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A Study of the Effectiveness of the Bigdeli Mind Silumation Method in Football Ball Control Using Functional Magnetic Resonance Imaging

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ABSTRACT

Purpose: This study aimed to investigate the effectiveness of the Bigdeli Mind Silumation method in football ball control using functional magnetic resonance imaging (fMRI).

Methods and Materials: The present research employed an experimental single-case design with pretest and posttest assessments. The participant was a 35-year-old female student at Payame Noor University, Karaj, in 2022, who was selected through convenience sampling. An fMRI scan was initially obtained before the participant received Bigdeli Mind Silumation training for football ball control. Twenty days after the Bigdeli Mind Silumation intervention, another fMRI scan was conducted, and activity in different brain regions was examined using criteria similar to those applied in the first assessment. Each fMRI session lasted 10 minutes, during which the participant remained at rest. The data were analyzed by Engineer Malekian using FSL software.

Findings: The results showed that, following subtraction analysis of the activity identified within the network, motor-network activity and signal intensity increased after the specified training period.

Conclusion: Given the study design, this increase may indicate the effects of the training and practice intervention. Increased motor-network activity was diffusely observed in both the right and left hemispheres. This network was associated with the participant's motor activity of keeping the ball balanced on the foot.

Keywords: *Bigdeli Mind Silumation, ball control, football, fMRI.*

1. Introduction

Football is a complex, dynamic, and externally paced sport in which successful performance depends on the coordinated integration of perceptual, cognitive, and motor processes. Players are continuously required to detect relevant environmental information, anticipate the movement of the ball and other players, select appropriate responses, and execute precise motor actions under considerable temporal pressure. Among the fundamental technical skills in football, ball control is particularly important because it creates the basis for passing, dribbling, shooting, changing direction, and maintaining possession. Effective ball control requires the accurate regulation of posture, balance, lower-limb coordination, force production, movement timing, and visuomotor processing. Even apparently simple actions, such as receiving the ball or keeping it balanced on the foot, involve complex interactions among sensory feedback, motor planning, movement execution, and continuous error correction. Consequently, learning ball-control skills is not merely a matter of strengthening muscles or repeating physical movements; rather, it involves the development and refinement of neural representations that enable the performer to organize and regulate movement efficiently.

Motor learning refers to relatively permanent changes in the capacity to perform a skill as a result of practice and experience. During the acquisition of a new motor skill, the learner must establish an internal representation of the task, identify the relevant sensory cues, formulate an appropriate movement plan, execute the response, and use feedback to modify subsequent attempts. Repeated practice gradually improves the accuracy, consistency, timing, and automaticity of the movement. In sport settings, however, physical practice may be limited by fatigue, injury, insufficient access to facilities, environmental restrictions, or the learner's initial inability to perform the movement correctly. These limitations have encouraged researchers and practitioners to investigate complementary approaches, including mental imagery, action observation, mental practice, simulation, relaxation, attentional training, and neurofeedback. Such approaches are based on the premise that motor learning can be facilitated not only through overt bodily movement but also through structured cognitive rehearsal and activation of movement-related representations.

Mental imagery and mental practice have long been used in sport psychology to improve skill acquisition, self-efficacy, attentional control, emotional regulation, and performance. Mental imagery generally involves the generation or recreation of perceptual and motor experiences in the absence of corresponding external stimulation or overt movement. During motor imagery, an individual internally simulates an action while inhibiting its actual physical execution. The imagined movement may include visual, kinesthetic, auditory, and spatial components, depending on the nature of the task and the imagery ability of the performer. Mental practice refers to the systematic rehearsal of a skill through imagery or related cognitive processes without observable muscular execution. Research on athletes has suggested that mental imagery can contribute to improved performance by increasing confidence, regulating arousal, clarifying movement sequences, and strengthening the cognitive representation of a skill. Narimani et al. compared mental imagery and relaxation methods and showed that psychological training can contribute to athletic self-efficacy and performance, indicating that internal cognitive processes may exert measurable effects on sport-related behavior (Narimani et al., 2007). Similarly, Ghaffari and Shahbazi examined arousal-control ability through mental imagery and biofeedback, emphasizing the importance of psychological self-regulation in athletic performance (Ghaffari & Shahbazi, 2015).

