Cognitive Modelling of Emotion Contagion in a Crowd of Soccer Supporter Agents

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Abstract. This paper introduces a cognitive computational model of emotion contagion in a crowd of soccer supporters. It is useful for: (1) better understanding of the emotion contagion processes and (2) further development into a predictive and advising application for soccer stadium managers to enhance and improve the ambiance during the soccer game for safety or economic reasons. The model is neurologically grounded and focuses on the emotions "pleasure" and "sadness". Structured simulations showed the following four emergent patterns of emotion contagion: (1) hooligans are very impulsive and are not fully open for other emotions, (2) fanatic supporters are very impulsive and open for other emotions, (3) family members are very easily influenced and are not very extravert, (4) the media is less sensible to the ambiance in the stadium. For validation of the model, the model outcomes were compared to the heart rate of 100 supporters and reported emotions. The model produced similar heart rate and emotional patterns. Further implications of the model are discussed.

Keywords: Cognitive modelling · Crowd behaviour · Emotion contagion

1 Introduction

Do you remember the soccer game of the Champions League Final in 2005? This match between the soccer teams Liverpool F.C. from England and AC Milan from Italy, showed why soccer is played and enjoyed by people all over the world. In the first half of the match the score was 0–3 in favour of AC Milan. Within fifteen minutes after the break the score was 3–3. After 90 min the score was still 3–3. During the extra time, none of the teams scored a goal. After the penalties, Liverpool F.C. won the Champions League. During such a match all kinds of emotions arise. Especially the switch between pleasure at first and sadness in a later stage for the supporters from AC Milan, and the other way around for the supporters from Liverpool F.C. is very interesting. How these emotions arise and influence the ambiance in the stadium is not only very fascinating to understand in general, but can also be important for economic and safety reasons. For example, during almost every soccer game some supporters sing racist passages or show racist activities. The mood of the crowd has a big influence on this behaviour [1]. Another interesting effect of the crowd's mood is on the sales of beverages and food. It is known that when the supporters enjoy their game more, sales in and around the stadium rise [2]. With these reasons in mind, the focus of the current

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work is on understanding how sadness and pleasure arise and distribute through a crowd of soccer supporters. The aim is to build a cognitive computational model of this emotion contagion process to better understand the dynamics and with a future application in mind where an ambient intelligent system can monitor the crowd's behavior and emotions and to provide advice and support to soccer stadium managers on possible interventions.

During a soccer game, supporters are mainly feeling sadness or pleasure [3]. The feeling of "pleasure" and "sadness" are processed and controlled in the brain. Human pleasure reactions occur across a distributed system of brain regions. Furthermore, emotions are spread amongst people through emotion contagion. Emotion contagion is part of the cognitive system and categorized as: (1) automatic subconscious contagion through mimicry and feedback or (2) conscious transfer through social comparison of moods and appropriate response in groups, mediated by attention [4]. Automatic emotion contagion is represented in this work, based on the principle of mirror neurons. [5, 6]. The conscious emotion contagion is represented in this work as a social phenomenon, where emotions of group members can be absorbed by the other group members or can be amplified, in the way that the real emotion of other group members will be reinforced. [7]. This social phenomenon is based on the social connections the supporters have with each other. Our work is based upon [7–9]. We have chosen for modeling a social process with a neurologically grounded model for two reasons: (1) to model human mental processes in relation to reality, namely representing the continuous dynamic processes of firing neurons and (2) because this modeling approach with cognitive and affective mental states can be more effective in predicting human behaviour than a model without them. [8].

This paper examines how the dynamical pattern of pleasure and sadness can be represented and modelled based on neuro-scientific concepts and theories, such as reward mechanisms in the brain, mirror neurons and somatic marking. The hypothesis of this research is that the emotions sadness and pleasure show specific dynamical patterns during a soccer game and these patterns are dependent on anticipation and people influencing other people with their emotions and cognitions. More specifically, we postulate that: (1) on an individual level, a supporter will experience a higher intensity of pleasure if its preferred team scores a goal. In the same fashion, a supporter will experience a higher intensity of sadness if the non-preferred team scores a goal; (2) on a group level, supporters are sensitive for the emotions of other supporters (For instance, when the preferred team has scored a goal for the home supporters, the away supporters will experience a higher intensity of pleasure over time, because the whole stadium more or less feels the emotion 'pleasure'). As a first step in validating this model, the simulation results will be compared to the heartbeats of 100 persons, measured during an entire soccer game. Also, the model outcomes are compared with real-time reported emotions and in hindsight reported emotions of soccer supporters. The rest of this paper is organised as follows. In Sect. 2 the underlying neurological underlying theories and the proposed cognitive computational model are described. Next, in Sect. 3 the results from the structured simulations are shown. Section 4 presents the validation of the model. The paper concludes with a discussion in Sect. 5.

