidimensional challenges of assessing and optimizing physiological profiles in orienteering athletes. Nutritional imbalances persist even at elite levels, and body composition differs according to performance level. Furthermore, commonly used assessment methods show sex-dependent variability, which should be considered when interpreting results. These findings support the need for integrated, sex-specific approaches

to body composition assessment and individualized nutritional strategies to enhance performance, health, and long-term athlete development in elite orienteering.

Semi-Automated Production of ISOM-Compliant Orienteering Maps Using a Modular Human-in-the-Loop Framework Based on Airborne LiDAR and Artificial Intelligence

Øyvind Hjermsstad

Chalmers University of Technology, Gothenburg, Sweden

Keywords: AI, mapping, lidar

Producing competition-ready orienteering maps to the International Specification for Orienteering Maps (ISOM) standard is a time-consuming task. Skilled cartographers typically require upward of 40 hours of fieldwork per square kilometer, manually interpreting terrain, vegetation, water features, paths, and rock details before digitizing them into a finished map. At the same time, national LiDAR programmes now provide freely available airborne laser scanning data covering entire countries, and tools like Karttapullautin, OCAD, and the Mapant projects have demonstrated that raw auto-generated maps derived from these data sources can serve as useful basemaps for training and area investigation. However, these automatically generated products fall far short of complete ISOM-compliant maps and still demand substantial field hours to bring to competition standard. I argue that remote sensing technologies is not being utilized to its full potential for orienteering mapping, and that a modular, AI-assisted approach, decomposing the mapping problem into specialized sub-tasks rather than pursuing full end-to-end automation, offers the most promising path forward.

Generating a complete ISOM-compliant map end-to-end from LiDAR-data (and possibly aerial photography) is at the present time unrealistic. Gustav Lundberg’s master thesis (Automatic map generation from nation-wide data sources using deep learning, 2020) tried this approach focused on the local area around Linköping. For a model to learn all the nuances and local knowledge of the terrain utilized during mapping, would demand constructing a huge dataset of both accurate maps and lidar data, both produced at the time. Instead I propose to split the orienteering map into it’s components and utilize existing research and models and keep the mapper in the loop to tune and piece together the final map.

Contours are the single most important information carrier on most orienteering maps. While extracting analytic isolines from a LiDAR-derived digital elevation model (DEM) is straightforward, the resulting contours are cartographically poor: jagged, excessively detailed, and unable to communicate the landforms that lie between contour levels. Orienteering contours require simplification and deliberate deformation so that the set of contour lines, read by an experienced orienteer, conveys slope, small features and terrain shape far beyond what strict isolines can express. Current state of the art algorithms are based on a combination of smoothing, feature exaggeration, slope analysis and intermediate knoll and depression detection (Karttapullautin, Jarkko Ryypö). While the output is better than both raw isolines and smoothed contours, it is far of the quality and feel of human-made contours. Before applying machine learning to the task of improving contour lines we need to define a measure for the goodness of a contour set with respect to the true landforms. In "Contour extraction from digital elevation models for topographical mapping with minimal information loss" (2025) Hjermsstad defines this by measuring how faithfully a contour set reproduces the true DEM when interpolated through Sibson’s C^1 natural neighbour interpolant with a penalty term based on the bending energy of the contour lines. He used DEMs as surrogates for contour sets with a fixed function for contour extraction, allowing for using standard image-to-image models such as a U-net for optimizing the problem. The author deems this approach as promising, but not without problems. The evaluation function is not differentiable and as such cannot be used as a target for the backpropagation optimization step. This can be solved by training a surrogate model for

learning the evaluation function and using that in the U-net optimization. Another problem is the expensive nature of the back-interpolation from contour set to evaluation DEM.

ISOM defines discrete runnability and visibility classes, making accurate vegetation classification important, both for speed and navigation. The current state of the art in orienteering, layered pulse penetration ratios computed from LiDAR returns, demands much manual iteration and struggles with varying tree types and heights. The wider remote sensing literature has advanced considerably further: high-density LiDAR (50+ points/sqm) now enables per-tree segmentation, species classification, and structural analysis that could enable more nuanced runnability estimates (ForestFormer3D, Xiang et al. 2025). However that level of point density is seldom available for the orienteering community. But it is not unreasonable to expect the density required to continue to drop in the coming years.

For paths and roads, even faint trails affect route choice and LiDAR-derived DEMs can reveal paths as shallow linear depressions. Recent work using CNNs to detect trails in boreal forest, terrain closely resembling Scandinavian orienteering terrain, demonstrates that automatic segmentation of even indistinct paths is feasible. Larger roads and vehicle tracks are easier still, and path networks can potentially be classified into ISOM categories based on width, planarity, length, and depth, with the mapper confirming the subjective distinct-versus-indistinct threshold in the field.

Identifying buildings is a solved problem: they are clearly visible in LiDAR, and building detection is among the most mature AI tasks in remote sensing, requiring only geometric cleanup for map output.

Water features present a mixed picture. Flow-accumulation algorithms extract useful stream networks, and recent Swedish research has produced impressive AI models for detecting streams and ditches (Automatic detection of ditches and natural streams from digital elevation models using deep learning, Bussarello, Lidberg et al. 2025). Lakes are straightforward to detect from the large planar gaps they create in LiDAR returns. Marshes, however, remain challenging, especially under tree cover. In "Predicting soil moisture conditions across a heterogeneous boreal catchment using terrain indices" (2021) Lidberg et al. used machine learning to improve the marsh coverage of national Swedish maps from an estimated 36% to 60%. The cartographically important distinction between marsh and indistinct marsh likely require an orienteering-specific training dataset. In the next version of the Swedish soil wetness map that Lidberg is working on marsh polygons from orienteering maps are used as ground truth labels together with field survey data.

Remote sensing rock features span the range from tractable to very difficult. Cliffs can be approximated through slope-break and curvature methods, but need generalization and a classifier to separate true rock faces from steep earth. Large boulders are visible when rasterizing last return near ground points in LiDAR data. Separating true boulders from false positives is the hard part and is still an open problem.

Most of the methods mentioned are applied to rasterized features of the LiDAR data and much faster to work with than working directly on the pointcloud. The point density needed for good rasterization is also not out of reach for high quality national scans, 5-20 points/sqm should be enough unless the vegetation cover is too dense.

It is important to emphasize that generalization, selectively omitting or simplifying features to avoid clutter while preserving navigational value, is important to every layer. Algorithms such as Lloyd's relaxation algorithm for point symbols and collapse operators based on Delaunay triangulation and medial axes can assist, but many generalization decisions ultimately require human judgment and local knowledge.

The orienteering community's existing archive of hand-made maps, paired with the LiDAR data available at the time of their creation, is a potential ready-made labeled dataset for supervised learning that could accelerate progress across multiple feature classes. The metric that ultimately matters is not whether AI can replace the orienteering cartographer, but how many field hours per square kilometer it can save and the potential for dramatic savings is real.

Using Wikidata to investigate the relative age effect in orienteering and other sports

Graham Kemp

Chalmers University of Technology and University of Gothenburg, Sweden

Keywords: relative age effect, Wikidata, SPARQL

Introduction The relative age effect refers to bias in the distribution of birth dates within a selection period, e.g., a calendar year, where individuals born towards the start of the selection period are more highly represented than individuals born towards the end of the selection period. Those born early in the selection period can have greater opportunities for the identification, development and retention of talent. Since competition classes for junior orienteers are based on the calendar year in which they are born, orienteering is a candidate sport for exhibiting a relative age effect. Any investigation of the relative age effect depends on the availability of data, and the aim of this study was to explore whether conveniently accessible data in Wikidata (Vrandečić and Krötzsch, 2014), a free and open knowledge base, can be used to find whether there is a relative age effect in orienteering, and whether this effect is stronger or weaker than that in other sports.

Methods Data were obtained via the Wikidata Query Service, starting with a SPARQL query that finds all notable orienteers (interpreted here to be those who have entries in Wikidata, who are generally elite international orienteers), and their dates of birth. This query gave 1036 result rows and highlighted some issues with Wikidata birth dates that need to be considered when investigating the relative age effect. First, when only the year of birth is present in Wikidata, 1 January is used as the date of birth – 1 January was recorded as the date of birth for 227 orienteers, and these records should be excluded from our study. To take into account that months have different numbers of days, the following queries consider, only those individuals with birth dates between 2 and 28, inclusive, of each month were included in the study. The earliest orienteer recorded in Wikidata was born in 1864; we decided to limit the study to athletes born after the second world war. More than one date of birth is recorded in Wikidata for four orienteers; these were excluded from our study. Applying the filters listed above resulted in 595 orienteers born after the second world war who have only one recorded date of birth in Wikidata, and whose date of birth falls between the 2nd and 28th of a month, inclusive. Other sports used for comparison were selected to include sports where physical strength and coordination might be expected to give the older and generally larger children born near the start of the selection period an advantage e.g., we might expect ice hockey players to benefit more from being born near the start of the selection periods compared with footballers and handball players. To enable comparison of the relative age effect between different sports, the percentage of athletes born in a month was used instead of a count of the number of athletes born in a month. For each sport the percentage of athletes born in each month (2nd to 28th of the month) was plotted. The Scikit-learn machine learning library was used to fit a linear model to the data. The gradient of the fitted line gives a rough indication of the strength of the relative age effect for that sport.

Results An accompanying figure shows the distribution of birth dates for orienteers ($n = 595$, gradient = -0.25), handball players ($n = 11235$, gradient = -0.29), Swedish football players ($n = 4426$, gradient = -0.42) and Swedish ice hockey players ($n = 2263$, gradient = -0.62). For comparison, plots are also shown for novelists ($n = 8188$, gradient = 0.0060) and singers ($n = 61777$, gradient = -0.028). A gradient close to zero indicates no clear relative age effect for these occupations.

