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# Analyzing Soccer Dynamics Using the Motion in Mind Model

# Menganalisis Dinamika Bola Sepak Menggunakan Model Motion in Mind

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## ABSTRACT

In soccer, understanding both the overall dynamics of the game and team performance is crucial for developing effective strategies and enhancing overall success. This study employs the Motion in Mind (MiM) model to analyze the dynamics of soccer and teams' performance, with a particular focus on the FIFA World Cup 2022. The objective is to understand how different phases (opening, middlegame, and endgame) of a soccer sport are influenced by the key performance matrices such as total attempts and goals, as well as strategic adaptations by teams. Utilizing data from 64 matches involving 32 teams, we applied a phase-specific analysis to examine metrics such as velocity, mass, acceleration, force, potential energy, and momentum. The findings reveal distinct performance patterns across the game phases: the opening phase is characterized by higher challenges and uncertainties, the middlegame phase shows improved success rates and strategic adaptations, and the endgame phase highlights optimal performance levels with peak velocity and strategic efficiency. The study also provides a comparative analysis of Argentina and France, identifying key factors that contributed to Argentina's victory. These insights enhance the understanding of competitive sports dynamics and suggest practical applications for improving team strategies and performance in future tournaments.

Keywords**:** Soccer; Game phases; Soccer dynamics; Motion in Mind

## ABSTRAK

Dalam bola sepak, memahami kedua-dua dinamika keseluruhan permainan dan prestasi pasukan adalah penting untuk membangunkan strategi yang berkesan dan meningkatkan kejayaan keseluruhan. Kajian ini menggunakan model Motion in Mind (MiM) untuk

menganalisis dinamika bola sepak dan prestasi pasukan, dengan fokus khusus pada Piala Dunia FIFA 2022. Objektifnya adalah untuk memahami bagaimana fasa-fasa berbeza (pembukaan, pertengahan permainan, dan akhir permainan) dalam sukan bola sepak dipengaruhi oleh matriks prestasi utama seperti jumlah percubaan dan gol, serta adaptasi strategik oleh pasukan. Menggunakan data daripada 64 perlawanan yang melibatkan 32 pasukan, kami menerapkan analisis khusus fasa untuk mengkaji metrik seperti halaju, jisim, pecutan, daya, tenaga berpotensi, dan momentum. Dapatan kajian menunjukkan corak prestasi yang berbeza dalam fasa permainan: fasa pembukaan dicirikan oleh cabaran dan ketidakpastian yang lebih tinggi, fasa pertengahan permainan menunjukkan kadar kejayaan yang lebih baik dan adaptasi strategik, manakala fasa akhir permainan menyerlahkan tahap prestasi yang optimum dengan halaju puncak dan kecekapan strategik. Kajian ini juga menyediakan analisis perbandingan antara Argentina dan Perancis, mengenal pasti faktor utama yang menyumbang kepada kemenangan Argentina. Penemuan ini meningkatkan pemahaman tentang dinamika sukan kompetitif dan mencadangkan aplikasi praktikal untuk memperbaiki strategi pasukan dan prestasi dalam kejohanan akan datang.

Kata kunci: Bola Sepak; Fasa Permainan; Dinamika Bola Sepak; Motion in Mind

## INTRODUCTION

Sports encompass a diverse array of competitive activities, ranging from casual to highly organized events, all aimed at enhancing or maintaining physical abilities and skills while providing entertainment for both participants and audience (Jenny et al., 2017, Thiel and John, 2018, Parry, 2019). The spectrum of sports includes various participation formats, from individual to team-based engagements, and structures that range from informal, free-for-all competitions to formal tournaments with established rules. Among these activities, soccer, or football as it is known in many parts of the world, stands out as the most globally popular sport. It involves two teams of 11 players each, competing to score by pushing a ball into the opponent's goal using any part of the body except for the hands and arms (Lees and Nolan, 1998).

The 2022 FIFA World Cup, hosted in Qatar from November 20 to December 18, showcased the sport's universal appeal, featuring 32 teams competing in 64 matches (2022, ESPN, 2022). This tournament provided a rich dataset for analyzing various aspects of team performance and the dynamics of soccer as a time-limited sport. To complement this, we created our own dataset specifically focused on the different phases of each match opening, middlegame, and endgame. This custom dataset allows for a more granular analysis of team strategies and performance dynamics within these distinct phases. Such a structured competition, combined with our phase-specific dataset, offers an ideal platform to study how teams strategize and adapt throughout different phases of a match. While previous research has often focused on aggregate statistics (Carling et al., 2007), there is an emerging need to delve into the detailed dynamics that occur within different phases of soccer.

In competitive events, whether an event is time-limited or score-limited significantly influences the entertainment and engagement value at different phases opening, middle, and ending of the competition. In time-limited events, the ending phase often holds heightened excitement, entertainment, and engagement value due to increased urgency and intensity as the time limit approaches, leading to a strong finish. However, the starting stage in score-limited events can also hold significant interest, as initial strategies and early moves set the foundation for the rest of the competitive phases. We hypothesize that the structured phases of a soccer match have distinct dynamics that influence team strategies and match outcomes. Specifically, we expect to see a marked increase in success rates and strategic adaptability as teams progress from the opening to the endgame phases.

This study aims to analyze soccer dynamics and teams competitiveness using the Motion in Mind (MiM) model (Iida and Mohd Nor Akmal, 2020, Mohd Nor Akmal and Iida, 2021). By applying this model to data from the FIFA World Cup 2022 tournament, the research seeks to offer new insights into the dynamics of engagement during different phases of the game. The MiM model provides a framework for understanding player performance dynamics through metrics such as velocity, mass, acceleration, force, potential energy, and momentum. This study is twofold: first, to explore the broader dynamics of soccer throughout the tournament and second to assess the performance dynamics of the participating teams, with a particular focus on the top two teams. By systematically categorizing and analyzing performance metrics across the different phases of each match, this research aims to offer a nuanced understanding of how the key indicators such as attempts and goals vary across the opening, middlegame, and endgame phases of a soccer game. This research highlights the critical importance of understanding the dynamics of different game phases to optimize engagement and performance in competitive sports. The findings provide valuable insights into the strategic adjustments made by teams, offering a framework for future analyses of sports tournaments. This study aims to contribute to the broader understanding of competitive sports dynamics, enhancing the strategies employed by teams and informing the design of more engaging and competitive sporting events.

The remainder of this paper is structured as follows: Section 2 reviews related work on strategic game analysis in soccer, focusing on attempts and goals dynamics. Section 3 outlines the methodology employed in collecting, processing, and analyzing the data using the Motion in Mind (MiM) model. Section 4 presents the results of our analysis, including overall findings from the FIFA World Cup 2022 and a detailed comparison of the top two teams, Argentina and France. Section 5 discusses the implications of our findings for understanding phase-specific dynamics in soccer and their practical applications. Finally, Section 6 concludes the paper with a summary of our contributions and suggestions for future research.

## RELATED WORK

This section reviews the literature on strategic game analysis in soccer, focusing particularly on studies related to goals scoring. This section outlines the major findings from previous work,

identify limitations, and show how this study extends the current understanding of goal scoring into attempts and goals dynamics in different phases of soccer sport.

