Paradigm Shift and Pathway Reconstruction in Sports Psychology in the Digital and Intelligent Era

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Abstract: Research in sports psychology is undergoing a profound paradigm shift. By reviewing the latest research trends in this field, this paper identifies a core trend: a shift from traditional single-dimensional analysis toward multidimensional, dynamic, and ecological integration enabled by digital and intelligent technologies. the deep integration of artificial intelligence (AI) technology has given rise to four core dimensions of research: multimodal fusion enables the synergistic analysis of psychological characteristics alongside physiological and behavioral data; explainable AI resolves the "black box" dilemma of models, enhancing the credibility of practical applications; intelligent feedback systems significantly improve training outcomes through the mediating role of psychological mechanisms; and the establishment of a "brain-body-behavior" closed-loop provides the technological foundation for real-time monitoring and personalized interventions. However, technological progress is accompanied by challenges such as data quality issues, privacy and ethical concerns, and a lack of humanistic care. This paper argues that the healthy future development of sports psychology requires establishing the fundamental concept of "human-machine symbiosis." By grounding research in theory and utilizing technology as a tool, a balance between technological innovation and humanistic care can be achieved, thereby driving the high-quality development of sports psychology in the digital and intelligent era.

Keywords: Sports Psychology; Artificial Intelligence; Multimodal Fusion; Psychophysiological Integration; Human-Machine Symbiosis

1. Introduction

As a bridge discipline linking physical movement and psychological activity, sports psychology has consistently sought to uncover the psychological patterns underlying athletes' behaviour during training and competition, whilst providing theoretical underpinnings and practical guidance for the optimisation of sporting performance [1]. As we enter the third decade of the 21st century, the research paradigm of sports psychology is undergoing profound transformation, driven by the rapid development of technologies such as artificial intelligence, big data and wearable devices. This transformation has been particularly pronounced between 2025 and 2026, with a shift from traditional questionnaire-based measurements and behavioural observation towards a new paradigm that places equal emphasis on multimodal data fusion, psychophysiological integration and intelligent intervention. An analysis of research hotspots at the 14th National Sports Science Conference revealed that the theme of 'Artificial Intelligence and Digital Empowerment' ranked among the top three for the first time, serving as a direct manifestation of new-quality productive forces within the sports sector. Concurrently, the establishment of the China Gymnastics Digital and Intelligent Training Research Centre signifies the emergence of a research ecosystem characterised by collaborative efforts among 'sports teams, researchers and technology enterprises'. These developments indicate that sports psychology stands at a crossroads where technological empowerment meets theoretical reconstruction.

However, the rapid development of technology has also prompted profound reflection: does artificial intelligence provide the key to solving the challenges facing sports psychology, or does it bring new perplexities? How can we embrace technology whilst preserving the discipline's humanistic foundation? These are questions that every sports psychology researcher must now consider.

2. Paradigm Shift: From a Single Dimension to Multimodal Integration

2.1 Theoretical Foundations of Psychophysiological Integration

At the theoretical level, the Multi-States Theory provides a crucial framework for psychophysiological integration. This theory emphasises that optimising athletic performance requires an understanding of the dynamic interactions between the individual, the task and the environment; self-regulatory strategies centred on emotion and action are realised precisely by revealing the psychophysiological dynamics underlying skilled information processing and the efficacy of peak performance. In other words, an athlete's psychological state does not exist in isolation but is closely coupled with physiological indicators and behavioral performance, together constituting a dynamic system. the breakthrough of this theoretical perspective lies in its transcendence of the limitations of traditional research, which treats psychological variables as static 'traits', shifting instead to focus on their dynamic 'state' changes within specific contexts. For example, anxiety levels not only influence an athlete's subjective experience but are also manifested through physiological indicators such as heart rate variability and cortisol levels, thereby affecting the stability of motor execution and the quality of decision-making. Consequently, only by integrating multi-dimensional data can one truly understand the complex relationship between psychological state and athletic performance.

