Modeling emotional contagion based on experimental evidence for moderating factors

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ABSTRACT
There is a lot of evidence for the phenomenon describing the spread of emotion from one person to another, called emotional contagion. Although there is a large body of research on this topic, research containing evidence for factors that moderate the process of emotional contagion, is limited and inconclusive. Furthermore most of these studies are done in a dyadic lab-setting and consequently little is known about emotional contagion in groups. This paper presents, for the first time, a dynamic computational model of contagion in groups of agents based on factors that moderate contagion. These factors are strictly based on experimental evidence in the psychological literature. In this paper we first present our review of the psychological literature. We then present our computational model as well as a pilot study investigating several group contagion cases showing the flexibility and potential of this strategy.

Categories and Subject Descriptors
I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence–Intelligent agents

General Terms
Human Factors.

Keywords
Emotional Contagion, agent based modeling, multi-agent systems

1. INTRODUCTION
If we perceive another person's emotional expressions, for example seeing a happy person smile, we tend to suddenly find ourselves also smiling and sharing this person's happiness without ever having intended to do so. This phenomenon of catching each other's emotions is called emotional contagion.

A specific, and predominant definition of emotional contagion describes it as the tendency to automatically mimic and synchronize facial expressions, vocalizations, postures and movements with another person's and, consequently, to converge emotionally[13]. This definition is based on the theory of primitive emotional contagion [12] and follows one of two predominant perspectives regarding possible mechanisms behind emotional contagion. The perspective emphasizes a subconscious level on which emotional contagion occurs. Some research suggests that emotional contagion is directly induced by the activation of neural representations of similar emotions in the observer. Emotional Contagion can also occur through a more conscious process. Following this perspective some studies suggest that emotional contagion can happen through social comparison processes, in which people evaluate their affective state in comparison with that of other people in their environment and respond according to what seems appropriate [11,28].

Most of the research on emotional contagion to date has been done in a dyadic setting and therefore little is known about the occurrence of emotional contagion within groups, of which the existence is also known [2]. To better understand contagion in groups, computational modeling can be used in the same way as it is used in other dynamic systems, especially if moderating factors for emotional contagion can be systematically varied in a computational agent. In terms of more concrete application value, our work can contribute to the development of virtual characters; especially VC's that need to show behavior that is emotionally plausible at the group level [33], or in dyadic setting involving a VC and a user.

To date there are only a few studies concerning computational models specifically for emotional contagion. Tsai et al. [31] present an interesting empirical evaluation of several recent computational emotional contagion models. In their evaluation they compare two models which differ substantially in the underlying modeling-approach. They find a thermodynamics based model created by Bosse et al. [4] generates superior results when compared to a model by Durupinar [9] which is based on an epidemiological process; implying that to date first mentioned specific underlying modeling-strategy is best suited to represent the process of emotional contagion. Bosse's model is inspired on recent studies involving group affect. However, the model approaches the dynamic nature of contagion in a relatively abstract manner; taking into account only the basic aspects necessary for contagion. Other studies utilize a similar abstraction strategy. For example Bispo and Paiva [3] based their model on the emotional contagion scale; a measurement instrument for susceptibility to emotional contagion. They take into account the specific emotions and susceptibility to emotional contagion as the only moderating factors.

We present a novel approach of computational modeling of emotional contagion solidly based on psychological evidence for contagion moderating factors. While we share a dynamical system approach with Bosse et al. [4], our model explicitly simulates the effect of individual moderating factors. We first review experimental evidence for moderating factors based on the psychological literature, then we present our computational model and pilot study showing its potential.

2. REVIEW METHODOLOGY
Although there is a large body of research on the topic of emotional contagion, research directly studying emotional

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contagion containing evidence for potential factors that influence the process of emotional contagion is limited and inconclusive, illustrating the importance of a structured review of the evidence found in this area.

First an exploratory search was performed using Google Scholar in September 2011. Search-terms included emotional contagion, affective contagion, mood contagion and affect contagion. All types of relevant studies in English were taken into account. Possibly relevant studies were added based on the references in these studies.