The effectiveness of mental practice is commonly explained through functional equivalence between imagined and executed actions. According to this perspective, motor imagery and action observation partially recruit neural and cognitive mechanisms that are also involved in actual movement planning and execution. Although imagined action does not produce the same level of muscular output as physical performance, it may activate internal movement representations, facilitate motor-program organization, and strengthen associations between perceptual information and motor responses. Contemporary neurocognitive research has increasingly supported the view that mental simulation, motor imagery, and action observation engage overlapping components of the motor system. Frank et al. described advances in the neurocognitive foundations of motor imagery and action-observation training in sport and emphasized that mental simulation can support motor learning through the activation and refinement of action-related representations (Frank et al., 2020). From this standpoint, repeated mental simulation may function as a form of covert motor practice through which the learner rehearses the timing, direction, coordination, and sensory consequences of an action before or alongside its physical execution.

Nevertheless, the effectiveness of mental practice is influenced by several methodological and individual factors, including the learner's experience, imagery ability, motivation, attentional control, task complexity, imagery perspective, practice schedule, and the degree of similarity between imagined and actual performance. A vague or inaccurate image may reinforce an incorrect movement representation, whereas a clear, structured, and multisensory simulation may facilitate more effective learning. The organization of practice also plays a significant role. Sohrabi compared physical practice with random and blocked mental-imagery schedules in the performance and learning of a tracking task, demonstrating the importance of practice structure in determining learning outcomes (Sohrabi, 2016).

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Roozbehani also investigated contextual interference in mental practice during the learning of several football skills, indicating that variations in the sequencing and organization of mental exercises may influence both immediate performance and longer-term learning (Roozbehani, 2014). These findings suggest that mental training should not be regarded as a single, uniform intervention; instead, it should be designed systematically according to the characteristics of the skill, the stage of learning, and the cognitive needs of the learner.

Simulation-based methods have also been examined in relation to the formation of mental representations and the performance of sport skills. Moradi and Fazeli compared routine introduction, simulation, and combined methods in the performance and mental representation of the volleyball float serve and reported evidence supporting the role of simulation in skill acquisition and representational development (Moradi & Fazeli, 2017). Their findings are relevant because complex sport skills depend on the learner's ability to construct an organized mental model of the action, including its sequential components, temporal features, spatial direction, and expected sensory outcomes. When an athlete develops a more precise representation of a movement, the execution of that movement may become more accurate and efficient. In football ball control, simulation may allow the learner to rehearse the visual trajectory of the ball, the position of the supporting leg, the angle of the controlling foot, the regulation of muscular force, and the maintenance of postural stability. Such rehearsal may be particularly valuable for novices who have not yet developed stable motor schemas through extensive physical experience.

Bigdeli Mind Simulation has been introduced as a structured method for representing, programming, and rehearsing mental and behavioral processes. Within this framework, the mind is conceptualized as capable of receiving, organizing, and reproducing coded patterns that may influence speech, movement, cognition, and behavior. Bigdeli Shamloo presented the method in relation to the language of the mind, mental programming, speech intervention, and intelligent football, proposing that carefully designed simulation procedures can facilitate the establishment of desired patterns (Bigdeli Shamloo, 2017b). In a related publication, the method was described as a system of mind simulation intended to modify internal representations and promote more effective behavioral performance (Bigdeli Shamloo, 2017a). Although some theoretical claims associated with the method require further empirical evaluation, its central emphasis on structured internal rehearsal is broadly consistent with established concepts in motor imagery, cognitive simulation, and mental practice.

The Bigdeli Mind Simulation method differs from general, unstructured imagery in that it attempts to provide a systematic mental framework through which the learner repeatedly encodes and rehearses the target behavior. In relation to football, the method may involve the internal simulation of successful contact with the ball, the stabilization of the lower limbs, the maintenance of balance, and the precise timing of movement. Repeated internal rehearsal may increase the accessibility of the relevant movement representation and prepare the nervous system for subsequent execution. Kamarzarin, Beygi, and Bigdeli examined the effectiveness of mind simulation in soccer-skills training among adolescents, providing preliminary evidence that this approach may be applicable to the development of football-related abilities (H. Kamarzarin, M. Beygi, et al., 2021). This line of research suggests that mind simulation may have practical value as a supplementary method in sport training, particularly when physical repetition is limited or when learners require a clearer cognitive representation of the target movement.