In the realm of soccer performance analysis, a significant body of literature has focused on the temporal patterns of goal scoring within matches. Studies have consistently highlighted an increase in goal scoring frequency as matches progress, with a maintained peak in the final 15 minutes. Therefore, several studies have examined the overall patterns of goal-scoring in soccer. For instance, research by Armatas et al (Armatas et al., 2007) highlights the temporal distribution of goals, indicating that a significant proportion of goals are scored during the final 15 minutes of each half. This finding suggests that fatigue and strategic adjustments made by teams play a crucial role in these periods. Also, the article (Simiyu, 2014) by Wycliffe, analyzes the distribution of goals in major football competitions. It reveals that a significant number of goals are scored in the last 15 minutes of matches, highlighting this period as critical. The study attributes this trend to factors like player fatigue, tactical changes, and increased urgency. These findings suggest that effective game management, including physical and mental conditioning and strategic substitutions, is crucial for optimizing performance. Furthermore, Alberti et al. (Alberti et al., 2013) analyzed goal scoring patterns across four major European leagues. Their findings confirmed a higher goal scoring frequency in the second half (55.1%) compared to the first half (44.9%), with the highest rate observed in the final quarter-hour. This pattern suggests that factors such as player fatigue, which diminishes high-intensity running and technical precision, and the urgency to score as time runs out, significantly impact goal scoring dynamics. Prior research by Abt et al. (Abt et al., 2001) and Armatas et al. (Armatas et al., 2009) supports these findings, indicating that the interplay between physical exertion and strategic gameplay contributes to this temporal scoring trend. These studies collectively underscore the complex interaction of physical and psychological elements influencing goal scoring, advocating for a multifaceted approach to performance analysis in soccer. The authors in (Kubayi and Toriola, 2019) analyzed goals scored in five successive FIFA World Cup tournaments (1998-2014) and found that most goals were scored in the final 15 minutes of the game. This pattern was attributed to factors such as physical and mental fatigue, tactical adjustments, and increased urgency as the game nears its conclusion. Similarly, studies (Alberti et al., 2013, Kubayi and Toriola, 2019) confirmed that goal scoring frequency increases significantly in the latter stages of a match, with the highest rates observed in the final quarter-hour. The role of player conditioning, strategic changes, and psychological factors were highlighted as key contributors to this trend. Moreover, the spatial analysis of goals showed that a significant proportion of goals were scored from inside the penalty area, emphasizing the importance of close-range opportunities and effective attacking strategies. This strategic variation aligns with the findings of Wright et al. (Wright et al., 2011), who observed that goal scoring opportunities are often created through specific tactical setups, such as combinative attacks and central assists, particularly in professional men's soccer. These findings underscore the complexity of goal scoring in soccer, influenced by an interplay of physical, tactical, and psychological elements, and provide valuable information for coaches and analysts aiming to optimize team performance. Furthermore, previous studies extensively utilized the concept of average velocity to measure the rate at which players/teams progress or resolve uncertainties. However, these studies have notable limitations, particularly their lack of focus on scoring

dynamics across different phases of the game. For instance, Iida and Mohd Nor Akmal (Hao et al., 2022, Naying et al., 2023) applied this concept in the context of sports and board games, demonstrating how average velocity can quantify the engagement value and enhance the overall game experience. However, while this approach offers valuable insights into the general pace of gameplay, it overlooks the dynamic nature of gameplay and team performance across different phases of a game.

To address these gaps, this study is the first to investigate scoring dynamics from a motion-in-mind perspective, providing a comprehensive understanding of soccer scoring patterns by examining three distinct phases: overall soccer scoring dynamics, and competition between the top two teams. Specifically, expanding on the concept of average velocity, this study introduces the concept of velocity dynamics. By examining velocity across the distinct phases of a soccer match namely, the opening, middlegame, and endgame, this approach captures the fluctuations the overall soccer and the team's performance as the game progresses. This phase-specific analysis offers a more granular understanding of how teams adjust their strategies and how overall soccer dynamics evolve in response to changing game conditions, thereby providing a more holistic view of game performance. The introduction of velocity dynamics not only advances the theoretical framework established by previous research but also delivers practical insights for optimizing team strategies during critical phases of a match. In this work, the MiM model provides a more nuanced analysis of how key performance metrics, such as attempts and goals, vary across different phases of a soccer game, offering insights into player performance dynamics through metrics like velocity, mass, acceleration, force, potential energy, and momentum. This model has been instrumental in understanding how players, teams, and audience engage with game dynamics.

## METHODOLOGY

This section outlines the methodologies employed in collecting, processing, and analyzing the data to explore soccer dynamics in different phases, by utilizing Motion-in-Mind Model. These methodologies are critical for understanding how the dynamics in soccer sport influence the tactical complexity across different phases: opening, middlegame, and endgame. This methodological approach combines quantitative analysis with theoretical modeling to provide a comprehensive understanding of how strategies evolve in different phases of soccer and impact game performance.

### 1. Data Collection and Processing

In this study, we focused on the FIFA World Cup 2022, an international football tournament that was held in Qatar from November 20 to December 18, 2022. To ensure the reliability and accuracy of our analysis, we exclusively utilized data sourced from verified authorities, specifically cited as (2022, ESPN, 2022). The tournament featured 32 teams competing in a total of 64 matches. The structured format of the competition, depicted in Figure 1, shows the number of matches played by each team and provides a comprehensive dataset ideal for statistical analysis. Leveraging this rich dataset, our study aims not only to track team

performance metrics but also to interpret these metrics within the broader context of soccer dynamics. This data forms the backbone of our subsequent analysis.

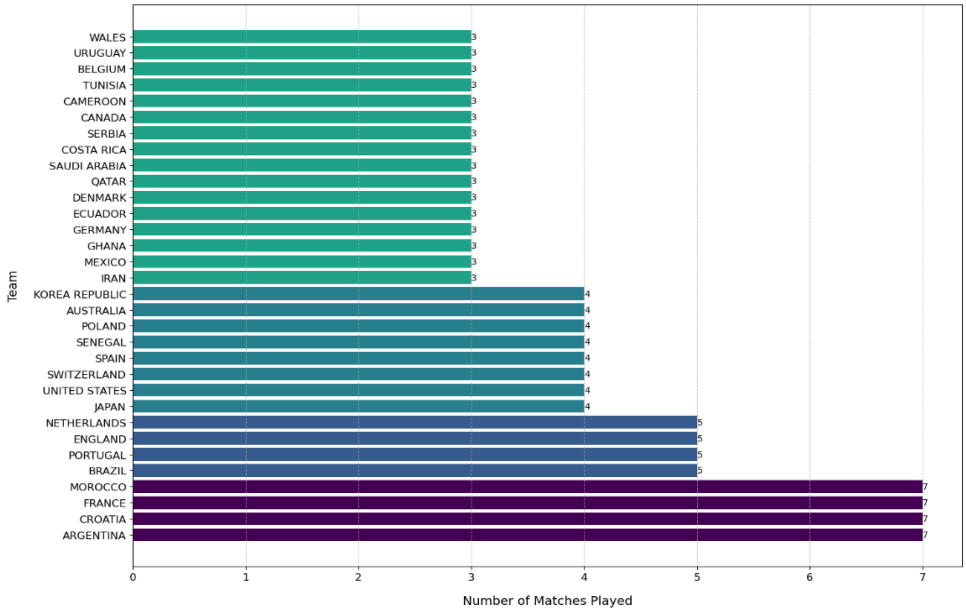


FIGURE 1. Teams with total number of matches played

Before central to our approach was the systematic organization and sorting of team performance metrics with respect to the total number of attempts and goals by each team throughout the tournament depicted in Figure 2. This process was essential for facilitating a nuanced analysis of the relationships between offensive actions (attempts) and scoring outcomes (goals), and for ensuring the accuracy and relevance of our subsequent findings. This format allows us to track and compare performance metrics across different phases of the competition, offering insights into team scoring strength, strategies, adaptability, and resilience under varying levels of pressure.

