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Review Article

Epistemological Foundations of Modeling in Motor Action Research: A Narrative Review

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Abstract

Background. Modeling is widely used in motor action research; however, its epistemological role remains insufficiently conceptualized. Existing approaches primarily treat modeling as a descriptive or predictive tool, overlooking its function in scientific knowledge construction.

Objectives. The aim of this study was to substantiate modeling as an epistemological mechanism of scientific cognition in motor action research and to systematize its key functions in the transition from data to knowledge.

Materials and Methods. A narrative review was conducted based on the analysis of conceptual publications, including author's works and conference materials, as well as studies addressing general principles of modeling and scientific cognition. The analytical strategy involved reconstruction of conceptual development and identification of epistemic structures underlying modeling processes.

Results. Modeling is interpreted as a mediated cognitive process that integrates analogy, analysis, synthesis, and formalization. Its epistemic functions include structuring empirical data, reducing uncertainty, establishing relationships between system elements, and enabling the transition from data to information and knowledge. Motor actions are considered as complex, hierarchical systems requiring integrative models that account for biomechanical, physiological, and cognitive components. The concept of biotechnical systems is introduced as a framework for instrumental mediation, enabling synchronized data acquisition, interpretation, and feedback-based control. A conceptual epistemic model of the transition from data to information and knowledge is proposed.

Conclusions. Modeling should be regarded as a central epistemological mechanism in motor action research, providing a theoretical and methodological basis for understanding, analyzing, and managing complex movement systems.

Keywords: modeling, epistemology, motor actions, complex systems, biotechnical systems, knowledge construction, information processing.

Introduction

Modern research in the field of physical education and sport is increasingly based on a systems approach, within which motor actions and the training process are considered as complex, hierarchically organized systems that function on the basis of mechanisms of regulation, feedback, and adaptation (Wolpert et al., 2001; Araújo et al., 2006). Such an interpretation makes it possible to describe the educational and training process as a controlled system in which the achievement of the result is determined by the coherence of structural and functional components.

At the same time, despite the active use of systems terminology and descriptive models, the question of how knowledge about such systems is formed remains insufficiently disclosed. In particular, the methodological status of modeling requires clarification: whether it is only a tool for description and analysis, or whether it acts as an independent mechanism of cognition that ensures the transition from empirical data to generalized representations of the structure and functioning of motor actions (Rowley, 2007).

In the classical understanding, modeling is associated with the construction of a simplified representation of the object of study, which makes it possible to investigate

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its properties indirectly (Kawato, 1999). However, in the context of studying complex biological and biomechanical systems, such an interpretation is insufficient. Modeling acquires a broader meaning, acting as a process that includes the formation of analogies, the identification of essential variables, the establishment of relationships between system elements, and their subsequent formalization (Campos & Calado, 2009).

This becomes especially important in the analysis of human motor actions, which are characterized by a high level of complexity, multidimensionality of parameters, and interaction of heterogeneous subsystems. Under such conditions, direct investigation of the object is often limited, and obtaining knowledge is possible only through the construction and analysis of models that reflect the most essential aspects of system functioning (Sabes, 2000).

An important aspect of the modern understanding of modeling is its connection with information processes. A motor action can be considered as the result of information processing in a system, where the reduction of state uncertainty is achieved through the acquisition, transmission, and interpretation of data (Rowley, 2007). In this context, modeling acts as a means of structuring information and transforming it into knowledge that has practical significance for movement control and improving performance efficiency.

Particular attention should be paid to biotechnical systems, in which biological and technical components are combined. In such systems, the modeling process goes beyond purely theoretical description and includes the use of instrumental control tools that ensure the acquisition of data about the system state in real time. This creates conditions for the transition from parameter recording to their interpretation and further use in the control process (Kawato & Cortese, 2021; Russo et al., 2025).

In this work, modeling is considered not as a tool of description, but as an epistemological mechanism that ensures a structured transition from data to scientific knowledge in the study of motor actions.

The aim of this work is to provide a theoretical substantiation of modeling as a methodology for knowledge construction in the study of motor actions, as well as to generalize approaches to its use in the analysis of complex biological systems. In this context, the contribution of this work is the formalization of modeling as an epistemological mechanism for knowledge construction in the study of motor actions.

