An Agent-Based Model of Emotion Contagion and Group Identification: A Case Study in the Field of Football Supporters

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Abstract. When people who strongly identify with different competitive groups meet, this can result in negative affect and aggression. A significant body of work has applied agent-based modelling to study the spread of emotions in the crowds, called emotion contagion. Although some of these models consider the effect of pre-existing social relationships, this is mostly limited to dyadic relationships (e.g. friends) or clearly defined roles (e.g. police-civilian). In the present study we propose an extension of the agent-based model DECADE, that combines emotion contagion with continuous variation in how much an agent identifies with a group. We explore the spread of aggression among football supporters in the form of pitch invasions, in which spectators enter the playing field illegally. We test management strategies that alter the supporter composition on the stands with regards to placement (separating by teams and/or fanaticism) and composition (stadium bans, limiting the promotion of identification). The results show that measures that decrease the number of fanatics, or that promote a balanced mix regarding group identification, decrease collective aggression. Finally, the model is evaluated against recent footage and descriptions of a real pitch invasion. The simulations resembled the real incident in several behavioural patterns, but not all. We conclude that further research is required to determine which individual traits and processes are essential in simulating collective aggression among competitive groups, to come to a model that can be employed in society.

Keywords: Emotion contagion · Group identification · Crowd simulation · Supporter aggression · Agent-based model

1 Introduction

Group-based conflict and aggression are universal phenomena across societies and encompass many forms of groups [1]. Social identity theory offers an explanation for this behaviour by pointing to the nature of people to automatically identify with groups via self-categorisation, via which they develop a social identity that favours their own group in comparison to other groups [2]. By identifying with a group, the group becomes to an extent part of the psychological self, such that events that affect the group are also felt by the individual. People who identify stronger with a group are more susceptible

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for shared sentiment and empathy for group members compared to people outside the group [3, 4]. They are also more likely to interpret events that impact the group as if these were directed to themselves, feeling for example success and failure of the group as their own [3].

A familiar example of group identification is in supporting sports teams in competitive games as a viewer. Identifying with a team as a spectator is commonplace, and sports clubs aim to foster this process since it is an important driver for consumption [5]. However, when many people who identify strongly with opposing groups are part of the same crowd, friendly support and banter can quickly escalate into conflict [5]. Football matches are an example where the emotions of fans regularly run high and incidents of public disorder and aggression are frequent [6].

In this study we focus on a specific type of aggression by football supporters, called pitch invasions [6–8]. During pitch invasions, some spectators decide to leave their place and enter the playing field, even though this is explicitly forbidden. We chose this focus because supporter violence in pitch invasions is easier to observe relative to violence on the stands or around the stadium. Although a large share of the invasions occurs out of celebration, pitch invasions can also have severe consequences when negative sentiment is involved or develops. A particularly tragic example is a pitch invasion during 2012 in Egypt that resulted in at least 74 deaths and hundreds of wounded [9]. Large scale pitch invasions are particularly dangerous due to their sudden nature and because those that guard the crowd can be severely outnumbered by the spectators simultaneously participating in the invasion.

Agent-based modelling techniques may contribute to this challenge in the future by providing event organisers and security personnel tools to make (real-time) predictions, and practice without personal risk of injury or high costs. Among others, this requires the development of an accurate model of the relation between group identification and the spread of emotions in crowds, called emotion contagion. While significant work has been done on simulating emotion contagion in crowds, especially during evacuations, much less studies have considered the impact of social subgroups on this process [10]. Models of emotion contagion that consider social relationships often do so in a dyadic fashion, considering the impact of factors like intimacy and trust towards others [10]. Other studies have assigned binary roles to agents like leader-follower, parent-child and authority-civilian [10]. However, neither approach captures the variation in how strongly people identify with subgroups and how this affects patterns in collective emotion and behaviour.