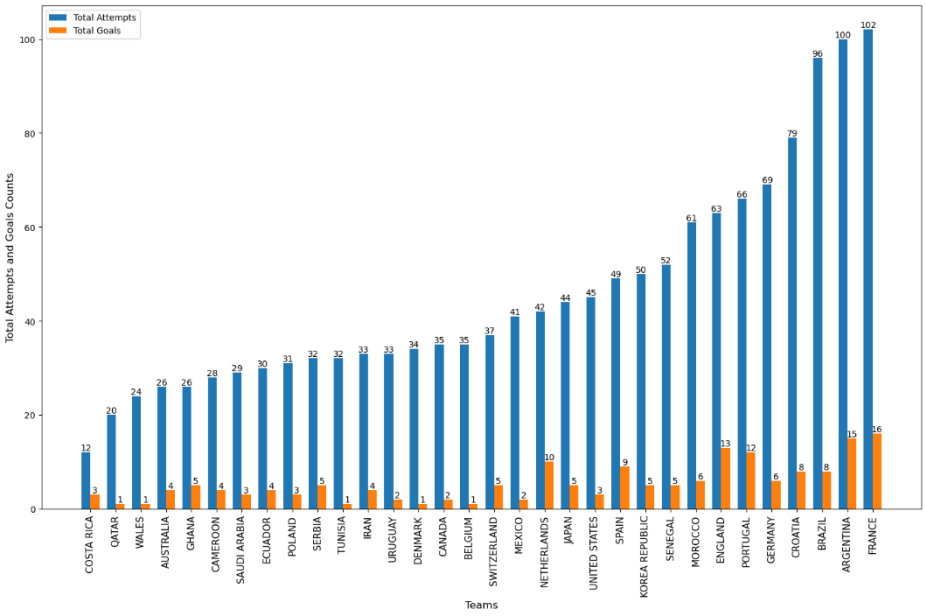


FIGURE 2. Teams with total number of attempts and goals

Additionally, we sought to explore not just the fluctuating dynamics of team performances, but also how these dynamics manifested across different phases of tournament, categorized as opening, middlegame, and endgame phases. To this end, we aggregated the total attempts and goals recorded by all teams during each phase of their matches. These statistics (see Figure 3) was crucial for highlighting the strategic adjustments made throughout the tournament, helps in which phase is most aggressively played and which resulted in higher scoring efficiency. This method not only confirms the quantitative aspects of team strategies but also underscores the qualitative shifts that occur as the game progresses.

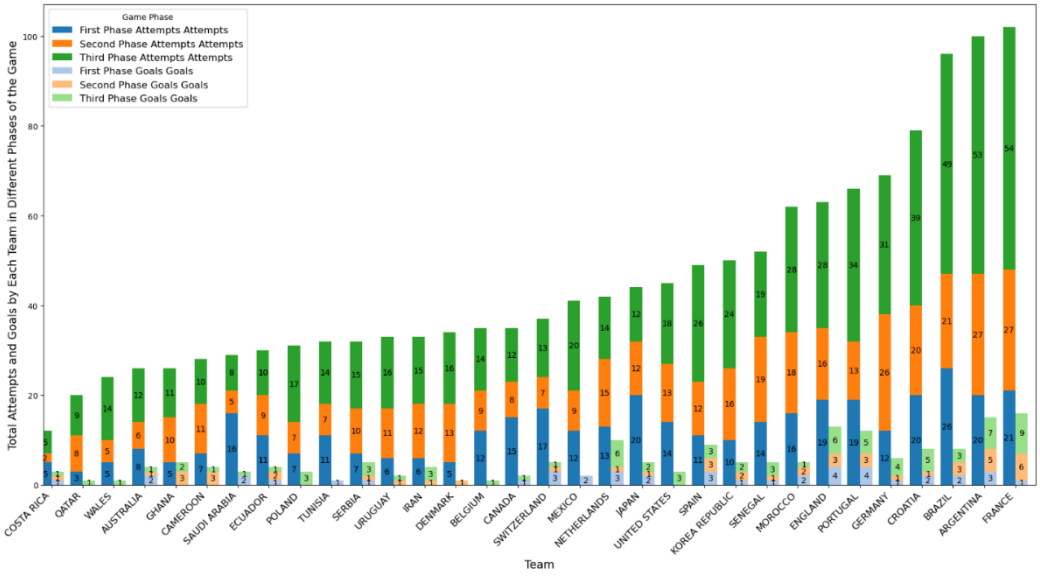


FIGURE 3. Teams with total number of attempts and goals in the Opening, Middlegame and Endgame phases

Finally, we explore the dynamics of overall soccer and the performance of the top two teams, Argentina and France, across different phases in the tournament, depicted in Figures 4 and 5 respectively. It is observed that the endgame phase is notably more aggressive and engaging, with a significant increase in both attempts and goals, highlighting the critical nature of the final moments in matches. Comparing the performance of Argentina and France, both teams showed balanced attempts throughout the phases, but with a remarkable spike in the endgame. These statistics underscore the importance of the endgame phase in determining match outcomes and emphasize the strategic efforts exerted by teams in the closing moments.

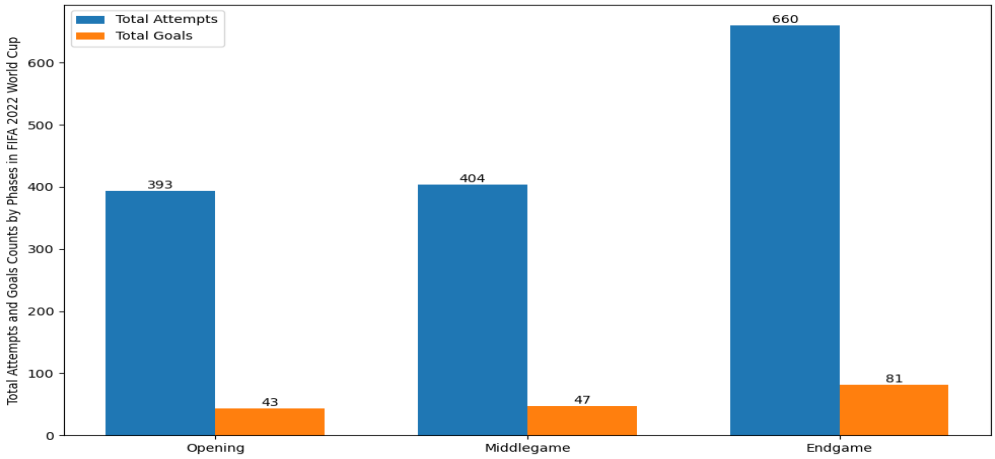


FIGURE 4. Total number of attempts and goals in Opening, Middlegame and Endgame phases of FIFA World Cup 2022

