



RELATIONSHIPS BETWEEN GENERAL ATTENTION AND MEMORY MEASURES AND ORIENTEERING-SPECIFIC COGNITIVE PERFORMANCE IN COMPETITIVE ORIENTEERS

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Abstract:

Cognitive abilities play an important role in orienteering, where athletes must interpret complex map information, select appropriate routes, and retain navigationally relevant features. However, the extent to which general cognitive abilities are associated with orienteering-specific performance remains unclear. The aim of this study was to examine the relationships between general attention and memory measures and orienteering-specific cognitive performance in competitive orienteers. The study included 60 adult orienteers aged 18–35 years (39 men and 21 women). Five general cognitive measures were assessed using the Bourdon Figure and Digit Tests, Intertwined Lines Test, Attention Span Test, and Ten-Word Memory Test. Orienteering-specific performance was evaluated through two map-based tasks assessing route-choice decision time and quality, as well as map-viewing time and route-memory accuracy. Spearman's rank-order correlations were calculated, with Benjamini–Hochberg false discovery rate correction applied to 20 primary comparisons. The results revealed predominantly weak associations between general cognitive measures and orienteering-specific outcomes. Two correlations reached the unadjusted significance threshold: verbal memory and route-choice decision time ($\rho = .281, p = .030$), and figure-based attention and route-choice quality ($\rho = -.256, p = .048$). However, neither remained statistically significant after correction for multiple comparisons. Exploratory analyses identified modest associations between decision time and route-choice quality ($\rho = .286, p = .027$), and between map-viewing time and route-memory accuracy ($\rho = .344, p = .007$). These findings suggest that general attention and memory measures do not consistently correspond to the selected orienteering-specific cognitive outcomes, highlighting the potential value of sport-specific assessments in evaluating navigational cognitive performance.

Keywords: orienteering; cognitive performance; attention; memory; route choice; navigational decision-making

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1. Introduction

Cognitive abilities play an important role in sports performance, particularly in activities requiring continuous information processing, decision-making, and the coordination of perceptual and motor responses. However, an important methodological question concerns the extent to which general cognitive tests reflect the demands of specific sporting activities. Standardized psychological assessments typically evaluate cognitive processes under controlled conditions, whereas sport-specific performance involves the integration of these processes with acquired technical knowledge, contextual information, and task-related experience. Consequently, the relationship between general cognitive abilities and sport-specific cognitive performance represents an important area of investigation.

Research on cognitive expertise in sport has highlighted the distinction between domain-general cognitive functions and domain-specific perceptual-cognitive skills. Voss *et al.* (2010), in a meta-analysis examining laboratory-based cognitive performance among athletes, reported advantages in processing speed and several attentional measures, although the magnitude of these advantages varied across cognitive domains and sporting activities. Similarly, Mann *et al.* (2007) demonstrated that expert athletes generally outperform less experienced performers in perceptual-cognitive tasks, particularly in response accuracy, response time, and visual-search behaviour. These findings indicate that cognitive performance in sport is multidimensional and may depend substantially on the characteristics of the assessment task.

The distinction between general and sport-specific cognitive assessment has received further attention in recent research. Kalén *et al.* (2021), in a meta-analysis comprising 142 studies, found that differences between higher- and lower-skilled athletes were more pronounced when assessments involved sport-specific stimuli and decision-making requirements than when general cognitive tests were used. More recently, Mancini *et al.* (2025) highlighted considerable methodological heterogeneity in studies assessing cognitive performance among athletes, emphasizing the importance of appropriate testing procedures and careful interpretation of results. Together, these findings suggest that general cognitive tests and sport-specific assessments may provide complementary rather than interchangeable information about athletes' cognitive functioning.

Empirical research has also examined the relationship between general cognitive abilities and performance in sport-specific tasks. Furley and Memmert (2015) investigated the association between working memory capacity and creative decision-making in 61 experienced soccer players. Their findings did not support the assumption that individual differences in general working memory capacity necessarily constrain sport-specific creative performance. Although the cognitive requirements of soccer differ from those of orienteering, this study illustrates the importance of directly examining relationships between general psychological measures and tasks representing the demands of a particular sport.

