ORIGINAL ARTICLE

Dynamics of collective organization during and across successive momentum phases in elite football matches

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ABSTRACT

Purpose: Recent research (Gautier et al., 2024) has identified collective organization patterns associated with momentum phases in elite football. However, how these patterns evolve remains unknown. The present study aimed to identify their dynamics during momentum phases and across their succession in football matches. Method(s): Based on expert coaches' video-based descriptions of football teams experiencing positive than negative momentum (or vice versa) phases, qualitative patterns were classified according to score evolution. Results: Over the positive-then-negative momentum scenario, the frequency of patterns of "*stretched block*", "*disconnected actions*", "*ball carrier far from direct opponent*," and "*backward defensive runs*" increased, whereas the frequency of patterns of "*forward block*", and "*compact block*" decreased. Over the negative-then-positive momentum scenario, the frequency of patterns of "*connected actions*," "*defenders close to the ball carrier*", and "*forward offensive and defensive runs*" increased, whereas the frequency of patterns of "*compact block*", "*forward block*", "*forward offensive runs*", and "*forward defensive runs*" exhibited an increase that began even before the momentum phase transition. Conclusion(s): These findings suggest that some patterns may act as precursors or triggers of momentum transitions. Whatever the answer, these patterns can be used by coaches and players as warning signals of impending momentum transition.
Keywords: Behavioural dynamics, Collective organization, Momentum, Qualitative analysis, Team sports.

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INTRODUCTION

In sport, momentum is a multidimensional dynamics that is highly sensitive to the history of ongoing events (Gernigon et al., 2010). This dynamics, whether positive or negative, involves cognitive, affective, motivational, and physiological dimensions, as well as the behavioural responses of athletes experiencing it (Taylor & Demick, 1994). Research that has explored the relationships between momentum and athletic performance mainly focused on the individual experience of momentum (e.g., Briki et al., 2012a; Briki et al., 2012b; Briki et al., 2013; Briki et al., 2014; Den Hartigh & Gernigon, 2018; Den Hartigh et al., 2016; Gernigon et al., 2010; Perreault et al., 1998; Vallerand et al., 1988). In contrast, collective momentum, or team momentum, remains understudied.

Adopting a collective unit of analysis implies considering a team "*as an aggregate organism whose behaviour is functionally similar to that of an individual subject*" (Mace, Lalli, Shea, & Nevin, 1992, p. 662). Taylor and Demick (1994) proposed a multidimensional cascade model of momentum applicable to both individual athletes and teams. According to this model, specific in-game events trigger cognitive, affective, and physiological changes, which in turn alter players' behaviour, subsequently influencing the performance of both their team and the opposing team, in opposite directions. Events such as game interruptions (Weimer et al., 2023) and score changes (Den Hartigh et al., 2020; Jones & Harwood, 2008; Taylor & Demick, 1994) have been identified as major determinants of the experience of team momentum in sports. While the relationship between such events and team momentum experience is becoming well documented, how this experience translates into collective behaviour remains underexplored.

A few studies have qualitatively highlighted the impact of unfavourable score evolution on intra-team interactions during collective collapse (Apitzsch, 2009; Wergin et al., 2018). Den Hartigh et al. (2014) investigated the effects of positive and negative momentum experiences on interpersonal synchronization within rowing dyads experimentally placed in competition against virtual opponent dyads on ergometers. Positive and negative momentum were associated with increased and decreased rowers' perception of cohesion, respectively. Behaviourally, synchronization within dyads was lower and less stable in the negative momentum condition than in the positive momentum conditions. While these findings provide initial insights into the effects of momentum experiences on synchronization and cohesion within teams, their limitation to dyadic interactions calls for extending the investigation to collective organization in team sports.

In a recent study (Gautier et al., 2024), patterns of collective organization in elite football teams were qualitatively identified as specific to positive or negative momentum experiences defined as significant and gradual score variations. These organizational patterns were classified into three levels: macroscopic (global team level), mesoscopic (within-line player groups), and microscopic (individual players). Key findings revealed that positive momentum phases were associated with a team block (i.e., position of the players of a team without the goalkeeper) that was compact (i.e., lines of players close to each other) and forward-positioned (i.e., the spatial arrangement of all players in front of the longitudinal axis of the field), with players often making forward runs (i.e., without-the-ball runs toward the opponent's goal) both when their team is in possession of the ball (offensive phase) and when their team is not in possession of the ball (defensive phase).