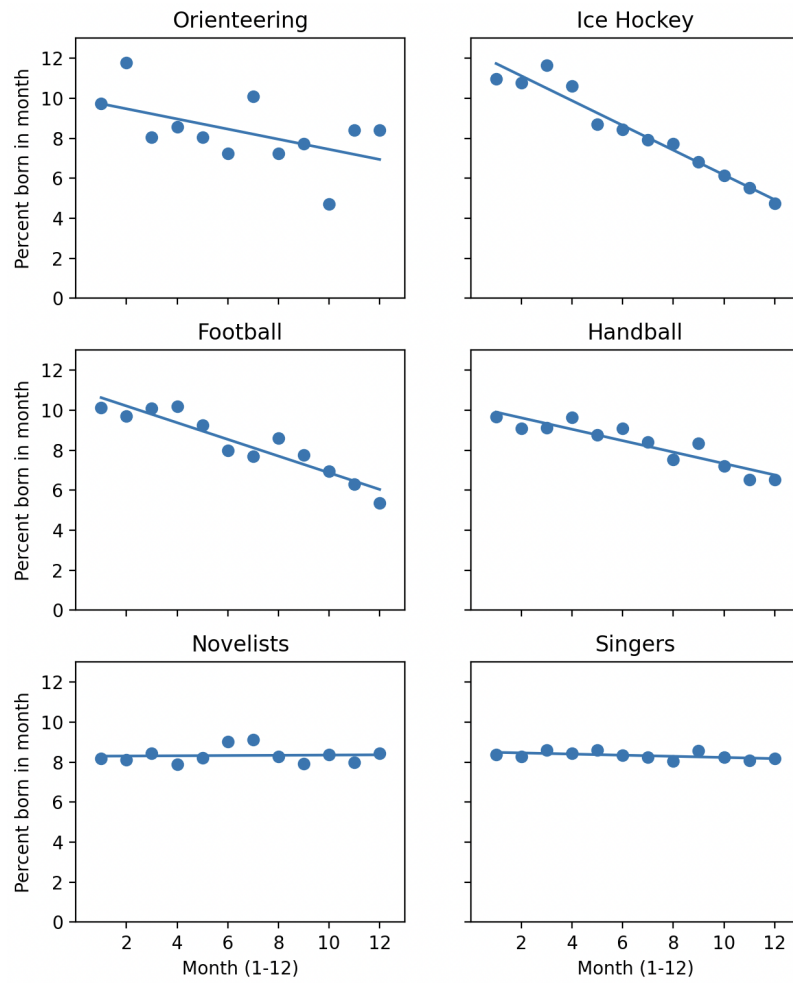


Figure 1: Relative age effect in orienteering and other sports, and for novelists and singers.

Discussion While a relative age effect can be seen for orienteering, the effect is not as strong as that observed for the other sports. This indicates that advantages due to those born near the start of a selection period typically being larger and having greater coordination are more important in the other sports than in orienteering. The largest relative age effect is seen in ice hockey; this phenomenon is examined in the book *Outliers* (Gladwell, 2008). The relative age effect in orienteering has been investigated with a focus on elite Spanish orienteers ($n = 384$) (Montiel-Bonmatí et al., 2025a) and considering the wider Spanish orienteering population ($n = 34718$) (Montiel-Bonmatí et al., 2025b). Those studies required special arrangements for access to data and this access permitted more careful analysis than that performed in the study presented here. However, the study presented here demonstrates that some insights can be gained from using free and open data, even though such data are incomplete and are dependent on what has been gathered in Wikidata. Nevertheless, the use of free and open data can permit initial data exploration and hypothesis formulation, before effort is spent obtaining and analysing more comprehensive and specialised data sets.

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Spatial Strategies under Spatial Reference Frame Incongruence: Effects of Orienteering Experience on Task Performance

Wei Cheng Lin* and Chun Ming Chen

National Chung Cheng University, Taiwan

Keywords: orienteering, spatial perspective-taking, trail orienteering, map-control description incongruence, spatial strategies

Context Previous studies have shown that experienced orienteers perform better in spatial tasks such as mental rotation. In contrast, spatial perspective-taking ability has received less attention in the literature. Spatial perspective-taking may be involved in anticipatory planning, as it supports the evaluation of spatial relationships between one's future position and the surrounding terrain. In addition, in trail orienteering competitions, the control description (always north-up) may not align with the north orientation of the oriented map, depending on the task. To resolve this allocentric reference frame incongruence between map and control description, different cognitive strategies may be employed. Previous literature on simulated aircraft navigation and trail orienteering (Trail-O) has shown that incongruence between egocentric and allocentric spatial frames can impose cognitive costs; however, spatial incongruence between two allocentric frames (map and control description) has been relatively less explored.

Purpose This study aims to investigate three main aspects using an original cognitive task designed to incorporate orienteering elements: (1) differences in performance between experienced orienteers and completely inexperienced participants, (2) performance across four map conditions: default, map-control description incongruence, non-oriented, and combined, and (3) the use of cognitive strategies under different map conditions.

Methods A two-way mixed design was used to examine the effects of orienteering experience (between-subject factor) and map conditions (within-subject factor) on task performance. Sample size estimation was conducted using G*Power 3.1.9.7. Assuming a medium effect size ($f = .25$), an alpha level of .05, and statistical power of .80, the analysis indicated that a minimum sample size of 24 participants was required for the planned repeated-measures ANOVA. A total of 34 participants were recruited, including 17 experienced orienteers ($M_{age} = 21.94 \pm 2.58$ years) and 17 participants with no prior orienteering experience ($M_{age} = 20.71 \pm 1.72$ years). The experienced group had 6.06 ± 4.16 years of experience in Foot orienteering (minimum 1 year). Ten participants had previously been selected for the national team, six of whom had competed internationally multiple times, while the remaining participants were varsity-level athletes.

Procedure Participants first received standardized instructions regarding the task procedure. They then completed a practice session (16 items, presented in a fixed order of conditions) to familiarize themselves with the task before commencing the experimental trials (50 items, presented in a randomized order). Participants who made errors during the practice session received feedback and repeated the practice until they demonstrated a correct understanding of the task. During the trials, participants integrated information from north orientation, control description, and line of sight to determine the position of the control flag relative to the tree from the observer's perspective. Responses were made using the arrow keys. (behind [$\uparrow$], in front [$\downarrow$], right [$\rightarrow$], or left [$\leftarrow$] of the tree). After completing the main task, participants reported their strategies for each map condition.

Materials & Measures Each item consisted of several elements, including north orientation, observer position, target control (tree), line of sight, and control description (see Figure 1). North orientation and observer position were systematically manipulated (i.e., rotated) to create different experimental conditions (see Figure 2). Accuracy, reaction time, and competition time were recorded. Competition time was calculated based on Trail-O rules, with a 15-second penalty applied for incorrect responses or responses exceeding the time limit. Participants were required to respond within 15 seconds per item, with a 2-second interval between items. The total task duration ranged from 4 to 11 minutes, depending on individual response speed.

Key contribution The present study yielded three main findings. First, experienced orienteers may demonstrate faster processing speed in spatial perspective-taking and visual processing. Second, allocentric reference frame incongruency between the map and control description imposes additional cognitive load. Third, different strategies are employed to resolve map–control description incongruence.

Evidence Experienced orienteers showed slightly higher accuracy than the inexperienced group across all conditions without reaching a significant difference ($p > .05$). Moreover, the experienced group demonstrated faster reaction time ($p = .028$, partial $\eta^2 = .141$) and lower competition time ($p = .032$, partial $\eta^2 = .136$). For the within-subject factor, map condition showed a significant main effect on all dependent variables (all $ps < .001$). Performance significantly decreased in both the map–control description incongruence and non-oriented conditions compared to the default condition, with the combined condition posing the greatest cognitive challenge. Furthermore, positive correlations were found between competitive level, indicated by the number of national team selections, and accuracy in both the non-oriented and combined conditions ($r = .58$ and $.79$, respectively). In contrast, a negative correlation was observed between competitive level and competition time in the combined condition ($r = -.55$). Regarding strategy use, spatial perspective-taking was the dominant strategy in the non-oriented condition, whereas mental cardinal directions and mental rotation were primarily used in the map–control description incongruence condition.

Insights When facing incongruence between egocentric and allocentric reference frames, a common approach is to physically or mentally rotate the map to achieve map–terrain alignment. However, the present findings suggest that spatial perspective-taking—imagining oneself moving to a future position and judging spatial relationships from that viewpoint—may provide an alternative way to resolve such incongruence. Additionally, understanding how different strategies are applied to resolve map–control description incongruence may have practical value for trail orienteering, as well as for teaching how controls are set in orienteering. From a broader perspective, track-up map displays (i.e., congruence between egocentric and allocentric reference frames) have been implemented in modern real-world and virtual navigation systems to reduce cognitive load and facilitate interaction with the environment. In contrast, introducing spatial incongruence in navigational tasks or open-world games may serve as a training approach to enhance engagement with maps and potentially develop spatial abilities.

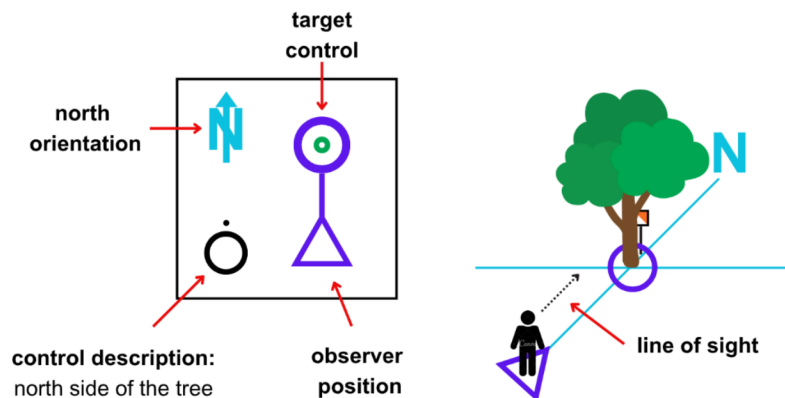


Figure 1: Item explanation (left) and 3D demonstration (right)