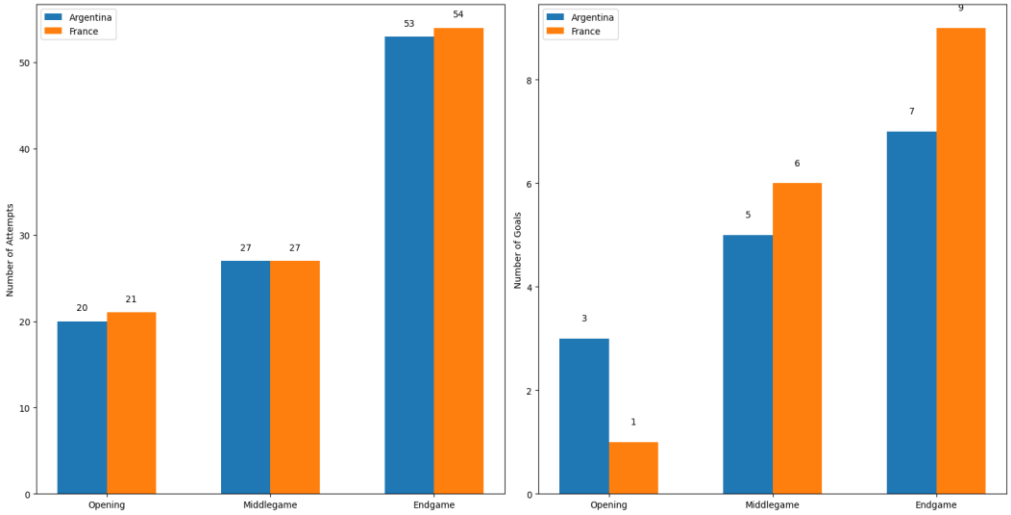


FIGURE 5. Total number of attempts and goals in Opening, Middlegame and Endgame phases by top two teams Argentina and France

2. Division of soccer game into phases

Soccer typically played in two halves, each lasting 45 minutes, with a halftime interval of approximately 15 minutes for rest. The standard match duration is 90 minutes, however, if the game ends in a tie, it proceeds to an additional 30 minutes of play, known as 'extra-time' (ET) (Russell et al., 2015). This leads to a total playing time of 120 minutes in such cases. In this study, we have categorized both 45-minute half, plus additional time, of play into three distinct phases as follows. This is done for both phases separately.

- Opening Phase (1-15 minutes)
- Middle Phase (16-30 minutes)
- Closing Phase (31-45 minutes, including any extra time)

This study represents the inaugural exploration of soccer by dissecting the game into three distinct phases - opening, middle, and endgame in conjunction with the motion in mind model.

## 3. Data analysis via MiM Model

The "Motion in Mind" framework is a novel approach that blends physical dynamics with psychological processes to analyze player interaction and engagement in games. This conceptual framework is built upon analogies from classical mechanics, applying terms such as mass, velocity, acceleration, momentum, and potential energy to describe and quantify the cognitive and emotional experiences of players during gameplay. Therefore, the soccer sports game can be effectively analyzed through the Motion in Mind (MiM) model (Iida and Mohd Nor Akmal, 2020) to understand soccer dynamics and how teams process and act upon game information. This model not only helps in designing more engaging and satisfying games but also serves as a tool for academic exploration into the cognitive processes involved in gaming. By applying these principles, game developers can create more nuanced and player-centric game experiences.

**Velocity ($v$):** In the context of sports such as soccer, the concept of velocity is interpreted as the rate at which uncertainty in the game's outcome is resolved over time. This is quantified using the game progress model. Specifically, in this study, velocity $v$ is defined as the ratio of the total number of goals $G$ to the total number of shooting attempts $T$ per game:

$$v = \frac{G}{T} \tag{1}$$

This formula captures the effectiveness or success rate of scoring attempts in each phase of the game. The velocity here reflects how quickly a game progresses towards outcome from opening to endgame phase based on the rate at which goals are scored relative to the number of attempts made. A higher velocity in each phase indicates that goals are being scored more efficiently, leading to faster resolution of the game's outcome. A higher velocity might suggest a greater role of skill or performance in scoring.

**Mass ($m$):** In the context soccer, "mass" is interpreted as the magnitude of the challenge a player faces during a game, which is inversely related to the rate at which the game's outcome uncertainty is resolved. This concept is adapted from physics, where mass typically represents the resistance to acceleration. In each phase, mass is defined as $m = 1 - v$ where $v$ is the velocity, which represents the rate of solving uncertainty or scoring rate. By understanding mass, we can gauge how engaging a game might be. A higher mass indicates a game that is harder to score in, which might lead to lower engagement if not balanced properly with other game elements. A lower mass would suggest that chance plays a larger role, while a higher mass indicates that skill is more critical.

**Acceleration (a):** Acceleration is defined as the rate of change of velocity with respect to time (total attempts). In this study, it is interpreted as the rate at which the informational uncertainty in the game's outcome accelerates. Acceleration is given by:

$$a = \frac{2v}{T} \tag{2}$$

Where, $v$ is the velocity, which represents the rate of solving uncertainty or scoring rate and T is the game length or total time (total attempts in each phase). Acceleration is used to measure the thrill or excitement of the game. A higher acceleration indicates a more thrilling and rapidly changing game, which can be more engaging for players, teams or audience. A higher acceleration might suggest a game that relies more on skillful play, while lower acceleration could indicate a more chance-driven game.

**Force (F):** Force represents the interaction of the player's challenge and the game's difficulty, reflecting the level of engagement and effort required. The force in the game can be expressed as a function of mass and acceleration, drawing an analogy from Newtonian physics which is represented by $F = ma$, where $m$ is the mass, representing the challenge or difficulty of scoring and $a$ is the acceleration, representing the rate of change of velocity or how quickly the game progresses towards a outcome. A higher force indicates a more challenging game that requires greater skill and effort to score. Higher force can lead to increased player engagement and a more immersive experience.

**Potential Energy ($E_p$):** Potential energy represents the anticipation and the amount of information required by a player to solve the uncertainty of the game's outcome. This concept is adapted from the gravitational potential energy in physics, where it typically represents the potential for an object to do work due to its position in a gravitational field is given by:

$$E_p = \frac{1}{2}ma^2t^2 = 2mv^2 = 2(1-v)v^2 \tag{3}$$

Where, $m$ is the mass, representing the challenge or difficulty of scoring, $a$ is the acceleration, representing the rate of change of velocity, $v$ is the velocity the scoring rate and $t$ is the game length or total time (total attempts in each phase). A higher potential energy indicates a game with higher anticipation, keeping players engaged as they work towards resolving the game's uncertainty. By understanding potential energy, game designers can balance the difficulty and anticipation, ensuring that the game is challenging enough to be engaging but not too frustrating.