Conversely, negative momentum phases were linked to a stretched (i.e., lines of players far to each other) and backward-positioned (i.e., the spatial arrangement of all players behind the longitudinal axis of the field) team block, frequent defensive backward runs (i.e., without-the-ball runs toward one's goal) and

disconnected individual actions (i.e., Action of players unrelated to the action of other players in the same line).

The results from Gautier et al. (2024) were derived from comparisons between different grouped phases of positive momentum and grouped phases of negative momentum. As such, they did not address one of the most distinctive properties of momentum: its dynamic nature (Gernigon et al., 2010). How collective organization patterns evolve within a team during the development of a single type of momentum or across transitions between types of momentum (e.g., from positive to negative or vice versa) remains unexplored. The present study, a follow-up to Gautier et al.'s (2024), aims to identify the dynamics of collective organization in elite football teams during the development of positive momentum phases followed by negative momentum phases (or vice versa). Using an exploratory approach and consistent with Gautier et al. (2024), collective organizational patterns at macroscopic, mesoscopic, and microscopic levels will serve as reference frameworks for identifying variations throughout gradual and temporal score developments.

In teams experiencing a positive-to-negative momentum sequence (PM-NM sequence), patterns identified by Gautier et al. (2024) as associated with positive momentum were expected to increase in frequency over the positive momentum phase and then decrease until disappearing over the negative momentum phase. The patterns concerned are forward block, compact block, connected actions (i.e., Action of players unrelated to the action of other players in the same line), defenders close to the ball carrier, forward offensive and defensive runs. Conversely, patterns previously identified as associated with negative momentum were expected to appear and then increase in frequency only over the negative momentum phase. The patterns concerned are backward block, stretched block, disconnected actions, defenders far from the ball carrier, backward offensive and defensive runs. The opposite dynamics were expected for teams experiencing a negative-to-positive momentum sequence (NM-PM sequence).

MATERIALS AND METHODS

Participants

The present study covers the two international matches featuring significant comebacks examined by Gautier et al. (2024). One match was the 2005 UEFA Champions League final between AC Milan and Liverpool FC, where Liverpool won in a penalty shootout after recovering from a 0-3 deficit to 3-3. The other match was a 2012 World Cup qualifier between Germany and Sweden, which ended in a 4-4 draw after Sweden overcame a 0-4 deficit. A total of 56 male professional players participated in these matches. In Gautier et al. (2024), patterns of collective organization associated with positive and negative momentum phases were identified and counted from match videos by four expert football coaches. For the present study, these qualitative data were reorganized based on the score evolution of each team by the first author, a former professional football player and expert football coach. This reorganization, based on previously identified data, minimizes subjectivity.

Procedure

The data used were the patterns of collective organization identified at macroscopic, mesoscopic, and microscopic levels by Gautier et al. (2024). For this study, these data were categorized by their occurrence timing and classified according to each match's score evolution.

RESULTS

Occurrences of collective organization patterns are presented separately for PM-NM (AC Milan and Germany) and NM-PM (Liverpool FC and Sweden) scenarios.

PM-NM Scenario

For both PM-NM teams, some patterns were either absent or exhibited no specific temporal differentiation. Such is the case for the "*connected action*" pattern which was not detected for either AC Milan nor Germany. The "*defenders close to the ball carrier*" pattern was not observed for AC Milan but was detected for Germany during the positive momentum phase. Similarly, the pattern "*backward offensive run*" did not appear for AC Milan but occurred during both positive and negative momentum phases for Germany.

Other patterns showed temporal differentiation over the course of the PM-NM sequence, but only for one of the two PM-NM teams. Such is the case for the "*backward block*" pattern which increased in frequency for AC Milan by the end of the positive momentum phase to become prevalent during the negative momentum phase, while its occurrences remained relatively stable across momentum phases for Germany.

