Leveraging Feedback Through Personalized Recommendations within Intelligent Tutoring Systems for Psychomotor Skill Development

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Abstract

In recent years, Intelligent Tutoring Systems (ITS) have been developed for psychomotor skill training. However, we see three main problems. First, the feedback provided is not enough, and there is no real evidence in terms of long-term studies to support the effectiveness of the presented systems. Second, the underlying model is evaluated instead of the whole ITS. Third, and consequently, task, student, and teacher models are not explicitly defined. That is why we present organizing exercises within a hierarchy of domain-specific and generic skills that is used to recommend personalized workouts within dimensions to cover abilities that, in consequence, improve psychomotor skill development.

Keywords

Intelligent Tutoring System, Psychomotor, Skill Training

1. Introduction

The integration of Intelligent Tutoring Systems (ITS) in psychomotor skill training has shown promise in enhancing learning outcomes. Motion capturing systems, cameras, or other sensors are used to digitize human performances [1, 2, 3, 4, 5]. Machine Learning techniques are applied to make sense of those and consequently provide instructed feedback [1, 5, 4]. ITS are applied in various fields such as medicine, i.e. training of surgical skills [6] or emergency procedures [5], or sports, i.e. dancing [1, 4, 3], or table tennis [2]. We are aware that the presented literature is not enough for solid statements, but to the best of our knowledge, we have consistently seen the following shortcomings across the research field. Also note that we have to restrict the number of references due to the page limit. Existing studies, for example, have low sample sizes [6], or evaluate mostly the underlying model [4, 6] making it hard to understand the true impact of these solutions. Furthermore, the provided feedback often revolves around distinguishing between experts and novices [4, 3, 6] which at most addresses the imitation of various psychomotor taxonomies for learning goals like Dave's [7]. Consequently, it remains unclear how to effectively leverage feedback to drive meaningful progress in skill acquisition. The feedback provided by existing solutions is not effective, according to [8] because it misses the "Where to next?" aspect. With our concept, we believe we can address this issue by recommending exercises based on

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past performances, hence explicitly stating where to go next. We further believe that the nature of evaluating machine learning solutions yield ITS with a view of task models that is too narrow to reflect the domain of psychomotor skill training.

In this article, we suggest modeling psychomotor skill training with a hierarchy of skills that is used to provide feedback and workout plans for micro, meso, and macro training cycles. Specifically, we interpret skill training as a combination of technique and ability. We highlight the need for comprehensive, longer-term studies that investigate the true learning outcomes facilitated by these systems.

Understanding that abilities are influenced by genetic predispositions but can be developed through training, our proposed approach involves the system recommending exercises tailored to specific abilities such as strength, flexibility, and coordination. By adopting this broader framework, we aim to foster a more comprehensive and effective approach to psychomotor skill development.

In conclusion, this article highlights the need for a paradigm shift in feedback mechanisms within ITS for psychomotor skill training. It emphasizes the necessity of moving beyond comparisons and generic instructions and instead exploring the potential of ability-driven exercise recommendations. By bridging the gap between technique and ability, we believe that ITS can provide more meaningful support for learners, enabling them to enhance their psychomotor skills in a holistic and sustainable manner.

2. Hierarchy of Psychomotor skills

A fundamental distinction within this hierarchy lies between generic skills and domain-specific skills. Generic skills encompass exercises that have broad applicability and can be considered foundational to psychomotor development. A prime example of a generic skill is the classic push-up exercise, which involves coordinated movements of the upper body and requires core strength and stability.

In contrast, domain-specific skills are exercises that are tailored to a particular field or discipline. For instance, in martial arts, punches are specific to the domain and require precise coordination of the arms, shoulders, and torso. Similarly, in the context of running, arm swings play a crucial role in maintaining balance and rhythm during the locomotion process.

It is important to note that training generic abilities serves as a pathway to enhance the acquisition of domain-specific skills. By targeting and refining fundamental physical and cognitive capacities, individuals can lay a solid foundation for the development of more complex psychomotor skills. This process facilitates the transfer of skills from generic abilities to the execution of domain-specific skills, leading to enhanced overall psychomotor performance.

Understanding the hierarchical structure of exercises for psychomotor skill development provides valuable insights into the systematic progression of training programs. By recognizing the distinction between generic and domain-specific skills, educators and practitioners can design targeted interventions that address the specific needs of learners in various domains. Furthermore, by emphasizing the training of basic abilities, instructors can optimize the acquisition and mastery of generic skills, thereby fostering the development of proficient psychomotor abilities in academic and practical contexts.