Materials and Methods

Methodology of the Narrative Review

This study was conducted in the format of a narrative review aimed at the conceptual reconstruction of approaches to modeling in the study of motor actions. Unlike systematic reviews, the main purpose of which is to summarize empirical results, a narrative review is oriented toward the analysis of theoretical provisions, the identification of the logic of scientific idea development, and the formation of a holistic understanding of the problem under study.

The selection of sources was carried out taking into account their conceptual significance for revealing the epistemological aspects of modeling. The analysis included: (1) original scientific publications presenting the development of approaches to modeling motor actions; (2) works devoted to general issues of modeling theory and scientific cognition; (3) materials from scientific conferences reflecting the evolution of ideas and their validation in applied research. This approach made it possible to combine theoretical and applied levels of analysis and ensure consistency of presentation.

The analytical strategy of the study was based on the principles of conceptual synthesis. The main stages of the analysis were: reconstruction of key ideas that determine the understanding of modeling as a method of scientific cognition; identification of the epistemic functions of modeling; establishment of relationships between theoretical provisions and their application in the study of motor actions. Particular attention was paid to the alignment of concepts used in different works and their integration into a unified conceptual structure.

The methodological basis of the analysis consisted of general scientific approaches, in particular the systems approach, which makes it possible to consider motor actions as complex, hierarchically organized systems, as well as the information approach, which provides interpretation of regulation and control processes as processes of information processing. This approach is consistent with studies in which systems analysis and mathematical modeling are considered as the methodological basis for investigating processes in physical education and sport, ensuring the integration of theoretical provisions and experimental data into a unified system of knowledge (Lopatiev et al., 2017). The use of these approaches made it possible to form a coherent theoretical framework for analyzing the role of modeling in knowledge construction.

The limitations of the study are related to the specificity of the narrative review, which does not involve formalized search procedures or quantitative evaluation of sources. The selection of literature was purposeful, which may affect the representativeness of the results. At the same time, such an approach is justified given the aim of the study, which is not to provide exhaustive coverage of all publications, but to form a holistic conceptual model.

Thus, the chosen methodology provides the possibility of an in-depth theoretical analysis of modeling as an epistemological mechanism and creates a basis for integrating the obtained results within the context of the study of motor actions.

Results

Modeling as a Method of Scientific Cognition

Modeling occupies a special place among the methods of scientific cognition, as it provides the possibility of investigating complex objects and processes under conditions where their direct study is limited or impossible (Kawato, 1999; Campos & Calado, 2009; Lopatiev, 2007). In general terms, modeling can be considered as the process of constructing and analyzing a specially designed object—a model—that reflects the most essential properties of the real system and allows obtaining new knowledge about it indirectly.

One of the fundamental logical foundations of modeling is analogy. It is through establishing similarity between the object of study and its model that the transfer of knowledge from the model to the original becomes possible. Analogy is not reduced to superficial similarity but involves the identification of structural or functional correspondence between systems, enabling the representation of one system in terms of another (Hesse, 1966; Frigg & Hartmann, 2021). In this context, the model acts not as a copy of the real object but as its theoretically grounded representation, constructed on the basis of identifying key variables and relationships.

The modeling process is inseparably connected with the combination of analytical and synthetic procedures. At the analytical stage, the researcher decomposes the object, identifying its constituent elements, parameters, and factors that determine its functioning. At the synthetic stage, these elements are integrated into a coherent system, relationships between them are established, and a generalized structure of the model is formed. It is precisely the combination of analysis and synthesis that ensures the transition from empirical description to theoretical generalization (Bunge, 1973).

An important characteristic of modeling is its mediated nature. Unlike direct experimental research, where interaction with the object occurs directly, modeling involves the use of an intermediate link—the model—which serves as an instrument of cognition. This makes it possible to investigate the properties of a system under conditions where direct experimentation is difficult due to the complexity, scale, dynamism, or inaccessibility of the object (Kawato, 1999). In the case of human motor actions, such limitations are associated with the multidimensionality of parameters, variability of states, and interaction of physiological, biomechanical, and psychological processes (Wolpert et al., 2001).