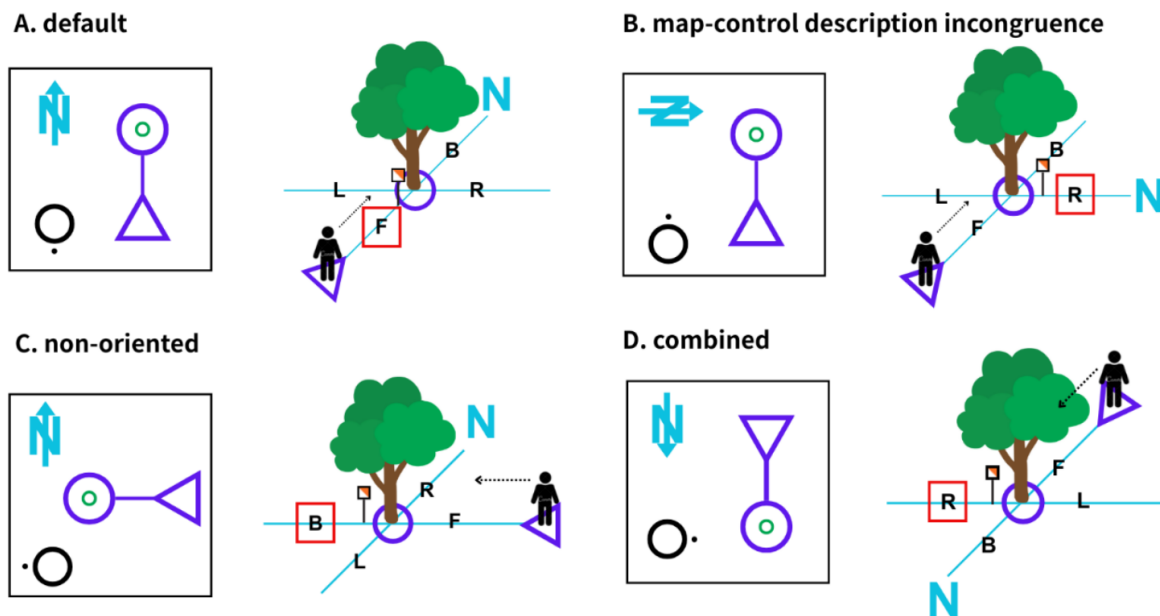


Figure 2: Examples of four different conditions: (A) default: map north is faced up and line of sight is forward, (B) map-control description incongruence: map north is rotated to directions other than “up”, (C) non-oriented: line of sight is switched to third-person perspective as observer position is changed, (D) combined: map north and line of sight are both rotated. (Letter [F], [R], [L], [B] stand for front, right, left, and behind respectively, according to the observer’s perspective)

Orienteering 4 Research: Strategic Partnership between Scientific Institutions and Sports Associations

Jessica Lucchetta*, Dario Cabrini, Andrea Manca, and Lucia Cugusi

University of Trento, Italy

Sardegna Ricerche, Italy

University of Sassari, Italy

Keywords: Orienteering, Collaboration, Living Lab

This contribution presents the design and implementation of a collaborative model between the regional research agency, Sardegna Ricerche and the orienteering club Park World Tour (PWT) Italia. The study analyzes how the synergy between scientific bodies and sports associations can advance research within the scientific community, specifically within the domain of orienteering.

Sardegna Ricerche functions as the primary agency for the Autonomous Region of Sardinia (Italy) dedicated to research, innovation, and technology transfer. They operate in the Scientific and Technological Park of Sardinia, hosting laboratories, research centers, and innovative enterprises where they facilitate synergy between universities, the industrial system, and public institutions.

In parallel, Park World Tour Italia stands as one of the leading clubs in the Italian orienteering landscape. Since its foundation in 2002, PWT Italia has been a promoter of research and innovation in the Mediterranean area, constantly experimenting with new frontiers for the sport, ranging from sports tourism to the development of novel competition formats for elite-level athletes. The club has organized several international events and hosted the World Masters Orienteering Championships in 2022 and the European Orienteering Championships in 2023.

The collaboration between PWT Italia and Sardegna Ricerche was implemented through the “Orienteering 4 Research” project, part of the broader “Sport & Wellness 4 Research” initiative launched in late 2024, with the first co-organizers’ meeting in December 2024. The model focused on analyzing the complex interaction between physical exercise, the natural environment, and psychophysical well-being, demonstrating how sport can serve as a powerful engine for innovation in health and active aging. This project lasted ten months and involved a network of collaborators including the Gutturu Mannu Natural Park and the local Universities of Cagliari and Sassari, as well as the University of Verona.

The project was structured through a series of integrated activities which included the creation of permanent cartographic installations, the organization of specialized training courses for school teachers to integrate orienteering into educational curricula, the hosting of sporting events specifically designed for schools and young people to foster early engagement, and the delivery of federal technical courses at both basic and advanced levels. To ensure deep regional penetration, the project also established numerous collaborations with local amateur sports associations.

The project reached its operational peak last October during a two-week international orienteering event known as the “5+5 Sardegna”, with more than 500 athletes of diverse age groups representing more than 25 different nations. These two intensive weeks served as a field laboratory where a wide array of physical and psychological tests were conducted on the participants to gather a robust dataset for several researches that are going on inside Sardegna Ricerche. Central to this scientific effort was the study titled “Integrated Functional Evaluation in Orienteering Athletes: Analysis of Respiratory, Cardiovascular, and Metabolic Systems, Dietary Habits, Motor Skills, and Cognitive-Motor Functions”. Each participating athlete underwent approximately one-hour of testing, which included detailed questionnaires regarding spatial attitudes, strength evaluation tests, reaction capacity assessments, and specific visuo-spatial evaluation tests lasting roughly 25 minutes per athlete. The primary objectives of these scientific

assessments were to delve deeper into cognitive performance and spatial orientation by studying decision-making processes, memory, and attention within complex natural environments. The research also focused on wearable technologies and monitoring, specifically the development and testing of sensors and devices designed to analyze physiological parameters in real-time under competitive stress. Moreover, the project addressed health and injury prevention by investigating the impact of outdoor activity on stress levels, active aging, and general psychophysical well-being.

While the resulting data is currently in the analysis phase, it is already possible to assert that this multi-day event served as an excellent occasion to bridge the gap between sport and science, exploring new perspectives on athlete performance and well-being. The project highlighted that creating a dense network of collaborations between public entities, research centers, local administrations, educational institutions, and universities is fundamental for success. Thanks to these synergies, the event has left the territory a legacy of new permanent cartographic infrastructures that can be used for future sporting and tourist activities. By leveraging the logistical and organizational experience provided by PWT Italia in managing the sporting event itself, Sardegna Ricerche was able to access a significant and diverse pool of athletes and analysis subjects, allowing for the execution of numerous tests that will prove valuable for future studies regarding the intersection of sport, health, and orienteering. This collaborative design demonstrates that when a research agency and a high-level sports club align their goals, they can transform a traditional competition into a “living lab”, producing high-quality scientific evidence that benefits not only the sporting community but also broader public health initiatives and technological development. Key takeaways suggest that the Orienteering 4 Research project and design stands as a replicable model for other regions, countries and sporting disciplines.

Route Estimation from Headcam Video in Orienteering

Enrico Mannocci

University of Bologna, Bologna, Italy

Chalmers University of Technology, Gothenburg, Sweden

Keywords: Localization, Depth Estimation, Visual Odometry, Slam, Route Estimation

To solve any localization problem in an outdoor context, the standard solution nowadays is to use GPS. We have two main problems with it: quite large errors without base station corrections (~ 20 m), and it can be jammed in security/military contexts. Humans, and in particular orienteers, are able to track their route in an unknown environment with high precision (~ 5 m) using a compass, a map, and their eyes. Is it possible to let a machine mimic this behavior? In this work, we removed the map complexity as a starting point, and we tried to answer this question. We propose a method to estimate the route of a runner using only an RGB video recorded with a regular headcam. The algorithm is also provided with the starting position and heading.

Two different methods are introduced: a lightweight one that relies on certain assumptions, and a heavier but more generic one that operates without any assumptions.

Method 1: Sparse Non-Metric Visual Odometry Each RGB frame of the video is processed by a non-metric visual odometry neural network named DPVO [1]. The network searches for sparse matches in consecutive RGB frames and uses them to compute the pose between them. The lightness of the network comes from the sparse depth estimation performed only on the matched points (~ 90). We end up with an accurate shape of the estimated route, but it is not to scale, and more critically, its scale is not constant over time. To make this usable, we need to state some assumptions to spatially rescale the neural network’s estimation. We propose two assumptions that fix, in order of truthiness, the vertical oscillation period of a runner and its average speed. We tried to use mainly the first one and, in its absence, the second one. The results are meaningful over a small time horizon ($< \sim 100$ s) and real-time on low-end GPUs. An example is shown in the supplementary material.

Method 2: Dense Metric Depth and SLAM A dense metric depth map is computed from each RGB frame of the video using a neural network such as DAV2 [2] or Metric3D [3]. Both tested models are huge neural networks (not real-time) based on DinoV2 [4] visual feature extractors. The latter was trained on a huge quantity of data from the Internet in an unsupervised manner. Its knowledge of the world lets the depth heads estimate metric measurements. Both the depth and the RGB frames are given as input to Droid-Slam [5], a neural network that returns the camera’s trajectory as output. We end up having a metric route without having stated any assumptions: the method should also work in other environments, such as vehicles or bikes, as it is. The results are meaningful for a larger time horizon ($< \sim 240$ s). Of course, we pay for that by giving up real-time performance on general user hardware.

Dataset Both methods are evaluated on a dataset of orienteers running in forest environments. Ground truth trajectories are obtained from GPS tracks (without RTK correction). The dataset covers a variety of conditions designed to stress-test the methods: forest density ranges from open trails to dense off-path woodland, and seasonal variation is represented with sequences recorded both in winter under snow cover and in summer with full green canopy. Difficulty is further stratified by scene type, from simpler sequences where the runner follows a well-defined track, to harder ones where the runner navigates through unmarked deep forest with no visible path.