**Momentum ($\vec{p}$):** Momentum represents the product of the challenge or difficulty (mass) and the rate at which the uncertainty of the game outcome is resolved (velocity). This concept is adapted from the physical definition of momentum, where it is the product of mass and velocity. Momentum is defined as $p = mv$, where $m$ is the mass, representing the challenge or difficulty of scoring and $v$ is the velocity, the scoring rate. Momentum reflects the dynamic progress of the game. Higher momentum implies a game where both challenge and progress are balanced optimally. Higher momentum can lead to increased player engagement and a more immersive experience.

Utilizing the MiM model, we analyze the soccer dynamics and competitiveness of two teams across different phases of the game: opening, middlegame, and endgame.

# RESULTS

## 1. Overall FIFA World Cup 2022

Table 1 presents the Motion in Mind (MiM) measures such as velocity, mass, acceleration, force, potential energy, and momentum for the entire FIFA World Cup 2022, segmented into three game phases: opening, middlegame, and endgame.

TABLE 1. Motion in Mind Measure of FIFA World Cup 2022

| Phase | $v$ | $m$ | $a$ | $F$ | $E_p$ | $\vec{p}$ |
|---|---|---|---|---|---|---|
| Opening | 0.109 | 0.890 | 0.035 | 0.031 | 0.019 | 0.097 |
| Middlegame | 0.115 | 0.884 | 0.036 | 0.032 | 0.021 | 0.102 |
| Endgame | 0.123 | 0.876 | 0.023 | 0.02 | 0.023 | 0.108 |

The velocity values across the different phases of the game provide insights into the soccer dynamics. In the opening phase, a velocity of 0.1092 suggests that teams are adjusting to the game environment, reflecting an initial success rate. As the game progresses to the middlegame phase, the observed increase in velocity to 0.1157 indicates an enhancement in the players' ability to convert attempts into successful outcomes, likely due to increased familiarity with the game mechanics and strategic adjustments aligning with theories of learning curves and skill acquisition (Ericsson et al., 1993, Macnamara et al., 2014). The peak velocity value of 0.1232 in the endgame phase denotes optimal performance, where players leverage their accumulated experience and refined strategies, demonstrating effective execution and decision-making capabilities.

The mass values represent the difficulty or uncertainty faced by players throughout the game phases. Initially, in the opening phase, a higher mass value of 0.8908 indicates significant challenges and uncertainties. As the game advances to the middlegame phase, a marginal decrease in mass to 0.8843 suggests a reduction in difficulty, reflecting players' adaptive strategies and problem-solving skills (Newell and Simon, 1972). By the endgame phase, the lowest mass value of 0.8768 signifies a further reduction in uncertainty, indicating that players have effectively navigated the game's complexities and optimized their performance through strategic mastery.

Acceleration values across the game phases provide insights into the rate of change in success rates. During the opening phase, the moderate acceleration value of 0.0356 suggests initial adjustments by the players as they adapt to the game's demands. In the middlegame phase, the increased acceleration to 0.0366 indicates a rapid improvement in performance, potentially due to heightened cognitive and motor skills engagement. However, in the endgame phase, the decreased acceleration value of 0.0239 reflects a stabilization in performance, suggesting that players have reached a performance level where further improvements are incremental rather than rapid reflected by (Ericsson and Pool, 2016).

The force values represent the effort required by players to progress through the game. In the opening phase, the force value of 0.0317 indicates the initial effort needed to overcome early challenges. The increased force in the middlegame phase to 0.0324 reflects intensified competition and the necessity for greater exertion to maintain progress. By the endgame phase, the reduced force value of 0.0209 suggests that players have achieved a high level of proficiency, allowing them to navigate the game with less effort while sustaining high performance. This aligns with the concept of automaticity in skill acquisition, where skilled performance requires less conscious effort (Schneider and Chein, 2003).

Potential energy values highlight the stored engagement potential within each game phase. In the opening phase, the initial potential energy reflects the game's capacity to capture players' interest. As the game moves to the middlegame phase, the increased potential energy indicates growing player engagement. The highest potential energy in the endgame phase suggests maximum engagement, as players are deeply immersed in the gameplay, driven by the imminent resolution and outcomes of their efforts (Abuhamdeh and Csikszentmihalyi, 2012).

Momentum values signify the engaging force experienced by players. In the opening phase, the initial momentum value of 0.0973 represents the baseline level of player engagement. The increased momentum in the middlegame phase to 0.1023 suggests heightened engagement and competitive focus, as players refine their strategies and adapt to the evolving game dynamics. The peak momentum value of 0.1080 in the endgame phase denotes the highest level of player engagement, driven by the culmination of strategic play and the heightened significance of final outcomes. This reflects the players' deep immersion and sustained motivation, crucial for peak performance.

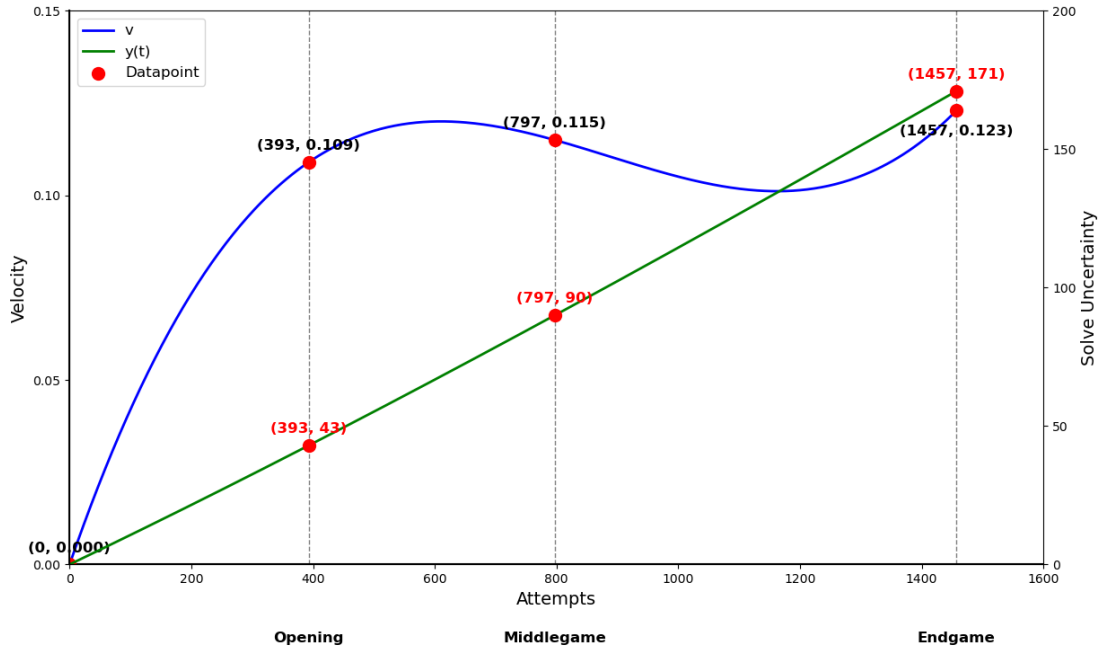


FIGURE 6. Velocity and Solve Uncertainty Across Game Phases in the FIFA World Cup 2022

Figure 6 provides a comprehensive analysis of the overall dynamics of the FIFA World Cup 2022, segmented into three game phases: opening, middlegame, and endgame. It illustrates key performance indicators, such as total goals velocity and solve uncertainty, in relation to the number of attempts made. The opening phase shows a steady increase in both total goals velocity and solve uncertainty, reflecting initial adaptation and significant challenges. The middlegame phase exhibits improved performance with increased velocity and heightened solve uncertainty, indicating competitive and challenging conditions. The endgame phase reaches peak velocity and maximum solve uncertainty, highlighting optimal performance and the culmination of strategic play. This analysis underscores the evolving nature of soccer dynamics throughout the FIFA World Cup 2022, providing valuable insights into the overall dynamics of soccer.