Orienteering provides a particularly relevant context for investigating these relationships because successful navigation requires the continuous integration of visual attention, spatial information processing, memory, and decision-making. Athletes must interpret symbolic map information, identify relevant terrain features, evaluate possible routes, and retain navigational information while moving through unfamiliar environments. Unlike general cognitive tests, these activities require the application of sport-specific knowledge and strategies developed through training and competitive experience. Consequently, performance in orienteering depends not only on the ability to process information but also on the capacity to select and apply relevant information within a complex navigational context.

Studies involving orienteers have demonstrated the importance of specialized perceptual-cognitive processes. Liu (2019) examined visual-search behaviour during precise map-reading tasks and identified differences between orienteers of varying skill levels, indicating that experience influences how relevant map information is processed. These findings suggest that effective navigation involves not only general attentional capacity but also the strategic selection and interpretation of task-relevant information. The importance of specialized technical preparation has also been highlighted by Sirakov and Belomazheva-Dimitrova (2018), who examined the role of technical training and its analysis in the preparation of world-class orienteers.

Spatial memory represents another important component of orienteering-specific cognition. During navigation, athletes must retain relevant map information, relate it to environmental features, and continuously update their representation of the intended route. Waddington and Heisz (2023) reported more proficient spatial-processing strategies and self-reported spatial memory among experienced orienteers, while finding no corresponding association with episodic memory. More recently, Zhu *et al.* (2025) investigated visuospatial working memory during map-cognition tasks using behavioural and electroencephalographic measures. Their findings indicated differences between expert and novice orienteers in map-processing performance and patterns of neural-resource allocation. These studies support the importance of spatially organized, task-specific information processing and suggest that different forms of memory should not automatically be treated as equivalent.

The practical relevance of memory-related processes in orienteering has also been addressed by Belomazheva-Dimitrova and Sirakov (2019), who investigated the views of world-class orienteers regarding memorization as a method of technical preparation. Their work provides an additional perspective on the importance of memory-related strategies within the specific context of navigational performance. However, the perceived importance and practical application of memorization techniques do not necessarily establish a direct relationship between general memory-test performance and the ability to retain and reproduce information from an orienteering map.

Previous research involving competitive orienteers has also examined general attention and memory measures in relation to specialized training. Sirakov and Belomazheva-Dimitrova (2021) reported improvements in several attention-related

measures following a structured training programme, whereas verbal memory performance did not demonstrate a statistically significant improvement. These findings highlight the possibility of differences between cognitive domains and provide a basis for further examining how general cognitive test performance relates to orienteering-specific tasks. Nevertheless, changes in cognitive measures following training do not directly establish whether individual differences in general cognitive performance correspond to differences in sport-specific decision-making or route-memory performance.

Despite growing interest in cognitive expertise and map-related information processing, the relationships between general measures of attention and memory and specific navigational performance indicators remain insufficiently understood. General attention tests assess performance in structured visual-search, concentration, and tracking tasks, while verbal memory tests evaluate the retention and reproduction of non-spatial information. In contrast, route-choice and route-memory tasks involve interpreting, selecting, and reproducing information organized according to the symbolic and spatial conventions of orienteering maps. Examining associations between these measures may therefore help clarify the extent to which general cognitive performance corresponds to specific aspects of navigational decision-making and memory.

The aim of the present study was to examine the relationships between general attention and memory measures and orienteering-specific cognitive performance in competitive adult orienteers. Five general cognitive measures were analysed in relation to four outcomes obtained from two sport-specific tasks: route-choice decision time, route-choice quality, map-viewing time, and route-memory accuracy. The study sought to determine the strength and direction of these associations and to explore whether performance on general cognitive tests was consistently related to sport-specific cognitive outcomes. Given the differences in task requirements, the relationships were expected to vary across measures rather than follow a uniform pattern.