Within modeling, the issue of the adequacy of the model to the object of study is important. Adequacy does not imply complete correspondence but is determined by the model's ability to reproduce those properties of the system that are essential for solving the given scientific problem (Box, 1976). Thus, any model is the result of conscious simplification, which makes it possible to focus on the key aspects of system functioning while ignoring secondary factors.

Depending on the mode of representation and the level of formalization, different types of models are distinguished, among which mathematical and simulation models occupy a special place. Mathematical models involve a rigorous quantitative description of the system in the form of equations, functions, and relationships between variables. Simulation models, in turn, make it possible to reproduce system behavior without a complete formal description, using algorithmic procedures and computational tools. In the study of complex biological systems, in particular human motor actions, simulation modeling becomes especially important, as it allows taking into account a large number of interacting factors under conditions of limited formalization (Campos & Calado, 2009; Russo et al., 2025; Lopatiev, Vlasov et al., 2017).

Thus, modeling acts not only as a technical tool of description but as a universal method of scientific cognition that ensures the transition from observation to understanding (Lopatiev, 2007). It makes it possible to structure knowledge about complex systems, establish cause-and-effect relationships, and form theoretical representations of the mechanisms of their functioning. In the context of the study of motor actions, this opens opportunities for a deeper analysis of the processes of regulation, coordination, and adaptation that determine the effectiveness of human activity (Wolpert et al., 2001).

From Model to Knowledge: Epistemic Functions of Modeling

The transition from model to knowledge is a central problem in the methodology of scientific cognition, especially in the study of complex systems, which include human motor actions (Kawato & Cortese, 2021). In this context, modeling cannot be considered only as a tool for description or prediction, but should be interpreted as an epistemic mechanism that ensures the transformation of empirical data into structured knowledge (Giere, 2004; Rowley, 2007).

One of the key functions of modeling is the organization of the transition from data to information and further to knowledge. Data obtained in the process of observation or experiment do not possess explanatory power by themselves if they are not embedded in a certain system of relationships. The model acts as the environment in which these data acquire structure, are related to each other, and are interpreted in the context of the system under study. Thus, modeling ensures the transition from a set of fragmented measurements to a generalized understanding of the functioning of the object (Rowley, 2007).

In this process, the concept of information as a reduction of uncertainty of the system state plays an important role. Complex biological systems are characterized by a large number of possible states, and without an appropriate data structure their behavior appears random or uncontrolled. The construction of a model makes it possible to organize these states, identify the most probable scenarios, and establish regularities of transitions between them. As a result, uncertainty is reduced, and the obtained results can be interpreted as information about the system (Shannon, 1948).

Formalization is another important epistemic function of modeling. It involves the transition from qualitative description to quantitative representation of system properties. In the process of formalization, variables, parameters, and relationships between them are defined, which makes it possible to describe the system in the form of mathematical or algorithmic structures. Formalization not only increases the accuracy of description but also creates opportunities for hypothesis testing, analysis of system development scenarios, and prediction of its behavior (Bunge, 1973).

An important aspect is also the establishment of relationships between system elements. In complex systems, individual parameters cannot be considered in isolation, since their values and dynamics are determined by interaction with other elements. Modeling makes it possible to identify these interrelationships, represent them in a structured form, and assess their influence on the overall result. It is precisely through the establishment of such relationships that the model acquires explanatory power and ceases to be merely a descriptive scheme (Wolpert et al., 2001).

Of particular importance is the ability of the model to integrate heterogeneous data. In the study of motor actions, these may include biomechanical, physiological, and psychophysiological indicators that reflect different aspects of system functioning. Without a model, these data remain fragmented and do not allow obtaining a holistic understanding of the object. Modeling ensures their integration, making it possible to consider the system as a whole and identify interdependencies between its subsystems (Russo et al., 2025).

In the context of human motor actions, modeling also performs the function of complexity reduction. Biological systems are characterized by a high level of variability and nonlinearity, which complicates their direct analysis. The model makes it possible to reduce this complexity by identifying key parameters and discarding secondary factors. Such reduction does not imply a loss of meaning; on the contrary, it contributes to a clearer understanding of the mechanisms of system functioning (Campos & Calado, 2009).