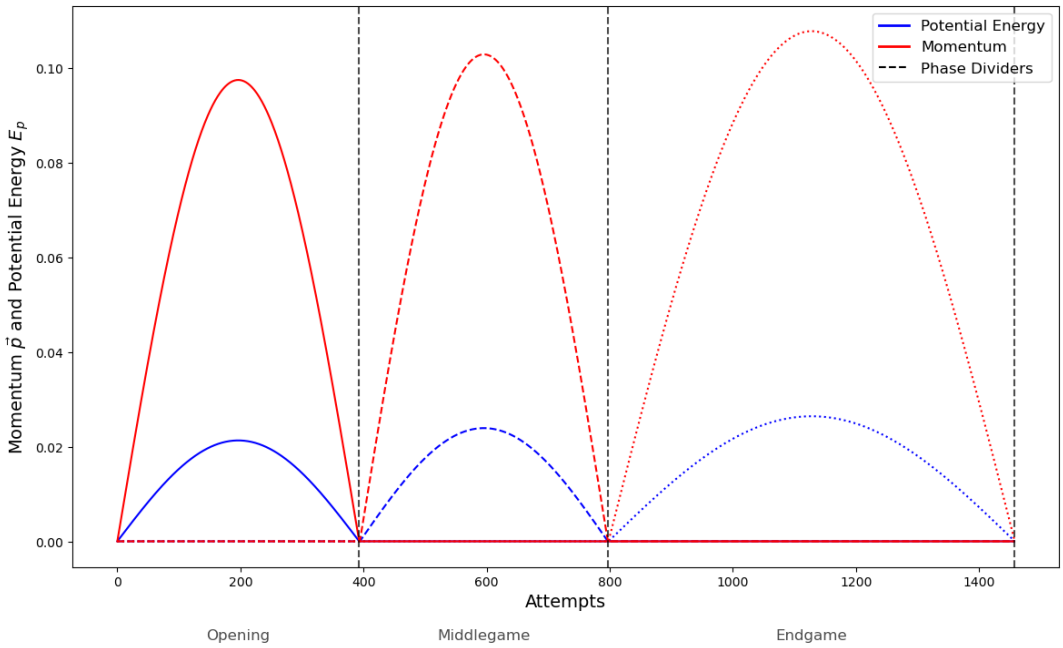


FIGURE 7. Momentum and Potential Energy Across Game Phases in the FIFA World Cup 2022

Figure 7 provides a detailed analysis of momentum and potential energy throughout the different phases of the FIFA World Cup 2022, segmented into opening, middlegame, and endgame phases. In the opening phase, both potential energy and momentum increase steadily, indicating significant team engagement and a high capacity to capture interest as teams adapt to the game. The middlegame phase shows an initial dip in both metrics followed by a rise, reflecting a period of adjustment and renewed energy as teams refine their strategies. The endgame phase peaks in both potential energy and momentum, with momentum reaching its highest value, demonstrating maximum team engagement and motivation as the game concludes. This figure highlights the dynamic nature of soccer performance, showing high engagement in the opening, a dip and recovery in the middlegame, and peak performance in the endgame, providing insights into the overall dynamics of the FIFA World Cup 2022 and emphasizing the importance of strategic adaptations for team success.

2. Argentina vs. France

Table 4 provides the Motion in Mind measures for the top two teams, Argentina and France, across the three game phases.

TABLE 2. Motion in Mind Measure of top two teams, Argentina and France

| Team | Phase | $v$ | $m$ | $a$ | $F$ | $E_p$ | $\vec{p}$ |
|---|---|---|---|---|---|---|---|
| Argentina | Opening | 0.15 | 0.849 | 0.105 | 0.089 | 0.032 | 0.127 |
| | Middlegame | 0.185 | 0.814 | 0.096 | 0.078 | 0.045 | 0.15 |
| | Endgame | 0.132 | 0.868 | 0.034 | 0.030 | 0.026 | 0.114 |
| France | Opening | 0.047 | 0.952 | 0.031 | 0.03 | 0.004 | 0.045 |
| | Middlegame | 0.222 | 0.777 | 0.115 | 0.089 | 0.059 | 0.172 |
| | Endgame | 0.166 | 0.833 | 0.043 | 0.036 | 0.038 | 0.138 |

2.1 Opening Phase

In the opening phase, Argentina exhibits a velocity (v) value of 0.1501, indicating a relatively high success rate of 15.01%. This suggests that Argentina's players are effectively converting a significant portion of their attempts into successful outcomes early in the game. In contrast, France's opening phase shows a velocity value of 0.0477, indicating a low success rate of 4.77%, suggesting initial struggles in converting attempts into successful outcomes. The mass (m) value for Argentina is 0.8499, reflecting a substantial level of difficulty or uncertainty, with 84.99% of attempts presenting significant challenges. Conversely, France's mass value of 0.9523 reflects a very high level of difficulty or uncertainty, with 95.23% of attempts being challenging. The acceleration (a) value for Argentina is 0.1050, indicating a high rate of improvement in performance, suggesting that Argentina is rapidly adjusting and enhancing their gameplay. France's acceleration value of 0.0318 suggests moderate improvements in performance. The force (F) value for Argentina is 0.0892, quantifying the considerable effort required to overcome initial challenges, reflecting intense competition. France's force value of 0.0303 similarly quantifies substantial effort required to overcome initial challenges. The potential energy ($E_p$) value for Argentina is 0.0325, signifying moderate engagement potential, indicating that the game can maintain player interest but has room for further engagement. In contrast, France's potential energy value of 0.0043 indicates low engagement potential, highlighting the need for greater player motivation and interest. The momentum (p) value for Argentina is 0.1275, representing a strong engaging force, demonstrating substantial player engagement and effective gameplay. France's momentum value of 0.0454 reflects minimal engagement and effectiveness.