In the second phase the final corpus was obtained with an additional exhaustive search in October 2011 using the following EBSCOhost online databases: PsycINFO, PsycARTICLES, Acedemic Search Premier and the Psychology and Behavioral Sciences Collection. Basic exact-phrase searches were done consisting of the following relevant keywords: emotional contagion, affective contagion, affect contagion and mood contagion. The resulting collection of articles was compared with previous findings and relevant articles were added to the collection.

During the last phase the resulting collection was filtered based on the following criteria. The study contains results based on quantitative studies directly involving psychologically healthy subjects. The study explicitly presents evidence for factors that can, or evidently cannot possibly moderate emotional contagion.

3. RESULTS REVIEW

Emotional contagion moderators can be categorized in three categories (Table 1.) and these categories will be described in more detail in the rest of this section:

- *individual differences* accounting for factors such as personality and gender
- *interpersonal factors* comprising for example similarity and group membership, and
- *miscellaneous* factors.

Table 1. moderating factors for emotional contagion.

				Susc-eptibility	Cont-agability
Individual differences	emotion related trait	sender			+
		receiver		+	
	gender	female		+	+
interpersonal factors	similarity	attitudinal similarity		+ *	
		situational similarity		+	
			group membership	+ **	
	social power			+/- ***	+/- ***
	intimacy			+	
miscellaneous	pre-existing positive mood			+	

** effect only found for positive emotions; ** non-group membership induces opposite emotion (divergence); *** effect found in both directions*

We further found it useful to separate the moderation effect of factors in a moderation of susceptibility to contagion ("in") and a moderation of what we call contagability ("out"). Concretely this means that a factor can influence the susceptibility of a person but also the contagability. The overall contagion one person (let's say *Marie*) experiences is thus determined by that person's (*Marie's*) susceptibility ("in") and by the other's (*Bob's*) contagability ("out"). This is different from a person's sender and receiver traits. These two factors contribute to contagability and susceptibility respectively but are not equivalent to these constructs, as will become clear in the review.

3.1 Individual Differences

3.1.1 Emotion Related Trait

The theory of primitive emotional contagion of Hatfield et al. implies that a differentiation can be made between people who are strong transmitters of emotions and people who are strong receivers (catchers) of emotions. Hatfield et al. state that contrary to the often charismatic, entertaining or dominant people who by their innate bodily circuitry communicate their emotions more strongly to others, the people who are especially susceptible to emotional contagion are those who pay close attention to others and are therefore more likely to read and mimic other people's emotional expressions. Consequently their emotional experience is more influenced by the afferent feedback, which results in stronger emotional convergence [12,13]. In theory strong transmitters of emotion demonstrate insensitivity to the emotions of others compared to strong receivers. However, Hatfield et al. suggest that these characteristics are not mutually exclusive. We now review studies concerning sender and receiver differences.

3.1.1.1 Senders

Sullins [28] found evidence for individual differences in emotional (nonverbal) expressiveness. Based on social comparison theory, their study additionally provides evidence for the relationship between these differences and the ability to infect another person with emotions. Subjects who scored high in nonverbal expressiveness had more influence on the emotions of the unexpressive subjects in a dyadic setting than vice versa.

3.1.1.2 Receivers

Doherty [6] attempted to develop a measure of individual differences in susceptibility to emotional contagion. The study resulted in the now commonly used Emotional Contagion Scale. One of the methods they used for the validation of the Emotional Contagion Scale was a comparison with other measurements of potentially related psychological concepts. This analysis showed that susceptibility to emotional contagion was positively associated with amongst other things emotionality and sensitivity to others and negatively associated with self-assertiveness and emotional stability.

A study done by Laird et al.[18] demonstrates a relation between individual differences in so called 'cue responsiveness' (the degree to which a person is affected by his/her own expressions) and emotional contagion. Participants that were more responsive to self-produced cues proved to be more likely to feel the emotions of those they mimic and thus were more susceptible to emotional contagion. Additional support for this effect was found in a different study by Doherty [8]. More recent research done by Papousek et al. [24] corresponds with- and complements most of these findings. They used self-reports for emotional contagion and

measured physiological indicators for emotional arousal (cardiovascular measures). Interesting is that both methods had almost identical results; participants who were strong emotion regulators and weak at emotion perception showed the weakest emotional contagion to sad emotions. Participants who were weak emotion regulators and were good at emotion perception showed the strongest responses to happy (cheerful) emotions.