Some patterns exhibited opposing distributions between the two teams. The frequency of "*forward offensive runs*" decreased from the positive momentum phase to the negative momentum phase for AC Milan, while it increased during the same transition for Germany.

Table 1A. AC Milan. Summary of the occurrences and temporal distributions of organizational patterns for the two PM-NM teams.

Levels of Collective Organization *Dimensions* Themes	**Positive Momentum (*n*)**			**Negative Momentum (*n*)**		
Scoring	1/0	2/0	3/0	3/2	3/3	3/3
Timing	0'–1'	30'–44'	45'–53'	54'–59'	60'–75'	76'–90'
Macroscopic Level						
Longitudinal position of the team block						
Forward Block		2				
Backward Block			2	18		
Mesoscopic Level						
Team Block Compactness						
Compact Block		4		3		
Stretched Block					6	
Team Block Connectivity						
Connected Actions						
Disconnected Actions				12	4	
Microscopic Level						
Ball Carrier – Nearest Opponent Distance						
Ball Carrier Close to Direct Opponent						
Ball Carrier Far from Direct Opponent				9	1	
Without-ball Offensive Runs						
Toward Attacked Goal			4			
Non-goal-oriented Runs						
Toward Defended Goal						
Without-ball Defensive Runs						
Toward Attacked Goal		15	5	1		
Non-goal-oriented Runs				3		
Toward Defended Goal		3		5	5	

Table 1B. Germany. Summary of the occurrences and temporal distributions of organizational patterns for the two PM-NM teams.

Levels of Collective Organization								
Dimensions	**Positive Momentum (*n*)**				**Negative Momentum (*n*)**			
Themes								
Scoring	1/0	2/0	3/0	4/0	4/1	4/2	4/3	4/4
Timing	0'–8'	9'–15'	30'–45'	46'–62'	63'–64'	65'–76'	77'–89'	90'–93'
Macroscopic Level								
Longitudinal position of the team block								
Forward Block		1	3					
Backward Block			1	2		1	1	
Mesoscopic Level								
Team Block Compactness								
Compact Block		1	3					
Stretched Block					1	15	6	
Team Block Connectivity								
Connected Actions								
Disconnected Actions						6	22	
Microscopic Level								
Ball Carrier – Nearest Opponent Distance								
Ball Carrier Close to Direct Opponent		3	1					
Ball Carrier Far from Direct Opponent					5	1	12	
Without-ball Offensive Runs								
Toward Attacked Goal						1		
Non-goal-oriented Runs						2	6	
Toward Defended Goal				1			1	
Without-ball Defensive Runs								
Toward Attacked Goal		3	2					
Non-goal-oriented Runs					4	2	6	
Toward Defended Goal						2		

Some patterns increased in frequency from the positive momentum phase to the negative momentum phase. For both AC Milan and Germany, the occurrences of "*stretched block*," "*disconnected actions*," "*ball carrier far from direct opponent*," and "*backward defensive runs*" were either absent or rare during the positive momentum phase but became increasingly frequent and sometimes numerous during the negative momentum phase.

Finally, some patterns decreased in frequency during the PM-NM sequence. For both AC Milan and Germany, the "*forward block*" pattern was observed only during the positive momentum phase. Similarly, the "*compact block*" pattern was more frequently observed during the positive momentum phase than during the negative momentum phase for both teams. Furthermore, the decline in occurrences of certain patterns sometimes began by the end of the positive momentum phase and continued during the negative momentum phase. This is the case for "*forward defensive runs*", which were most frequent at the start of the positive momentum phase for both AC Milan and Germany, but became increasingly rare, disappearing entirely by the end of the positive momentum phase or the beginning of the negative momentum phase.

NM-PM Scenario

For both NM-PM teams, no occurrences of the pattern "*backward offensive runs*" were observed. Some patterns showed an increase in frequency from the negative momentum phase to the subsequent positive momentum phase. For both Liverpool FC and Sweden, the occurrences of the patterns "*connected actions*," "*defenders close to the ball carrier*", increased during the transition from negative to positive momentum phases.

Table 2A. Liverpool FC. Summary of the occurrences and temporal distributions of organizational patterns for the two NM-PM teams.