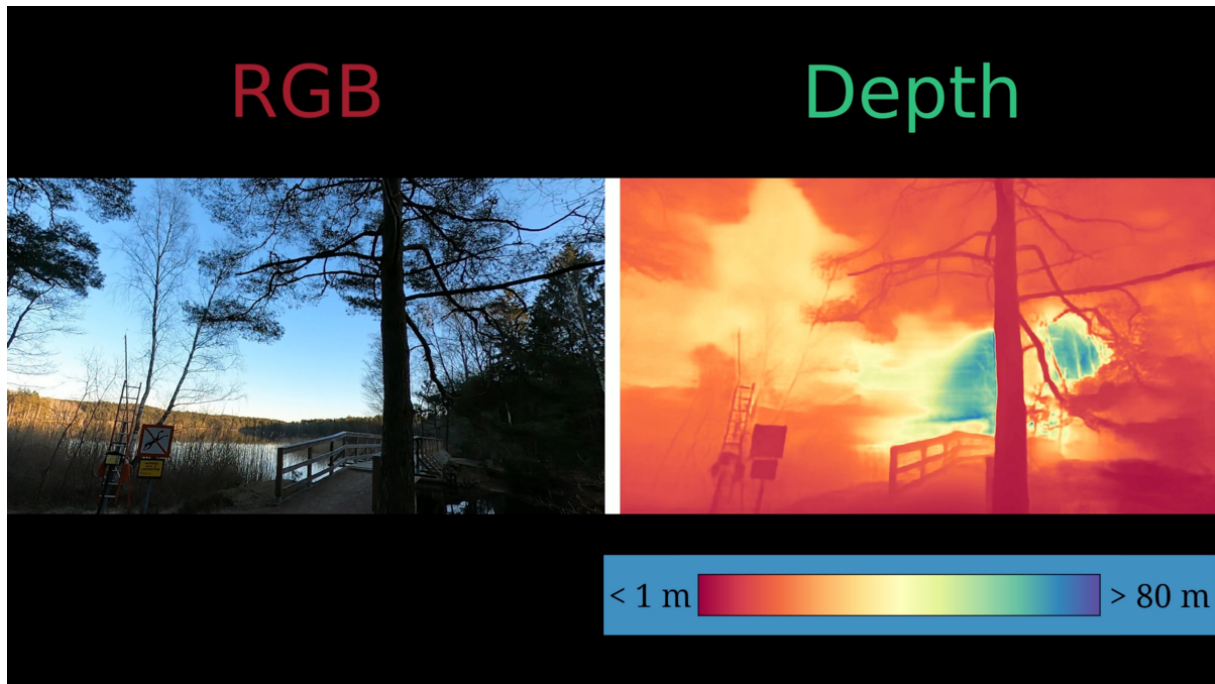


Figure 1: A frame from the sample video available on [YouTube](#). On the left the headcam video and on the Right the depth predicted from Depth Anything V2 Neural Network.

Conclusion Both methods obtain position by integrating incremental pose estimates from the starting point, so errors accumulate over time and the position estimate drifts monotonically. This is the fundamental instability of both approaches. Method 2 produces more accurate metric increments at each step, resulting in a slower drift rate and a correspondingly longer useful time horizon compared to Method 1. In conclusion, route estimation based only on RGB video can be performed for short time windows, and it could definitely be a good starting point for more complex systems that also take advantage of the map.

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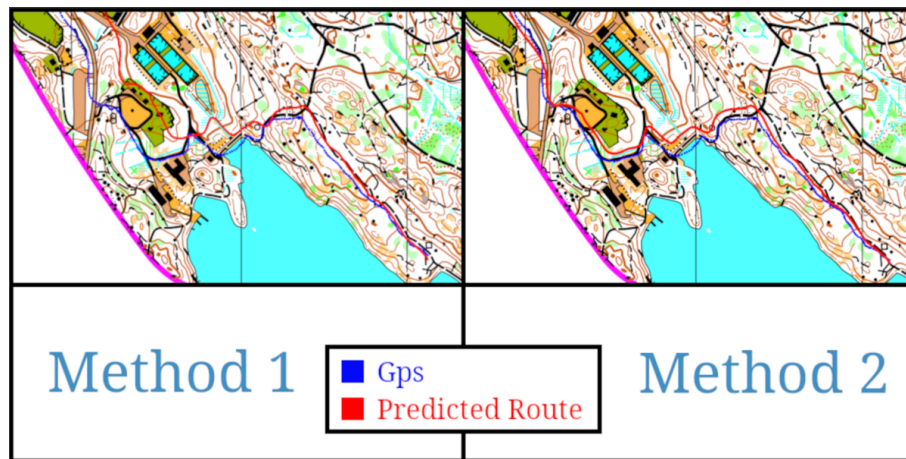


Figure 2: Comparison of the two proposed methods using the same video. The predicted routes are shown in red, while the GPS track is shown in blue for reference. Focusing on Method 1, we see that its assumptions hold reasonably well up to the intersection highlighted by the purple circle, where the terrain is flat and allows normal running speed. However, in the subsequent downhill section, the method incorrectly predicts the scale. Notably, the runner never left the paths or roads throughout.

Is orienteering an inclusive sport?

Carmen Martínez Villanueva* and Nuria Caus Pertegaz

Inclusive Orienteering Committee, Spain

Keywords: Inclusion, Inclusive orienteering, Disability

Introduction Orienteering is one of the most individual sports there is and, paradoxically, one of those with the strongest social element. The ‘support network’ in our sport is evident in every second of every event, from the starting lines to the finish areas and competition zones, where runners of all ages, genders and abilities come together. However, despite this strong sense of community, we must ask ourselves whether orienteering is actually an inclusive sport. Are we taking sufficient account of functional diversity? We pride ourselves on being a sport for everyone, but are we not forgetting someone? Can orienteering be a sport practised by anyone with a disability? We believe that the time has come to tackle this unresolved issue from an international perspective, so that all countries can move forward together.

Contextualisation Approximately 16% of the world’s population has some form of disability (WHO, 2023). Participation in sport by people with disabilities is a key factor in their social inclusion, personal development and improved well-being. However, individual, social and structural factors continue to limit their equal access to physical activity. From this perspective, identifying and understanding the barriers and enablers to participation in our sport is essential for pinpointing the factors that influence participation and enabling the design of more effective interventions tailored to the real needs of this group, drawing on technical and practical knowledge and building on organizational structures designed with universal accessibility in mind, whilst taking a holistic view of the current context in order to move towards truly inclusive models.

What does it mean to be inclusive? Inclusion is understood as a system of beliefs and values that holds that all people, regardless of whether or not they have a disability, are active members of the society in which they live. In the sporting arena, this means that they must be a real and effective part of sporting provision, with equal opportunities and genuine choices. Consequently, the ultimate aim of inclusion is to guarantee equal opportunities in sport, enabling individuals to take part in orienteering with their peers, in their local community and at the highest level their abilities and interests allow.

Pedagogical approach Based on the functional capacities of the athletes, and the potential impact on the execution of the sport, thinking and running, the purpose of this proposal is to ensure accessibility for people with visual, physical and intellectual disabilities to orienteering, with full safety conditions in practice. Potential factors affecting the athlete can be grouped in:

- a) Functionality of the lower limbs, trunk and hands (physical).
- b) Map reading ability (visual).
- c) Map interpretation and decision-making ability (intellectual).

How can this be turned into reality? From a practical perspective, we can propose two key models. A model in which athletes with disabilities have access to competition in an inclusive open category, which guarantees the necessary accessibility conditions, for example, a wheelchair-accessible route, an enlarged scale to facilitate readability, or the use of pictograms to make it easier to understand the map and the surroundings. A second model based on the classification systems traditionally used in most Paralympic sports, which we have developed and defined in recent years, using the following abbreviations: W = wheelchair user; S (standing) = athlete with lower limb disability and ambulation ability; B (blind) = athlete with visual impairment; I (intellectual) = athlete with intellectual, psychosocial or psychological disability. In the global description, letter “O” is the acronym for Orienteering.

Given that we have examples of development initiatives in various countries, and that this is an area yet to be implemented within the IOF, we would like to contribute to the creation of a

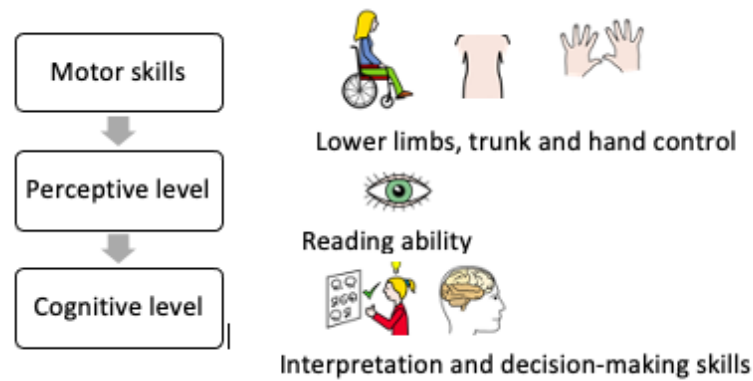


Figure 1: Classification of athletes with disabilities in orienteering.

global system that will help us all establish a common framework for eligibility and participation, with a universal system that facilitates the genuine development of inclusive orienteering.

Regardless of whether Trail-O continues or not as an official competitive event, this model will provide a tailored approach that meets all participants' needs, promoting inclusion across a wide range of activities. It views 'sprint' races and mazes as ideal settings for development, given the flexibility in course length and the greater ease with which the route and map layout can be adapted.

We also hope that these ideas, together with all the experiences already gained in various countries, instead of making isolated efforts, will help to establish an international framework, endorsed by the IOF, and will serve as a benchmark for inclusive orienteering.

Let's join forces to create an inclusive and welcoming environment in our sport!

The thinking runner: How navigational demands in orienteering, compared to regular running, are associated with better cognitive performance across adulthood

Martina Palumbo*, Lorenzo Budel, Samuel D’Emanuele, Giorgio Storti, Simone Bettega, Angela Marotta, Chiara Zoppirolli, Cantor Tarperi, and Federico Schena

University of Verona, Verona, Italy

Keywords: Orienteering, Master Athletes, Successful Aging

Context During the aging process, an inevitable decline in physical and cognitive capacities occurs. However, regular exercise appears to mitigate these effects. The structured training undertaken by master athletes seems to help maintain high functional capacities, rendering them models of successful aging (1). The sport of orienteering combines endurance with cognitive challenges and may offer a unique opportunity to preserve both physical and mental abilities (2).

Key contribution This study aims to assess whether the regular practice of orienteering offers greater benefits in preserving cognitive and physical abilities in master athletes compared to running.

