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Mediated Cues of Group Emotion during Knowledge-Work Tasks: Effects on Subjective and Physiological Responses

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We examined how mediated cues of group emotion influence the emotional state of the members of a non-co-located group when performing knowledge-work tasks in a laboratory. The emotion displayed was determined by the experimenter and the participants were led to believe that there were three other group members simultaneously performing the same tasks (four routine tasks and four planning tasks) in different rooms. Prevailing emotional state of the group (depressed, nervous/stressed, pleasantly excited and pleasantly relaxed), allegedly based on self-report, was displayed in textual format on a web page before the first task and after each task. Facial electromyographic (EMG) activity and electrodermal activity (EDA) were recorded during task performance. Negative cues of group emotion elicited lower self-reported pleasure, lower perceived confidence in the other group members, higher corrugator supercilii EMG activity and higher EDA compared with cues of positive group emotions. Planning tasks elicited higher self-reported pleasure and arousal, lower corrugator EMG activity, and higher EDA compared with routine tasks. The results suggest that mediated textual cues of group emotion can lead to emotional contagion to the individual group members during distributed knowledge work.

RESEARCH HIGHLIGHTS

- Mediated group emotion influences individual's emotional state;
- Planning tasks evoked higher pleasure and arousal ratings compared to routine tasks;
- Negative group emotion evoked more physiological arousal versus positive.

Keywords: emotional contagion; psychophysiology; distributed work; knowledge work

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1. INTRODUCTION

Emotions have a significant role in all human communication, not only in face-to-face communication but also in computer-mediated communication (CMC). Besides textual expressions in e-mail and other messages, emotions are expressed by different types of status updates in social media and other services. It seems that we have an inherent need to communicate and reflect on our emotional experiences (see, for example, Derks *et al.*, 2008) and this need persists even when the communication is mediated. Emotional expressions often lead to emotional contagion, that is, transfer of emotions between two or more people. Besides face-to-face situations, previous studies have shown that emotional contagion can occur also in CMC (Hancock *et al.*, 2008). The purpose of the current study is to examine how computer-mediated short verbal cues of group emotion influence the emotional state of the members of a non-co-located group when performing knowledge-work tasks in a laboratory.

Emotions on a group level are a phenomenon different from individual-level emotions. Smith et al., (2007) reported confirmatory results for the four previously suggested key criteria that define group-level emotions: (a) group emotions can be distinct from the individual-level emotions of a person, (b) group emotions depend on the person's degree of group identification, (c) group emotions are socially shared in a group and (d) group emotions regulate both intra- and intergroup attitudes and behavior.

Affect in groups, including emotions, has two different coordinating functions. Group-level affect serves as a quick and effective way to mediate information about the surrounding environment and group structure to other group members; in addition to this communicative function, group affect strengthens group bonding and loyalty (Spoor and Kelly, 2004). Spoor and Kelly (2004) suggest that, in the prehistoric environment, negative emotions served as warning signals for nearby predators and, for the preservation of the group, the rapid spreading of the negative affective information within the group was important. Various studies have demonstrated that positive group mood can also lead to increased group cohesion and this can improve cooperation and coordination (e.g. Sanna et al., 2003).

1.1. Emotional awareness in work context

Social awareness is one work-task-relevant form of group awareness, other forms being, for example, work space awareness, group-structural awareness and informal awareness (Gutwin et al., 1996). Group awareness in all its forms provides information that is essential for effective and fluent collaboration. In a face-to-face work group, awareness is often taken for granted, but in a distributed group this awareness is somewhat difficult to maintain. In a face-to-face situation, the emotional state of the other can be observed from facial expressions and other bodily movements, tone of voice and other behavior. Emotional awareness, one form of group awareness, can be defined as consisting of awareness of one's own emotions and awareness of emotions on a group level (Saari et al., 2008). In the previous studies, increasing the group's emotional awareness with affective user interface elements, like icons and avatars, led to positive effects and the users found these elements useful (e.g. Garcia et al., 1999; Sánchez et al., 2005).

1.2. Emotional contagion

The tendency to express and feel emotions that are similar to and influenced by those of others is called emotional contagion. Emotional contagion is one mechanism for transmitting emotional awareness between the individual and the group. The process of emotional contagion is the primary mechanism through which emotions are shared and become social and thus create collective emotions (Barsade and Gibson, 2007). On a primitive level, emotional contagion occurs when we mimic the facial or vocal expressions, postures and behavior of people around us and, as a consequence, catch others emotions (Hatfield et al., 1993; Spoor and Kelly, 2004). Emotional contagion is deeply rooted in developmental processes; it has been suggested that it develops to facilitate the bonding between a mother and an infant (Preston and de Waal, 2002).