The proposed structure can be defined as an epistemic model of the transition "data → information → knowledge" in the modeling process, which includes three interrelated levels: (1) data structuring; (2) formation of information through uncertainty reduction; (3) knowledge construction through formalization and integration of relationships between system elements. Such an interpretation makes it possible to present modeling as a holistic mechanism of cognition rather than a set of separate analytical procedures (Rowley, 2007) (Table 1).

Thus, modeling acts as a multifunctional epistemic instrument that ensures data structuring, uncertainty reduction, knowledge formalization, and the establishment of cause-and-effect relationships. These functions determine its key role in the study of motor actions, where the complexity of the object requires the use of mediated methods of cognition. In this sense, modeling should be considered not only as an auxiliary method but as a central mechanism for constructing scientific knowledge about motor systems (Kawato & Cortese, 2021) (Table 2).

Modeling of Motor Actions as Complex Systems

Human motor actions belong to the class of complex biological systems characterized by multidimensionality of parameters, hierarchical organization, and dynamic interaction with the environment (Wolpert et al., 2001; Araújo et al., 2006). This nature of the object necessitates the use of models capable of reflecting not only individual components of movement but also the system of relationships between them, which determines the final result of activity as the behavior of a complex system.

One of the key characteristics of motor actions is their hierarchical nature. The formation of movement occurs at different levels of organization—from central control mechanisms to executive structures that implement motor commands. At each of these levels, information is processed, movement parameters are refined, and adaptation to performance conditions occurs (Kawato, 1999). Modeling makes it possible to represent this hierarchy in the form of interconnected subsystems, each of which performs a specific function in achieving the target result.

Another important property of motor actions is their multidimensionality (Lopatiev et al., 2009). The effectiveness of movement execution is determined not by a single parameter but by a set of biomechanical, physiological, and psychophysiological characteristics. This complicates analysis, as a change in one parameter may affect others, forming a complex system of interdependencies. Under such conditions, the model serves as a means of integrating heterogeneous parameters into a unified system, allowing the assessment of their combined influence on the result (Campos & Calado, 2009; Lopatiev et al., 2009).

A significant aspect is also the dynamic nature of motor actions. Unlike static systems, a motor action unfolds over time, and its parameters change depending on the internal state of the organism and external conditions. This requires the use of models that take into account the temporal structure of the process, including the phase organization of movement, the sequence of actions, and variability of execution. Modeling makes it possible to analyze not only individual moments of movement but also its development over time, which is critically important for understanding regulatory mechanisms (Sabes, 2000; Russo et al., 2025).

Control of motor actions is carried out on the basis of feedback and regulation principles. Information about the current state of the system is transmitted to control centers, where it is compared with the set goal, after which corrective actions are formed (Kawato, 1999). In this process, an important role is played by the system's ability to maintain stability of functioning under changing environmental conditions, which is related to the concepts of homeostasis and adaptation. Modeling makes it possible to describe these

Table 1. Epistemic model of the transition "data → information → knowledge"

Level	Characteristic	Modeling function	Result
Data	Unorganized measurements	Structuring; parameter selection	Organized data
Information	Data with reduced uncertainty	Establishing relationships; interpretation	Meaningful relationships
Knowledge	Integrated system of relationships	Formalization; generalization	Theoretical model

Table 2. Epistemic functions of modeling in motor action research

Function	Essence	Epistemic result
Structuring	Organization of data	Elimination of randomness
Uncertainty reduction	Identification of regularities	Transition to information
Formalization	Quantitative representation	Hypothesis testing
Integration	Combination of heterogeneous data	Holistic knowledge
Complexity reduction	Identification of key variables	System controllability

mechanisms in the form of closed control loops that ensure the achievement of the target result.

A particular complexity lies in the fact that motor actions are not purely mechanical processes. They include psychophysiological components related to motivation, attention, level of activation, and other factors that directly influence performance outcomes. This means that models built exclusively on mechanistic assumptions are insufficient for an adequate description of motor systems. It is necessary to consider the integrity of the biological system in which physical, physiological, and psychological processes interact (Araújo et al., 2006).