The aim of this study is to use agent-based modeling to examine how individuals with varying levels of identification with rivaling group identities affect patterns in collective emotion and aggression during football matches. For this purpose, we extend an agent-based model of emotion contagion called DECADE [11]. Specifically, we add the desire of agents to belong to a social group as an agent parameter. The belongingness hypothesis states that people share an innate desire to belong to social groups, and can go to great lengths to obtain or keep these relationships, including violating their beliefs, norms and in extreme cases their well-being or that of others [12]. Furthermore, the desire to belong to a social group was found to be positively correlated with the degree to which people identify with a local team [5]. Building on this, in the proposed model the desire

of an agent to belong determines the impact group identity has on emotion contagion and the appraisal of sport events, as well as the tendency of the agent to participate in collective aggression. To study the effect of several management strategies against supporter violence, we simulate scenarios with different supporter compositions and seating arrangements. Finally, the proposed model is evaluated against a real incident of supporter aggression that included pitch invasions, by using data collected from social and traditional media.

2 Methods

2.1 The DECADE Model

We build upon the DECADE (Dimensional Emotion Contagion via Agent-based Dyadic Exchanges) model [11], that is itself based on the ASCRIBE model [13]. DECADE was previously used to simulate the spread of emotions among supporters in a football stadium [11]. The agents in this model exchange emotion in the form of two continuous dimensions, valence and arousal (Fig. 1). These dimensions spread independently, yet together form the emotional state of the agent. How strongly valence and arousal can spread from one agent to the other is determined by the expressivity of the sender, the susceptibility of the receiver, the social and/or physical distance between the agents and the share of attention that the sender claims in competition with other stimuli.

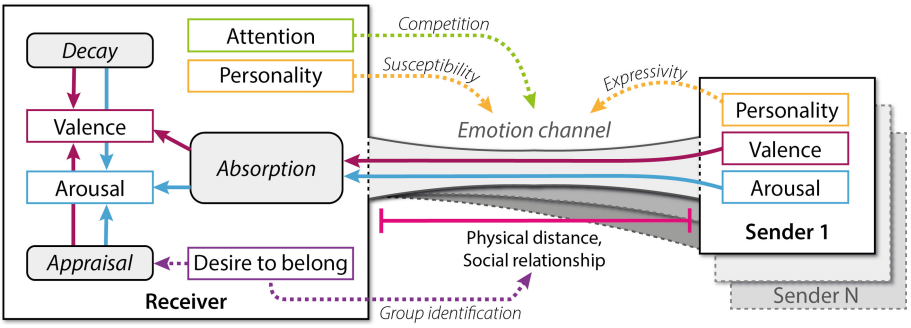

Fig. 1. Flow chart of the proposed emotion model. The 'desire to belong' and 'social relationship' factors are the additions to the DECADE model [11] proposed in the present study.

The effect of contagion on the valence and arousal of an agent is expressed as two components, 1) the total connection strength between a receiver and its neighbours and 2) the influence of the senders. Since the extensions introduced in this study only concern the connection component of DECADE, for brevity we will shortly explain this component below, while we refer to the previous study in its entirety for details about the influence of the senders [11].

$$\begin{aligned} \Delta E_{r\,valence} &= < connection > \cdot < influence_{valence} > \\ \Delta E_{r\,arousal} &= < connection > \cdot < influence_{arousal} > \end{aligned} \tag{1}$$

The total connection (Γ_r) of the receiver with its neighbours (N_r) is defined as the sum of each dyadic connection. The connection between each sender and the receiver (γ_{sr}) represents how well emotion can flow from the sender to the receiver. In the previous study [11], the strength of the connection was determined by the susceptibility of the receiver (δ_r), the physical distance between the agents (α_{sr}) and the weighted attention for the sender ($\theta_s{}^*$).

$$connection = \Gamma_r = \sum\nolimits_{s \in N_r} \gamma_{sr} \tag{2}$$

$$\gamma_{sr} = \delta_r \alpha_{sr} \theta_s{}^* \tag{3}$$

Susceptibility (δ_r) is a personality characteristic of the receiver. In the present study we set this parameter by drawing a random value from a normal distribution for each agent ($\mu = 0.5, \sigma = 0.2$), limited between 0 and 1. The physical distance (α_{sr}) is defined as the inverse of the Euclidean distance between the agents. The attention for a sender ($\theta_s{}^*$) is determined in competition with the other senders. A larger share of the receiver's attention is directed towards others with strong emotional expressions, yet all neighbours receive at least some amount of attention. Further in distributing its attention the receiver has a preference in the direction of valence and arousal, where $\mu_d < 0.5$ is a preference for negative valence or arousal, $\mu_d > 0.5$ for positive valence or arousal and $\mu_d = 0.5$ indicates no preference either way. In the present study we set no preference for valence and a positive preference for arousal ($\mu_{val} = 0.\,5, \mu_{aro} = 0.7$). This setting is motivated by a study that found that participants looked longer at stimuli higher in arousal, but attention did not vary with the valence of the stimulus [14].