2 Cognitive Model for Emotion Contagion in Agents

Neurological background. Human emotions occur across a distributed system of brain regions. The Nucleus Accumbens (NAcc) is related to the reward system. The reward system is a group of brain structures that mediates the reinforcement. The most important pathway of the reward system is the dopamergic pathway (Ventral Tegmental Area (VTA) – NAcc). The feeling of pleasure or desire to pleasure is regulated among this pathway. Furthermore, the Orbitofrontal Cortex (OC) is responsible for the controlling of the emotion state and the Anterior Cingulate Cortex (ACC) is responsible for the progressing and expression of the emotion state [10]. This ACC has a very strong and important connection with the Amygdala. The Amygdala is responsible for processing both positive and negative emotions. Until recently it was thought that it was only associated with negative processing. [11]. The Amygdala links different information, that comes from different senses, to different emotions. In every different situation, the Amygdala determines which emotional reaction is the most useful in that particular situation. In most of the situations the emotional response is fast and automatic (e.g. fear; fight or flight reaction). The connections between these brain regions that are involved in the processing of pleasure and sadness can be mapped in an abstract relation mapping.

There is little scientific knowledge about the connections between the related brain regions at the lower level of the brain (on the level of neurons). There is, however, neurological research available about the connections at a higher level (the abstract idea). For example, as described earlier, a dopaminergic pathway connects the VTA and the NAcc with each other. This connection is related to the Amygdala. The Amygdala (emotion processing) has an important connection with the ACC (emotion expression) [12, 13]. Besides different brain regions that are related to the emotions "pleasure" and "sadness", hormones and somatic markers are important as well. The ACC has an important function in the regulation of blood pressure and heart frequency. These two body processes are modelled in this work as well and used for validation of the model.

Agent-based Computational Model. The previously described theories are modelled in concepts and their relations, expressed in numerical values. Figure 1 gives an overview of the structure and organization of all states and relations, for each agent. Tables 1 and 2 show all the states and connections that are included in the model. Every state will be described below.

Input States. The Context state (Eq. 1) represents the situational context, which can be the current score, the importance or the current stage of the match. Its value is either 0 or 1; 0 means the state is not active (no importance or urgency) and 1 means the state is active (high importance or urgency). The Goal state (Eq. 2) is active when a goal is made by one of the two teams. It remains active for 100 time steps. Its value is either 0 or 1: 0 means not active and 1 means active. The Emotion Sensor state (Eq. 3) is the state where the emotions of other supporters are aggregated, as a weighted sum, to influence the agent. Its range is [0,1], whereby 0 means there is no incoming emotion