In this context, it is important to understand a motor action as a goal-directed system in which the goal acts as a system-forming factor. It is precisely the presence of a goal that determines the structure of interactions between system elements, the selection of movement parameters, and the nature of regulatory processes. Modeling makes it possible to formalize this goal-directedness by representing it in the form of performance criteria, optimization functions, or other parameters that reflect the achievement of the result (Wolpert et al., 2001).

Thus, modeling of motor actions as complex systems involves taking into account their hierarchical organization, multidimensionality, dynamism, and regulatory mechanisms. It provides the possibility of transitioning from the description of individual parameters to understanding the holistic structure and functioning of the system, which is a necessary condition for further analysis and interpretation of motor activity (Russo et al., 2025).

Biotechnical Systems and Instrumental Mediation of Knowledge

One of the most important conditions for the practical implementation of modeling in the study of motor actions is the inclusion of technical means in the process of data acquisition, processing, and interpretation. This leads to the formation of biotechnical systems in which biological components (the human as the object of study) and technical means that ensure the recording, transmission, and analysis of information are combined. Within this approach, modeling goes beyond purely theoretical description and acquires an instrumentally mediated character (Kawato & Cortese, 2021; Lopatiev, Vlasov et al., 2017).

In this context, modeling acquires the features of instrumental epistemology, within which knowledge is formed through the interaction of the biological system and the technical environment of measurement and analysis. Within this study, this approach is defined as an instrumental-epistemic model of modeling motor actions (Winsberg, 2010).

A biotechnical system can be considered as an integrated structure that includes the object of study, measurement and analysis tools, as well as the subject of interpretation. It is important to emphasize that technical means are not neutral instruments for recording data. They determine the mode of information representation, its accuracy, temporal resolution, and possibilities for further processing. Thus, the technical component becomes an active element of the cognition process, influencing the formation of the model of the system under study (Kawato & Cortese, 2021).

Of particular importance is the synchronous collection of data of different nature. In the study of motor actions, this may include the simultaneous recording of biomechanical movement parameters, physiological indicators (for example, heart rate), and performance outcomes. Such synchronization makes it possible to consider the system in dynamics, establish temporal relationships between different parameters, and identify patterns that remain inaccessible in the isolated analysis of individual indicators (Russo et al., 2025).

Instrumental mediation of modeling creates conditions for the transition from measurement to interpretation. Data obtained using technical means do not possess explanatory power by themselves if they are not included in a certain model structure. It is the model that determines which parameters are essential, how they are related to each other, and how their changes affect performance outcomes. In this process, signals recorded by technical means are transformed into information that carries meaning (Rowley, 2007).

The next stage is the use of the obtained information in the control process. Biotechnical systems make it possible to implement closed feedback loops in which measurement results directly influence the correction of motor actions. This can occur both in the form of external control (by a coach or researcher) and through the formation of internal self-regulation mechanisms in the athlete. Thus, modeling becomes not only a means of analysis but also an instrument of active influence on the system (Kawato, 1999).

An important aspect of biotechnical systems is their ability to integrate different levels of organization of motor activity. Technical means make it possible to simultaneously account for parameters that reflect both the mechanical characteristics of movement and the functional state of the organism. This creates prerequisites for constructing comprehensive models that more adequately reflect the real structure of motor action and allow identifying relationships between different subsystems (Campos & Calado, 2009).

In this context, a special role is played by the subject of interpretation—the researcher or coach—who analyzes the obtained data and forms management decisions on their basis. It is at this stage that the final transition from information to knowledge occurs, when modeling results are used to explain the mechanisms of system functioning and optimize its activity. Thus, the biotechnical system includes not only technical and biological components but also a cognitive level associated with the decision-making process (Kawato & Cortese, 2021).

Thus, biotechnical systems act as the environment in which the epistemic functions of modeling are realized. They ensure the instrumental mediation of cognition, integration of heterogeneous data, their interpretation, and their use in the process of controlling motor actions (Lopatiev et al., 2017). This makes it possible to consider modeling not only as a theoretical method but as a practical mechanism for knowledge construction directly related to the effectiveness of human activity (Russo et al., 2025).