2.2 Social Relationship

When a person strongly identifies with a group, the emotional influence of in-group members was found to be stronger than that of people outside their group [3, 4]. Further, the tendency of a person to identify with a team was found to correlate with his/her desire to belong to a social group [5].

To reflect these findings in the model, we introduce the desire to belong as an agent parameter. The desire to belong affects emotion contagion via the connection strength between a receiver and a sender, depending on whether they share a group identity. In the present study, Eq. 4 of the DECADE model is extended with the social connection between the agents (σ_{sr}). When the sender belongs to the same group as the receiver, the social connection between the agents increases with the desire of the receiver to belong (d_r). In contrast, if the sender belongs to a different group, we assume the connection is weaker relative to the desire to belong of the receiver. When the receiver is not part of a group (neutral), its social relation with all agents is equal to a half.

$$\gamma_{sr} = \delta_r \alpha_{sr} \theta_s{}^* \sigma_{sr} \tag{4}$$

$$\sigma_{sr} = \begin{cases} g_r = g_s & 0.5(1 + d_r) \\ g_r \neq g_s & 0.5(1 - d_r) \\ g_r = \varnothing & 0.5 \end{cases} \tag{5}$$

2.3 Emotion Decay

Emotions decay over time due to self-regulation [15]. DECADE proposed a non-linear decay, where the emotion of the receiver decreases with decay rate λ_r for each dimension of emotion separately [11]. A higher λ_r results in a faster decay of emotion, while at a decay rate of zero there is no decay of emotions. The decay rate of the agents is set to 0.01 in the present study.

2.4 Perceived Threat

Feeling like your group has been targeted or done injustice can pose a threat when the degree of group identification is high and may result in aggressive behaviour [5, 16, 17], for example due to police actions, ridicule or shame. How much an individual feels his identity is threatened, was found to be positively correlated to the desire to belong of that person [5]. Further, it stands to reason that the display of aggression by others can also present a threat, especially if this is displayed nearby. Perceiving a threat in turn positively affects arousal [18]. We hypothesise that this may be the case whether aggression comes from group members or not; when the aggressor does not belong to someone's group, this poses a direct threat to the individual's safety, while aggression by a group member signals that one's group is threatened [4]. For simplicity, we did not consider the effect of perceiving anxiety on identifying threats.

To reflect this description, we define the perceived threat (χ_r) as the inverse of the distance to the nearest aggressive neighbour, combined a logistic function of the impact of external events on the group identity (Ext_{group}) modified by the agent's desire to belong (d_r). Due to the logistic function, negative group events are perceived as a threat by an agent that identifies strongly with this group, while positive and neutral events for the group result in a threat perception close to zero.

$$\mathrm{X}_r = \frac{1}{\min\limits_{s \in N_{agr}} D_s} + \frac{e}{1 + e^{-2(-d_r Ext_{group} e - e)}} \tag{6}$$

Finally, to model the emotional effect of the external event on the agent, perceiving a threat increases the arousal of the agent proportional to the size of the threat. Additionally, the appraisal of the external event affects the agent's valence depending on its desire to belong (e.g., a red card for their team decreases valence, while their team winning the game increases valence).

$$\begin{aligned} \Delta E_{aro} &= 0.1 \chi_r \\ \Delta E_{val} &= 0.1 d_r e_{group} \end{aligned} \tag{7}$$