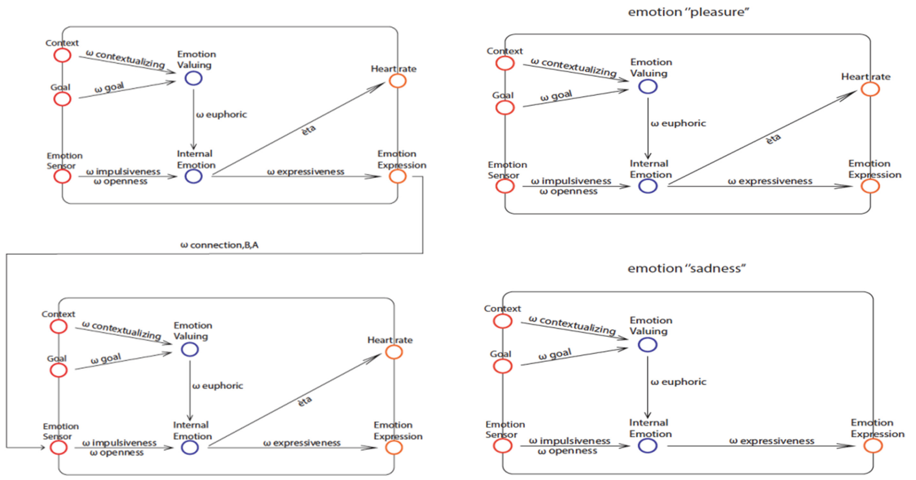

Fig. 1. Meta-model: cognitive model emotion contagion soccer supporters agents (left); concepts and relations specified per emotion pleasure and sadness (right)

Table 1. Description of all states

State	Description	Value
Context	Representation of context during the game. The current situation of the match at that moment (for example; qualification, current score, period of the match)	0 or 1 (0 representing a context of low importance and low urgence and 1 representing a highly important or urgent context)
Goal	A goal is made by one of the two teams	0 or 1 (0 representing no goal is scored and 1 representing a goal is scored)
Emotion Sensor	Level of all incoming emotions from other (connected) supporters.	[0,1] (0 representing no incoming emotion and 1 representing a maximal incoming emotion)
Emotion Valuing	This state represents the incoming internal valuing of the game related to the emotions	0 or 1 (0 representing no incoming values from context state and goal state and 1 representing incoming values from both context state and goal state or only from value state)
Internal Emotion	This state represents the processing part of both positive and negative emotions	[0,1] (0 representing no incoming emotion and 1 representing a maximal incoming emotion)
Emotion Expression	The expression of the emotion from the processing state	[0,1] (0 representing no incoming emotion and 1 representing a maximal incoming emotion)
Heart rate	This state mimics the heart rate of the agent	[70,180] (70 representing the minimal heart rate and 180 representing the maximal heart rate)

Table 2. Parameter descriptions

Parameter	Representing:
$\omega_{euphoric}$	Level of euphoria in the brain (Connection VTA-Nacc with Amygdala)
ω_{goal}	The importance of a goal
$\omega_{contextualizing}$	Internal valuing (VTA-Nacc)
$\omega_{impulsiveness}$	A person's impulsivity in the brain (related to OC)
$\omega_{openness}$	Level of openness to emotions of others (DS-ACC)
$\omega_{expressiveness}$	Level of expressiveness of agent A (Amygdala-ACC)
eta	Speed with which internal emotion is transformed into a heart rate
$\omega_{connection,B,A}$	Level of social connection from agent B to agent A
beta	Speed factor (representing fight-flight response)

from other supporters and 1 means there is a maximum level of incoming emotion from all others.

$$\text{Context (t)} = 0 \text{ OR } 1 \tag{1}$$

$$\text{Goal (t)} = 0 \text{ OR } 1 \tag{2}$$

$$\text{Emotion Sensor(t)} = \text{Emotion Sensor(t)} + \left(\sum\nolimits_{B \in G \setminus \{A\}} (\omega_{connection,B,A} * \text{Emotion Expression}_B(t))\right) / (\text{total } \textit{numberof } \omega_{connection,B,A}) \tag{3}$$