Discussion

The obtained results make it possible to consider modeling not as an auxiliary research tool but as a central epistemological mechanism that ensures the construction of knowledge about complex motor systems (Kawato & Cortese, 2021; Lopatiev, 2007). Unlike approaches in which modeling is used primarily for describing or predicting individual parameters, in this work it is interpreted as a process that includes the formation of analogies, identification of essential variables, establishment of structural relationships, and their formalization. It is precisely this interpretation that allows the transition from fragmented analysis to a holistic understanding of system functioning.

In this context, it is essential to distinguish between the descriptive and epistemic functions of modeling. The descriptive function is associated with reproducing the characteristics of the object, whereas the epistemic function is related to constructing knowledge about the mechanisms of its functioning. The results of the analysis show that it is the epistemic function that determines the potential of modeling in the study of motor actions, as it enables the establishment of cause-and-effect relationships, integration of heterogeneous data, and formation of generalized representations of the system (Bunge, 1973).

An important result is the substantiation of the role of the informational dimension of modeling. Motor action is considered as a system in which the reduction of uncertainty is achieved through the acquisition, processing, and interpretation of information. In this process, the model acts as a structure that organizes data and transforms them into information suitable for further use (Shannon, 1948; Rowley, 2007). This approach makes it possible to reinterpret the role of feedback and regulation, considering them as information processes that ensure stability and efficiency of system functioning.

The consideration of motor actions as complex systems confirms the need to move beyond purely mechanistic models that do not account for multilevel organization and psychophysiological aspects of activity (Araújo et al., 2006). The proposed approach, based on the integration of biomechanical, physiological, and cognitive components, allows for a more adequate representation of the real structure of motor action. In this context, modeling acts as a means of synthesizing different levels of analysis, which is a necessary condition for constructing a coherent scientific picture (Wolpert et al., 2001).

Of particular importance is the introduction of the concept of a biotechnical system as the environment for the implementation of modeling. The inclusion of technical means in the research process makes it possible to obtain synchronized data of different nature, significantly increasing the informativeness of analysis. At the same time, technical means not only expand measurement capabilities but also influence the process of cognition itself, determining the mode of representation and interpretation of information. This makes it possible to consider biotechnical systems as integrated structures in which measurement, modeling, and control are combined (Kawato & Cortese, 2021; Lopatiev et al., 2017).

The obtained results have important implications for understanding the processes of controlling motor actions. Modeling makes it possible to move from an intuitive approach to control toward evidence-based decisions grounded in the analysis of system structure and its dynamics. This creates prerequisites for increasing the effectiveness of the educational and training process, as it allows taking into account individual characteristics of the athlete, adapting load parameters, and optimizing conditions for performing motor actions (Russo et al., 2025).

At the same time, the results of the study indicate the need for further development of modeling methodology toward increasing its level of formalization and integration with modern information technologies. In the applied dimension, this opens opportunities for combining the proposed epistemic model with methods of mathematical modeling already used in physical education and sport, including factorial experiments, logistic models, and discriminant analysis, which make it possible to formalize processes of learning and control of motor actions (Lopatiev et al., 2017). Particularly promising is the integration of mathematical and simulation modeling with methods of big data processing, which expands the possibilities for analyzing complex systems and increases the accuracy of the obtained results (Kawato & Cortese, 2021).

The proposed approach defines modeling as a fundamental epistemological mechanism in the study of motor actions, which fundamentally differs from system-organizational and applied approaches by focusing on the processes of knowledge construction rather than solely on the structure or functioning of the system.

Thus, the conducted analysis makes it possible to consider modeling as a key element of scientific research on motor actions, ensuring not only their description but also explanation and prediction of their functioning. In this sense, modeling acts as a universal tool for knowledge integration that combines theoretical and applied aspects of research and creates a basis for further development of the science of human motor activity (Wolpert et al., 2001).

Limitations and Future Research Perspectives

In addition to the methodological limitations inherent in narrative reviews, the proposed epistemic model of the transition "data → information → knowledge" has conceptual limitations that should be taken into account.