At least in some contexts, emotional contagion can lead to positive outcomes. Barsade (2002) reported on a simulated managerial group decision-making task in which the degree to which individuals within the group experienced positive contagion predicted how positively other group members rated their performance. Positive emotional contagion led to improved cooperation, decreased conflict and increased perception of task performance.

1.3. Emotions and psychophysiology

One approach to defining emotions is to see them as biologically based action dispositions that play an important role in the determination of behavior (e.g. Lang, 1995). Emotions can be considered to be constituted by three reactive systems: (a) expressive and evaluative language, (b) physiological response and (c) behavioral response (Lang, 1995). According to some theorists, distinct emotions (such as surprise, happiness, disgust, anger, fear and sadness) are inborn and have different behavioral and physiological responses (e.g. Ekman, 1992). A competing view states that emotions are, in most respects, fundamentally similar with differences in one or more dimensions. The dimensional theories of emotion state that all emotions can be located in a coordinate defined by some set of different dimensions (e.g. Lang, 1995). Various researchers have named the dimensions differently, but Larsen and Diener (1992) stated that all dimensions could be defined as combinations of valence and arousal dimensions. The valence dimension varies from unpleasant to pleasant and the arousal dimension defines the level of bodily activation related to the emotional experience and ranges from calm to excited. Another approach classifies the range of emotions with the negative activation (NA) and positive activation (PA) axes (Watson and Tellegen, 1985). The NA axis ranges from high-arousal negative emotions (e.g. fear) to low-arousal positive emotion (e.g. pleasant relaxation) and the PA axis ranges from high-arousal positive emotion (e.g. joy) to low-arousal negative emotion (e.g. depression). It has been suggested that the self-reported NA and PA dimensions represent the subjective components of the two primary brain motivational systems, that is, the behavioral inhibition system related to withdrawal behavior and the behavioral activation system related to approach behavior (e.g. Watson et al., 1999).

Facial electromyography (EMG) has often been used to study hedonic valence (e.g. Cacioppo et al., 1986). Increases in the activation of the zygomaticus major (cheek) muscle area have been associated with positive emotions, whereas increases in the activation of the corrugator supercilii (brow) muscle region have been associated with negative emotions (Witvliet and Vrana, 1995; Dimberg, 1997; Dimberg *et al.*, 2000; Larsen *et al.*, 2003; Hazlett, 2006). For the measurement of emotional arousal, electrodermal activity (EDA) is an important index. EDA has been shown to correlate with self-reported emotional arousal in studies where affective pictures have been used as stimuli (e.g. Lang *et al.*, 1993). Two typically analyzed indices calculated for EDA signal are the (continuous) skin conductance level (SCL) and the (discrete) frequency of non-specific skin conductance responses (NS.SCR.freq).

2. CURRENT STUDY AND HYPOTHESES

We conducted a laboratory experiment where we studied the effects of mediated cues of group emotion on an individual user's emotional state while performing knowledge-work tasks. The mediated cues of group emotion were determined by the experimenter and in reality there were no other group members, only one participant performing the task. The majority of emotional contagion research has been carried out in face-to-face settings, but we suggest that emotional contagion can also occur during a distributed knowledge-work task through technology-mediated cues. We hypothesized that the effects of emotional contagion are visible in both self-report data and psychophysiological indices. More specifically, we hypothesize that both the emotional valence and the emotional arousal are contagious. Thus, we formed the following two main hypotheses.

Hypothesis 1: negatively valenced cues of group emotion (depressed and nervous/stressed) will elicit lower self-reported pleasure and zygomatic EMG activity, and higher corrugator supercilii EMG activity, compared with positively valenced cues (pleasantly excited and pleasantly relaxed). Similarly, positively valenced cues of group emotion will elicit higher self-reported pleasure and zygomatic EMG activity and lower corrugator supercilii EMG activity.

Hypothesis 2: high-arousal cues of group emotion (pleasantly excited and nervous/stressed) will elicit higher self-reported arousal and EDA compared with low-arousal cues (depressed and relaxed).

Because of the detrimental effects of felt stress on an individual (Kerr and Tindale, 2004) and on group (Adelman *et al.*, 2003), we wanted to study specifically whether cues suggesting stress in the group members would be contagious to the individual.

Hypothesis 3: cues of high nervousness/stress in the group will lead to increased perceived stress.

Positive emotional contagion in a group has been shown to lead to improved cooperation and decreased conflict (Barsade, 2002). Thus, we hypothesize as follows:

Hypothesis 4: positively valenced cues of group emotion will lead to higher perceived cohesion with the other group members compared with negatively valenced cues.