Internal States. The $\omega_{contextualizing}$ parameter mimics the connection between the VTA and the NAcc in the brain, better known as the dopaminergic pathway. The range of Emotional Valuing state is [0 or 1]; 0 means there is no incoming value from Context and Goal, 1 means either there is an incoming value from Context and an incoming value from Goal (4a) or there is an incoming value from Context and no incoming value from Goal (4b). Formula 4a is used for input Goal(t) = 1, and 4b for Goal(t) = 0. This choice was made, because in Eq. 4a, w hen a goal is scored, both Context and Goal and therefore Emotion Valuing will be 1. Thereafter, Context will stay 1, Goal will become 0, and Emotion Valuing will be 0.5, which means a decrease of Emotion Valuing, and eventually a decrease of the Emotion Expression. However, this is not supposed to happen after a goal is scored, since the emotion has to be steady. Therefore, when Goal(t) = 0, Emotion Valuing is only dependent on Context. In this way, Emotion Valuing will stay 1. The $\omega_{euphoric}$ portrays the connection between the VTA - NAcc and the Amygdala in the brain [14] (Limbic system; NAcc). The $\omega_{impulsiveness}$ mimics the impulsivity of a person in the brain, which is related to the OC [15] (OC). This is the connection between the Emotion Sensor state and Internal Emotion state. The Internal Emotion state portrays the Amygdala [11] (Amygdala). The $\omega_{openness}$ portrays the openness from a person to emotions from other persons. This connection is related to the Dorsal Striatum and ACC [16] (Dorsal and ventral striatum). The Dorsal Striatum is involved in anticipating emotion expression and regulation of the heart rate. The Ventral Striatum is more related to anticipating the reward mechanism [17]. The range Internal Emotion for “pleasure” (5a) or “sadness” (5b) is [0,1]; 0 means there is no incoming emotion (“sadness” or “pleasure”) from Emotion Valuing and Emotion Sensor and 1 means there is a maximum level of incoming emotion (“sadness” or “pleasure”) from Emotion Valuing and Emotion Sensor. The parameter beta in formula 5b is based on the evolutional neurological theory about fear and the ‘fight or flight’ theory. Stress and negative feelings are processed faster compared to positive feelings, based on the flight and fight reactions [18]. Furthermore, people with a negative feeling act more narrow-minded and will most likely not open up completely to other people. In this way, their own emotion disrupts the incoming emotion from other people [19].

$$\text{Emotion Valuing}(t+\Delta t) = \text{Emotion Valuing}(t) + \eta\left(\left(\left(\text{Goal}(t) * \omega_{goal}\right) + (\text{Context}(t) * \omega_{contextualizing}\right)/2\right) - \text{Emotion Valuing}(t)\right)\Delta t \tag{4a}$$

$$\text{Emotion Valuing}(t+\Delta t) = \text{Emotion Valuing}(t) + \eta\left(\left(\text{Context}(t) * \omega_{contextualizing}\right) - \text{Emotion } \mathit{Valuing}(t)\right)\Delta t \tag{4b}$$

$$\text{Internal Emotion}(t+\Delta t) = \text{Internal Emotion}(t) + \eta\left(\text{EmotionSensor}(t) * \omega_{impulsive} * \omega_{openess} + \left(\text{InternalValuing}(t) * \omega_{euphoric}\right)/2\right) - \text{Internal Emotion}(t)\right)\Delta t \tag{5a}$$

$$\text{Internal Emotion}(t+\Delta t) = \text{Internal Emotion}(t) + \eta\left(\left(\text{Emotion Sensor}(t) * \omega_{impulsive} * \omega_{openess} + (1-\text{beta})\right) + \left(\left(\text{Internal Valuing}(t) * \omega_{euphoric}\right) * \text{beta}\right)\right) - \text{Internal emotion}(t)\right)\Delta t \tag{5b}$$

Output States. The $\omega_{expressiveness}$ is the connection between Internal Emotion state and Emotion Expression. This connection portrays the relation between the Amygdala and the ACC with the related functions. [Knutson et al., 2001a,b] (ACC; Amygdala). The Emotion Expression state mimics the function of the ACC [20, 21] (ACC). The range of Emotion Expression is [0,1]; 0 means there is no incoming emotion (“sadness” or “pleasure”) from Internal Emotion and 0 means there is a maximum level of incoming emotion (“sadness” or “pleasure”) from Internal Emotion. The heart rate is connected and correlated with the ACC. The ACC plays a role in the regulation of heart rate frequency [21]. For Heart Rate a range of [70,180] was chosen, representing a common minimum heart rate of 70 and a maximum of 180, calculated as follows.

$$\text{Emotion Expression}(t+\Delta t) = \text{Emotion Expression}(t) + \eta\left(\text{Internal Emotion}(t) * \omega\text{expressiveness} - \text{Emotion Expression}(t)\right)\Delta t \tag{6}$$

$$\text{Heart rate}(t+\Delta t) = \text{Heart rate}(t) + \text{eta} * ((\text{Internal Emotion}(t+\Delta t) - \text{Internal Emotion}(t)/\max(\text{Internal Emotion}(t)) * ((\max(\text{Heartrate}(t) - \text{Heart rate}(t)/((\max(\text{Heart rate}(t) - \text{Heart rate}(t)/\text{Heart rate}(t))) * \Delta t \tag{7}$$