Research on Bigdeli Mind Simulation has also extended beyond sport and has examined its application to speech and psychological difficulties. Virtual mind-simulation therapy has been introduced for individuals with stuttering and associated psychological problems, suggesting that simulation-based procedures may be delivered through technology-assisted formats and may influence both behavioral and psychological components of performance (Hamid Kamarzarin et al., 2021). Kamarzarin, Fallahi, and Tehranizadeh investigated the effect of the mind-simulation method on stuttering and communication attitudes, reporting findings that support the potential therapeutic relevance of the approach (H. Kamarzarin, Z. Fallahi, et al., 2021). Fallahi similarly examined the effectiveness of Bigdeli Mind Simulation therapy in children and adolescents aged 7 to 16 years with stuttering and reported reductions in stuttering-related difficulties and unfavorable communication attitudes (Fallahi, 2021). More recently, Kamarzarin and Bigdeli Shamloo investigated the effects of the method on stuttering and communication attitude, adding further evidence to the developing empirical literature on the method (Kamarzarin & Bigdeli Shamloo, 2025). Although speech production and football ball control are distinct behaviors, both require the acquisition, sequencing, and regulation of complex motor

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patterns. Findings from speech-related applications therefore provide indirect support for examining whether structured mind simulation can affect other forms of motor control.

Despite growing interest in mental simulation, a substantial proportion of sport-related research has evaluated effectiveness through behavioral indicators, including performance accuracy, execution time, error frequency, self-report measures, or observational ratings. These outcomes are valuable, but they do not directly demonstrate whether an intervention is associated with changes in brain-network activity. Neuroimaging methods provide an opportunity to investigate the neural processes that accompany motor learning and mental practice. Functional magnetic resonance imaging is a noninvasive technique used to examine changes in brain activity through the blood-oxygen-level-dependent signal. The BOLD signal reflects localized alterations in blood oxygenation and hemodynamic responses associated with neural activity. Although fMRI does not measure neuronal firing directly, it provides spatially detailed information about patterns of functional activation and connectivity across the brain.

The motor system includes interconnected cortical and subcortical regions involved in movement preparation, initiation, coordination, sensory integration, and error correction. Relevant areas include the primary motor cortex, premotor cortex, supplementary motor area, somatosensory cortex, basal ganglia, cerebellum, and parietal regions. The primary motor cortex, located in the precentral gyrus of the frontal lobe, contains a somatotopic representation of the body commonly described through the motor homunculus. Movements requiring precise control are represented by relatively extensive cortical areas because they depend on complex neural regulation. Ball-control activities rely particularly on lower-limb motor representations, postural regulation, proprioceptive processing, and visuospatial coordination. Mental rehearsal of these actions may activate portions of the neural network responsible for movement preparation and representation even when the body remains physically inactive.

Resting-state fMRI has further demonstrated that the brain remains functionally organized in the absence of an explicit external task. During rest, spontaneous fluctuations in the BOLD signal reveal coherent networks whose components exhibit temporally correlated activity. These resting-state networks include the default mode, motor, visual, auditory, attentional, executive-control, and salience networks. Examination of these networks may reveal changes in functional organization associated with learning, training, treatment, neurological conditions, and psychiatric disorders. Methodological developments have also enabled the acquisition and analysis of fMRI data across extended periods and under different physiological conditions. Moehlman et al., for example, demonstrated the feasibility and methodological importance of extended functional neuroimaging in all-night sleep studies, illustrating the sensitivity of fMRI to changes in brain-state organization and emphasizing the need for careful acquisition and processing procedures (Moehlman et al., 2019). In shorter resting-state designs, comparison of network activity before and after an intervention may provide preliminary evidence of training-related neurofunctional change.

The use of fMRI is particularly relevant to the investigation of mind simulation because the intervention is hypothesized to influence internal neural representations rather than merely observable performance. If structured mental rehearsal strengthens the functional organization of motor representations, changes may be detectable within the motor network after training. An increase in motor-network signal or connectivity following an intervention may indicate greater recruitment, enhanced readiness, or altered coordination of movement-related regions. Such interpretations must nevertheless be made cautiously, particularly in single-case investigations. Changes in BOLD activity can be affected by attention, arousal, fatigue, movement artifacts, physiological variation, scanner conditions, and analytic decisions. Increased activation is not always equivalent to improved performance, because learning may also be associated with reduced activation as neural processing becomes more efficient. Therefore, neuroimaging results should be interpreted in relation to the intervention protocol, behavioral context, imaging design, and limitations of the study.