2.2 Technological Breakthroughs in Multimodal Fusion

At the technical level, multimodal fusion is emerging as a cutting-edge direction in current research. Relevant scholars have proposed a remarkable multimodal deep learning framework that combines boxers' psychological profiles with video motion data for motion recognition. the results show that, following the integration of psychological features, the model's recognition accuracy for movements that are visually similar but have different psychological backgrounds increased from approximately 85% to 91.2%. This finding holds significant theoretical importance: it empirically demonstrates that psychological state constitutes key contextual information for understanding motor behaviour; psychological variables are not external factors independent of movement, but rather are intrinsic to the core composition of athletic performance. A similar research approach has also emerged in sports dance training. Researchers have developed a training framework based on digital twins. Through 3D modelling and real-time data acquisition, this framework simultaneously analyses learners' biomechanical and psychological indicators, utilising convolutional neural networks for motion detection and support vector machines for emotion classification, thereby achieving the synergistic optimization of physical and mental states.

2.3 Longitudinal Tracking and Dynamic Modelling

In addition to cross-sectional multimodal fusion, longitudinal tracking research has also made significant methodological progress. Traditional tracking studies are often constrained by insufficient sample sizes and missing data, whereas the introduction of artificial intelligence technologies has provided new tools for handling complex longitudinal data. Researchers have begun to utilise models such as hybrid Bayesian networks to learn the directed relationships between psychological traits—such as anxiety, self-confidence and motivation—and to construct causal networks depicting their mutual influences. This approach no longer views psychological variables in isolation, but quantifies how improvements in specific psychological skills influence other psychological states through these networks, thereby providing a theoretical basis for phased interventions.

3. Four Core Dimensions of AI Application

3.1 Precise Analysis: Multimodal Fusion and Psychophysiological Coupling

As mentioned earlier, multimodal fusion forms the foundational level of current AI applications. However, its value lies not only in technical breakthroughs, but also in the fact that it redefines the subject matter of sports psychology research. Traditional research often treats psychological variables as independent factors in predicting performance, whereas multimodal fusion reveals complex coupling relationships between psychological states and physiological and behavioural data. Taking boxing movement recognition research as an example, the 'PsyBox-20' dataset constructed by researchers pairs standardised psychological test results with

specific movement examples on a one-to-one basis. This meticulous approach to data construction enables models to learn the subtle differences in the same movement under different psychological states—for instance, a jab executed in a state of high anxiety may exhibit hesitation and a high centre of gravity, whereas a jab performed with high confidence is more decisive and fully powered. This concept of 'psychological feature-enhanced motion recognition' provides a technical pathway for understanding how psychological states concretely shape movement execution. At a more macro level, researchers have proposed a concept for the integration of 'brain-body-behaviour'data. By simultaneously collecting EEG, heart rate variability and kinematic data, and utilising artificial intelligence for pattern recognition, researchers can monitor athletes' psychological states in real time within real or simulated sporting environments [2]. This shift from the laboratory to the sports field signifies that sports psychology research is moving away from controlled experiments towards field studies with higher ecological validity.

3.2 Deep Understanding: Explainable Artificial Intelligence and Trust-Building

Although multimodal fusion can improve predictive accuracy, complex deep learning models are often difficult for coaches and athletes to trust due to their 'black-box' nature. Imagine a model telling a coach, 'This athlete is likely to underperform in high-pressure matches', yet failing to explain why it reached this conclusion; it would be difficult for the coach to make personnel decisions based on this. Consequently, explainable artificial intelligence has become a hot topic in current research. In an analysis of professional tennis matches, researchers employed the TabNet deep learning architecture in conjunction with the SHAP explainability method to classify high-pressure matches. the model not only achieved 98% accuracy but also clearly identified 'number of break points' and 'match duration' as the most significant predictors of psychological pressure, rather than merely technical statistics. This interpretability enables coaches to understand the basis for the model's judgements, thereby allowing them to simulate break-point scenarios in training in a targeted manner, enhancing the athletes' psychological preparedness. For the complex relationships between psychological traits, hybrid Bayesian networks provide an intuitive visualisation method. Researchers can construct causal diagrams of psychological traits such as anxiety, confidence and motivation, quantifying how improvements in a particular psychological skill influence other psychological states through mediating pathways.