Agents and their Environment. The agents representing supporters, are placed in a virtual stadium, see Fig. 2. In every stadium section, five supporter agents are placed: one agent from each of the five supporter subgroups explained below. Only when mentioned, the amount of supporters in a section is increased to 20. Agents in every section are connected with agents from three other sections. In this way all the supporters are directly or indirectly connected with each other, which is based on reality

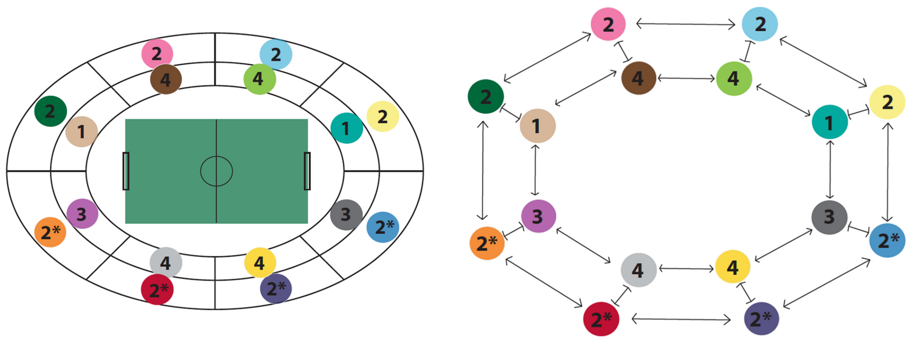

Fig. 2. Schematic overview of the agent environment, with the related connections between them

and meant for emotion contagion to arise. The five different supporter subgroups in the model are: (1) hooligans; (2) Fanatic supporters; (3) family members; (4) neutral supporters; (5) away supporters. Hooligans always have a believe to win the game and the thought that they can influence the game by their enthusiasm. They think that supporting their own players and provoking the opponents will help their team win the game (songs, choruses and choreographies). Hooligans are a group of hostile interacting people [21]. Often, hooligans have cognitive and mental problems. This is related with changes in function of the reward system and the limbic system. It is suggested that they have a very active reward system in combination with other cognitive problems. The desire to feel pleasure by visiting a soccer game is high (relatively high $\omega_{euphoric}$). Besides this, they have a reduced control system for emotions (relatively high $\omega_{impulsiveness}$). In addition, they are not fully open for emotions of other supporters (relatively low $\omega_{openness}$). However, they are very sensitive to emotions evoked by the game, like a goal. Fanatic supporters do not show the behavioural characteristics of a hooligan (e.g. violence), but have clearly visible emotions. They try to maintain a good ambiance in the stadium by singing and screaming during the game. They are also very sensitive to emotions evoked by the game and other supporters. Most of the time there is excessive use of alcohol (though less excessive than the hooligans' use of alcohol). Family members are stereotypically represented by a father who is visiting the game with his son. This is the largest group of supporters. They are quite silent during the game (compared with the fanatic supporters and hooligans). They are very happy when their favourite team scores a goal, and are sad when the opposite team scores a goal. Furthermore, this group does not sing during the game and does not drink any alcohol. Neutral supporters represent either the press, media, sponsors or business partners. They do not have any relatable emotion during the game and do not have any preference for one of the two teams. This is the smallest group of supporters. Away supporters have the same characteristics as the fanatic supporters as described above. However, their team of preference is the opposite team.