2.5 Decision Model

To model supporter aggression, a simple decision tree is implemented that is chance-based. To travel through the tree, a random number is drawn (P) that is compared to a threshold determined by parameters of the agents, where P_1 and P_3 are drawn

from a uniform distribution and P_2 from an exponential distribution ($\mu = 0.25$). First, the perceived threat and the arousal of the agent determine whether the agent remains seated calmly or reacts. When the agent decides to react, it decides whether it responds with aggression or fear, depending on its desire to belong. When the agent reacts with aggression, the tendency to invade the field comes from perceiving aggression nearby and a strong group identity. Otherwise, the agent will display aggression on the stands and move to the border between the stands and the field without passing it. When the agent reacts anxiously, the chance it moves toward the exit increases with negative valence and nearby aggression. Otherwise, the agent remains seated anxiously.

$$act = \begin{cases} P_1 < E_{aro}\chi_r & \begin{cases} P_2 > 1 - d_r & \begin{cases} P_3 < d_r \frac{1}{\min\limits_{s \in N_{agr}} D_s} & Invade\ field \\ else & Aggression\ on\ stand \end{cases} \\ else & \begin{cases} P_2 < \frac{1+E_{val}}{2} \frac{1}{\min\limits_{s \in N_{agr}} D_s} & Leave\ stadium \\ else & Static\ anxiety \end{cases} \end{cases} \\ else & Static\ calm \end{cases} \tag{8}$$

2.6 Analysis

The proposed model was implemented in the agent-based simulation environment Netlogo [19]. We made a stadium setup with 3000 agents located in a rectangle around the pitch. Each agent supports either the home team, the away team or no team (neutral). A supporter is either fanatic or a regular supporter. Based on these characteristics its desire to belong is drawn from a normal distribution, where neutral spectators draw from a distribution with a low mean, regular supporters from a distribution with an intermediary mean and fanatic supporters from a distribution with a high mean. To represent variation in personality types, the susceptibility and expressivity of all agents are drawn from the same normal distribution at the start. The valence and arousal of the agents start at zero. We chose a general setting for the simulations and studied the effect of varying the proportion of fanatic supporters (default is 0.2 and 0.4 for the home and away team respectively) and the seating arrangement (default is a loose separation of fanatic and away supporters) over 500 time-steps. To setup the model for the validation, we used the same general setting as for the other results, but with a larger crowd (n = 6000) and a seating arrangement that only separates the away supporters. Then we manually tuned the model to the observations via the parameter that represents the impact of events on the identity of the home team. The complete settings are available in Appendix 1. To account for the variation due to stochastic factors in the model, each condition was repeated 16 times. The figures are produced in RStudio using the Ggplot2 package. The model, scripts and data are included in the supplementary material.

2.7 Validation

While negative feelings may be shared broadly in a stadium, only a (small) share of the spectators is actively involved in incidents of supporter aggression, while others remain

calm or distance themselves from the aggression. Our validation of the model focusses on the behaviour of the crowd as opposed to its emotion, as to our knowledge no datasets are available of the emotional development of spectators during pitch invasions. For this purpose, we examine two cases of pitch invasions with the use of descriptions, videos and photos from both traditional and social media. We compare several qualitative patterns from our observations of the real incident to the simulation output from the proposed model. Additionally, we measure the percentage of spectators on the field at the height of pitch invasion. For this, we counted the spectators on half of the field and divided this by the estimated total number of spectators to get the percentage of spectators that entered the field. See Appendix 2 for more details about the validation.

3 Results

3.1 Spectator Composition

To study the impact of stadium bans and limits on the promotion of team identification, the effect of the percentage of fanatics is considered on the percentage of spectators that invades the pitch for both a positive and negative event for the home team ($Ext_{home} = 0.4$ and -0.4, $Ext_{away} = -0.4$ and 0.4 respectively). All measures are with the away fans and home fanatics being loosely separated in the stadium (see next subsection). For the away team we assumed the percentage of fanatic supporters is double that of the home team. This assumption is inspired by literature suggesting that people who identify less with a team are more likely to favour practicality in their decision to attend a game [3], while away games generally require higher costs and effort.

A higher proportion of fanatic supporters increases the number of agents that invade the pitch and that leave the stadium, especially in the case of a home loss (Fig. 2). Most of the supporters that invaded the pitch are fanatic supporters. Further, the model predicts that pitch invasions following a home loss almost exclusively involve fanatic supporters of the home team, while those following a loss by the away team more often involve supporters from both teams. These findings suggest that measures to limit the total number of fanatics in the stadium, particularly those of the home team, are effective in lowering the scale of the pitch invasions as well as the threat to other supporters, as illustrated by the proportion of agents that left the stadium.