Levels of Collective Organization						
Dimensions	**Negative Momentum (*n*)**			**Positive Momentum (*n*)**		
Themes						
Scoring	0/1	0/2	0/3	2/3	3/3	3/3
Timing	0'–1'	30'–44'	45'–53'	54'–59'	60'–75'	76'–90'
Macroscopic Level						
Longitudinal position of the team block						
Forward Block			1	3	2	
Backward Block		4	4			
Mesoscopic Level						
Team Block Compactness						
Compact Block			1	6		
Stretched Block		7	4			
Team Block Connectivity						
Connected Actions			1	2	2	
Disconnected Actions		11	8			
Microscopic Level						
Ball Carrier – Nearest Opponent Distance						
Ball Carrier Close to Direct Opponent				4	1	
Ball Carrier Far from Direct Opponent		13	1			
Without-ball Offensive Runs						
Toward Attacked Goal		1	1	1	5	
Non-goal-oriented Runs		7	3			
Toward Defended Goal						
Without-ball Defensive Runs						
Toward Attacked Goal		1	1	3		
Non-goal-oriented Runs		3	5			
Toward Defended Goal		3	2			

Table 2B. Sweden. Summary of the occurrences and temporal distributions of organizational patterns for the two NM-PM teams.

Levels of Collective Organization								
Dimensions	**Negative Momentum (*n*)**				**Positive Momentum (*n*)**			
Themes								
Scoring	0/1	0/2	0/3	0/4	1/4	2/4	3/4	4/4
Timing	0'–8'	9'–15'	30'–45'	46'–62'	63'–64'	65'–76'	77'–89'	90'–93'
Macroscopic Level								
Longitudinal position of the team block								
Forward Block			2		3	7		
Backward Block		8	2					
Mesoscopic Level								
Team Block Compactness								
Compact Block			2		1	6	2	
Stretched Block			1					
Team Block Connectivity								
Connected Actions						3	2	
Disconnected Actions		9	14	1		3		
Microscopic Level								
Ball Carrier – Nearest Opponent Distance								
Ball Carrier Close to Direct Opponent					3	8	3	
Ball Carrier Far from Direct Opponent		13	14					
Without-ball Offensive Runs								
Toward Attacked Goal			1		1	17	9	
Non-goal-oriented Runs		7						
Toward Defended Goal								
Without-ball Defensive Runs								
Toward Attacked Goal				2	4	11	13	
Non-goal-oriented Runs		4	6	1				
Toward Defended Goal			5					

Other patterns exhibited an increase in frequency even before the momentum phase transition. Occurrence of patterns "*compact block*", "*forward block*" and "*forward offensive and defensive runs*" for both Liverpool FC and Sweden began to increase during the negative momentum phase, and this trend continued or even intensified during the subsequent positive momentum phase.

Some patterns, however, saw their occurrences decrease from the negative momentum phase to the positive momentum phase for both teams. Specifically, for Liverpool FC and Sweden, the occurrences of the patterns "*backward block*", "*stretched block*", "*disconnected actions*", "*ball carrier far from direct opponent*", and "*backward defensive runs*" declined significantly or disappeared entirely during the transition from the negative to the positive momentum phase.

DISCUSSION

The aim of the present study was to identify the dynamics of collective organization in elite football teams during the development of positive (or negative) momentum phases and across the succession of opposing momentum phases (from positive to negative or vice versa). For some collective organizational patterns, it was not possible to interpret typical evolutions due to either the absence of occurrences (e.g., PM-NM scenarios: "*ball carrier close to direct opponent*"; NM-PM scenarios: "*backward offensive runs*") or a limited number of changes in occurrences (e.g., PM-NM scenarios: "*backward block*", "*backward offensive run*", and "*non-goal-oriented offensive runs*"), or divergent evolutionary trends between the two teams experiencing the same momentum sequence (e.g., "*forward offensive runs*"). However, other collective organizational patterns, whether macroscopic, mesoscopic, or microscopic, exhibited interpretable dynamics.