Since positive emotional contagion can lead to increased perception of task performance (Barsade, 2002), we hypothesize as follows:

Hypothesis 5: positively valenced cues of group emotion will lead to higher perceived task performance.

In addition, we present a hypothesis that the planning tasks are perceived as more enjoying and arousing, whereas the routine tasks are perceived as boring and frustrating, thus leading to the hypothesis:

Hypothesis 6: planning tasks evoke higher self-reported pleasure and arousal, zygomatic activity, EDA and less corrugator activity than the routine tasks.

3. METHODS

3.1. Participants

The participants were 33 Finnish undergraduates (8 men and 25 women) with varying majors. The sample had a mean age of 23.8 years. Each participant received three movie tickets for participation.

3.2. Design

A2(task type)×4(group emotion cue) within-subject design was employed.

3.3. Experimental tasks

Each participant performed eight 7.5-min tasks during the experiment: (a) four routine tasks requiring sustained attention and (b) four planning tasks. The routine tasks required the participant to check the grammar of text excerpts with technological content. The topics of the texts were (a) internet, (b) positioning technologies, (c) programming and (d) broadband technologies. The text excerpts were taken from Wikipedia and various solecisms and typos were inserted into them. The planning tasks required the participant to plan use cases or scenarios for different mobile phone technologies/services: (a) a positioning service for mobile phones, (b) measuring physical activity with sensors and sending this information to mobile phones of other members of a work group or sports team, (c) showing on a mobile phone information from sensors that are attached to various places in the environment (e.g. temperature or humidity sensors or bluetooth anchors transmitting historical facts about the specific location) and (d) a mobile phone application that visualizes the group's communication network (the application would utilize data on made calls and sent text messages to draw the communication network).

3.4. Procedure

When arriving at the laboratory, the participant was guided to an electrically shielded room and they were given a short description of the study. In this description, the participant was informed that the purpose of the study was to test a newly developed concept for group-work technology. Also, the participant was told that a total of four participants would be participating in the experiment and they would be simultaneously performing the same eight tasks (four routine tasks and four planning tasks) in different rooms. In addition, in the end, there would be a group discussion about each participant's answers/performance. The participants were also told that they were randomly chosen to be the one on whom psychophysiological measurements would be performed. Since there was only one measurement system, the other participants would be sitting in normal office rooms and they would arrive a little later because the attaching of the electrodes would take some time. When the electrodes were attached to the participant, two male confederates arrived and they were introduced to the participant. The participant was told that these two males were participants in the experiment, when in reality, they were researchers of the laboratory and did not participate in the study. The fourth (female) participant was told to arrive a bit late. After performing a baseline physiological recording of 7 min, the participant was told that the fourth participant had arrived and the experiment was ready to begin. During a pause in the middle of the experiment, the experimenter told the participant that he had to visit the other participants to give them further instructions as well. This was done to maintain a feeling of the other group members really being present and participating in the experiment.

The experimental tasks were presented on an HTML page. Before the first task and after each task, the participant rated his or her emotional state and answered various questions presented on an HTML page. The participant was told that the average emotional state of the group (i.e. group emotion cue), calculated as a mean of each participants' self-reports, would be displayed in textual format at the top of an HTML page to each group member during the tasks. The displayed group emotion cues were: depressed (i.e. negatively valenced low-arousal emotion), nervous/stressed (i.e. negatively valenced high-arousal emotion), pleasantly excited (i.e. positively valenced high-arousal emotion) and pleasantly relaxed (i.e. positively valenced low-arousal emotion). The group emotion cues were, in fact, pre-defined and independent of the participant's self-ratings. The two task types (routine and planning) were presented in a counterbalanced order across participants. Within each task type, the four tasks were presented in four different presentation orders. For the different presentation orders, each task was always paired with a different group emotion cue.

After the experimental session, the participant was debriefed and told that in reality no other group members existed and that the group emotional states presented during the experiment were actually pre-determined by the researchers.