Approach The study initially recruited 173 athletes: 103 orienteers aged 30–82 years, who practised orienteering approximately 1–2 times/week, with most of them having 26–40 years of sport experience, and 70 runners aged 31–72 years, who trained approximately 3–4 times/week and had 6–15 years of running experience. In the end, 109 athletes were included in the analysis and stratified into three age groups: 30–49, 50–64, and ≥ 65 years. Sex distribution was balanced among orienteers across age groups, whereas the ≥ 65 runner subgroup included only nine male participants because of recruitment constraints. Group characteristics are reported in Table 1. Cognitive performance was assessed using the Trail Making Test (TMT), the Elithorn’s Perceptual Maze Test (EPMT), and the Stroop Color and Word Test, Caffarra version (Stroop). The TMT consists of two parts assessing executive function, visual search, and psychomotor speed. TMT-A was used as an index of visuoperceptual and visuomotor tracking abilities, whereas TMT-B assessed working memory and cognitive flexibility. The derived TMT B–A score was calculated to reduce the influence of baseline processing speed and isolate executive control processes. The EPMT assessed visuospatial abilities, logical reasoning, and planning, while Stroop interference time and interference errors were used as indicators of inhibitory control. Physical performance was assessed through an isometric handgrip test measuring maximal voluntary muscle strength. Statistical analyses were performed using jamovi, version 2.6. Normality and homoscedasticity were assessed using the Shapiro–Wilk and Levene’s tests. Since these assumptions were violated for most cognitive and physical outcomes, outcome-specific linear and generalized linear models were applied. In each model, the test score was entered as the dependent variable, while age group, sport type, and their interaction were included as fixed factors. Education level was not included as a covariate because it was comparable across experimental groups (all $p > 0.05$). Generalized linear models with gamma distribution and log-link function were used for TMT-A, TMT-B, and Stroop interference time; a negative binomial model with log-link function was used for EPMT; and Gaussian linear models with identity link were used for TMT B–A, Stroop interference errors, and handgrip strength.

Evidence In TMT A, B, and B–A a significant effect for both group (all $p < 0.05$; $\eta^2 = 0.69$, 0.49 and 0.12, respectively) and sport (all $p < 0.05$; $\eta^2 = 0.79$, 0.41 and 0.08, respectively)

were found, with no interaction effect (all $p > 0.05$, all $\eta^2 < 0.06$). For both orienteers and runners, TMT times became longer with advancing age with the latter spending more time doing the task. On the contrary, in EPMT a significant effect was found only for group ($X^2 = 6.66$, $p = 0.036$), driven by a worse performance of 50–64 (Bonferroni $p = 0.047$, rate ratio = 0.55), whereas neither the effect of sport nor the interaction was significant (all $p > 0.05$). For Stroop interference time, both sport and group effects were significant ($p < 0.001$; $\eta^2 = 0.48, 0.65$, respectively), but no interaction was found: while performance worsened with age, orienteers remained systematically better. Interference errors showed a significant effect of sport, group and their interaction (all $p < 0.05$; $\eta^2 = 0.26, 0.08, 0.11$). Aging affected the two sports differently: while runners showed a progressive increase in errors with age, orienteers maintained near-zero errors across all cohorts. A significant age effect was found for handgrip strength in both females ($p = 0.015$) and males ($p < 0.001$), with a decline over the years; no significant sport or interaction effect emerged (all $p > 0.05$) (table 2). Overall, the regular practice of orienteering appears to be positively associated with better cognitive performance during aging. While a mild, gradual decline is observable in specific cognitive functions, orienteers consistently outperformed runners in most cognitive tasks across nearly all age cohorts, with the lack of interaction confirming a stable advantage across the investigated age range. Specifically, in tasks measuring visuo-perceptual speed (TMT Part A), general processing speed (TMT Part B), and cognitive flexibility (TMT B-A) orienteers systematically outperformed runners, and both groups scored better than the normative reference population, highlighting the cognitive benefits of aerobic exercise (3). However, a different trend emerged in the EPMT where only an age effect was detected. This may be due to behavioural rather than cognitive factors. Orienteers are trained to select routes rapidly in motion, an approach that paradoxically led to more errors in the rigid EPMT protocol, which lacks real-world flexible path recalculation. Moreover, the small ≥ 65 runners sample was sufficient to detect sport advantages in the TMT and Stroop but lacked statistical power for the EPMT. The most interesting evidence emerged within executive functions, specifically inhibitory control (Stroop), it seems that orienteering may mitigate age-related decline, maintaining stable interference times and error rates compared to the marked worsening observed in runners. In contrast to the cognitive differences, physical strength showed similar values between the groups, with both being close to a normative reference population. This is likely due to the physiological demands of orienteering and running, which may not translate into significant gains in muscular strength.

Relevance to O-Conference Regular orienteering practice may favour successful cognitive aging by uniquely combining aerobic exercise with navigational challenges. Compared to runners, orienteers showed superior processing speed, cognitive flexibility, and inhibitory control across adulthood. Therefore, the sport's unique integration of physical and mental demands can serve as a robust tool for promoting successful aging.

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Age Group	Gender	Characteristic	Orienteers	Runners
30–49 years	F ($n = 10 / n = 10$)	Age (yrs)	43 ± 5	42 ± 6
		BMI (kg/m ²)	23.3 ± 2.0	20.9 ± 1.7
		Education (yrs)	14.9 ± 3.1	15.8 ± 1.9
	M ($n = 10 / n = 10$)	Age (yrs)	43 ± 5	41 ± 6
		BMI (kg/m ²)	24.4 ± 3.1	23.8 ± 2.6
		Education (yrs)	13.7 ± 2.8	15.0 ± 2.1
	Whole group	Age (yrs)	43 ± 6	42 ± 6
		BMI (kg/m ²)	23.8 ± 2.6	22.3 ± 2.6
		Education (yrs)	14.3 ± 2.9	15.4 ± 2.0
50–64 years	F ($n = 10 / n = 10$)	Age (yrs)	55 ± 6	56 ± 4
		BMI (kg/m ²)	21.4 ± 1.6	22.0 ± 1.6
		Education (yrs)	13.4 ± 1.3	13.8 ± 1.7
	M ($n = 10 / n = 10$)	Age (yrs)	57 ± 6	57 ± 3
		BMI (kg/m ²)	23.8 ± 1.6	24.3 ± 1.7
		Education (yrs)	13.0 ± 0.0	14.5 ± 3.0
	Whole group	Age (yrs)	56 ± 3	57 ± 4
		BMI (kg/m ²)	22.6 ± 1.9	23.2 ± 2.0
		Education (yrs)	13.2 ± 0.9	14.2 ± 2.4
O65	F ($n = 10 / n = 0$)	Age (yrs)	72 ± 5	
		BMI (kg/m ²)	21.6 ± 2.4	
		Education (yrs)	12.8 ± 3.0	
	M ($n = 10 / n = 9$)	Age (yrs)	72 ± 5	68 ± 2
		BMI (kg/m ²)	22.6 ± 1.8	23.3 ± 2.4
		Education (yrs)	13.4 ± 1.3	13.8 ± 2.9
	Whole group	Age (yrs)	72 ± 5	68 ± 2
		BMI (kg/m ²)	22.1 ± 2.1	23.3 ± 2.4
		Education (yrs)	13.1 ± 2.3	13.8 ± 2.9

Table 1: Characteristics of orienteers and runners divided by age group and gender (F = Female, M = Male). n = sample size; data are presented as mean ± standard deviation.

Variable	Sport	30–49 yrs	50–64 yrs	65+ yrs	Group effect (p)	Sport effect (p)	Group*Sport effect (p)
TMT Part A (s)	Orienteering	19.0 ± 3.7	22.0 ± 5.2	24.6 ± 4.9	0.016	0.002	0.987
	Running	23.7 ± 6.6	27.8 ± 20.7	31.7 ± 7.9			
TMT Part B (s)	Orienteering	46.9 ± 17.6	54.8 ± 20.9	57.3 ± 23.7	0.010	0.006	0.584
	Running	53.4 ± 20.0	67.5 ± 37.8	81.3 ± 26.2			
TMT B–A (s)	Orienteering	27.9 ± 17.8	32.8 ± 20.5	32.6 ± 21.8	0.044	0.033	0.337
	Running	29.6 ± 16.8	39.8 ± 22.0	49.7 ± 23.7			
EPMT (Maze score)	Orienteering	15.0 ± 1.2	13.7 ± 1.8	12.8 ± 2.2	0.045	0.913	0.150
	Running	14.2 ± 1.8	13.3 ± 3.1	14.2 ± 1.9			
Stroop Interf. Time (s)	Orienteering	10.8 ± 6.1	13.1 ± 5.5	14.9 ± 7.0	< 0.001	< 0.001	0.533
	Running	13.5 ± 5.2	16.1 ± 5.9	23.1 ± 7.1			
Stroop Interf. Errors	Orienteering	0.2 ± 0.5	0.0 ± 0.3	0.0 ± 0.0	0.005	< 0.001	< 0.001
	Running	0.4 ± 0.6	1.0 ± 1.5	2.1 ± 2.2			
Handgrip (kg) F	Orienteering	31.6 ± 3.27	28.1 ± 3.70	25.1 ± 5.67	0.015	0.325	0.928
	Running	27.7 ± 4.89	24.5 ± 3.91	-			
Handgrip (kg) M	Orienteering	48.4 ± 9.09	47.2 ± 8.07	39.0 ± 6.01	< 0.001	0.266	0.834
	Running	45.6 ± 7.27	46.6 ± 10.2	35.3 ± 7.74			

Table 2: Cognitive (TMT, EPMT, Stroop) and physical (Handgrip) test scores of orienteers and runners, divided by group and gender. Data are presented as mean ± standard deviation.

Performance analysis in orienteering to support the orienteer's autonomy in the Vikazimut app

Eric Pigeon, Régis Clouard, and Ayao Parfait Agbeto*

ESIX Normandie, Cherbourg-en-Cotentin, France

Keywords: Evaluation, Performances, App

Introduction Progression in orienteering relies on the orienteer's ability to analyse his or her route choices and to identify his or her technical errors. However, without an expert on-site, self-evaluation remains a challenge. While viewing a GPS track on a map has been widely available since the Quickroute app (2008), it remains difficult for beginners to interpret it: they struggle to correlate their speed fluctuations to cognitive processes (poor choices, map reading and so on). A second analysis approach based on the GPS track (Mottet, 2017) proposes a classification of orienteers using speed histograms during a course. This approach, which is used in the Vikazimut app, makes it possible to estimate the user's level of expertise. While this tool, which takes into account physical and technical capabilities, is easily understood by beginners, it can only provide very general advice and does not pinpoint the errors made. In this article, we propose a tool that is able to breakdown the performance according to a pedagogical structure defined by the French Orienteering Federation, to generate a detailed feedback on the various legs of the course. It highlights the imperfections detected, so that a beginner becomes aware of his or her shortcomings. This new tool is available in the Vikazimut app, which is a joint university project between ESIX Normandie, ENSICAEN, Université de Caen, and the LIS and GREYC laboratories(UMR CNRS-6072). The performance analysis tool presented was sponsored by the SHIFT ministerial project, whose purpose is to develop distance learning for the Sports Science (STAPS) degree.