3 Results

To examine if the proposed model exhibits the patterns that can be expected from literature (described in Sect. 1), four different scenarios were simulated: matches (1) that are different in contexts (importance of the match), (2) with difference in distribution of the supporters within the stadium, (3) that are different in the final score and by (4) with and without emotion contagion. Figures 3 and 4 show the results of the simulations of a match with a 'non-important' context (representing a standard random friendly match) and a match with a 'highly important' context (representing the very important Champions League final from 2005). Parameter settings for the simulations are shown in Table 3. During the rest period, there is no emotion contagion between the supporters. Figure 3 shows that supporters feel some positive stress (emotion 'pleasure') at different periods during the match: at the beginning, before the rest, after the rest, shortly before the end of the match and after a goal has been scored. In the 'high' importance scenario, positive stress is felt during almost the entire match. See Fig. 4. Here, supporters are more euphoric. Also, higher levels of both emotions 'pleasure' and 'sadness' are visible, representing more intense emotions and 'more being at stake'. In both Figs. 3 and 4, there is clear emotion contagion between the supporters at the start: all the emotions converge/are averaging out. In this way, general emotional patterns arise for every different subgroup within different simulations. After this first period of the game, the process of emotion contagion is clearly present as well in different values of emotions between the supporters groups. In general, the subgroups 'hooligans' and 'fanatic supporters' (both home and away supporters) have the highest values of the emotions 'pleasure' and 'sadness'. These two subgroups are generally the most loudly represented supporters during a soccer game. When the preferred team has scored a goal, the fanatic supporters and hooligans show the highest increase of the emotion 'pleasure'. The subgroups media and family members all show only a small increase in the emotion 'pleasure'. Regarding the emotion 'sadness', this emotion shows the same yet opposite pattern compared with the emotion 'pleasure'. Overall, the subgroups 'family members' and 'media' have a lower value of the emotions 'pleasure' and 'sadness' than the other subgroups. Family members mostly behave less extravert than hooligans and fanatic supporters. The subgroup media is the neutral group, which has no preference for neither one of the two playing teams. They are fully influenced by the ambiance in the soccer stadium. However, taken into account the difference of the values of the emotions 'pleasure' and 'sadness' between the different subgroups, all the emotional patterns are more or less the same. This finding reflects the general and collective ambiance during a soccer game. Figure 5 shows the simulation results of the Champions League final in 2005 without emotion contagion. It can be seen that the supporters do not influence each other's emotions. Most prominently the emotions do not converge from the start of the simulations and are generally a bit more intense or less intense on average. From the simulations with different distributions of supporters similar patterns were found. Especially in the hooligans and fanatic supporters subgroups the influence of emotion contagion was shown in the results by stronger convergence of emotions. In the different scoring

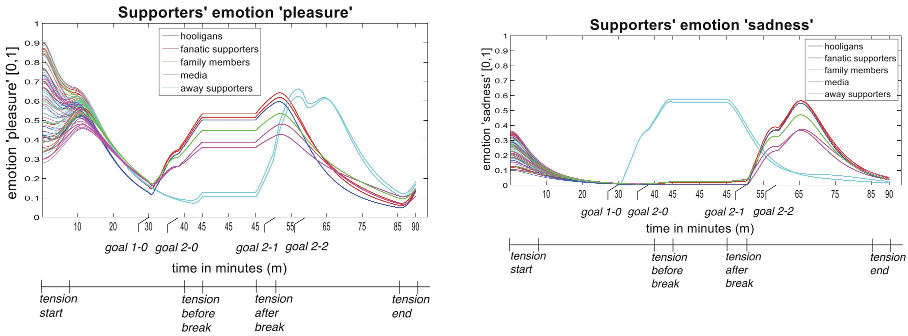

Fig. 3. Pleasure (left) and sadness (right) levels during a non-important context match

Table 3. Simulation settings

Parameter	Value
Delta time; eta; length	0,01; 1; 6300 time steps (representing 6300 s)
$\omega_{euphoric}$	Hooligans, fanatic and away supporters:1; family members: 0,8; media: 0,6
$\omega_{impulsiveness}$	Hooligans, fanatic and away supporters: 0,9; family members and media: 0,6
$\omega_{openness}$	Hooligans: 0,7; Fanatic, away supporers: 0,9; family members and media: 1
$\omega_{expressiveness}$, $\omega_{contextualizing}$, ω_{goal}	All supporters: 1