These findings are in line with the idea that there is a difference between people with a strong tendency to regulate one's emotions reducing one's susceptibility to emotional contagion and people strong in perceiving emotions of others reacting more to these emotions resulting in high contagion susceptible.

3.1.2 Gender

In light of the findings that individuals differ in the degree to which they are good senders of emotion and the degree to which they are good receivers of emotion, it is also found that there is a difference between men and women regarding this construct. One example is a study of gender differences in facial reactions to facial expressions [5] by Dimberg and Lundqvist. They found differences in facial expressiveness of men and women when reacting to emotional stimuli. In this EMG-study women showed stronger imitative responses to angry and happy facial expressions than men, indicating that woman are more facially reactive than men are. Similar results were also found in a study by Lundqvist who complements these findings by investigating them in the context of primitive emotional contagion [22] and providing evidence consistent with the theory that facial emotional expressions are contagious.

Hatfield et al. theorize that females tend to be more susceptible to emotional contagion than males are and that this is amongst other thing due to traditional gender roles; woman are taught by the way they are socialized to be more sensitive to others' emotional displays as compared to males. The following studies provide supporting empirical evidence regarding this theory.

In the context of primitive emotional contagion Doherty et al. [6] found compelling evidence that women are more susceptible than men to the emotions of others and thus to emotional contagion, for both positive and negative emotions. Women from a variety of occupations reported being more susceptible to emotional contagion then men. These results were consistent with the findings in a second study where they used judges' ratings to measure the actual responsiveness to other's emotions. The judges rated women as displaying more emotional contagion than did men. A study by Stockert [27] came up with similar results additional showing that women also reported more intense emotion than men after watching emotional videos, significantly so for happiness.

A number of studies regarding the adaptation of the emotional contagion scale within a different culture resulted in additional compelling evidence supporting the theory that gender is a moderating factor for emotional contagion; Most of them conclude with almost identical findings as found with the original version. [7,16,20,21]

Within the data used for this review we found one interesting result by Hsee et al. [14] that is not in conformity with previously mentioned findings. Although gender was not included in the original design in their study but later taken into account, they found no significant gender differences in emotional contagion when showing participants another person's happy and sad expressions.

In conclusion, and in line with Kevrekidis [16] we can state that that although more research is needed to explore if gender differences in emotional contagion exist, these differences must be taken into account when studying emotional contagion. Woman tend to be better in transmitting and receiving emotions as compared to men, and therefore are more susceptible to emotional contagion.

3.2 Interpersonal Factors

3.2.1 Similarity

Perceived similarity is a factor moderating contagion. A basis for the assumption of this effect can for example be found in the social comparison theories, for it is known that emotional contagion can happen through social comparison processes where people evaluate their affective state in comparison with that of other people and their environment to come with an appropriate response [11,28]. Although similarity as a single construct has been shown to influence contagion in a study by Paukert et al. [25], other studies indicate that a differentiation can be made with regards to types of similarity.

3.2.1.1Attitudinal Similarity

Stockert [27] specifically researched perceived similarity and emotional contagion. She investigated similarity in a attitudinal context using attitude questionnaires and assigned subjects to either a similar or dissimilar partner, hypothesizing that similarity will lead to increased emotional contagion. Additionally she took dissimilarity into account, questioning whether this would have the opposite effect or maybe would even reflect in the induction of opposite (discordant) emotions. She proposed that similarity would have a positive effect on emotional contagion regarding happiness and sadness and that dissimilarity would not lead to discordant emotions within the research setting; subjects in the dissimilar condition were hypothesized to show less emotional contagion then subjects in the neutral condition and the subsequent similar condition. The results partially supported the proposition. Although there were a number of seemingly random effects hampering theoretical interpretations, a significant positive relation was found both by judge's ratings of facial expressions and subject's self reports between perceived attitudinal similarity (and subsequent attraction) and the contagion of happiness. However the results did not support the same effect for the contagion of negative emotions (the sadness condition). In this context identical results were also found by Paukert et al. [25]. Regarding dissimilarity it was found that although dissimilar subjects tended to catch more emotion then expected (the results were close to the controls in one of the measures), the overall results show that in this research setting the dissimilar subjects did not experience discordant emotions compared to subjects in the similar condition.