The approach An orienteering course is made up of successive legs connecting the various mandatory checkpoints (also known as controls). In order to optimise the learning of orienteering, the French Orienteering Federation proposes a model that divides each leg in 3 zones, where the orienteer's behaviour must differ: (i) Exit from the checkpoint, (ii) Following a handrail, (iii) Entry into the checkpoint.

To encourage beginners to think within this framework, our analysis provides a grade for each zone. The algorithm that calculates these grades is detailed below.

1. Simplification of the GPS track (Ramer-Douglas-Peucker, 1973) by creating a series of vectors.
2. Calculation of the various motion-related parameters along the vectors obtained (speeds, directions and their fluctuations, stop stages, u-turns and so on).
3. Use of these parameters for all the 3 zones of each leg as an entry point for a rule-based expert system developed with the help of experts of the French Orienteering Federation. The outcome is a grade for each zone of each leg.
4. An explanation is proposed for each grade below a given threshold.
5. Calculation of the average grade for attack point, exit and handrail zones for the full course.

It should be noted that this algorithm analyses the technical skills of an orienteer irrespective of his or her physical capabilities given that all the running speed-related measures are standardised based on the average running speed during the course. The tool was tested on several dozens of

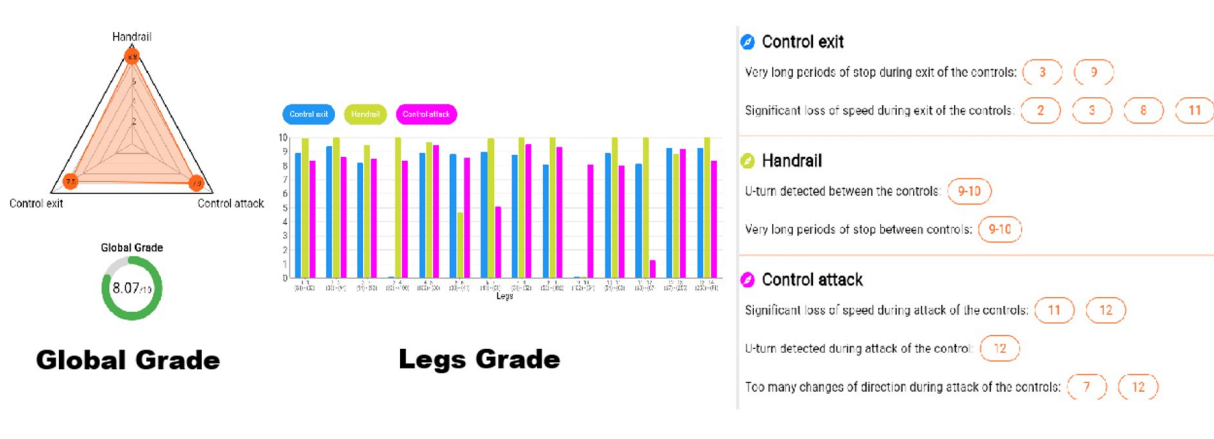


Figure 1: Example of an evaluation of an orienteering race in the Vikazimut app

courses in the Vikazimut app. The evaluation compares the automated grades to the analyses made by the Federation's experts. The results show a strong correlation between the grades and the level of success in a given leg. This correlation is very important in the checkpoint attack point and exit zones, in spite of the uncertainty around the entry into and exit from these zones. Preliminary feedback indicates that this objective grading enables a coach to understand the qualitative monitoring of the students' technical levels, even without direct observation of the session. The feedback also validates the app's ergonomics because the information supplied by the app is considered easily understandable by users.

Conclusion The key contribution from this work is the creation of an automated evaluation mechanism that makes it possible to compare the adequacy of an orienteer's course and the behavioural model defined by the Federation's bodies. By incorporating this expertise in the Vikazimut app, the smartphone may be used as an "on-board coach" that improves the comprehension and analysis of performance during orienteering. Future work will focus on the automated identification of the entry or exit times in and from checkpoint attack point and exit zones and on translating the rules of the analysis engine into a fuzzy inference system in order to facilitate the development of the rules of the engine in line with new courses.

The historical geography of orienteering: origins and cultural practices of foot navigation

Richard Powell

University of Cambridge, Cambridge, United Kingdom

Keywords: history of orienteering, historical geography, cultural history, forests, national identity and geographical imagination, history of geopolitics

The basic outline of the early history of orienteering is known by most current practitioners of the sport. This brief story encompasses instruction to soldiers in Karlstad in 1886, introduction to civilians in Norway in 1897, rapid popularisation in Sweden by Ernst Killander (1882-1958), and internationalisation by the IOF (International Orienteering Federation) from 1961. However, the history of orienteering has not been subject to sustained attention by scholarly historians or historical geographers, despite the fact that its origins bear on a number of important debates in cultural history.

There has been significant work by historians of cartography about the development orienteering mapping. This important research has concentrated specifically on the period following the establishment of the IOF and the need for international standardization of maps for competition. The foundation period in the late nineteenth- and early twentieth-century has not had significant attention.

There has also been a range of recent work within human geography focusing on the geographies of running cultures and practices. This work has emplaced running as an inherently geographical practice, drawing on the wider mobility turn and practice theories. However, this work has ignored the sport of orienteering despite the cognate issues around bodily navigation through environments.

This paper argues that, like all sports and cultural practices, orienteering as a pursuit developed from a specific milieu. This place and context speaks to a number of important themes that remain critical in contemporary research in cultural history. Examining these proves fruitful for consideration of the origins and assumptions of the sport.

In the first place, the specific intellectual origins of orienteering can be traced within the Swedish natural science tradition that focused on the exploration, collection and depiction of northern, forested areas of northern Scandinavia, originating in the work of Carl Linnaeus (1707-1778).

Second, in its modern form, orienteering developed as a mode of military instruction at the Swedish Military Academy at Karlberg in the 1880s for the training of infantry to navigate successfully and accurately through terrain at speed. This attention on new training and instruction for military leaders coincided with the emergence from Sweden of geopolitik (geopolitics), as defined by Rudolf Kjellén (1864-1922). This school of thought, heavily influential across northern Europe during the early twentieth-century, was initially associated with the importance of land power through infantry and its coordination with naval strength.

Third, orienteering as an activity was associated with navigation through ‘unknown land or terrain’. The focus for these activities were specific Nordic forest landscapes – i.e. forested areas of Sweden, Norway and Finland. These lands overlap figuratively and imaginatively with Sápmi. In this case, recent work on nation-building and resource development in twentieth-century Sweden, Norway and Finland speak to key issues of national imagination and the role of forests within them. These dimensions have not been confronted by historians of orienteering.

Moreover, the Nordic origins of the sport of orienteering means that many cultural formations are embedded within the contemporary sport. For example, the origins in the geographical focus on (sub)Arctic and Northern landscapes means that such areas are still seen as the purest test of

orienteering by international (non-Nordic) orienteers. This is despite the vast internationalisation of the sport in the twenty-first century.

In summary, the paper argues for further discussion and investigation of the history of orienteering as a mode of navigational and physical practice.

Performance analysis of orienteering elite athletes in sprint competitions, a comparative study during EOC 2023

Stefano Raus*, Simone Bettega, Martina Palumbo, Barbara Pellegrini, Federico Schena, and Chiara Zoppirolli

University of Verona, Verona, Italy

Keywords: sprint orienteering, technical difficulty, performance analysis, physiological analysis

Context Orienteering is a demanding navigation sport, where the sprint format is characterized as a distinct, high-intensity discipline. In accordance with the International Orienteering Federation (IOF) Competition Rules, sprint races are held in urban or semi-urban environments that demand full concentration at high speed¹. Prior research has established that route choice [1], terrain complexity [2], and cognitive management under acute physical stress [3] are critical determinants of athletic success. The European Orienteering Championships (EOC) is one of the main annual events and has sprint disciplines every alternating year. EOC 2023, held in Veneto, Italy, included all the sprint disciplines, with a total of 3 competitions over a period of 5 days. For the Sprint and the Knock-Out Sprint events, Qualification races were organized on the morning of each competition day, structured into three separate heats for both males and females. This format is used to select a limited number of runners for the Finals (n.45 for the Sprint Final and n.36 for the Knock-Out Sprint Final).

Key contribution The aim of this study is to explore the key factors affecting the performance of elite athletes in sprint orienteering, based on the races of EOC 2023. Therefore, we analyzed performance across different course segments (legs) to see what separated qualifiers from non-qualifiers in the Sprint and Knock-Out Sprint Qualification races (Performance analysis). Additionally, within a more specific subgroup, we investigated the exercise intensity distribution based on heart rate zones in male and female athletes (Physiological analysis).

Approach For the Performance analysis, a large dataset comprising all elite competitors was utilized, including 127 females and 135 males in the Sprint Qualification, and 130 females and 137 males in the Knock-Out Sprint Qualification. Three expert coaches evaluated and categorized each course leg from both Qualification competitions into three difficulty levels: Easy, Medium, and Hard. The classification was based on the number of route choice options and variants, presence of artificial barriers, decision points during the leg and total length, cognitive load, and difficulty of the previous leg (Fig. 1). Differences in the percentage of time losses relative to the best split times were examined to determine which difficulty levels most effectively discriminate between qualified (Q: best 15 in each heat for Sprint Qualification and best 12 in each heat for Knock-Out Sprint Qualification) and non-qualified athletes (NQ1: until rank 30; NQ2: the rest of the runners). Finally, focusing on the Hard legs only, we evaluated whether the presence or absence of artificial barriers further altered this performance gap between Q and NQ runners. For the Physiological analysis, a smaller subgroup of athletes was considered (Sprint Qualification: 4 females and 3 males; Knock-Out Sprint Qualification: 5 females and 5 males). They completed a questionnaire providing personal information, including their maximum heart rate, from which the five exercise intensity zones were calculated: Zone 1 (60–72%), Zone 2 (73–82%), Zone 3 (83–87%), Zone 4 (88–92%), and Zone 5 (>93%) [5]. During the races, the athletes' heart rate was continuously recorded using GPS watches with chest straps. These second-by-second

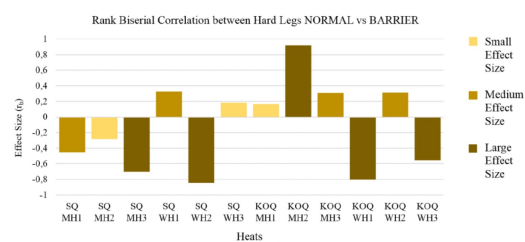
¹International Orienteering Federation. (2025). Competition Rules for Orienteering. Retrieved January 22, 2025, <https://orienteering.sport/orienteering/competition-rules>

data were then divided into the respective zones and expressed as a percentage of total race duration. Performance data were analyzed using the Kruskal–Wallis test with Dwass–Steel–Critchlow–Fligner post hoc comparisons, and effect size was assessed using epsilon squared (ϵ^2). Comparisons between Hard legs with or without artificial-barrier were performed using the Wilcoxon Signed-Rank Test with rank biserial correlation as effect size (rb). Physiological data were analyzed with repeated-measures ANOVA; when data did not meet the criteria of normality or homogeneity, a nonparametric test (Friedman test) was used. All analyses were conducted with Jamovi (The Jamovi Project, 2023; Version 2.3.28).