2.1. Dimensions of Psychomotor Skill Training

In a top-down approach, skills in various dimensions have been extensively examined in the existing literature. The first dimension, strength, is essential for skills training as it is strongly associated with improved force-time characteristics that contribute to overall athletic performance [9]. Greater muscular strength allows athletes to perform general sport skills such as jumping, sprinting, and change of direction tasks more effectively [10]. Research also indicates that stronger athletes produce superior performances during sport-specific tasks [11]. In addition to enhancing performance, greater muscular strength also reduces the risk of injury [12]. Therefore, the first dimension, strength, encompasses three distinct aspects: static, dynamic, and explosive strength. Static strength refers to the maximum amount of weight an individual can lift or support without movement. Dynamic strength, also referred to as endurance, measures the individual's ability to sustain the movement of a weight over a given period of time. Finally, explosive strength is characterized by the ability to swiftly move as much weight as possible.

The second dimension, flexibility, comprises two key components: static and dynamic flexibility. Static flexibility refers to the capacity to maintain a stretched position without any movement. On the other hand, dynamic flexibility involves introducing movement while maintaining flexibility. Flexibility is an important component of sports skill training. It allows for a greater range of motion around joints and muscles, which is essential for many athletic movements [13].

The third dimension, coordination, encompasses technique, body, balance, and rhythm. Technique refers to domain-specific coordination, such as arm swings in running. Body coordination involves the synchronization of actions, like hand-eye or hand-foot coordination. Balance refers to the ability to maintain equilibrium while performing exercises. Rhythm introduces a sense of musicality and harmonious movement in coordinated actions. Coordination is of great importance in sports skill training. It is defined as the ability to perform complex motor skills and includes abilities such as reaction, rhythm, balance, kinesthetic differentiation, and space-time orientation [14]. Developing coordination abilities is necessary during childhood and adolescence as part of additional technique training [15].

Moving on to the dimension of speed, it includes three aspects: reaction, orientation, and velocity. Reaction speed involves responding swiftly to external stimuli, such as reacting to a thrown ball. Orientation denotes the ability to rapidly determine the appropriate direction to take, as exemplified in situations like receiving a pass in football and quickly deciding which direction to move in. Velocity refers to the speed at which an individual executes their decision. Speed is a crucial skill in sports training, as it sets athletes apart from their competition and determines their performance level [16]. Speed is expressed by the ratio of space to time and incorporates elements such as reaction time, frequency of motion, and running level [17]. The relationship between strength and speed is important for optimizing training and preventing injuries in sports [18].

The dimension of team encompasses communication and tactics. Communication within a team, as observed in sports like soccer, plays a crucial role in coordinating actions with fellow team members. Tactics involve being aware of both one's own strategies and those of team members and opponents. Team skills training is important for sports skills development as it contributes to the improvement of team performance and effectiveness [19]. Team building, on the other hand, is not effective without prior team skills training [20]. In team sports, decision-making is a crucial aspect of performance, and the use of intuitive decision-making and shared configurations of play have been found to be effective [21].

The final dimension, mental, consists of focus, stability, and endurance. Focus is the ability to concentrate and dedicate oneself to the current moment, minimizing distractions. Stability refers to maintaining a steady state of mind without faltering. Endurance, in the context of mental skills, entails sustaining stability for the longest possible duration. Mental training is important for sports skill development [22, 23, 24, 25]. It has been shown to improve athletes' performance by enhancing their psychological skills, such as anxiety control, confidence, and concentration [26].

By considering these multifaceted dimensions of skills, researchers can gain a comprehensive understanding of the various components that contribute to human performance and achievement in academic and athletic contexts.

3. Implementation

Based on the previous section, we created an Entity Relationship Model (ERM) that is shown in figure 1. The ERM is not complete and showcases only how entities and relations are organized. For the creation process we followed some principles when creating knowledge bases [27]. We formulated a set of keywords and questions the knowledge base should address. For instance, "What dimensions of psychomotor skill training does a student focus on in his micro cycle?", or "What generic and domain specific exercises can be trained for which sport?".

In the knowledge base, a user can have multiple workout plans for micro, meso, macro cycles. A workout plan focuses on one or multiple psychomotor skill domains, such as strength or flexibility. Furthermore, a workout plan consists of exercises that are either generic or specific. Generic exercises are applied to multiple psychomotor skills. For example, push-ups are generally part of workout plans for all kinds of sports. Specific exercises are used in one sport. For example, a boxing drill exercise is not part of the workout plans for dancing. Every exercise targets one or more psychomotor skill domains. For example, push-ups target strength for the most part, and kicking exercises can also target flexibility. Moreover, exercises affect different body parts. For example, push-ups mostly affect the chest and arms.