Single-case experimental research can provide an initial means of exploring novel interventions before conducting larger controlled studies. A pretest–posttest single-case design enables researchers to examine whether an individual demonstrates measurable changes after exposure to a specified intervention. This design is particularly useful in pilot investigations involving expensive or technically demanding procedures such as fMRI. However, the absence of a control group, the limited ability to control confounding variables, and the lack of statistical generalizability mean that findings must be considered preliminary. In the present context, examining a participant without previous football experience may be advantageous because preexisting

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expertise is less likely to influence the baseline organization of the motor representation. At the same time, changes observed over a 20-day interval may reflect not only the mind-simulation procedure but also familiarity with the scanning environment, spontaneous variation, expectancy effects, or other experiences occurring between assessments.

The existing literature provides several reasons for investigating Bigdeli Mind Simulation in relation to football ball control. First, research on mental imagery and mental practice indicates that internally rehearsed movement can influence athletic performance, self-efficacy, arousal regulation, and skill learning (Ghaffari & Shahbazi, 2015; Narimani et al., 2007). Second, studies of sport simulation and practice organization suggest that structured cognitive rehearsal may improve mental representations and motor performance (Moradi & Fazeli, 2017; Roozbehani, 2014; Sohrabi, 2016). Third, neurocognitive evidence indicates that imagined and observed actions can recruit neural processes that overlap with those involved in physical action (Frank et al., 2020). Fourth, preliminary research on Bigdeli Mind Simulation has reported potentially beneficial effects in speech-related disorders, communication attitudes, psychological difficulties, and soccer-skills training (Fallahi, 2021; Hamid Kamarzarin et al., 2021; H. Kamarzarin, M. Beygi, et al., 2021; Kamarzarin & Bigdeli Shamloo, 2025; H. Kamarzarin, Z. Fallahi, et al., 2021). Nevertheless, limited evidence is available regarding the neural correlates of this method, particularly its relationship with activity in the motor network following football-skill simulation.

Addressing this gap is important for both theoretical and applied reasons. Theoretically, neuroimaging may clarify whether a structured mind-simulation method is associated with detectable changes in brain systems involved in movement representation and control. Such evidence may contribute to understanding how cognitive rehearsal influences motor-network organization. From an applied perspective, an effective mental-simulation procedure could be used as a complementary component of football training, rehabilitation, novice instruction, or periods in which physical practice is restricted. It may also help coaches and sport psychologists design training programs that integrate mental and physical practice rather than relying exclusively on repetitive overt execution. However, the practical use of the method requires empirical evidence derived from objective measures, and fMRI provides one approach for examining whether the proposed mental processes correspond with measurable neurofunctional changes.

Accordingly, the aim of the present study was to investigate the effectiveness of the Bigdeli Mind Simulation method for football ball control by comparing motor-network activity in the cortical regions of the frontal lobe before and after the intervention using functional magnetic resonance imaging.

2. Methods and Materials

The present study was an experimental single-case investigation with a pretest–posttest design. Because it was a single-case study, no statistical population was defined. The study participant was required to have no previous experience playing football and to be a student at Payame Noor University, Karaj. The participant was selected through convenience sampling. The data-collection instrument consisted of functional magnetic resonance imaging (fMRI) of the participant's brain before and after the mental-simulation exercises. The data were analyzed using FSL software, and the findings were interpreted by a medical image-processing specialist. Anatomical and functional imaging was performed using a Siemens Prisma 3-Tesla MRI scanner. Two 10-minute brain scans were conducted at an interval of 20 days, during which the participant remained at rest inside the MRI scanner. The repetition time for acquiring an anatomical image was approximately 3,000 milliseconds. The echo time was 30 milliseconds, and the field of view was recorded as 1,344 × 1,470. The analysis was conducted using the general linear model based on the blood-oxygen-level-dependent signal and the corresponding model design.

3. Findings and Results

Football-related movements and ball-control activities are clearly represented in the motor structures of the brain, particularly in the motor cortex, which forms part of the brain's gray matter. The motor cortex, located anterior to the central sulcus in the frontal lobe, plays a key role in controlling bodily movements. Stimulation of each part of this region produces movement in a specific part of the body. These areas are represented on the cerebral cortex as a map of the body known as the "homunculus." In this representation, the hands and face appear larger than other body parts because of the greater complexity and precision of their movements.