The significance of interpretable artificial intelligence lies not only at the technical level, but also in the fact that it establishes a foundation of trust for human-machine collaboration. As researchers have pointed out, AI systems should be designed to augment rather than replace human contributions. Only when coaches and psychologists are able to understand and endorse the model's judgements can AI truly integrate into practical workflows and fulfil its role in supporting decision-making.

3.3 Intelligent Intervention: Personalised Feedback and Psychological Mechanisms

Once AI is capable of accurately analysing and deeply understanding psychological states, the next logical step is to provide intervention and feedback via intelligent systems. Current research indicates that AI-assisted teaching and training systems not only enhance athletic performance but, more importantly, that this improvement is partly achieved through positive psychological mechanisms. An eight-week intervention study on adolescent speed skaters, employing a three-arm quasi-experimental design, compared the effects of AI-assisted instruction, macro-unit instruction and traditional instruction. the results showed that the 500-metre performance improvements in the AI-assisted instruction group and/or the macro-unit instruction group were significantly superior to those in the traditional instruction group. More crucially, structural equation modelling revealed that learning motivation and self-efficacy played a significant mediating role between AI-assisted instruction and performance improvement. In other words, the effectiveness of AI feedback systems stems not only from their provision of timely and accurate technical corrections, but also from their ability to stimulate intrinsic motivation by satisfying students' sense of competence and autonomy, thereby facilitating skill acquisition. This finding offers significant insights for the theoretical development of sports psychology: the efficacy of technology is partly realised through positive psychological mechanisms. Self-determination

theory posits that environments supporting a sense of competence and autonomy can foster intrinsic motivation; whilst social cognitive theory emphasises that the accumulation of successful experiences can enhance self-efficacy [3]. AI-assisted instruction, through real-time, accurate and personalised feedback, provides athletes with a wealth of successful experiences, whilst avoiding the delays and uncertainties associated with 'waiting for the teacher's correction' in traditional teaching. In the field of basketball training, researchers have developed an augmented reality system called ViSTAR. This system analyses athletes' spatiotemporal joint data and utilises large language models to convert it into natural-language coaching prompts. Experiments have shown that participants even prefer this AI-generated feedback, believing it helps them identify issues that are difficult to detect through self-observation alone. This shift from 'human-to-human observation' to 'human-machine collaborative observation' expands athletes' metacognitive abilities, enabling them to gain a clearer awareness of their movement details and psychological states.

3.4 Future Prospects: Digital Twins and Human-Machine Symbiosis

Building upon the three levels described above, the future development of sports psychology will move towards a deeper level of human-machine symbiosis. the concept of 'digital twins' proposed by researchers involves constructing a digital mirror image of athletes within a virtual space, synchronously reflecting changes in their physiological, technical and psychological states, and predicting the potential effects of different intervention strategies. Once this technology matures, coaches and psychologists will be able to pre-test training programmes in a virtual environment, assess their impact on athletes' psychological states, and then select the optimal programme for implementation in the real world. At the same time, researchers are calling for a focus on research scenarios with greater ecological validity. Team dynamics and esports are considered particularly suitable domains for applying this integrated approach. In team sports, psychological phenomena such as emotional contagion, tacit coordination and collective efficacy among athletes are difficult to measure accurately using traditional methods. However, through wearable devices and social network analysis, researchers can capture the psychophysiological synchrony of team members in real time, revealing the mechanisms underlying the emergence of team flow. In terms of talent development, AI is also being utilised to construct personalised athlete development pathways. Addressing the issue of 'homogenisation' in the development of young basketball talent in China, researchers have designed an AI- and big data-driven personalised training system. By integrating multi-dimensional data—including physical, technical and psychological metrics—this system aims to provide dynamic, evidence-based training decision support tailored to players with different characteristics. This shift from a 'one-size-fits-all' approach to a 'tailor-made' one reflects sports psychology's respect for individual differences and highlights the humanistic dimension of technology.