3.2.1.2Situational Similarity

Sullins' [28] focused on similarity and contagion in specifically a situational context. One of the conditions incorporated in their 3x3 study design was the pairing of the participant with a relevant other; a person who they believed was going to engage in a similar situation, opposed to the irrelevant other condition where the participant was paired with a person whom they believed was there for a different reason. The results indicate that the moods of

participants who were experiencing the same situation as their partner were most likely to converge compared to the participants in the irrelevant other condition or control group. The latter two did not show significant differences in their scores, which can be interpreted as an absence of the reversed effect; dissimilarity having a negative effect on emotional contagion.

Interesting is the fact that in a later study done by Gump et al.[11] threat and perceived situational similarity was manipulated to investigate affiliation and emotional contagion specifically in threatening situations. They predicted that threat would increase the tendency for people's emotions to be influenced by the emotions of others, especially when facing the same situation. Although the presence of emotional contagion was ascertained, and the predictions were confirmed regarding the results for mimicry, they found no evidence that either threat or situational similarity was a significant moderator for emotional contagion. They conclude with the suitable statement that: 'although it would be premature to conclude that perceived situational similarity of the other's situation plays no role in emotional contagion, the importance of such perceptions may be less fundamental than has been assumed by social comparison theorists.' The aforementioned results of Stockert in a sense support these findings. Although similarity was addressed within a slightly different context and the studies focus on different emotions Stockert provides evidence for the presence of a difference in strength of the effect of different moderating factors for emotional contagion, by showing that for example susceptibility had more impact on emotional contagion compared to perceived similarity.

3.2.1.2.1Group membership

Situational similarity can also be interpreted more specifically in terms of group membership; questioning whether a person belongs to the same group or not. Van der Schalk et al. specifically investigated if group membership moderates emotional mimicry and contagion [32]. They found that expressions of anger and fear were mimicked to a greater extend by subjects in the in-group condition then subjects in the out-group condition. Interesting is the fact there was no such effect found for the mimicry of happiness. And although they offer some strong possible reasons for the lack of this effect it is interesting to note that in this context these results prove similar to for example the results found by Stockert. Van der Schalk et al. furthermore found some evidence for a divergence effect. Although these results were somewhat weaker than those for the convergence effect they found in one study that the expression of angry emotions in the out-group condition resulted in more self-reported fear and that the expression of fear in the out-group condition resulted in the experience of aversion which was found both in the subjects' self reports and their emotion display. An interesting observation was that although the effect was found for the mimicry of emotional expressions, they found no significant correlation between mimicry and self-reported emotions; thus for emotional contagion. Nevertheless they argue that the 'research shows emotional convergence is more likely to occur when individuals share a group membership.'

More indicative evidence for this divergence effect of dissimilarity was also found by Epstude et al. [10] They utilized the concept of similarity both in the context of group membership and in a context where subjects were primed to specially look for similarities or dissimilarities. Within both these contexts they found evidence confirming their hypothesis; subjects focusing on similarities experienced more concordant emotions when being confronted with pictures of a person pre-rated as conveying a specific (positive, neutral or negative affect), while subjects focusing on dissimilarities experienced more discordant mood in the same condition.

Although the amount of evidence is limited, overall these studies provide evidence that contagion is stronger in the in-group condition. Furthermore they show that emotional divergence is also a possible effect.

3.2.2 Social power

In the earlier mentioned historical review on social contagion [19] Levy et al. argue based on indicative evidence that contagion in the context of social status is most likely to happen in a top down fashion; from high status individuals to low status individuals.

Anderson et al investigated emotional convergence in the context of relationships [1]. Two studies provided similar results; one with partners in romantic relationships and one with college roommates. Examining amongst other things personality and emotional experiences, during two laboratory sessions they found that the low power subject was influenced to a greater extent by the emotions of his/her partner, then vice versa.

On first sight the statement by Sy et al. [29] that their findings are 'consistent with recent research showing that high status individuals are more likely to transmit their moods to low status individuals than vice versa' seems to support the findings of Anderson et al. They investigated the effect of a leader's mood on that of members of the group by priming a leader with a positive or negative mood before engaging in a complex group-task. Nevertheless, as they also state with regards to limitations of the study, the fact is that they only investigated contagion in the direction of a high power condition to a low power which consequently makes conclusions about the moderating effect of power on emotional contagion impossible. They propose that it is very possible that contagion can also happen in the opposite direction and with a different effect-strength.