The backward-positioned block, a macroscopic collective organizational pattern, emerged even when the team led significantly during the positive momentum phase and persisted over the subsequent negative momentum phase. This positioning, characterized by Gautier et al. (2024) as typical of negative momentum phases, can be interpreted as a behavioural manifestation of a team's defensive intentions (Gréhaigne et al., 1997). Such positioning is commonly observed in teams facing superior opponents (Fernandez-Navarro et al., 2018; Vogelbein et al., 2014). Thus, the leading team behaves as if its opponent were superior.

Regarding mesoscopic collective organizational patterns, the "*stretched block*" showed a notable increase during PM-NM scenarios. The widening of distances between players is a marker of team disorganization, as evidenced by Folgado et al. (2012). Similarly, "*disconnected actions*" increased during this transition. These uncoordinated player actions reflect the team's difficulty in functioning as an integrated unit (Araujo & Bourbousson, 2016), likely due to breakdowns in verbal and non-verbal communication between players (Higham & Harwood, 2005).

Furthermore, ineffective microscopic collective organizational patterns emerged during the PM-NM scenario. For example, the increase in defensive patterns such as "*ball carrier far from direct opponent*" highlights this trend, as defensive players distanced themselves from the ball carrier, allowing them greater freedom to initiate offensive actions. This passivity facilitates scoring opportunities for the opposing team (Gónzalez-Rodenas et al., 2016). Similarly, "*backward defensive runs*" increased, which reflects defenders' retreat toward their own goal and reduce their ability to recover the ball and launch counterattacks effectively (Cooper & Pulling, 2020; Gónzalez-Rodenas et al., 2016; Hughes & Lovell, 2019). Finally, the increase in backward defensive runs during the PM-NM scenarios caused the team block to adopt a lower position on the field. Despite still leading in the score, the team adopted a defensive posture, with players retreating and failing to advance into the field of play (Higham & Harwood, 2005). This behaviour may reflect intentions such as

performance-avoidance goals that have been found to be associated with negative momentum experiences (Briki et al., 2012). However, the appearance of this pattern at the end of positive momentum phases (i.e., when the team leads significantly) is surprising. It could either be a warning signal of the impending momentum reversal or one of its triggering factors, as highly positive momentum might lead players to relax their offensive pressure, feeling secure against a comeback (Higham & Harwood, 2005).

When the negative momentum phase was followed by a positive momentum phase within the same match, the forward-positioned team block—a macroscopic organizational pattern—emerged at the end of the negative momentum phase and became more frequent during the subsequent positive momentum phase. This observation corroborates the findings of Gautier et al. (2024), who showed that a forward-positioned team block was specific to positive momentum phases and could represent a behavioural manifestation of a team's offensive intentions (Gréhaigne et al., 1997). Such intentions, in the form of performance-approach goals, have been found to be linked to positive momentum experiences (Briki et al., 2012; Gernigon et al., 2010). These observations also apply to microscopic organizational patterns, particularly with respect to the direction of defensive runs. Players started to move forward on the pitch when defending in the initial negative momentum phase and did so even more during the following positive momentum phase, thus exerting pressing on the opposing team to disrupt their play construction (Frencken et al., 2012). This result, consistent with the findings concerning forward-positioned team blocks, aligns with Gautier et al.'s (2024) observations, which evidenced an association between forward-oriented runs and positive momentum experiences. It also confirms that offensive intentions, for instance in the form of performance-approach goals, are typically associated with positive momentum experiences (Briki et al., 2012; Gernigon et al., 2010). The added value brought by the present finding is that, in team sports, this happens even when a team does not possess the ball.

The anticipated occurrence—toward the end of negative momentum—of a forward-positioned team block raises questions about its status as a precursor or a triggering factor for the momentum transition. This issue also applies to block compactness. Compact team blocks occasionally appeared during the negative momentum phase, developing more prominently in the subsequent positive momentum phase. While Gautier et al. (2024) showed the association between compact blocks and positive momentum experiences, the occurrence dynamics of this pattern reveals a progression that begins before the appearance of the positive momentum phase. This raises questions about its role in momentum transitions.

In summary, the present findings indicate that collective organizational patterns evolve differently based on score progression within momentum phases and across successive momentum phases experienced by teams. While adaptive behavioural patterns appeared more frequently during positive momentum phases, as reported by Gautier et al. (2024), these patterns were often present, to a lesser extent, at the end of the preceding negative momentum phase. Conversely, a few maladaptive patterns were observed at the end of positive momentum phases and subsequently developed during negative momentum phases.