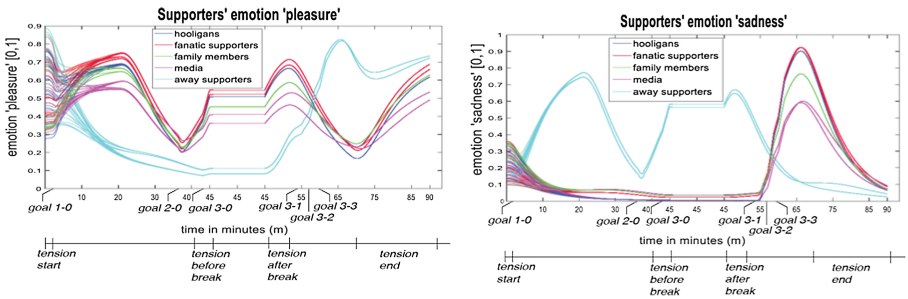

Fig. 4. ‘Pleasure’ (left) and ‘sadness’ (right) levels during a highly important context match

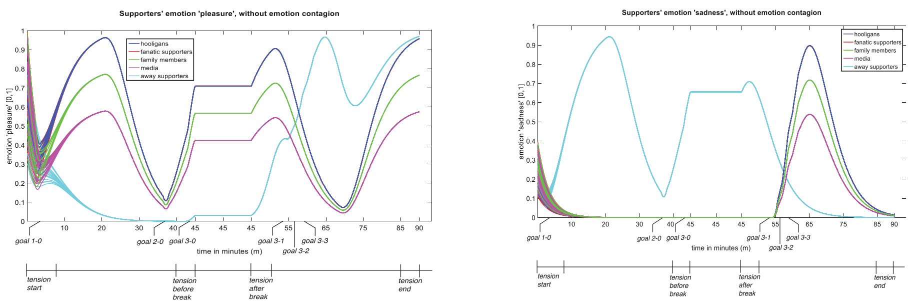

Fig. 5. 'Pleasure' (left) and 'sadness'(right) during a highly important context match without emotion contagion

matches, again the most prominent changes in emotion contagion were found in the hooligans and fanatic supporters and also pleasure and sadness reach more intense levels based on the context of the match.

4 Validation

As first steps in validating the model, the following data are compared with the outcomes of the model: (1) the heart rates from 100 supporters during the match between Feyenoord and AFC Ajax on November 8th, 2015; (2) and (3) 41 subjective reportings, in hindsight, of experienced emotions during a match gathered through questionnaires subjective reportings of three soccer supporters gathered in real time during a match. The result of step one are shown in Fig. 6. The model outcome (left) shows the same pattern as the average measurement of the heart rate of 100 supporters (right). The heart rate peak after a goal has been scored in the model outcome is not as high as in the real measurements, but the overall pattern is similar. The results of the pilot study, are shown in Fig. 7. The bold line in the figures, for both "pleasure" and "sadness", show the average reported emotion. It shows, more or less, the same pattern as the model outcomes. The results of the questionnaire study, are shown in Fig. 8. The bold line in the figures, shows the average reported emotions. Again, it shows the same pattern as the model outcomes. These validation tests confirm that the model can show real patterns of heart rate and emotions.

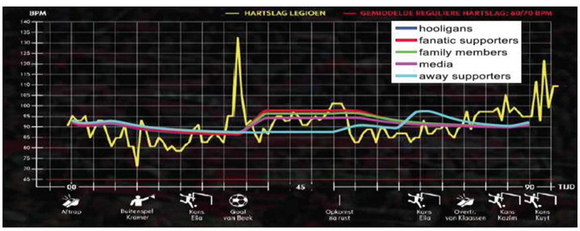

Fig. 6. Heart rates of soccer supporters; model outcomes (colour) and real data (yellow) (Color figure online)