Contrary to aforementioned research Sestak et al. [26] investigated the influence of social status on emotional contagion in a direct manner explicitly testing for a moderating effect. They collected trait based data from a number of dyads consisting out of a supervisor and subordinate working in a global manufacturing company which subsequently provided data regarding amongst other things their emotional state over a period of two weeks. In general their observations support the theory that the direction of emotional contagion in a group possibly goes from a high power to low power; at least within subordinate-supervisor context. Early research done by Hsee et al. also directly focused on the assumed relation between power and emotional contagion [14]. Test subjects were assigned to the role of teacher or the role of learner. The latter representing the powerless condition. Subjects were led to believe that the teacher had to teach the learner a list of words and had the power to punish the learner by administering an electric shock when he or she saw fit. They theorized that subjects in the low power condition would be more affected by the emotions of the other (powerful) subjects then vice versa. They found no evidence for this effect examining the subject's self-reports of the experienced emotion. However it is interesting that the results of the judges' ratings showed an significant effect in the opposite direction. Seemingly the powerful were more susceptible to the emotions of the subjects in

the low power condition. A possible discrepancy between the subjects self-reports and the judges' ratings further support the findings (the subjects' self reports seemed to be less reliable as a measurement for their feelings).

Kimura et al. [17] found almost identical results; participants were more susceptible to the emotions of juniors whose social power was low then to seniors representing high social power. However their results are somewhat debatable due to the lack of an initial manipulation check for social status and a questionable method.

Nevertheless it is interesting that both studies directly addressing the effect of social power on emotional contagion following a similar hypothesis, report similar findings in terms of a inverse effect, suggesting high social power increases susceptibility to emotional contagion. Overall, evidence indicates that social power is a moderating factor concerning for emotional contagion. However due to the fact that there is indicative evidence for two different directions of this effect it is hard to make any sound conclusions concerning whether it contagion is more likely to go from low power individuals to high power individuals or vice versa, of which the latter effect is predominantly theorized.

3.2.2Liking and Intimacy

Hatfield et al. theorized that emotional contagion is most likely to occur in relationships involving power or love. The latter concept is closely related with liking and intimacy which some studies indeed suggest can be a moderating factor for emotional contagion. Kimura et al [17] successfully manipulated intimacy by making the subjects assume one of the following roles: friend, acquaintance, senior junior and found evidence suggesting that participants were more susceptible to those with whom they shared the highest degree of intimacy. The effect was only found for experiences of positive emotions, but they argue that it is plausible that the absence of this effect for negative emotions might be due to Japanese display rules.

Another study done by McIntosh [23] provided similar results regarding mimicry of facial emotional expressions. However their results did not show that the evoked emotional expressions directly caused the found contagion and therefore conclusions about the effect of liking on contagion cannot be made. Nevertheless it is interesting to note that the results partially support previously mentioned findings.

3.3 Miscellaneous

3.3.1Pre-existing mood

A lot of experimental studies regarding emotional contagion utilize emotional priming as a means of control for a specific emotion. A logical continuation of this idea can be that mood can moderate emotional contagion. The following study by Hsee et al. specifically focused on this research-question. Hsee et al. investigating the impact that pre-existing mood has on an individuals susceptibility to emotional contagion [15]. Participants were primed with a happy, neutral or sad mood by letting them recall a series of events consistent with the specific condition after which they were asked to view a happy or sad video. The results suggest that pre existing mood can have a minimal impact on emotional contagion. Evaluating the judges' ratings of the facial expressions they found borderline significance. Subjects in the happy condition showed more attention to the emotions of the target person and were more likely to mimic the expressions of the target person. This can be interpreted as weak evidence for their hypothesis that people are most susceptible to emotional contagion when they are happy.

4. MULTI-AGENT BASED MODEL

To investigate emotional contagion within groups, we have developed a multi-agent simulation in which the agents influence each other based solely on the factors found in the review. The simulation system itself is in essence a simple dynamical system composed of the individual agents that populate a continuous 2D space. Time increments, *dt,* advance the state of the simulation. This section will discuss this agent model in more detail.

Behavior model.