2. Materials and Methods

2.1 Study Design and Participants

The study employed a cross-sectional correlational design based on measurements collected in March 2019 as part of a broader research project involving 60 competitive orienteers aged 18–35 years (39 men and 21 women). The sample comprised 30 candidates for the Bulgarian national orienteering team and 30 club-level athletes competing in elite classes. All participants were analysed as a single sample, as the objective was to investigate individual associations between cognitive measures rather than differences between athlete groups. Only baseline measurements were included. Selected attention- and memory-related findings from the broader project have previously been reported by Sirakov and Belomazheva-Dimitrova (2021); the present analysis addresses a different research question by examining relationships with orienteering-specific cognitive performance.

2.2 General Cognitive Assessment

Five measures of attention and memory were administered. The Bourdon Correction Test included a figure-based version (600 figures, four-minute limit) and a numerical version (1,080 digits, five-minute limit), both assessing visual attention through the identification of predefined targets (Rimskaya & Rimskiy, 1995). The Intertwined Lines Test required participants to visually trace 25 overlapping lines within seven minutes, assessing concentration and attentional stability (Platonov, 1970). Attention span was evaluated through the reproduction of geometric figures and their positions within a 16-cell grid (Voronov, 2007). Verbal memory was assessed using the Ten-Word Memory Test, in which participants recalled familiar words immediately after a single oral presentation (Ostrow, 2002). Scores represented the number of correctly identified, traced, reproduced, or recalled items, with higher values indicating better performance in all five measures.

2.3 Orienteering-Specific Cognitive Assessment

Two author-developed tasks were used to assess selected aspects of navigational decision-making and memory.

2.3.1 Route Choice

Participants examined three long route-choice legs from major international orienteering competitions. Each leg presented four colour-coded route alternatives (A–D), and participants selected the most appropriate option as quickly as possible. The alternatives were ranked using available GPS tracking data and post-race route analyses. Two outcomes were recorded: decision time (seconds) and route-choice quality, scored from 1 (excellent) to 4 (average). Total decision time across the three legs and the mean route-quality rank were calculated for each participant. Lower quality scores indicated better route selection, while shorter decision times indicated faster responses.

2.3.2 Route Memorization

Participants examined a map showing a medium-length leg with a marked route and memorized the information considered essential for navigation. After viewing the map, they reproduced the relevant terrain and navigational features schematically on a blank sheet. Map-viewing time was recorded in seconds, and reproduction accuracy was evaluated by the same assessor using a predefined five-point scale: 1 = all essential features and the principal support point reproduced; 2 = one feature or support point missing; 3 = up to two features missing, or one feature and a support point missing; 4 = three relevant features missing; and 5 = an unclear reproduction containing no useful navigational information. Lower scores indicated greater accuracy. Viewing time was considered separately from reproduction quality and was not interpreted as an independent measure of memory efficiency.

Both tasks were developed for the original research project and were treated as exploratory sport-specific assessments rather than formally validated psychometric instruments.

2.4 Statistical Analysis

Descriptive statistics were calculated for all nine variables. Associations between the five general cognitive measures and four orienteering-specific outcomes were examined using Spearman's rank-order correlation coefficient (ρ), selected because the dataset included ordinal performance measures.

The primary analysis comprised 20 correlations (five general measures $\times$ four sport-specific outcomes). To account for multiple testing, the Benjamini–Hochberg false discovery rate (FDR) procedure was applied across these 20 comparisons. Correlation coefficients, unadjusted p-values, and FDR-adjusted p-values were examined, with statistical significance set at an adjusted $p < .05$.

Two additional within-task correlations—route-choice decision time versus route-choice quality, and map-viewing time versus route-memory accuracy—were examined as secondary exploratory analyses and interpreted separately from the primary correlation family. All tests were two-tailed, and analyses were performed at the participant level.

2.5 Ethical Considerations

All participants were adults and received an oral explanation of the study procedures and intended use of the data. Participation was voluntary, and oral informed consent was obtained. The assessments were non-invasive and conducted within the athletes' normal sporting environment. No formal institutional ethics committee approval was obtained at the time of data collection. The present study involved secondary analysis of existing data without additional participant testing.