First, the model is a theoretical abstraction and has not been empirically verified within a single experimental system. Although it integrates established principles of modeling and scientific cognition, its applicability to different types of motor actions requires further empirical validation.

Second, modeling as an epistemic process is inevitably associated with the reduction of system complexity through the selection of key variables and relationships. Such reduction, necessary for analysis and formalization, may lead to a partial loss of system properties and limit the completeness of its representation.

Third, in the context of biotechnical systems, the process of knowledge construction depends on the characteristics of measurement tools, data collection procedures, and analytical approaches. These factors influence not only the quality of data but also the structure and interpretation of models.

Future research perspectives are related to the empirical verification of the proposed epistemic model, in particular through the development of operational indicators for each stage of the transition "data → information → knowledge." It is also promising to combine the conceptual approach with methods of mathematical and simulation modeling, as well as with modern big data processing technologies, which will increase the accuracy and reproducibility of results.

Conclusions

Modeling in the study of motor actions should be considered as an epistemological mechanism that ensures the transition from empirical data to structured scientific knowledge through the formation of analogies, identification of variables, and establishment of system relationships.

The epistemic function of modeling is realized through the organization of the transition "data → information → knowledge," reduction of uncertainty, and formalization of interactions between elements of a complex system.

Human motor actions as complex, hierarchically organized systems require the use of models that integrate biomechanical, physiological, and cognitive components and reflect mechanisms of regulation and adaptation.

Biotechnical systems provide instrumental mediation of modeling, integration of heterogeneous data, and implementation of closed feedback loops, which shifts modeling from the analytical to the control level.

Considering modeling as a central mechanism of knowledge construction creates a methodological basis for increasing the validity of motor action research and the effectiveness of practices for controlling motor activity.

Ethics Approval

This study is a narrative review and does not involve human participants or experimental procedures. Therefore, ethical approval was not required.

Informed Consent

This study does not involve human participants. Therefore, informed consent was not applicable.

Data Availability

No new data were generated or analyzed in this study. All information is derived from previously published sources cited in the manuscript.

AI Transparency Statement

AI-assisted tools were used solely for language editing and structuring of the manuscript. The authors take full responsibility for the content, interpretation, and conclusions presented in this work.

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Епістемологічні засади моделювання у дослідженні рухових дій: наративний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

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Обґрунтування. Моделювання широко використовується у дослідженні рухових дій; однак його епістемологічна роль залишається недостатньо концептуалізованою. Існуючі підходи переважно розглядають моделювання як описовий або прогностичний інструмент, ігноруючи його функцію у побудові наукового знання.

Мета. Метою дослідження є обґрунтування моделювання як епістемологічного механізму наукового пізнання у дослідженні рухових дій та систематизація його ключових функцій у переході від даних до знання.

Матеріали і методи. Проведено наративний огляд на основі аналізу концептуальних публікацій, включаючи авторські роботи та матеріали конференцій, а також досліджень, присвячених загальним принципам моделювання та наукового пізнання. Аналітична стратегія передбачала реконструкцію концептуального розвитку та ідентифікацію епістемічних структур, що лежать в основі процесів моделювання.

Результати. Моделювання інтерпретується як опосередкований когнітивний процес, що інтегрує аналогію, аналіз, синтез і формалізацію. Його епістемічні функції включають структуризацію емпіричних даних, зменшення невизначеності, встановлення зв'язків між елементами системи та забезпечення переходу від даних до інформації і знання. Рухові дії розглядаються як складні ієрархічні системи, що потребують інтегративних моделей, які враховують біомеханічні, фізіологічні та когнітивні компоненти. Запропоновано поняття біотехнічних систем як рамкової конструкції інструментального опосередкування, що забезпечує синхронізований збір даних, їх інтерпретацію та керування на основі зворотного зв'язку. Запропоновано концептуальну епістемічну модель переходу «дані → інформація → знання».

Висновки. Моделювання слід розглядати як центральний епістемологічний механізм у дослідженні рухових дій, що забезпечує теоретико-методологічну основу для розуміння, аналізу та керування складними руховими системами.

Ключові слова: моделювання, епістемологія, рухові дії, складні системи, біотехнічні системи, побудова знання, обробка інформації.

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