Each agent has a behavior model that defines how it moves through space. Initially an agent is set at a starting location. When the simulation starts, the behavior model defines how the coordinates of an agent change. Currently we have only one model implemented that represents a simple way of wandering through space based on constant movement with a random change in direction induced by a set timer or a collision with another agent.

The emotion model.

In the greater part of the studies the investigated contagion factors are limited to two basic emotions; namely positive emotions and negative emotions, without clear differentiation. As such, we have used a factor-based emotion representation based on the Pleasure Arousal Dominance factor model. Each factor, *P*, *A,* and *D* can have a value between -1 and 1. The emotional state decays in a linear fashion based on a constant change towards (0,0,0).

The contagion model.

To minimize assumptions around contagion, a direct interpretation of the factors and their effects on contagion was used. We assume that emotional contagion flows in the commonly theorized direction from high social power subjects to those with a lower social power [1,24]. The model is a description of what kind of effect a specific factor has on emotional contagion; a positive, negative or null effect. In this context contagion is defined by the effect of a specific factor on susceptibility and on so-called contagability of an agent. Nevertheless one factor had to be assumed, i.e., distance. Just like the other factors, the importance of distance as a factor can also be defined per agent in its personality.

Personality.

For the model to allow easy configuration of agents, separate of the definition of contagion factors and their effects, each agent has a personality type. In essence a personality is simply a vector of contagion factor weights with some additional agent variables such as power and group belonging, needed to calculate the effect of factors like social power and group membership. This enables us to vary the size of a specific factor's effect per individual agent. For the sake of clarity we call this a personality type.

Table 2. Overview of contagion factors used in the simulation model. Columns refer to factor effects on susceptibility and contagability, as well as three example male personalities for a high power leader ($Pers_a$), medium power leader ($Pers_b$) and a follower ($Pers_c$), as used in the pilot study described below.

Factor	Susc	Cont	$Pers_a$	$Pers_b$	$Pers_c$
Transmitter	0	1	1.0	1.0	0.5
Reciever	1	0	0.0	0.0	0.5
Female	1	1	0.0	0.0	0.0
Group_membership	1	0	0.5	0.5	0.5
Low_power	1	0	1.0	1.0	1.0
High_power	0	1	0.0	0.0	0.0
Distance	1	0	0.1	0.1	0.1
POWER			1.0	0.5	0.0
GROUP			A	A	A

Contagion

Contagion occurs from an agent a to an agent b after each dt and only if the distance $d_{ab} < maxViewingDistance$ as follows:

$$c_{ab} = \frac{\sum_F Succ_f \bullet Pers_{a(f)} \bullet State_{a(f)}}{|F|} \bullet \frac{\sum_F Cont_f \bullet Pers_{b(f)} \bullet State_{b(f)}}{|F|}$$

Succ and *Cont* refer to susceptibility and contagability relations between factors (see table), while *Pers* refers to the personality weights of an agent (see table for example personalities). The *State* defines to what extent factors play a role in the current situation of the agent. Currently all factors always play the same role (i.e., $State_f=1$), except for the following. If both agent a and b are in the same group:

if $Group_a=Group_b$ then $State_{a(group)}=State_{b(group)}=1$

Closer agents show stronger contagion. Actual distance between agents influences contagion as follows:

$$State_{a(distance)}=State_{b(distance)}=1-(d_{ab}/maxViewingDistance)$$

High and low social power are each others inverse in our current setting and are calculated as follows:

$$State_{a(high\_power)}=if\ (power_a>power_b)\ power_a-power_b\ else\ 0$$

$$State_{a(low\_power)}=if\ (power_a<power_b)\ power_b-power_a\ else\ 0$$

Eventually, the emotional state of agent a is influenced using a simple update function:

$$Emo_{a(t+dt)}=Emo_{a(t)}+dt*c_{ab}*(Emo_{b(t)}-Emo_{a(t)})$$

Obviously this is done for each agent pair a and b, and for each timestep in the simulation. By controlling dt, the resolution and speed of the simulation can be varied.