3.2 Seating Arrangement

It is common practice in European football stadiums to keep the home and away team fans separated to avoid conflict, among others by assigning a section of the stadium specifically to the fans of the away team. Moreover, fanatic fans of the home team usually also sit together in a section of stadium. In many cases these sections are not adjacent. However, while this arrangement is generally followed by the spectators, it is usually not strictly enforced. Supporters on the main stand can be fanatic too or can (openly) support the away team.

To study the impact of management strategies based on the seating arrangements, the location of the spectators is varied by type, while the total number per type and the

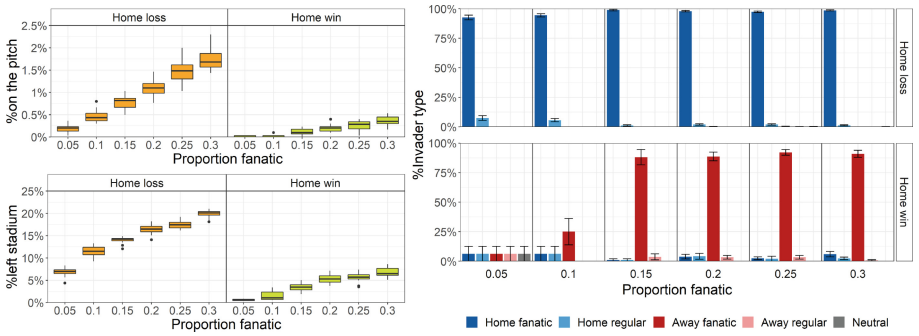

Fig. 2. Effect of the proportion fanatic home supporters (double for the away supporters) on the percentage of spectators that invades the pitch, leaves the stadium, and the supporter type of the agents that invade the pitch (±SE). Note that invader type does not add up to 100% for all conditions due to runs without pitch invaders.

density are kept equal. We tested four types of seating arrangements. In the 'random' condition, spectators are mixed throughout the stadium. In the 'away only' condition, the neutral spectators and home supporters are mixed, but the away supporters have their own section. In the 'strict' condition the fanatic home supporters also have their own section in the stadium on the opposite side of the section for the away supporters. In the 'loose' condition we assume that not all spectators will conform to the previous arrangement. In this arrangement the fanatic section is occupied by 50% of the fanatic home supporters, 20% of the regular home supporter and 5% of the neutral spectators, while the away section is occupied by 95% of the fanatic away supporters, 80% of the regular away supporters and 5% of the neutral spectators.

Contrary to common practice, our findings indicate that the tendency to separate fanatic fans might promote the severity of pitch invasions (Fig. 3). The loose and strict arrangements resulted in a higher percentage of pitch invaders and spectators that left the stadium than when all spectator types are mixed or when only the away supporters were seated separately. The fanatic supporters seem to amplify each other when placed together, while a more diverse mix downregulates the negative sentiment. The flipside is that in the 'random' condition pitch invasions are more likely to consist of rivalling supporters, increasing the opportunity for violence.

3.3 Case Study: Nigeria – Ghana

On March 29th 2022, Nigeria and Ghana played a game to determine which of their national teams would go to the world cup next summer, with a general expectation that this would be Nigeria. A strong rivalry exists between the countries with a long history, that has led to pitch invasions before and is not limited to sports [20, 21]. It was therefore not a complete surprise that when the most recent match in Nigeria ended in a draw, meaning that Ghana would go to the world cup, Nigerian supporters stormed the pitch upset. The stadium was vandalised and the police clashed with the invading supporters, using force and teargas [22].