2.2 Middlegame Phase

During the middlegame phase, Argentina's velocity increases to 0.1851, reflecting an improved success rate of 18.51%. This enhancement indicates that players are becoming more adept at converting attempts into goals, demonstrating increased familiarity with game dynamics and strategic adjustments. In contrast, France's velocity significantly improves to 0.2221, reflecting a high success rate of 22.21%. This indicates strong performance and strategic execution. The mass value for Argentina decreases to 0.8149, suggesting a reduction in difficulty to 81.49%,

as players effectively overcome initial challenges. France's mass value decreases to 0.7779, suggesting reduced difficulty as players effectively navigate challenges. The acceleration value for Argentina is 0.0961, indicating a steady rate of improvement, whereas France's acceleration value of 0.1151 indicates rapid improvements in performance. The force value for Argentina is 0.0783, still substantial but slightly decreased, reflecting ongoing but manageable competition. France's force value of 0.0895, though high, reflects the intense competition and effort required. The potential energy for Argentina increases to 0.0455, indicating higher player engagement and motivation, while France's potential energy increases to 0.0599, indicating even higher player engagement and motivation. The momentum for Argentina peaks at 0.1508, signifying the highest level of player engagement and effectiveness during this phase. France's momentum peaks at 0.1728, reflecting the highest level of player engagement and effectiveness during this phase.

2.3 Endgame Phase

In the endgame phase, Argentina's velocity decreases to 0.1320, indicating a reduced success rate of 13.20%. This suggests that performance effectiveness declines as the game progresses. Conversely, France maintains a high velocity value of 0.1667, indicating a success rate of 16.67%. The mass value for Argentina increases to 0.8680, reflecting higher levels of difficulty or uncertainty. France's mass value of 0.8333 reflects manageable challenges, with the difficulty level being lower than in earlier phases. The acceleration value for Argentina is 0.0349, indicating a significant reduction and suggesting stabilization or a performance plateau. France's acceleration value of 0.0433 indicates stabilization in performance. The force value for Argentina decreases to 0.0303, indicating less effort required due to increased proficiency in managing endgame challenges. France's force value of 0.0361, though moderate, reflects efficiency in managing endgame challenges. The potential energy for Argentina decreases to 0.0264, reflecting reduced engagement potential, while France's potential energy value of 0.0387 suggests sustained player interest and motivation. The momentum value for Argentina decreases to 0.1147, indicating lower engagement compared to the middlegame phase. France's momentum remains high at 0.1389, indicating strong engagement and performance effectiveness.

2.4 Comparative Analysis in the Competitive Context

In the competitive context of Argentina's World Cup victory, the detailed analysis of key performance metrics reveals how both teams navigated the tournament's demands, culminating in Argentina's triumph.

2.5 Argentina's Performance

Argentina's high initial success rate in the opening phase set a strong foundation for their performance, with players quickly adapting and overcoming early challenges. Their peak performance in the middlegame phase, characterized by the highest momentum and increased engagement, was crucial for building and maintaining a competitive edge. Despite a slight

decline in the endgame phase, Argentina's ability to manage challenges with reduced effort and sustained proficiency contributed significantly to their overall success.

## 2.6 France's Performance

France, while showing substantial improvement in the middlegame phase with rapid acceleration and high success rates, struggled in the opening phase, which may have impacted their overall momentum. Although their endgame performance remained strong, with high engagement and effective management of challenges, it was not sufficient to overcome Argentina's consistent and strategically sound gameplay.

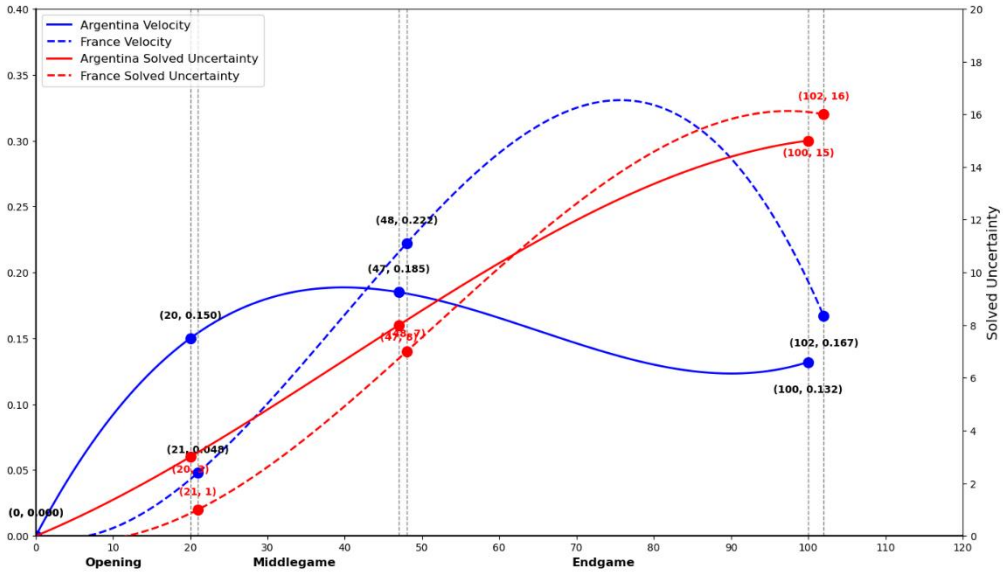


FIGURE 8. Comparative Analysis of Velocity and Solved Uncertainty Between Argentina and France Across Game Phases in the FIFA World Cup 2022

Figure 8 provides a comparative analysis of the performance dynamics of Argentina and France throughout the different phases of a soccer match: opening, middlegame, and endgame. It illustrates key performance indicators, such as velocity and solved uncertainty, in relation to the number of attempts made by each team. In the opening phase, Argentina demonstrates a higher initial velocity and lower solved uncertainty compared to France, indicating a better adaptation to the game. During the middlegame phase, both teams show increased velocity, with Argentina slightly outperforming France in terms of success rate but facing significant challenges as indicated by solved uncertainty. In the endgame phase, both teams reach similar velocity peaks, yet Argentina encounters the highest level of solved uncertainty, reflecting intense competition and strategic complexities. This figure highlights the evolving performance dynamics and challenges faced by both teams, emphasizing the critical importance of understanding performance metrics and strategic adaptations to enhance team success in competitive soccer.

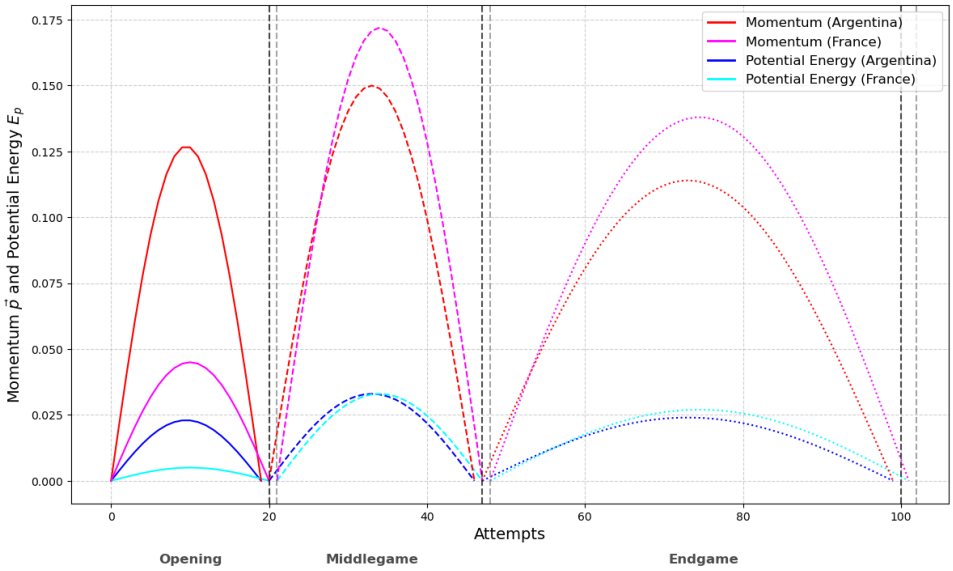


FIGURE 9. Comparative Analysis of Momentum and Potential Energy Between Argentina and France Across Game Phases in the FIFA World Cup 2022