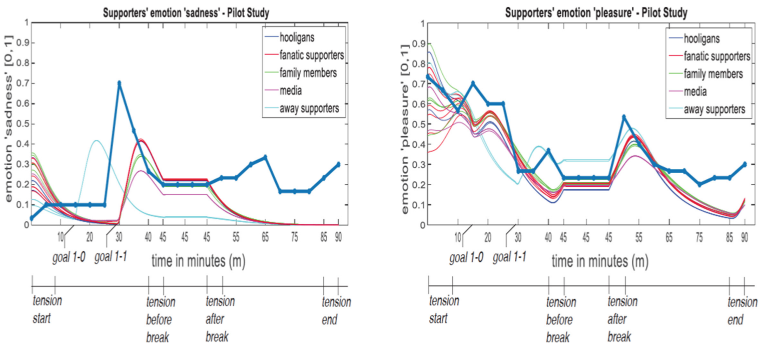

Fig. 7. Model Outcomes and reported emotions (thick lines) of pilot study

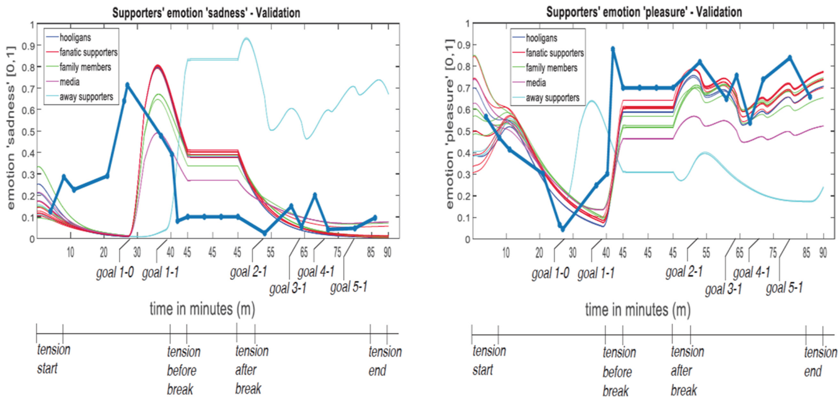

Fig. 8. Model outcomes and reported emotions (thick lines) of questionnaire study

5 Conclusions and Discussions

In this work the emotion contagion and patterns of the emotions "pleasure" and "sadness" were simulated during a soccer game in a virtual stadium, by a dynamic agent-based computational model. The main research question was "how does emotion contagion work in different situations during the game?" All stated phenomenon in Sect. 1, were verified in the simulation results, together with the emerging emotion contagion mechanisms. The main findings are that the emotions "pleasure" and "sadness" have different patterns during a soccer game and amongst different types of supporter. Furthermore, emotion contagion starts very clearly at the beginning of the match, and continues, yet to a lesser extent, during different activities during the soccer game.

One of the strengths of the current work is that the model is based on real life activities. The cognitive model is based on neurological theories and thus mimics a mechanism that exists in reality. Functions of specific brain regions and connections between those regions are related to specific functions and parts of the model. Furthermore, the different supporter groups are based on real supporters with their related characteristics that are visiting actual soccer games. The model heart rates outcomes show a similar pattern as the real life measurements, implying that it is reasonable to believe the model is based on relevant concepts. Another strength is that during the simulations different contexts were taken into account. Furthermore, to the author's knowledge, this paper presents the first model that simulates the ambiance during an activity that is related to crowd behaviour in sport stadiums. There is a lot of literature on different brain regions and their related functions and a large amount of models that model and predict human behaviour. Yet these models are mainly based on calculations derived from social interactions theories. The current work is based on existing neurological theories and social connections, unique in research on emotion contagion.

Aspects that need further development are the following. Firstly, there are more contextual situations during a soccer game, besides goals, like yellow cards, red cards and tackles that can also be included in the model. Secondly, parameter tuning can be improved; such as parameter 'eta' could have a value between 0 and 1, taken the new contextual situations into account. Also, the characteristics of the different subgroups, the omega parameters, can for now only be based on educative guesses, based on the neurological theories. Thirdly, interactions between the emotions 'pleasure' and 'sadness' could be modelled. Apart from that, a person's expectation of the game might influence the parameters and the emotion of that particular person. For example, when a supporter expects an easy win against the opponent, the value of the emotion could be lower when winning the game compared to the value of the emotion at low expectation of winning the game. Lastly, when looking at the validation, it becomes clear that the heart rate patterns are more or less the same, except for the peak after the moment when a goal is scored. Improvements are planned for future work.

In conclusion, the proposed model effectively simulates the emotions 'pleasure' and 'sadness' during a soccer game. It helps us understand the emotion contagion process of soccer supporters better. An envisioned future application of this model uses the current and predicted positive and negative emotions of the supporters, to advise on enhancing positive emotions and reducing or preventing negative emotions in order to improve the ambiance in a soccer stadium. This can be beneficial for both economic and safety reasons.

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