3. Results

3.1 Descriptive Statistics

Descriptive statistics for the five general cognitive measures and four orienteering-specific outcomes are presented in Table 1. The mean route-choice decision time across the three legs was 28.58 ± 9.09 s, while the mean route-choice quality rank was 2.11 ± 0.45 . In the Route Memorization task, participants spent an average of 44.78 ± 13.69 s examining the map, and the mean reproduction accuracy score was 3.60 ± 1.04 .

Table 1: Descriptive statistics of the assessed variables (n = 60)

Variable	M	SD
Bourdon – Figures	112.22	10.99
Bourdon – Digits	63.20	11.71
Intertwined Lines	9.58	3.24
Attention Span	26.58	3.65
Ten-Word Memory	7.13	1.23
Route-choice decision time (s)	28.58	9.09
Route-choice quality (rank)	2.11	0.45
Map-viewing time (s)	44.78	13.69
Route-memory accuracy (score)	3.60	1.04

Note: M = mean; SD = standard deviation. Route-choice decision time is the total time across three legs. Lower route-choice quality and route-memory accuracy scores indicate better performance.

3.2 Relationships Between General Cognitive Measures and Orienteering-Specific Performance

Spearman's rank-order correlation analysis revealed predominantly weak relationships between general cognitive measures and orienteering-specific performance (Table 2).

The strongest association was observed between Ten-Word Memory Test performance and route-choice decision time ($\rho = .281$, $p = .030$), indicating that participants who recalled more words tended to spend slightly longer selecting routes. A weak negative association was also found between Bourdon Figure Test performance and route-choice quality ($\rho = -.256$, $p = .048$), suggesting that higher attention-test scores tended to correspond to more favourable route selections.

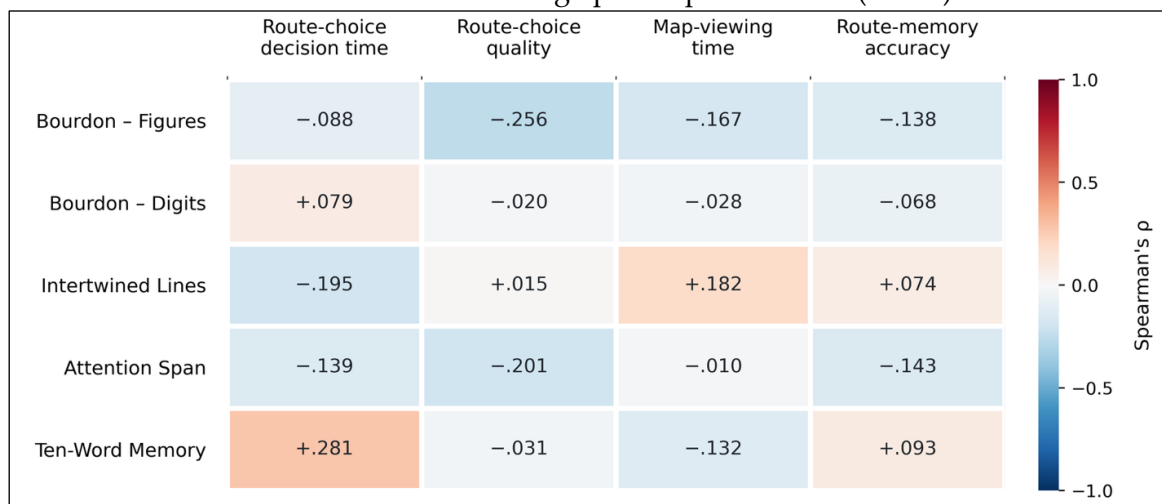
Table 2: Spearman correlations between general cognitive measures and orienteering-specific performance (n = 60)

General cognitive measure	Route-choice time	Route-choice quality	Map-viewing time	Route-memory accuracy
Bourdon – Figures	-.088 .504 / .810	-.256 .048 / .485	-.167 .203 / .631	-.138 .292 / .631
Bourdon – Digits	+.079 .548 / .810	-.020 .880 / .937	-.028 .831 / .937	-.068 .607 / .810
Intertwined Lines	-.195 .136 / .631	+.015 .912 / .937	+.182 .164 / .631	+.074 .575 / .810
Attention Span	-.139 .291 / .631	-.201 .124 / .631	-.010 .937 / .937	-.143 .275 / .631
Ten-Word Memory	+.281 .030 / .485	-.031 .814 / .937	-.132 .316 / .631	+.093 .481 / .810

Note: Each cell reports Spearman's correlation coefficient (ρ), followed by the unadjusted two-tailed p-value and the Benjamini–Hochberg FDR-adjusted p-value. FDR correction was applied across the 20 primary comparisons. Lower route-choice quality and route-memory accuracy scores indicate better performance.