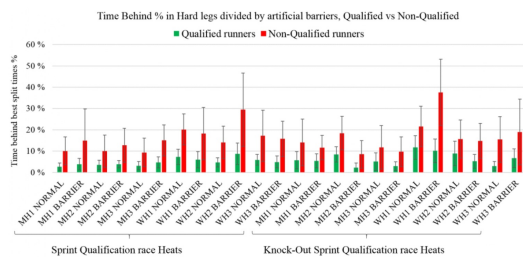
Evidence The Performance analysis revealed that the most critical segments in distinguishing finalists were the Hard legs with artificial barriers further increasing the difficulty compared to legs without them [Graph 1] [Graph 2]. Most of the race was spent in Zone 5, for both Sprint and Knock-Out Sprint Qualifications; no differences between genders were detected [Graph 3].



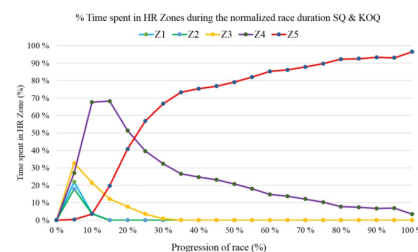
Figure 1 Example of an EASY leg (left), a MEDIUM leg (center) and a DIFFICULT leg (right). EASY leg: there are only 2 route choices and they have almost the same length. No matter the runner's choice it's an easy leg of ~300m of pure high-speed running and reading ahead. MEDIUM leg: this leg has 3 route choices, with one that is visibly longer. The only difficulty is choosing whether running north or south to exit the control; after that, both options offer plenty of time for high-speed running and reading the next legs (the leg starts with the control on the right). HARD leg: in total there are 4 route choices here, all of similar lengths in a complex and tricky park area with artificial barriers (specially built for the competition). The leg before this one was similar in terms of difficulty and the following leg too, adding technical pressure.



Graph 1 Rank Biserial Correlation (r_b) for all the competitors, between HARD legs with or without artificial barriers.



Graph 2 Percentage of time behind best split times divided by Hard legs type.



Graph 3 Percentage of time spent in HR Zones, considering both Qualification races.

Figure 1: Classification of course legs by difficulty level.

Relevance to O-Conference The Performance analysis revealed that athletes who did not qualify experienced significant time losses in hard segments, which required advanced map-reading skills and placed high cognitive demands on decision-making. Conversely, easy segments primarily tested an athlete's capacity to sustain high running speeds while minimizing navigational errors. Additionally, artificial barriers played an important role in performance outcomes, highlighting the importance of adaptability and race-specific preparation which should replicate real-race conditions. Within the performance analysis no differences were detected between male and female athletes. Similarly, physiological data shows that sprint orienteering demands a sustained, near-maximal physical effort for both genders alike. Athletes must adapt to the high-intensity nature, variable pace, and frequent direction changes of the discipline, emphasizing the crucial need for interval training, strength conditioning, and cognitive exercises under fatigue. Some limitations should be acknowledged when interpreting our results: the performance analysis was restricted to a single event (EOC 2023), therefore future research would benefit from incorporating

multiple competitions across diverse urban terrains. Additionally, the physiological data were collected from a small sample size, highlighting the need for larger cohorts to further validate these profiles.

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Experiences from the O-Challenge Initiative: Promoting Outdoor Participation Through Gamified Digital Orienteering

Susi Rutz-Rothacher

Independent Researcher, Switzerland

Keywords: orienteering promotion, GPS, gamification

The O-Challenge is a gamified digital orienteering initiative that encourages recurring participation through GPS-based virtual checkpoints and public ranking systems. The platform promotes sustained engagement by allowing users to collect points across multiple days, which supports repeat visits and long-term motivation. Its simplified participation process—downloading the MapRun app, scanning a QR code, and automatically tracking progress—creates a low barrier to entry for diverse user groups, including families and schools. The implementation demonstrates several strengths, such as scalable virtual controls, low maintenance requirements, and adaptable multi-location deployment across towns like Wetzikon, Pfäffikon, and Uster. Health and educational benefits include increased physical activity, improved navigation skills, spatial awareness, and stronger community engagement through outdoor exploration. Technically, the initiative relies on the MapRun mobile application, GPS tracking, QR-code onboarding, and Google Sheets for publishing rankings, creating a cost-effective and scalable digital infrastructure. However, limitations such as tailored app, ranking maintenance, and the absence of advanced analytics suggest opportunities for future development, including enhanced gamification features and dynamic data dashboards.

Onalysis: Uncovering the ‘Black Box’ of Orienteering Performance with Automated Map Reading Analysis

Ben Squire

University of Birmingham, United Kingdom

Keywords: Orienteering Analysis, Machine Learning, Sports Performance Analytics, Wearable Sensors, Human Activity Recognition

Context and Problem To succeed at orienteering, an athlete must maintain “Full Speed, No Mistakes”, balancing fast movement with constant navigational decision-making. However, performance analysis has historically been limited by the fact that these cognitive processes, specifically map reading, are inherently unobservable. Current post-session analysis tools rely primarily on GPS data to visualize where an athlete has been. Whilst insightful, these tools fail to capture the "why" behind an athlete’s movement; they cannot distinguish between a physical slowdown due to terrain and a cognitive pause for navigation. Existing methods for observing technique, such as head-mounted cameras or "shadowing" by a coach, are intrusive, labour-intensive, and susceptible to the Hawthorne effect, where the athlete’s behaviour changes due to the presence of an observer. This project addresses this "black box" by developing a non-intrusive, data-driven method to measure and analyse map-reading behaviour automatically.

Approach Onalysis is developed as an end-to-end system comprising a custom Garmin smart-watch application, a machine learning pipeline, and a web app (www.onalysis.app). The system samples data at a rate of 25Hz using the triaxial accelerometer found in modern Garmin watches. To prepare the raw signal for classification, the data is de-noised using a Butterworth low-pass filter and standardized to account for the inherent instability of the hand during high-speed running. The core of the analysis utilizes a soft-margin One-vs-One Support Vector Machine (SVM) to classify movement into four distinct activities:

- Map Reading (hand in the reading position)
- Checking Control Descriptions
- Checking the Watch
- Nothing (general movement)

To mitigate the noise further, a sliding window is applied during post-processing to remove any predicted activities lasting less than 200 milliseconds. This system was validated using data collected during British Orienteering Performance Program camps, as well as competitive races at the Lakeland Warrior and the British University Orienteering Championships (BUCS).

Evidence and Results Initial model training was conducted using 20 minutes of simulated orienteering to allow for precise data labelling. On a standard 80/20 training/test split, the model achieved 95% accuracy in a controlled environment. To evaluate the system’s real-world efficacy, we tested the model against data from British Performance Squad athletes in complex terrain, using head-mounted camera footage as a ground-truth source. In these field conditions, the model achieved an average accuracy of 76.9% for the "Map Reading" classification. While the model exhibits a high false positive rate (FPR) of 44.9%, qualitative review of the video footage confirms many of these instances occur when the hand is raised in a ‘ready’ position but the athlete’s gaze is directed at the terrain rather than the map. Crucially, a high average

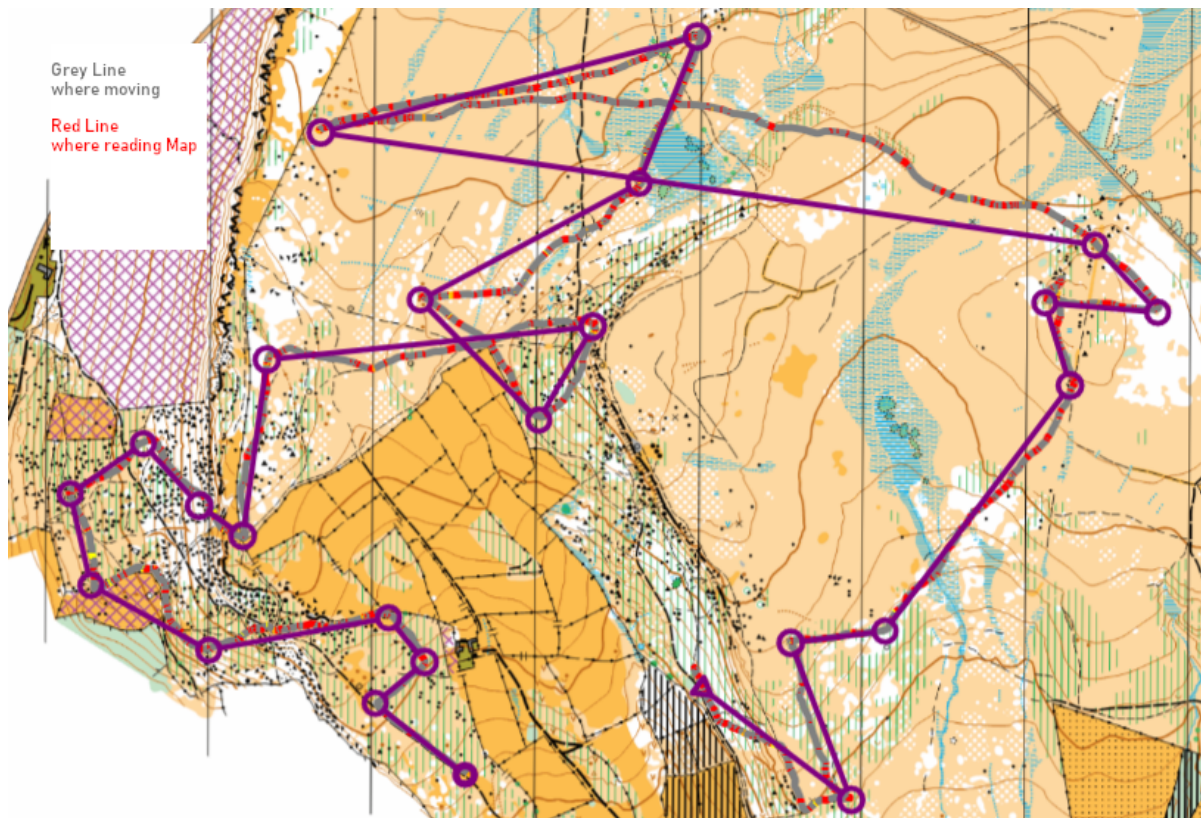


Figure 1: Example of route colored by predicted activity (Map Reading = Red, No Map Reading = Grey).