5. PILOT STUDY

For a first test-case we chose to simulate the spread of elatedness (intensely arousing and positive affective state) in the context of a recreational environment filled with students, induced by one individual. The almost instant spread of laughter and unrest amongst students after for example a funny remark by one individual is a phenomenon well known by teachers. Following Hatfield's reasoning in their theory of primitive emotional contagion regarding individual differences in emotional traits this specific initiator is likely to be a person who is very good at transmitting emotions and consequently has insensitivity to the emotions of others. Based on this reasoning the only effective factors varied between the two types of individuals is the tendency to be transmitter or a receiver. The simulation is constructed with the personality $Pers_a$ (the initiator) and $Pers_c$ (the other students). The recreational room is 10 x 10 meters, and is filled with 10 students at random locations and one initiator. The *maxViewingDistance* is set to 3 meters.

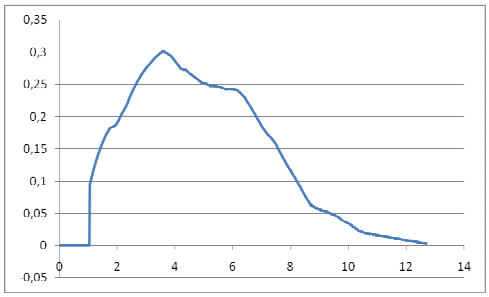

Figure 1. Initiator added in the middle. On the x-axis: time, on the y-axis: mean group Pleasure (*P*) intensity.

Around t=1 the initiator becomes happy (high *P*, *A* and *D* affective factors). When the initiator is in the middle of the group, as expected the results show a fast increase in the mean group happiness, continued by a gradual decrease of the emotion until all agents including the initiator reach the starting emotional state which is neutral. This is due to natural emotional decay.

In a second test run we generated the same situation but now the initiator was placed in a more secluded area of the room. Again the results show a similar pattern compared to previous test-run with the only difference that the overall mean scores for group happiness are lower, as expected due to less contagion induced by the increased distance between the initiator and the students.

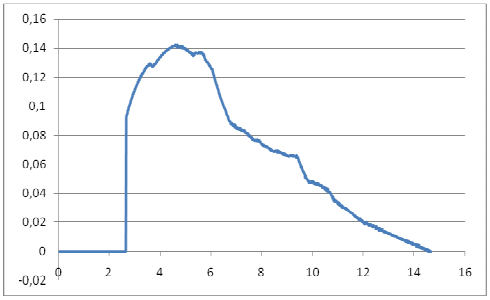

Figure 2. Initiator added in secluded area, axes same as above.

Running the same test but now with multiple initiators present resulted in a short increase of the emotion every time the initiator was added although with a smaller maximum intensity for every new initiation. The first contagion event (t=1) is similar to Figure 1 as it is a similar setup (10 students, 1 initiator). The second event (t=13) results in less contagion due to the presence of two initiators of whom only one becomes happy. The third shows the same effect when three initiators are present of which one becomes happy. This result can be easily explained. Neutral initiators are still bad receivers and are not influenced by an initiator who is happy. This means the neutral initiators influence the group with a neutral state functioning as a "resistor". It therefore becomes less likely for contagion to happen by happy initiator.

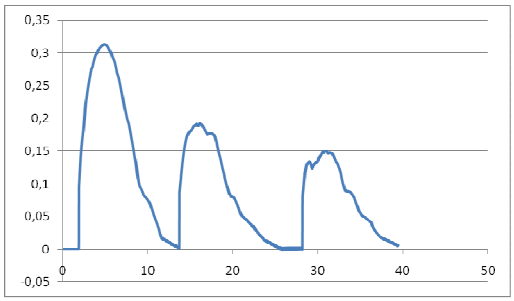

Figure 3. Multiple initiators present, axes as above.

In the above settings, contagion is a result the factors transmitter/receiver and a difference in social power between, although similar results would be obtained if the factor power was dropped as in the current setting power only makes contagion stronger (the transmitter is also the high power individual).

To expand the test-case we investigated the factor power in more detail. In addition to the initiator, who has leader characteristics (high power) we have a sub-leader personality $Pers_b$ (medium power). All other factors are the same for both personalities.

In a simulation similar to previous one, but now with the sub-leader becoming happy in the presence of an initiator, the effect of the sub-leader is strongly reduced (Figure 4, second contagion event) compared to when the sub-leader would be present alone (Figure 5, first contagion event). However, the effect of contagion of the initiator is amplified in the presence of a sub-leader (Figure 5, second contagion event) compared to in the presence of another initiator (Figure 3, second contagion event). The explanation is that the initiators and sub-leaders are sensitive to power. The sub-leader is influenced by the leader effectively functioning as an amplifier for the group, but the initiator is not influenced by the sub-leader still functioning as a resistor.