Figure 1 illustrates the direction and magnitude of the correlations, showing predominantly weak associations without a consistent pattern across the assessed cognitive measures.

Figure 1: Spearman correlations between general cognitive measures and orienteering-specific performance (n = 60).



Note: Cell values represent Spearman's rank-order correlation coefficients (ρ ; $n = 60$). Blue indicates negative correlations and red indicates positive correlations; stronger colour intensity indicates a larger absolute coefficient. Lower route-choice quality and route-memory accuracy scores indicate better performance. None of the 20 correlations remained statistically significant after Benjamini–Hochberg FDR correction (all adjusted $p \geq .485$).

Following Benjamini–Hochberg correction for the 20 primary comparisons, none of the correlations remained statistically significant (all FDR-adjusted $p \geq .485$). Overall, the findings indicated limited and inconsistent correspondence between general cognitive test performance and the selected orienteering-specific outcomes.

3.3 Relationships Within Orienteering-Specific Tasks

Secondary exploratory analyses identified a positive association between route-choice decision time and route-choice quality rank ($\rho = .286$, $p = .027$). Participants requiring longer decision times tended to select less favourable route alternatives.

Map-viewing time was also positively associated with route-memory accuracy score ($\rho = .344$, $p = .007$). Longer viewing times tended to correspond to less accurate reproduction of navigational information.

These findings suggest that temporal and qualitative performance indicators were related within both sport-specific tasks. However, these associations do not establish a causal relationship between task duration and performance quality.

4. Discussion

The present study examined the relationships between general attention and memory measures and orienteering-specific cognitive performance in competitive adult orienteers. The main finding was that these relationships were predominantly weak and inconsistent across the assessed variables. Although two correlations reached the conventional unadjusted significance threshold, neither remained statistically significant after correction for multiple comparisons. These results suggest that performance on the selected general cognitive tests was not consistently associated with route-choice decision-making or route-memory performance in the present sample.

This pattern is broadly consistent with research distinguishing domain-general cognitive abilities from sport-specific perceptual-cognitive expertise. Voss *et al.* (2010) demonstrated that athletes' advantages in laboratory-based cognitive assessments vary across cognitive domains, while Mann *et al.* (2007) highlighted the importance of perceptual-cognitive skills developed within specific sporting contexts. More recently, Kalén *et al.* (2021) reported that expertise-related differences are generally more pronounced in assessments involving sport-specific stimuli and decisions than in general cognitive tasks. Although the present study did not compare athletes with different expertise levels, its findings are compatible with the possibility that general cognitive performance and specialized navigational abilities capture partly different aspects of cognitive functioning.

The weak associations involving the attention measures are particularly relevant to the demands of orienteering. The Bourdon and Intertwined Lines tests primarily assess visual concentration, attentional stability, and information processing under structured conditions. In contrast, route-choice decisions require athletes to interpret complex map information, identify relevant terrain features, evaluate alternatives, and apply knowledge acquired through navigational experience. These processes involve more than the ability to identify or track visual stimuli. Consequently, strong correspondence between performance on general attention tests and route-choice outcomes should not necessarily be expected. This interpretation is consistent with research emphasizing the importance of specialized visual-search strategies and map-processing experience in orienteering (Liu, 2019; Zhu *et al.*, 2025).

One of the more notable findings was the positive association between verbal memory performance and route-choice decision time. Participants recalling more words tended to spend slightly longer selecting routes. However, the association was weak and did not remain statistically significant after FDR correction. Moreover, longer decision time cannot be interpreted independently of decision quality. It is possible that some athletes devoted more time to evaluating route alternatives, but the present data do not establish whether this reflected more detailed processing, uncertainty, or individual decision-making strategies. Therefore, this result should be regarded as exploratory rather than evidence of a meaningful relationship between verbal memory and navigational decision speed.