Several interpretations can be explored to explain the anticipatory nature of some behavioural patterns for upcoming momentum phases. First, the presence of a pattern typically associated with the opposite momentum type during a given phase could signify an early manifestation of a new momentum phase. Alternatively, the early appearance of such a pattern might indicate a causal relationship, with the pattern acting as a trigger for the new momentum type. In both cases, the momentum experience would not be strictly demarcated by score variations but would begin before the first score reduction. Instead, score progression might serve as a possible consequence of an already initiated momentum phase. Therefore, this hypothesis challenges the commonly accepted notion that score evolution is a key determinant of momentum

experiences (e.g., Briki et al., 2012; Jones & Harwood, 2008; Taylor & Demick, 1994). While a goal scored against the run of play could plausibly trigger momentum, it is likely that in the amplifying spiral of momentum experiences (Briki et al., 2012), score evolution functions as both an antecedent and a consequence of momentum.

Beyond the question of whether the egg (scoring) or the chicken (the momentum experience) comes first, counterfactual behavioural patterns relative to an ongoing momentum phase may correspond to reactions to that phase. For example, the occurrence of adaptive patterns during a negative momentum phase preceding a positive momentum phase could reflect phenomena such as negative facilitation (Cornelius et al., 1997; Perreault et al., 1998; Silva et al., 1988) or reactance (Brehm, 1972). Negative facilitation involves increased effort to compensate for a temporary failure, while reactance corresponds to an effort to regain control over a situation perceived as slipping away. Both negative facilitation and reactance have been observed during negative momentum experiences in sports settings (Briki et al., 2012; Briki et al., 2013; Perreault et al., 1998).

Conversely, the occurrence of maladaptive patterns during a positive momentum phase preceding a negative momentum phase could reflect phenomena such as positive inhibition (Silva et al., 1988) or coasting (Carver, 2003). These involve a form of relaxation stemming from the perception that substantial progress has been made toward achieving a goal, rendering its attainment seemingly inevitable. This relaxation phenomenon, which can negatively impact performance (Adler, 1981), has also been observed during positive momentum experiences in sports (Briki et al., 2012; Briki et al., 2013; Perreault et al., 1998).

From an applied perspective, regardless of the hypothesis adopted to explain the presence of counterfactual patterns during a momentum phase, these patterns can serve as warning signals for players and coaches about an impending momentum transition. On one hand, recognizing behavioural patterns indicative of an upcoming positive momentum phase can facilitate a psychological transition toward cognitive (e.g., attention, efficacy beliefs), affective (e.g., hope), and motivational states (e.g., effort intentions, determination) conducive to adaptive behavioural modifications (e.g., increased effort, improved interpersonal coordination). On the other hand, recognizing behavioural patterns that signal an impending negative momentum phase can highlight the need to intensify efforts to maintain adaptive states. Identifying these counterfactual patterns thus constitutes a valuable help for both coaches' and players' decision-making and behaviour-change (Higham et al., 2005). The ability to recognize these patterns is a skill that should be specifically developed through training.

CONCLUSION

This study is the first to examine the evolution of collective organizational patterns in teams experiencing two distinct momentum phases (positive and negative) within a single football match. The primary limitation of this research lies in the difficulty of obtaining exploitable video footage of matches featuring such scenarios, resulting in a small sample size (n = 4) of analysed teams. Consequently, the findings should currently be interpreted within the context of these matches and cannot be generalized. Replicating this study with other teams experiencing both comeback and collapse scenarios in the same match would help confirm or refute the observed trends. Additionally, the present study focused on the objective (scoring) and behavioural dimensions of momentum (Hubbard, 2015). Behavioural momentum has often been shown to precede objective momentum. In future research, it would be interesting to examine whether a team's behavioural momentum experience is itself preceded by psychological momentum experiences at the individual player level (Hubbard, 2015).

AUTHOR CONTRIBUTIONS

Gautier, Cavailles and Gernigon wrote the paper and collected the data. All authors approved the final submission.

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