4. Challenges and Reflections: Concerns Lurking Behind Technological Advancements

4.1 Data Quality and Model Bias

The effectiveness of AI models relies heavily on the quality, volume and annotation accuracy of training data. This issue is particularly pronounced in research on athlete development. Firstly, tracking the long-term development of athletes requires data collection spanning several years, and data gaps are almost inevitable. Secondly, the number of individuals who actually go on to become top-level athletes is extremely small; this 'outcome imbalance' leads models to favour predictions about the majority, making it difficult to identify true talent. Thirdly, historical data reflects past talent development models and competitive environments, whereas the social context, training methods and competition rules surrounding athlete development are constantly evolving; predictive indicators that were effective in the past may not necessarily apply to the future. As researchers have noted, using AI for talent prediction implies a dangerous assumption: that factors which were important in the past will remain so in the future.

4.2 Interpretability and Trust in Practice

Although progress has been made in interpretable artificial intelligence, deep learning models remain, by their very nature, complex non-linear systems. When a model offers a counterintuitive recommendation, do coaches

and athletes have sufficient trust to adopt it? If the results are poor after adoption, who should bear the responsibility? These issues involve the philosophy of technology and professional ethics, and are far beyond the scope of the technology itself to resolve. In practice, coaches often rely on years of experience and intuition, whilst AI models may capture subtle patterns that coaches have not recognised. Bridging the gap between these two modes of cognition is a challenge that must be addressed for the practical implementation of AI.

4.3 Privacy Ethics and Data Sovereignty

With the proliferation of wearable devices and computer vision technology, vast amounts of athletes' physiological, behavioural and even emotional data are being collected. To whom does ownership of this data belong? Who has the right to access and use it? Do athletes truly give informed consent? These issues are frequently overlooked in practice. Some researchers have pointed out that athletes are often the last to be considered in discussions about data, despite being the primary generators of the data and the party most likely to suffer harm from data breaches or misuse. Some sporting organisations, such as the NBA and FIFA, are striving to grant athletes greater control over their data, but the reality is far more complex: the business models of technology companies often rely on the large-scale collection and commercial exploitation of data, and restricting data usage may hinder the continuous updating of technology.

4.4 Subjective Factors and the Lack of a Human Touch

The most difficult aspects of current AI models to quantify are precisely the core elements of sports psychology: a coach's intuitive judgement, an athlete's attitude and emotions, the quality of interpersonal relationships, resilience in the face of adversity, and the desire to win. Although these subjective factors are difficult to measure, they are often the key to distinguishing between excellence and greatness. Researchers warn that over-reliance on data may lead to the neglect of these unquantifiable factors, reducing athlete development to a mechanical pursuit of metrics. As one scholar quoted a famous saying: 'Not everything that counts can be counted, and not everything that can be counted counts. '

5. Reconstructing the Path: Sports Psychology Moving Towards 'Human-Machine Symbiosis'

5.1 Theoretical Level: Theory Leading Technology

No matter how advanced technological tools may be, they are ultimately means to achieve theoretical objectives, rather than ends in themselves. the current application of AI in sports psychology should be guided by mature theoretical frameworks. Classic theories such as the Multi-State Theory, Self-Determination Theory and Social Cognitive Theory can provide theoretical underpinnings for selecting dimensions of data collection, defining variable relationships in model construction, and explaining the mechanisms of intervention design. AI applications devoid of theoretical guidance are prone to devolving into mere technical displays of 'data for data's sake', struggling to yield genuine theoretical contributions or practical value. At the same time, AI technology may also feed back into theoretical development. the patterns of psychophysiological coupling revealed by multimodal data may prompt us to rethink theoretical models of the mind-body relationship; causal networks constructed from longitudinal tracking data may refine our understanding of the interrelationships between psychological variables. This virtuous interaction between theory and technology is a vital driving force for the future development of the discipline.