Mental simulation of movements may accelerate the otherwise lengthy process of learning ball control because the required information is transmitted to the brain through

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the sensory systems, thereby contributing to the formation of neural circuits associated with this skill. Neural networks, which can be examined through changes in cerebral blood flow and oxygenation levels, remain active even when the brain is at rest. Different networks, including the default mode network, motor network, visual network, and auditory network, interact with one another.

By extracting and analyzing these networks, differences in brain activity between healthy individuals and patients can be compared, potentially contributing to the diagnosis of neurological or psychiatric disorders. Furthermore, comparing the activity of a neural network before and after training or treatment may indicate the effectiveness of an intervention. For example, assessment of the motor network before and after sports training can demonstrate whether the training has resulted in improved motor functioning.

Figure 1

Activated cortical areas within the motor regions of the frontal lobe during preprocessing.

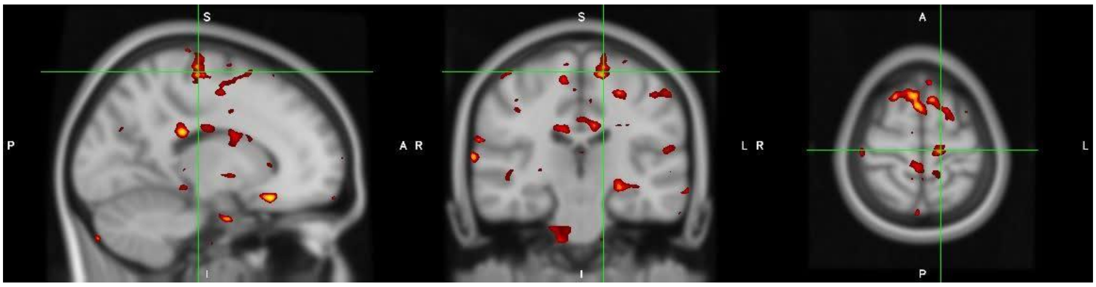
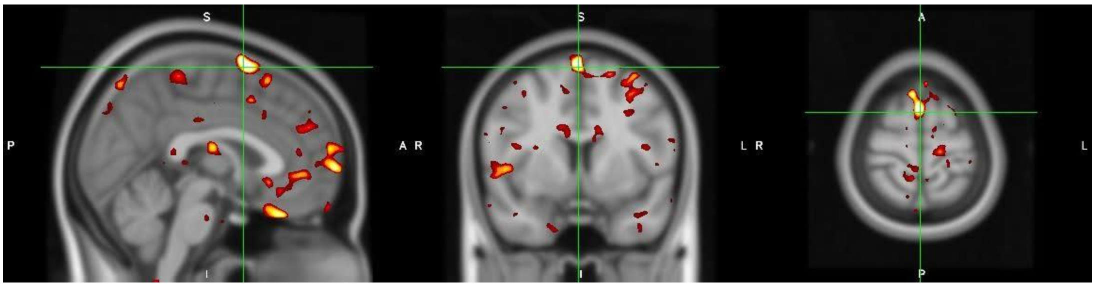


Figure 2

Activated cortical areas within the motor regions of the frontal lobe after processing.



According to the interpretation provided by the medical image-processing specialist, subtraction analysis of the activity identified within the network showed that motor-network activity and signal intensity increased after the specified training period. Considering the study design, this finding may reflect the effects of the training and practice intervention. Increased motor-network activity was diffusely observed in both the right and left hemispheres, and the relevant network was associated with the participant's motor activity of keeping the ball balanced on the foot. However, other factors may also have contributed to the increased activity of the motor network. A more precise examination of this process requires a larger number of participants and greater standardization and restriction of the type of exercise performed.

4. Discussion and Conclusion

The present study investigated the effectiveness of the Bigdeli Mind Simulation method in football ball control by comparing resting-state functional magnetic resonance imaging findings before and after a 20-day intervention in a 35-year-old female novice with no previous football-playing experience. The principal finding was an increase in the activity and signal intensity of the motor network after the intervention, as identified through subtraction analysis of the pre-intervention and post-intervention fMRI data. The observed increase was distributed across both the right and left hemispheres and involved neural regions associated with motor activity, particularly the movement pattern required to keep a football balanced on the foot. Given that the participant was initially inexperienced in football, the post-

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intervention increase in motor-network activity may indicate that repeated structured mental simulation contributed to the development or strengthening of a neural representation associated with the target skill. Nevertheless, because the study used a single-case pretest–posttest design without a control condition, the findings should be interpreted as preliminary evidence of a possible training-related neurofunctional change rather than as definitive proof of causality.