The relationship between general verbal memory and route-memory accuracy was also weak. This finding is noteworthy because both assessments involve retaining and reproducing information, although their cognitive requirements differ considerably. The Ten-Word Memory Test assesses immediate recall of verbally presented information, whereas the Route Memorization task requires the identification, organization, and reproduction of spatially structured map features. Orienteers may rely on specialized strategies for simplifying and remembering navigational information that are not adequately represented by general verbal recall. Waddington and Heisz (2023) reported differences in spatial-processing strategies and self-reported spatial memory among experienced orienteers without a corresponding association with episodic memory. Similarly, Zhu *et al.* (2025) identified expertise-related characteristics of visuospatial working memory during map-cognition tasks. These findings provide a relevant context for interpreting the limited correspondence observed between verbal memory and route-memory performance.

The secondary analyses revealed positive associations between decision time and route-choice quality rank, and between map-viewing time and route-memory accuracy score. Because lower scores represented better performance in both qualitative measures, longer task durations tended to correspond to less favourable outcomes. These relationships suggest that temporal and qualitative indicators may be related within specific navigational tasks. However, the correlations were modest and should not be interpreted as demonstrating that faster performance necessarily produces better decisions or more accurate memory. Longer processing times may also reflect greater difficulty in selecting or retaining relevant information. The findings therefore support considering both speed and quality when assessing orienteering-specific cognitive performance.

The present findings also have implications for the assessment of cognitive preparedness in competitive orienteering. General attention and memory tests may provide useful information about selected cognitive functions, but their results should not automatically be interpreted as indicators of technical-cognitive proficiency in navigation. Sport-specific tasks may offer complementary information by incorporating map interpretation, route evaluation, and the retention of navigationally relevant features. This perspective is consistent with methodological recommendations emphasizing the importance of matching cognitive assessments to the demands of the activity being investigated (Manci *et al.*, 2025).

Several limitations should be acknowledged. First, the cross-sectional design does not allow causal conclusions regarding the relationships between cognitive abilities and navigational performance. Second, the sample consisted of 60 competitive orienteers with different levels of competitive involvement, which may have introduced variability in technical experience and decision-making strategies. Third, the sport-specific assessments were author-developed exploratory tasks and had not undergone formal psychometric validation. In addition, the Route Choice and Route Memorization tasks were completed under controlled testing conditions rather than during actual navigation

under physical exertion. Their results therefore represent selected aspects of navigational cognition rather than comprehensive measures of competitive performance. Finally, the relatively modest sample size limits the precision with which small associations can be estimated, and the multiple-testing correction reduces the likelihood of identifying chance findings at the cost of lower sensitivity to weak relationships.

Future research should examine these relationships in larger samples and incorporate validated sport-specific assessments where available. Studies combining general cognitive tests with map-based decision-making, eye-tracking, and performance measures obtained during actual navigation may help clarify which cognitive characteristics are most closely related to successful orienteering. Comparisons across experience levels and between different competitive formats could also provide further insight into the role of domain-specific cognitive expertise.

5. Conclusion

The present study revealed predominantly weak and inconsistent relationships between general attention and memory measures and orienteering-specific cognitive performance in competitive adult orienteers. None of the 20 primary correlations remained statistically significant after correction for multiple comparisons, indicating that the selected general cognitive tests did not consistently correspond to route-choice decision-making or route-memory performance in this sample. Exploratory analyses identified modest associations between task duration and performance quality within the two orienteering-specific assessments. These findings highlight the importance of distinguishing general cognitive functioning from the specialized cognitive demands of navigation. General attention and memory tests may provide useful supplementary information, but they should not be considered substitutes for sport-specific cognitive assessment. Further research involving larger samples and ecologically valid navigational tasks is needed to clarify these relationships and their practical relevance to competitive orienteering.

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Conflict of Interest Statement

The author declares no conflicts of interest.

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