Figure 9 provides a comparative analysis of the momentum and potential energy dynamics of Argentina and France throughout the different phases of a soccer match: opening, middlegame, and endgame. In the opening phase, Argentina exhibits higher momentum and potential energy compared to France, indicating significant engagement and stored energy early in the game. During the middlegame phase, both teams show increased momentum and potential energy, with France slightly outperforming Argentina in terms of momentum, reflecting heightened engagement and strategic refinement. In the endgame phase, both teams reach peaks in momentum and potential energy, with France maintaining higher levels of momentum, indicating maximum engagement and competitive focus as the match concludes. This comparative analysis highlights the evolving performance dynamics and strategic adaptations of both teams, emphasizing the importance of understanding these metrics for optimizing team performance and strategy in competitive soccer.

Key Factors Leading to Argentina's Victory

- Consistent High Performance: Argentina maintained a relatively high success rate throughout all phases, particularly excelling in the middlegame.
- Effective Strategic Adjustments: Rapid acceleration in the opening phase and strategic improvements in the middlegame allowed Argentina to build momentum.
- Proficiency in Managing Challenges: Despite a slight decline in the endgame, Argentina's ability to handle difficulties with reduced effort was pivotal.

## DISCUSSION

The analysis of the FIFA World Cup 2022 using the Motion in Mind (MiM) model provides valuable insights into the dynamics of team performance across different game phases. By examining key performance metrics such as velocity, mass, acceleration, force, potential

energy, and momentum, this study sheds light on the strategic adaptability and effectiveness of teams, particularly Argentina and France, throughout the tournament.

1. Understanding Phase-Specific Dynamics

The phase-specific analysis revealed distinct patterns in team performance dynamics. The opening phase showed lower velocity and higher mass values, indicating that teams faced significant challenges and uncertainties as they adjusted to the game environment. This initial phase is crucial for setting the tone of the match, as teams deploy their opening strategies and gauge their opponents' tactics.

As the game progressed into the middlegame phase, an increase in velocity and a corresponding decrease in mass were observed. This phase is characterized by heightened strategic play and adaptation, as teams refine their tactics based on the unfolding match dynamics. The increased acceleration values during this phase suggest that teams were rapidly improving their performance, leveraging both cognitive and motor skills to enhance their gameplay. The force values during the middlegame phase indicated intensified competition, requiring greater exertion and strategic depth.

In the endgame phase, the velocity values peaked, reflecting optimal performance as players utilized their accumulated experience and refined strategies. However, the reduction in acceleration suggests a stabilization of performance, where further improvements were incremental. The force values decreased, indicating that players had reached a high level of proficiency, allowing them to manage the game's complexities with less effort. This phase is critical for determining the match outcome, as teams push for decisive goals while maintaining strategic control.

2. Comparative Analysis of Argentina and France

The comparative analysis of Argentina and France highlighted the strategic differences that influenced their tournament outcomes. Argentina's consistent high performance across all phases, particularly in the middlegame, was pivotal to their success. Their ability to quickly adapt and overcome early challenges set a strong foundation, and their peak momentum in the middlegame phase allowed them to build and maintain a competitive edge. Despite a slight decline in the endgame phase, Argentina's proficiency in managing challenges with reduced effort ensured their overall victory.

France, on the other hand, exhibited substantial improvement in the middlegame phase, with rapid acceleration and high success rates. However, their initial struggles in the opening phase impacted their overall momentum. While France's endgame performance remained strong, with high engagement and effective challenge management, it was insufficient to overcome the consistent and strategically sound gameplay of Argentina. This underscores the importance of a strong start and the ability to adapt quickly in competitive sports.

### 3. Strategic Implications and Practical Applications

The findings of this study have significant strategic implications for coaches, analysts, and players. Understanding the dynamics of different game phases can inform more effective training programs and match strategies. Coaches can focus on enhancing players' adaptability and decision-making skills, particularly in the crucial opening and middlegame phases. Emphasizing cognitive and motor skill development can lead to rapid performance improvements, as indicated by the increased acceleration values during the middlegame.

Additionally, the MiM model's metrics can be used to monitor and assess player engagement and effort throughout a match. By analyzing force and potential energy values, coaches can identify periods where players may require strategic substitutions or motivational interventions to maintain high levels of performance and engagement.

Beyond soccer, the application of the MiM model offers a robust framework for analyzing performance dynamics in other time-limited sports. The phase-specific approach can be adapted to various sports contexts, providing insights into how teams strategize and adapt throughout different stages of a competition. This can enhance the understanding of sports dynamics and contribute to the design of more engaging and competitive sporting events.

## CONCLUSION

This study provides a comprehensive analysis of soccer dynamics using the Motion in Mind (MiM) model, with a particular focus on the FIFA World Cup 2022. By examining key performance metrics across different phases of the game opening, middlegame, and endgame we have gained valuable insights into the strategic adaptations and dynamics. Teams exhibited distinct performance patterns across the three game phases. The opening phase was characterized by higher challenges and uncertainties, as reflected by lower velocity and higher mass values. In contrast, the middlegame phase showed improved success rates and strategic adaptations, with increased velocity and decreased mass. The endgame phase highlighted optimal performance levels, with peak velocity and stabilized acceleration, indicating refined strategies and effective execution. Furthermore, in the strategic adaptability, Argentina’s consistent high performance across all phases, especially during the middlegame, was a key factor in their championship victory. Their ability to quickly adapt and overcome early challenges set a strong foundation for success. In contrast, France’s significant improvement in the middlegame, though notable, was insufficient to counterbalance their initial struggles in the opening phase. The findings underscore the importance of understanding and leveraging phase-specific dynamics to optimize team performance. Coaches and analysts can utilize these insights to develop more effective training programs and match strategies, emphasizing rapid adaptability and strategic depth during the crucial opening and middlegame phases.

While this study provides valuable insights, it is based on data from a single tournament—the FIFA World Cup 2022. This limitation may affect the generalizability of the findings. The unique conditions and competitive environment of the World Cup may not be representative

of other tournaments or regular league matches. Additionally, the dataset created for this study, though comprehensive, may not capture all possible variables influencing team performance and dynamics.

Future research should explore longitudinal studies across multiple tournaments and leagues to validate and extend the findings of this study. Expanding the scope of analysis to include diverse sports contexts will further validate the MiM model's applicability and enrich our understanding of competitive sports dynamics in different phases. Additionally, future studies could incorporate more detailed player-specific metrics, such as physical and psychological factors, to provide a more holistic view of performance dynamics.

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