The observed increase in motor-network activity is consistent with the neurocognitive principle that mentally simulated actions and physically executed actions rely on partially overlapping neural systems. Motor imagery, action observation, and mental simulation can activate neural regions involved in movement preparation, action representation, temporal sequencing, and sensorimotor prediction, even when overt movement does not occur. Frank et al. explained that motor imagery and action-observation training can facilitate motor learning because imagined and observed actions engage neurocognitive processes that are functionally related to actual movement execution (Frank et al., 2020). From this perspective, the participant's repeated mental simulation of ball control may have increased the accessibility and organization of action-related representations in the motor system. The bilateral nature of the increased activity may also reflect the complexity of the target task. Keeping a ball balanced on the foot requires not only movement of the active lower limb but also postural stabilization, coordination of the supporting limb, integration of proprioceptive information, anticipatory control, and continuous adjustment of the body's center of gravity. Therefore, recruitment of a distributed bilateral motor network would be compatible with the functional demands of the skill.

The result can also be interpreted within the framework of motor learning and mental practice. During the early stages of learning, novice performers typically rely heavily on conscious movement planning, attentional control, sensory monitoring, and error correction. Because the participant had no previous football experience, she presumably lacked an established motor schema for ball control at baseline. Repeated simulation may have enabled her to construct a more coherent internal model of the target action, including the expected position of the foot, direction of the ball, degree of force required, maintenance of balance, and timing of corrective movements. Studies of mental imagery have shown that covert practice may influence both psychological readiness and athletic performance. Narimani et al. found that mental imagery contributed to increased self-efficacy and athletic performance among taekwondo athletes, supporting the view that internally rehearsed actions may facilitate subsequent motor functioning (Narimani et al., 2007). Ghaffari and Shahbazi likewise demonstrated the relevance of mental imagery to arousal control in athletes, indicating that imagery-based interventions can influence psychological processes that affect motor performance (Ghaffari & Shahbazi, 2015). Although the present study did not directly assess self-efficacy or arousal, improved attentional regulation and increased confidence during simulation may have contributed indirectly to greater engagement of the motor network.

The findings are also aligned with research examining the effects of structured simulation and mental representation on sport-skill acquisition. Moradi and Fazeli compared routine introduction, simulation, and combined training methods in the learning of the volleyball float serve and demonstrated that simulation can influence both skill performance and the quality of mental representation (Moradi & Fazeli, 2017). Their findings are especially relevant because successful execution of a sport skill depends on more than generalized motivation or imagery vividness; it requires the formation of an organized cognitive representation of the action. The present increase in motor-network activity may therefore reflect the neural correlate of a more differentiated representation of the ball-control task. In other words, the participant may have become better able to internally reproduce the sequential and spatial components of the skill after the intervention. Such a development would be expected to increase the functional involvement of brain regions responsible for movement planning and sensorimotor integration.

Practice structure is another factor that may help explain the present findings. Mental practice is most effective when it is systematic, task-specific, and sufficiently repeated. Sohrabi's comparison of physical practice and blocked and random mental-imagery schedules showed that the organization of imagery practice affects the performance and learning of motor tasks (Sohrabi, 2016). Roozbehani also reported that contextual interference during mental practice influences the performance and learning of football skills (Roozbehani, 2014). These studies indicate that mental rehearsal should be considered an active learning process rather than passive visualization. Bigdeli Mind Simulation is intended to provide a structured form of internal rehearsal in which the individual repeatedly encodes and reproduces a defined target pattern. The intervention may therefore have provided the participant with a consistent cognitive framework for rehearsing ball control, thereby strengthening associations among the perceptual, spatial, and motor components of the skill. The post-intervention increase in motor-network activity may be interpreted as a neural manifestation of this repeated task-specific organization.