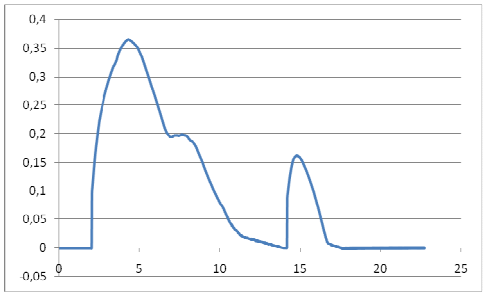

Figure 4. Initiator and sub-leader added respectively.

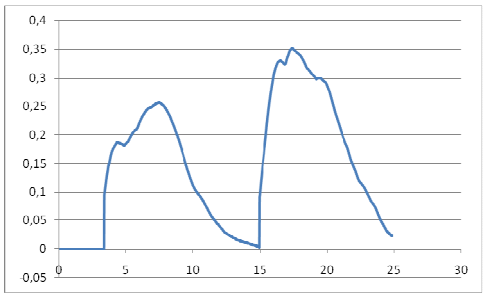

Figure 5. sub-leader and leader added respectively.

To expand this test-case even further within the context of students in a recreation room, simulated an annoyed teacher who enters the room after the initiator becomes happy. We used the same personality for the teacher and for the initiator ($Pers_a$). However, the teacher's initial emotional state is either negatively calm or negatively aroused to simulate a calm negative reaction and a very angry reaction.

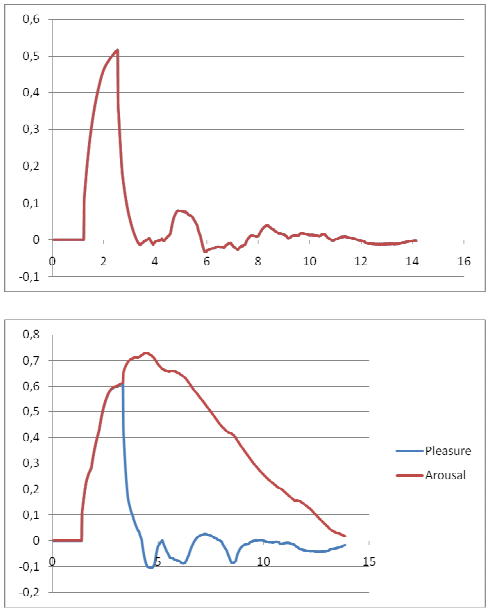

Figure 6. two types of reactions. Above both arousal and valence are reduced to neutral (in exactly the same way) due to calm negative teacher intervention. Below, arousal increases due to angry teacher intervention.

An interesting and explainable observation can be made. When the annoyed teacher reacts by expressing his negative emotions in a calm manner we can see that this results in a quick nullification of the spread of the initiated positive emotion and arousal. A negative but aroused reaction however, results in a nullification of the effect on pleasure spread, but not on arousal. The situation has not calmed down, only made less positive.

6. DISCUSSION

In this paper we show for the first time that a straightforward factor-based model of contagion can be used to study the details of how and due to which factors contagion spreads through a group. Current efforts focus on a validation of our approach. To this end we are in cooperation with social psychologists in order to investigate the model and use of the simulation system for both hypothesis testing and generation. We feel the strength of the system is the small number of additional assumptions needed to study contagion, other than those based on psychological findings. Although of preliminary nature, the pilot study is a clear example of the many potential settings in which our approach can be used to model and study emotional contagion. Other than simulating contagion in a multi-agent setting for the sake of understanding emotional contagion on a psychological level, we feel our review of factors is an important basis for the development of artificial agents that make use of or take into account contagion between agents and humans, such as the work recently published by Tsai et al [30], and Bispo and Paiva [3]. The novelty of our modeling approach is, when comparing it to existing models, that we are able to systematically vary moderating factors for contagion while other address the process of contagion in a relatively abstract manner. Further, we only introduce those factors that have shown to be moderators according to actual psychological experiments.

Our results show that modeling emotional contagion based on experimental evidence from psychology can give insight in the dynamics of emotional contagion within a group.

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