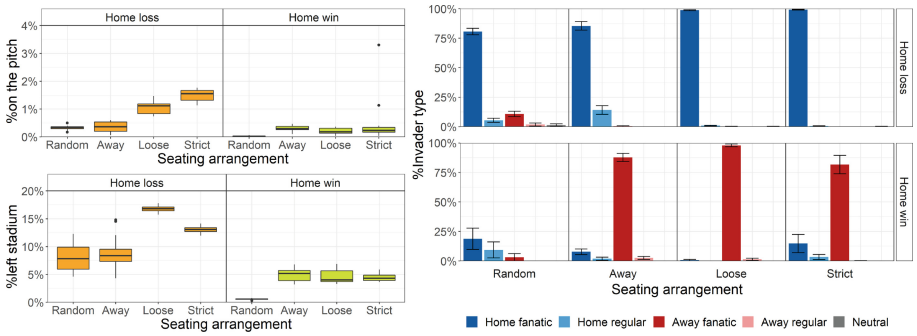

Fig. 3. Effect of seating arrangement on the percentage of spectators that invades the pitch, leaves the stadium, and the supporter type of the agents that invade the pitch (±SE).

From footage uploaded to social media, we observed several patterns in collective behaviour, the details and sources of which can be found in Appendix 2. First, before people entered the field, aggression was already displayed on the stands, where Nigerian supporters threw objects towards players and supporters of Ghana. Second, while a large number of people entered the pitch, many more presumably left the stadium as the majority of the seats are empty (Fig. 4). Many of the people that remained in the stadium are concentrated on and around the stairs toward the exits and appear relatively calm. Finally, we did not observe any Ghanaian supporters visibly participating in the pitch invasion, although a group was escorted over the pitch towards an exit by the police at some point. Based on a count of half the field and an estimated attendance of 60000 in the stadium, we conclude that around 1.5% of the spectators invaded the pitch.

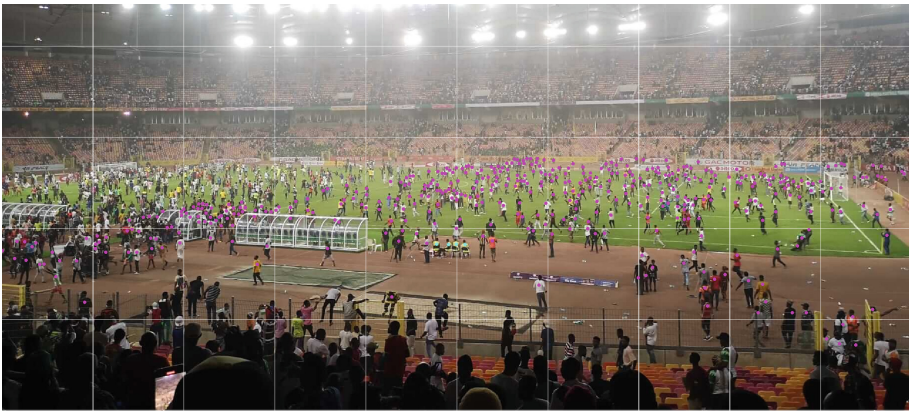

Fig. 4. Photo taken shortly before the police intervened [23]. The pink dots are the counted spectators, the blue dots are stadium staff.

The patterns of collective behaviour in our simulations resemble several of the observed patterns. The average percentage of individuals that entered the pitch matches closely to our count of the real incident with 1.66% (SE 0.06). On average 87.7% (SE

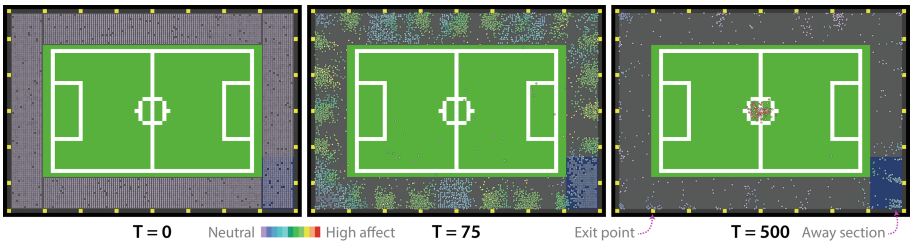

Fig. 5. Simulation output of the Nigeria – Ghana pitch invasion, for three time-steps showing the start, main onrush and end of the simulation. One agent represents 10 real supporters in scale. The colours of the agents indicate the strength of their emotions as the distance in valence-arousal space to the neutral state. A video of this simulation is included in the supplementary materials.