The present findings also correspond with the theoretical assumptions of Bigdeli Mind Simulation. Bigdeli Shamloo described the method as an approach based on the language of the mind, mental programming, simulation, and the construction of desired behavioral patterns, including applications to intelligent football (Bigdeli Shamloo, 2017b). A related presentation of the method similarly emphasized the role of structured mental simulation in modifying internal patterns associated with behavior and performance (Bigdeli Shamloo, 2017a). Within this conceptual framework, repeated exposure to a precisely defined mental model is expected to influence the way the nervous system organizes a behavior. The present results offer preliminary neuroimaging support for this assumption by showing greater motor-network activity after the simulation period. However, the finding does not establish the unique theoretical mechanisms proposed by the method, because comparable changes might also occur following conventional motor imagery, action observation, attentional training, or physical practice. A controlled comparison between Bigdeli Mind Simulation and established imagery protocols would therefore be necessary to determine whether the method produces distinctive effects.

The findings are further supported by preliminary studies applying mind simulation to soccer training. Kamarzarin, Beygi, and Bigdeli examined the effectiveness of mind simulation in teaching soccer skills to adolescents and reported results suggesting that the method may facilitate football-skill acquisition (H. Kamarzarin, M. Beygi, et al., 2021). The present study extends that line of work by examining a possible neural correlate of training rather than relying exclusively on behavioral performance. The increase in motor-network activity provides an initial indication that the reported improvement associated with mind simulation may be accompanied by changes in movement-related brain functioning. This is important because behavioral improvement alone may result from motivation, repeated testing, or strategic compensation, whereas neuroimaging can provide complementary information regarding changes in the neural systems supporting the skill. Nevertheless, the absence of a direct behavioral ball-control measure in the present study prevents a firm conclusion that the increased signal corresponded to objectively improved performance.

Research applying Bigdeli Mind Simulation to stuttering and communication attitudes also provides indirect support for the possibility that the method can influence organized motor behavior. Speech production, like football ball control, requires precise timing, sequencing, sensory monitoring, and coordination of multiple motor components. Kamarzarin, Akbari, and Bigdeli Shamloo described virtual mind-simulation therapy for individuals with stuttering and psychological difficulties, suggesting that simulation-based interventions may influence both behavioral output and associated psychological processes (Hamid Kamarzarin et al., 2021). Kamarzarin, Fallahi, and Tehranizadeh reported that the mind-simulation method reduced stuttering and improved communication attitudes (H. Kamarzarin, Z. Fallahi, et al., 2021). Fallahi similarly found that Bigdeli Mind Simulation therapy was effective in reducing stuttering and maladaptive communication attitudes in children and adolescents (Fallahi, 2021). More recently, Kamarzarin and Bigdeli Shamloo reported beneficial effects of the method on stuttering and communication attitude (Kamarzarin & Bigdeli Shamloo, 2025). Although these studies addressed speech rather than sport, their findings suggest that repeated mental simulation may influence learned motor patterns and the psychological responses associated with their execution. The present increase in motor-network activity may therefore represent another manifestation of the method's potential effect on complex motor organization.

The use of resting-state fMRI provides an additional perspective on the findings. The motor network remains active at rest, and its spontaneous signal fluctuations reflect functional coordination among movement-related brain regions. A post-intervention increase in signal may therefore indicate altered baseline organization or increased functional readiness of the motor system. Moehlman et al. demonstrated that fMRI can be used to investigate functional brain activity across prolonged and changing physiological states and emphasized the importance of carefully interpreting signal variations in relation to acquisition and analytic conditions (Moehlman et al., 2019). In the present study, the participant was scanned at rest rather than while performing or imagining ball control inside the scanner. Consequently, the identified increase cannot be interpreted as direct activation produced by the target task. It may instead reflect a change in resting-state motor-network organization following the intervention. This interpretation is plausible but remains tentative because resting-state activity is sensitive to multiple factors, including wakefulness, fatigue, emotional state, recent motor activity, respiration, head motion, and attentional fluctuations.

Another important consideration is that greater activation does not invariably indicate superior learning or more efficient performance. At the beginning of motor learning, increased neural activation may reflect greater cognitive effort, expanded recruitment of cortical resources, or the formation of a new movement representation. With extended practice and automatization, activation in some regions may subsequently decrease as processing becomes more efficient. The participant in the present study was a novice and received a relatively short intervention; therefore, increased motor-network activity is compatible with an early learning phase in which additional neural resources are recruited to represent and prepare the target movement. The result may indicate increased neural engagement rather than complete mastery of ball control. Future research should examine whether this increased activity is maintained, further strengthened, or reduced after longer periods of combined mental and physical practice.