true positive rate (TPR) of 89.3% highlights the model’s strength at capturing actual cognitive navigation moments. Future work incorporating gaze-tracking or hand focused camera data to filter out these physical ‘ready’ postures would allow for an adjusted evaluation framework that better reflects the system’s true classification potential. Additional work can also be done to take data from multiple athletes to build a more athlete-agnostic model accounting for different running styles.

Key Contributions The primary contribution of this work is the creation of a novel, accessible framework for quantifying the "unobservable" technical skills of orienteering. The main benefit of Onalysis, compared to other techniques, is that it operates on standard Garmin devices already owned by the vast majority of the orienteering community. By integrating the Garmin application into their standard routine, athletes gain access to previously unavailable metrics, including:

- Duration and Frequency of Map Reads: Identifying over-navigating or lack of simplification.
- Velocity during Map Contact: A key, research proven identifier of orienteering skill
- Automated Visualisation: An overlay of the map-reading events directly onto the GPS track, allowing coaches to identify exactly where cognitive load peaked on a course.

Conclusion and Relevance This work represents a significant advancement in athletic post-session analysis, bridging the gap between raw physical metrics and cognitive load. By making sophisticated technical analysis available via a standard smartwatch, Onalysis democratises high-level coaching insights previously reserved for national squads. This tool provides a foundation for future research into how orienteering technique varies across different terrains, fatigue levels, and skill brackets, ultimately fostering a more data-driven approach to technical training.

Exercise intensity distribution across race formats and determinants of sprint performance in orienteering

Samuele Tait*, Martina Palumbo, Federico Schena, and Chiara Zoppirolli

University of Verona, Verona, Italy

Keywords: Orienteering, Elite, Performance

Context The sport of orienteering represents a unique endurance challenge where success is dictated by the combination of high aerobic capacity and the cognitive ability to navigate unknown terrain. The physiological demands of traditional forest events like Middle and Long distances are well-established as primarily aerobic with varying intensity, whereas the Sprint format, a newer addition to the international program, demands more research as its specific physical and navigational determinants remain a significant gap in current literature [1].

Key contribution The aims of the study were to compare the exercise intensity distribution in different race formats (sprint vs middle vs long) in male and female tier 3, orienteers and to investigate factors associated with sprint performance.

Approach Eleven tier-3 Italian orienteers (6 males: 24.6 ± 3.2 years; 5 females: 23.4 ± 2.4 years), including national team members, were recruited for this study; their anthropometric data and training habits were reported. During spring 2021, 5 competitions: 3 sprints (2 races and 1 simulation), 1 middle, and 1 long were monitored using GPS watches with heart rate devices. Athletes were asked to perform 3 field tests: a sprint course rerun and two 3 km time trials, one on the athletics track (3000 track) and one on a sprint-specific urban terrain, including turns, stairs, uphill, downhill and changes of direction (3000 terrain). Furthermore, athletes underwent laboratory testing for body composition (7-site skinfolds), strength (Counter Movement Jump and Squat Jump), and metabolic profiling (VO₂max and ventilatory thresholds). Heart rate data from competitions were categorized into five intensity zones based on ventilatory thresholds to calculate the percentage of time spent at each intensity zone. Data are expressed as mean $\pm$ SD. Due to heart rate monitor malfunctions, exercise intensity distribution was analyzed in 8 athletes. A Friedman test was then used to compare this distribution across race specialties. To identify the factors associated with race time, different models were ranked using the Akaike Information Criterion (AIC), keeping gender as a factor. To prevent overfitting, a parsimonious approach was used, selecting only two key predictors based on the lowest AIC. Consequently, the final Linear Mixed-Effects Model included gender, 3000 terrain, and the percentage difference between a sprint and its rerun as fixed effects (Satterthwaite's method), with athletes as a random intercept. Due to a singular fit (zero random variance), the model collapsed into a standard linear regression. Significance was set at $p < 0.05$. All analyses were performed using jamovi (version 2.6).

Evidence The female athletes ($n = 5$) had a mean height of 164.0 ± 10.0 cm, weight of 52.9 ± 9.0 kg, BMI of 19.6 ± 0.9 kg/m², and body fat percentage of $16.8 \pm 2.1\%$. They reported training 7.3 ± 1.7 hours per week across 7.0 ± 1.4 sessions, which included 1.5 ± 0.1 hours in 1.8 ± 0.2 orienteering-specific sessions (approximately 45% of which were sprint-focused). Their laboratory profiling showed a VO₂max of 2.96 ± 0.40 L/min (56.4 ± 3.5 ml/min/kg), and they had 9.4 ± 2.5 years of experience in the discipline. The male athletes ($n = 6$) had a mean height of 179.3 ± 6.9 cm, weight of 70.7 ± 7.8 kg, BMI of 21.9 ± 1.3 kg/m², and body fat percentage of $11.3 \pm 4.2\%$. They reported training 6.8 ± 1.2 hours per week across 6.2 ± 1.2 sessions, including 1.8 ± 0.9 hours in 1.8 ± 0.2 orienteering-specific sessions (approximately 53% of which

were sprint-focused). Their VO₂max was 4.52 ± 0.30 L/min (64.4 ± 4.9 ml/min/kg), and they had 15.3 ± 3.2 years of experience in orienteering. Due to heart rate monitor malfunctions, exercise intensity distribution was analyzed in 8 athletes. Race intensity distributions differed significantly between race formats ($p < 0.05$). In the sprint, most of the race time was spent in Z5 (84%), followed by Z4 (10%). In the middle distance, 50% of the race time was spent in Z3, 20% in Z4, and 12% in Z5. Similarly, in the long distance, 54% of the time was spent in Z3, 16% in Z4, and 7% in Z5. Regarding sprint performance, the best overall model included 3000 terrain and the percentage difference between a sprint and its rerun, explaining 23% of the total variance ($R^2 = 0.228$; Residual SD = 686.9 s). Within this model, gender ($p = 0.209$) and the 3000 terrain ($p = 0.129$) were not statistically significant. In contrast, the percentage difference between a sprint and its rerun emerged as the key significant factor ($F = 6.77$, $p = 0.016$). Given the small sample size and the specific cohort of Tier-3 competitive athletes, these statistical associations should be interpreted with caution and may not be generalizable to other performance levels.

Relevance to O-Conference This study shows that Sprint races are uniquely high-intensity, requiring athletes to spend most of race time around VO₂max, whereas forest races are predominantly moderate-intensity. Sprint performance is determined by navigational efficiency rather than physical capacity alone, as highlighted by the significance of the sprint-rerun difference.

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Decomposing Orienteering Performance into Speed, Stability, and Mistake Severity Using Split Times

Xieheng Wang

University of Minnesota, Twin Cities, United States

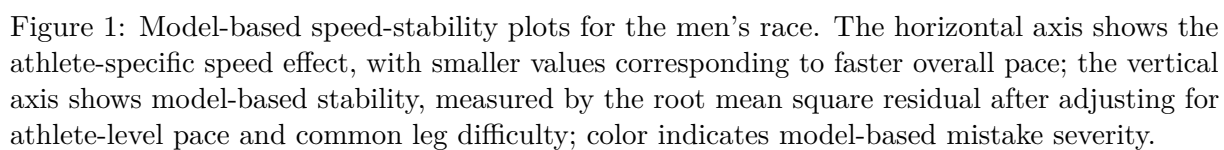
Keywords: orienteering, split times, sports analytics, performance decomposition, race analysis, statistical modeling

Official orienteering results are typically summarized by final time and rank, but these outcomes do not fully describe how an athlete performed across the course. Athletes with similar final times may differ markedly in within-race consistency and in the severity of one or two costly mistakes. We propose a split-time framework that decomposes performance into three interpretable components: speed, stability, and mistake severity.

The approach begins with descriptive summaries based on leg-level relative log-times and then formalizes the same ideas through an additive model for log split times. The log transformation makes relative split-time comparisons additive, so that multiplicative slowdowns or speedups can be represented as deviations on a common scale. In the model, each log split time is decomposed into an athlete effect representing baseline pace, a leg effect representing common leg difficulty, and an athlete–leg residual representing unexpectedly fast or slow performance on a particular leg. Speed is summarized by the athlete-level pace effect, stability by the residual spread across legs, and mistake severity by the largest positive residual.

We apply the framework to elite split-time data from the 2025 World Orienteering Championships middle- and long-distance finals. Across both formats, the speed component is most strongly aligned with final outcome, while stability and mistake severity provide complementary race-execution information rather than merely reproducing official results. The analysis also shows that athletes with nearly identical final times can nevertheless exhibit very different performance profiles: one athlete may race relatively evenly throughout, whereas another may achieve a similar total result despite one or more pronounced disruptions on individual legs.

In addition to point estimates, we report bootstrap uncertainty intervals for overall associations and include a minimal sensitivity analysis for incomplete split tables. The contribution is intentionally practical. Rather than replacing final time or rank with a single composite score, the framework provides a simple and statistically grounded way to describe how a race was run. It can support athlete comparison, race review, and post-race discussion of course structure, and more broadly illustrates how official split-time data can be turned into interpretable performance insights in elite orienteering.



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