5.2 Practical Level: Human-Machine Collaborative Decision-Making Models

At the practical level, researchers generally agree that 'human-machine collaboration' represents the optimal model for AI applications. Computers excel at rapidly processing large-scale data, identifying complex patterns, and providing consistent judgements; humans excel at understanding contexts, perceiving emotions, and making value-based trade-offs. Combining the strengths of both may yield a synergistic effect where '1+1>2'. Specifically, in talent selection, AI can be used for preliminary screening to identify potential candidates meeting certain criteria from a vast pool of applicants; coaches and psychologists, meanwhile, are responsible for the final assessment, focusing on qualities that cannot be quantified, such as interpersonal skills, intrinsic motivation and resilience. In training

interventions, AI can provide real-time feedback and technical corrections, whilst coaches are responsible for creating a supportive psychological environment, regulating athletes' emotional states, and stimulating deep-seated motivation. This model of division of labour and collaboration harnesses the efficiency advantages of technology whilst preserving the central role of the human element.

5.3 Educational Dimension: Cultivating 'Dual-Competence' Talent

Technological change has placed new demands on the training of sports psychology professionals. Future sports psychologists will need not only a solid grounding in psychological theory, but also basic data literacy, an understanding of the principles and limitations of AI models, and the ability to communicate effectively with technical experts. Cultivating this 'dual-competence' talent requires an update to the curriculum and innovation in training models. the establishment of the China Gymnastics Digital and Intelligent Training Research Centre embodies the concept of collaborative research involving 'sports teams, researchers and technology enterprises'. This cross-sectoral cooperation model represents not only an innovation in research organisation but also an effective pathway for talent development. By participating in practical projects, students gain exposure to theoretical research, technological development and applied practice simultaneously, thereby developing a multidisciplinary knowledge structure and interdisciplinary collaboration skills.

5.4 Value Dimension: Restoring the Centrality of the Individual

Ultimately, the purpose of all technological applications is to serve human development. the fundamental mission of sports psychology is to help athletes achieve harmonious physical and mental development through sport, rather than merely improving competition results. Whilst pursuing technological empowerment, we must not lose sight of this fundamental mission. This implies that technological applications should respect the athlete's agency. AI feedback should serve as a suggestion rather than a command, and should stimulate rather than replace the athlete's independent thinking. Data collection must be based on fully informed consent, and the use of data must prioritise the athlete's interests. Personalised training programmes should help athletes discover their own potential, rather than moulding them into a standardised template.

6. Conclusion

Sports psychology stands at a historic turning point. the deep integration of artificial intelligence technologies is driving the research paradigm from a single dimension towards multimodal convergence, from static description towards dynamic interpretation, and from empirical judgement towards data-driven approaches [4]. Multimodal integration enables the synergistic analysis of psychological traits alongside physiological and behavioural data; explainable artificial intelligence resolves the 'black box' dilemma of models, providing a foundation for trust in practice; intelligent feedback systems significantly enhance training outcomes by stimulating learning motivation and self-efficacy; and the establishment of a 'brain-body-behaviour' closed-loop system opens up new possibilities for real-time monitoring and personalised intervention. However, technological progress is never a one-way blessing. Issues such as data quality, privacy ethics, the interpretability dilemma, and the absence of humanistic values are all challenges we must confront and address head-on. the healthy development of sports psychology requires the establishment of the fundamental concept of 'human-machine symbiosis': grounded in theory, utilising technology as a tool, and with the comprehensive development of the individual as the ultimate goal.

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