0.40) left the stadium in the simulations. We could not make an exact estimate of the people on the stands in the real incident via counts from the available material, but based on the area of visible seats in Fig. 4 at least the majority of people seem to have left their seat. Moreover, the simulation matches the pattern that most of the people who don't leave, gather around the exits and are relatively calm compared to those on the pitch (Fig. 5). A point where the simulations significantly differ from the real incident is in the aggression by the away supporters. In our simulations on average 18.3% (SE 2.43) of the invaders belonged to the away team, while we did not observe pitch invasions by the real away supporters. Overall, we conclude that the combination of emotion contagion and group identity can produce some of the patterns observed in the real incident, but not all. We expect that this is partly due to several important factors that are missing in the decision-making process of the agents, like the ability to properly estimate risk.

4 Discussion

The proposed model in this study focusses on the exchange of affect and the impact of continuous variation in group identification with rival teams during events of supporter violence in stadiums. A wide variety of measures is employed by police, governments and sport clubs to combat violence in and around football matches [6]. We explored the effects of measures that alter the supporter composition on the stands with regards to placement (separating by teams and/or by fanaticism) and by composition (stadium bans, limiting the promotion of identification). The findings indicate that measures that lower the number of fanatic supporters (stadium bans, limits to promoting identification) decrease aggression, especially when the home team loses. Allowing, or even forcing, fanatic supporters of the home team to sit separately was found to increase the overall aggression due to amplification that occurred among these fanatic supporters. Mixing the fanatic supporters throughout the stadium resulted in less aggression, but when aggression occurred it was more likely to involve agents from both teams, which may increase the opportunities for violence. Based on these findings we hypothesise that also other measures aimed at separating fanatics from regular fans may work counterproductively, such as separate transport [6].

Moreover, the present study demonstrates that emotion contagion and group identification combined with a decision and behaviour model are able to produce several aspects of collective behaviour in a real incident of supporter aggression, based on written descriptions, photos and videos of the incident. Yet we also found important deviations in the behaviour of the away supporters. Agents in the minority group decided to join the aggression at the end of the simulation, while in footage of the real incident we observed no supporters of this group that did so. Possible explanations for this may include understanding the risk of being outnumbered or a motivation to enjoy the positive sentiment, neither of which are included in the model. With perhaps the exception of situations that are dominated by very strong emotions, cognitive processes and individual motivations, beliefs, knowledge and percept play important roles in human decision making. Due to the minimal representation of these factors in the proposed model, the results regarding the management strategies should not be interpreted as an evaluation of these strategies, but as suggestions for future study.

That being said, it is neither practical nor possible to capture the full complexity of crowds in a simulation. Ethics, privacy and the sheer amount of individual variation drive the development of models that can make reasonably accurate predictions based on limited input. This is an important challenge in the field of crowd simulation, and even more so for crowd models that include the spread of emotions. Emotions are highly challenging to detect accurately in a crowd and are seen as private. This makes validation of models of emotion contagion at the individual level a steep challenge that has not been met for any current model yet as far as we are aware [10]. However, while this is important in order to develop an agent-based model of emotion contagion that is widely applicable, we argue that for the narrow use cases envisioned in this study, high accuracy at the emotion level may not be crucial. The model may overlook certain patterns of individual or collective emotion if these do not strongly contribute to the problematic collective behaviour. For example, a system indicating whether a match may escalate that is correct half of the time, or misses the emotional development of less relevant subgroups, might still be a useful tool for the police in planning if it outperforms currently available indicators. The same holds for a training simulator that shows the effects of a management strategy on the dominant behaviour of aggressive groups, even if not all groups will behave in this way.

To develop such tools, future study could look at which factors can significantly improve predictions over the current model driven by affect and group identification, without requiring the input of data of which the collection is prohibitive in the real world. Furthermore, future work can explore the role of the interaction between group identification and emotion contagion with the use of agent-based models for other crowd types where competitive subgroups play an important role, like in protests, riots and online crowds. Finally, this study focussed mainly on fight-flight behaviour following the spread of negative sentiment due to a threat to the group, while the positive fans remain calmly seated. However, fans are known for reacting passionately towards positive events as well. Combined with an inflated sense of superiority in the case of group identification, there are opportunities to further explore the dynamics of causing and perceiving threats between rival groups.

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Appendix

The supplementary materials can be found at: https://osf.io/4hvm5.

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