ERMs are used in practice to show entities and the relationships between them. In practice, an ERM can be implemented differently. Both relational and graph databases have emerged as prominent solutions to implement ERM models. Each approach possesses distinct characteristics that offer unique advantages and disadvantages. This section presents a comparison of relational and graph databases, highlighting their respective strengths and limitations.

Relational databases excel in structured and tabular data management, performance optimization, and ACID compliance. However, they face challenges related to inflexible schemas, complex relationships, and hierarchical data. On the other hand, graph databases thrive in efficiently handling complex relationships, providing flexibility in schema design, and enabling real-time recommendations and analysis. Nevertheless, limitations regarding tabular data, increased complexity, scalability, and tooling must be considered when evaluating their suitability

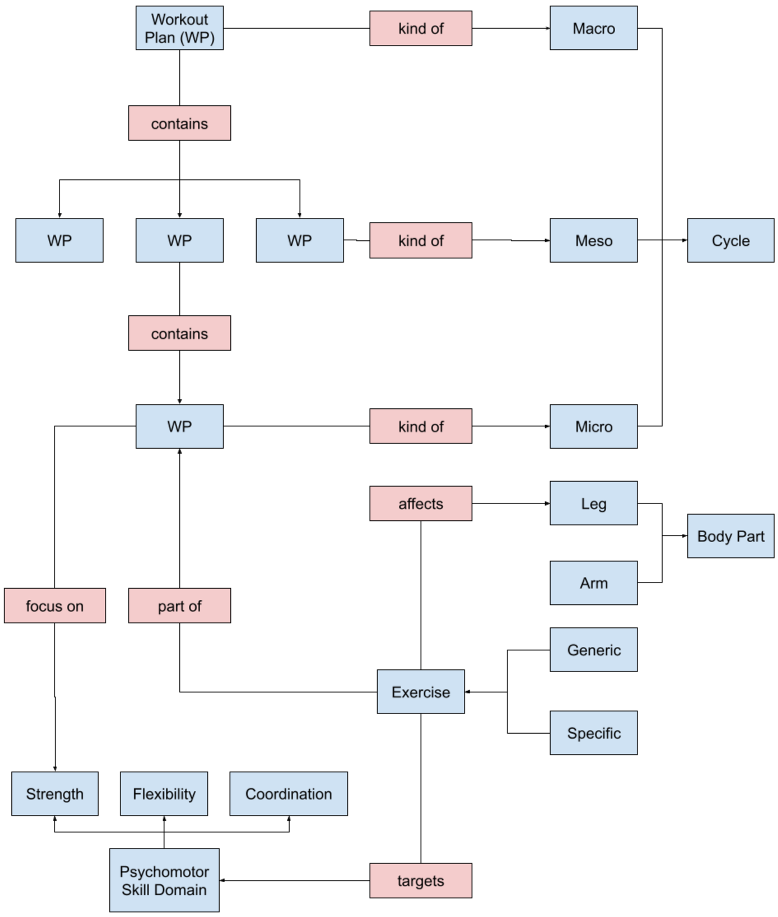

Figure 1: Example Entity Relationship Model (ERM) of the skill hierarchy. Blue Squares are entities. Red Squares are relationships.

for specific use cases. Understanding these nuances empowers researchers and practitioners to make informed decisions when selecting the most appropriate database technology for their specific data management requirements.

4. Workout Planning

4.1. Feedback

Traditionally, providing feedback meant giving simple instructions or comparing novice and expert executions. However, this does not cover the "Where to next" component of effective feedback. [8]. Undoubtedly, the provision of effective feedback plays a pivotal role in facilitating meaningful learning experiences. Descriptive feedback accompanied by Key Performance

Indicators (KPIs) can be employed to evaluate skill performance. KPIs, such as exerted force or execution time for specific actions like punching, can serve as valuable metrics for assessing skill proficiency. Moreover, we suggest utilizing these KPIs to identify potential areas for improvement and recommend personalized exercises, thus fostering a tailored learning path and goal for individuals. Potential areas of improvement directly relate to the dimensions of psychomotor skills, such as strength or flexibility.

Based on the identified potential for improvement, the framework generates personalized exercise recommendations. These recommendations, grounded in the hierarchical structure of skills, guide learners towards exercises that target the specific dimensions requiring improvement. By aligning exercises with the identified learning goals, learners embark on a personalized learning path tailored to their individual needs and areas of growth.

Furthermore, these exercise recommendations cover an integral component of effective feedback, guiding learners on what to do next [8]. By providing learners with a clear roadmap and actionable steps, instructors empower them to actively engage in their skill development journey. This personalized learning path enhances motivation and self-efficacy as learners witness tangible progress in the dimensions where they have the greatest potential for improvement.