The present findings therefore contribute to the limited literature on the neural effects of Bigdeli Mind Simulation. Previous studies have primarily examined behavioral, clinical, and psychological outcomes, whereas the present investigation used fMRI to evaluate possible change in a motor-related brain network. The results are broadly consistent with research on mental imagery, simulation, contextual interference, and neurocognitive motor rehearsal (Frank et al., 2020; Ghaffari & Shahbazi, 2015; Moradi & Fazeli, 2017; Narimani et al., 2007; Roozbehani, 2014; Sohrabi, 2016). They also align with earlier applications of the Bigdeli method to football skills, stuttering, and communication attitudes (Bigdeli Shamloo, 2017a, 2017b; Fallahi, 2021; Hamid Kamarzarin et al., 2021; H. Kamarzarin, M. Beygi, et al., 2021; Kamarzarin & Bigdeli Shamloo, 2025; H. Kamarzarin, Z. Fallahi, et al., 2021). Taken together, these findings support the possibility that structured mental simulation can influence motor-related neural processes. However, the present evidence should be regarded as exploratory and hypothesis-generating rather than confirmatory.

The most important limitation of the study was its single-case pretest–posttest design. Because only one participant was examined, the findings cannot be generalized to football players, novice learners, men, different age groups, or clinical populations. The absence of a control participant or comparison intervention makes it impossible to determine whether the observed increase resulted specifically from Bigdeli Mind Simulation, repeated scanning, expectation, familiarity with the procedure, spontaneous physiological variation, or activities undertaken during the 20-day interval. The study also lacked objective behavioral measurements of ball-control performance, and therefore no direct relationship could be established between increased motor-network activity and actual improvement in skill. In addition, the resting-state design did not require the participant to perform or imagine the target movement during scanning, which limits the specificity of the neural interpretation. Other limitations included the short intervention period, the absence of follow-up imaging, insufficient control over sleep, fatigue, medication, recent exercise, emotional state, and physiological conditions, as well as the possibility of head-motion and preprocessing effects. The unusual or incompletely reported imaging parameters also reduce methodological reproducibility.

Future studies should recruit larger and more diverse samples and use randomized controlled designs comparing Bigdeli Mind Simulation with conventional motor imagery, action observation, physical practice, combined mental–physical training, and a no-intervention control condition. Researchers should include standardized behavioral assessments of ball control, such as number of successful touches, duration of ball maintenance, movement accuracy, balance indices, and retention and transfer tests. Task-based fMRI could be used to examine brain activation while participants imagine or observe the specific football movement, while resting-state fMRI could assess changes in functional connectivity. Repeated assessments immediately after training and at longer-term follow-ups would clarify whether neural changes are temporary or stable. Future research should also examine dose–response relationships, imagery ability, prior athletic experience, sex, age, motivation, and adherence as potential moderators. Greater methodological detail regarding scanner parameters, preprocessing, motion correction, statistical thresholds, network extraction, and anatomical localization is essential. Multimodal approaches combining fMRI with electroencephalography, electromyography, motion analysis, balance assessment, and psychological measures could provide a more comprehensive account of the mechanisms involved.

In practice, Bigdeli Mind Simulation may be used as a complementary rather than substitute method for physical football training. Coaches and sport psychologists may incorporate short, structured simulation sessions before or

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after technical practice, particularly for novice athletes who need to develop a clear representation of movement sequences. The simulated content should closely correspond to the actual skill and include the visual trajectory of the ball, kinesthetic sensations of foot contact, postural alignment, timing, force regulation, and corrective responses. The method may also be useful when physical practice is temporarily restricted because of fatigue, limited facilities, travel, injury, or rehabilitation. Practitioners should monitor both subjective imagery quality and objective performance and should avoid assuming that increased mental rehearsal automatically produces skill improvement. Mental simulation should be individualized, progressively adjusted, and integrated with feedback, physical repetition, and appropriate coaching. Until stronger controlled evidence becomes available, the method should be regarded as a potentially useful adjunct to established motor-learning procedures rather than a standalone or definitively validated intervention.

Authors' Contributions

All authors significantly contributed to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this study, to observe ethical considerations, participants were informed about the goals and importance of the research before the start of the study and participated in the research with informed consent.

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