In conclusion, leveraging descriptive feedback with KPIs in psychomotor skill training opens up new avenues for personalized learning paths. By quantifying skill performance and identifying areas for growth, instructors can recommend exercises that align with learners' specific learning goals. This framework enhances the effectiveness of feedback and promotes individualized skill development, fostering a more engaging and rewarding learning experience. As the field of educational technologies continues to evolve, incorporating personalized learning paths based on descriptive feedback and KPIs holds immense potential for optimizing psychomotor skill training in diverse academic and practical contexts.

4.2. Micro vs. Meso vs. Macro Cycle

In the realm of psychomotor skill training, the formulation of structured workout plans is crucial for fostering progressive skill development. This article delves into the construction of effective workout plans that encompass short-term (micro), mid-term (meso), and long-term (macro) goals. By aligning recommended exercises with specific dimensions and adjusting the focus across these cycles, a comprehensive and targeted approach to skill improvement can be achieved.

Recommended exercises serve as the building blocks for developing workout plans. These exercises are carefully selected based on personalized recommendations derived from performance assessments through KPIs and the individual's potential for improvement. Assembling these exercises into a structured plan ensures a systematic approach to skill development.

Workout plans are organized into micro, meso, and macro cycles, each serving a distinct purpose in the overall training program [28, 29]. Micro cycles correspond to short-term goals and focus on specific recommended exercises. They provide a detailed framework for practicing and refining specific skills, targeting dimensions such as strength, flexibility, coordination, or speed. More specifically, micro cycle workout plans encompass a set of exercises for one training session.

Meso cycles represent the mid-term goals within the workout plan. In these cycles, the focus shifts from specific exercises to the type of dimension to emphasize. While the specific exercises within the micro cycles may vary, the meso cycles outline the overarching dimension that learners should concentrate on during a specific phase of their training. For example, a meso cycle may emphasize coordination, while a micro cycle predominantly recommends different exercises within this dimension.

Macro cycles encompass long-term goals and multiple dimensions of skill development. These cycles aim to create a balanced training regimen by incorporating exercises that target various aspects, such as strength, coordination, and flexibility. While the focus may shift during the meso cycles, the macro cycles ensure that multiple dimensions remain present throughout the training program, providing a comprehensive and holistic approach to skill improvement. For example, a macro cycle focuses on strength, flexibility, and coordination. The macro cycle contains three meso cycle workout plans that separately focus on strength, flexibility, and coordination. For every meso cycle, there are multiple micro cycle workout plans with explicit exercises that target the domain of psychomotor skill training of the respective meso cycle.

By integrating micro, meso, and macro cycles into workout plans, instructors can design personalized and progressive training programs for individuals. The micro cycles focus on fine-tuning specific skills, the meso cycles guide the emphasis on dimensions within specific phases, and the macro cycles ensure a well-rounded and diverse skill development journey.

In conclusion, the development of workout plans plays a vital role in psychomotor skill training. By incorporating micro, meso, and macro cycles, instructors can create structured and effective training programs. The micro cycles provide specificity and precision in practicing recommended exercises, while the meso cycles guide the emphasis on dimensions within each phase. Lastly, the macro cycles ensure a comprehensive approach by encompassing multiple dimensions throughout the training program. By embracing this framework, educators and practitioners can optimize skill acquisition and facilitate meaningful progress in psychomotor skill development for academic and practical purposes.

5. Conclusion

In the past, ITS started to be a choice for the implementation of psychomotor skill training with increasing levels of technology. However, the underlying model that, for example, distinguishes novices from experts is often evaluated instead of the ITS as a whole. Consequently, the student, task, and teacher models are not specified explicitly. Furthermore, the nature of machine learning solutions introduces a focus on domain-specific implementation, neglecting the bigger picture of psychomotor skill development. Hence, we present ideas to implement ITS for psychomotor skill development, considering it as a whole. We highlight the importance of acquiring abilities, which we introduce as dimensions inherently important to skill development, such as strength or coordination. We suggest organizing exercises within these domains in a hierarchy of domain-specific and generic skills and opting for an implementation with relational databases until exhausted. Therefore, we presented a preliminary ERM to organize the knowledge base. We are aware that the ERM needs to be evaluated and think that it can be evaluated by fitting online available workout plans with the model and comparing fitted and unfitted workout plans with coaches. Finally, we imagine using the hierarchy as an anchor to address the "Where to next" aspect of effective feedback by recommending personalized exercises and workout plans based on potential areas of improvement derived from KPIs. We envision that this will change how we think about implementing ITS and providing feedback for psychomotor skill development.

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