3.5. Psychophysiological recordings

Facial EMG activity was recorded from the left corrugator supercilii and zygomaticus major muscle regions as recommended by Fridlund and Cacioppo (1986), using surface Ag/AgCl electrodes with a contact area of a 4 mm diameter (Med Assoc. Inc., St. Albans, VT). The electrodes were filled with TD-240 electrode gel (Med Assoc. Inc). The raw EMG signal was amplified and frequencies <30 and >400 Hz were filtered out, using the Psylab Model EEG8 amplifier (Contact Precision Instruments, London, UK). The raw signal was digitally rectified and integrated over 1000 ms with the Psylab8 software. EDA was recorded with the Psylab Model SC5 24-bit digital skin conductance amplifier that applied a constant 0.5 V across the Ag/AgCl electrodes with a contact area of an 8 mm diameter (Med Assoc. Inc.). The electrodes were filled with TD-246 skin conductance electrode paste (Med Assoc. Inc.) and attached to the middle phalanges of the ring and the little fingers of the subject's non-dominant hand after the hands were washed with soap and water (the ring and the little fingers were used to reduce the interference between typing responses to experimental tasks and EDA recording.). From the EDA signal, the Psylab8 analysis software was used to calculate both SCL and NS.SCR.freq. (frequency (per minute) of non-specific skin conductance responses) indices. The digital data collection was controlled by the Psylab Stand Alone Monitor and Psylab8 software, and all physiological signals were sampled at a rate of 1000 Hz.

3.6. Self-report measures

Self-ratings of emotional valence and arousal were collected with 9-level scales using self-assessment manikins. These scales resemble Lang's (1980) self-assessment manikin (the original scales were modified slightly to make the characters more distinguishable on a screen). Other collected self-report data included single items for stress level ('I felt stressed'), task performance ('I felt that I performed well') and cohesion with the group ('I felt strong cohesion with the group'). All these items were measured with a 4-level scale (1—'I strongly disagree'; 4—'I strongly agree').

3.7. Data reduction and statistical analyses

Mean values for each physiological channel were derived for 1 min blocks and in the analyses reported here are based on an average of the first 7 min for each 7.5 min experimental task. Skin conductance and EMG data were (ln +1) transformed to normalize the distributions. All the data were then analyzed by the general linear model repeated measures procedure in Statistical Package for the Social Sciences (SPSS) version 14. Analyses of both the self-reported ratings data and psychophysiological data included two within-subject factors: task (two levels: routine and planning) and emotional state induction (4 levels: depressed, nervous and stressed, pleasantly excited and pleasantly relaxed). The *a priori* hypotheses were tested using the following planned contrasts (see Rosenthal *et al.*, 2000): (a) routine task versus planning task (Contrast 1), (b) positive cues of group emotion versus negative cues of group emotion (Contrast 2) and (c) high-arousal cues of group emotion

Table 1. Descriptive statistics: M (SD).

	Group emotional state							
	Depressed		Nervous and stressed		Pleasantly excited		Pleasantly relaxed	
	Task type							
	Rout	Plan	Rout	Plan	Rout	Plan	Rout	Plan
Valence rating	5.16 (1.65)	5.69 (1.49)	5.13 (1.68)	5.75 (1.55)	5.31 (1.73)	6.44 (1.13)	5.56 (1.46)	6.09 (1.17)
Arousal rating	4.91 (1.77)	5.28 (1.55)	4.88 (1.74)	5.47 (1.50)	4.81 (1.94)	5.56 (1.52)	5.03 (1.51)	5.53 (1.59)
Perceived stress	2.00 (0.84)	1.78 (0.79)	2.09 (1.03)	2.22 (0.91)	2.06 (0.88)	1.72 (0.85)	1.88 (0.79)	1.63 (0.79)
Perceived confidence in others	1.38 (0.66)	1.47 (0.62)	1.38 (0.55)	1.50 (0.67)	1.44 (0.62)	1.56 (0.67)	1.41 (0.62)	1.63 (0.75)
CS EMG	1.90 (0.42)	1.62 (0.39)	1.88 (0.40)	1.65 (0.43)	1.80 (0.40)	1.63 (0.44)	1.82 (0.41)	1.60 (0.36)
SCL	1.77 (0.40)	1.79 (0.44)	1.77 (0.39)	1.82 (0.40)	1.73 (0.41)	1.77 (0.44)	1.73 (0.44)	1.78 (0.44)
NS.SCR.freq.	1.91 (0.37)	1.98 (0.51)	1.81 (0.49)	2.04 (0.47)	1.78 (0.50)	1.97 (0.52)	1.77 (0.57)	1.98 (0.52)

Rout = Routine task; Plan = Planning task; EMG = electromyography; CS = corrugator supercilii; SCL = skin conductance level; NS.SCR.freq. = frequency of non-specific skin conductance responses.

Table 2. Summary of Contrast Analyses.

Variable source	*df*	MS	MSE	*F*	η^2
Valence rating					
Contrast 1	1, 31	126.563	19.788	6.396*	0.171
Contrast 2	1, 31	45.563	4.982	9.146**	0.228
Arousal rating					
Contrast 1	1, 31	78.766	16.959	4.644*	0.13
Perceived stress					
Contrast 2	1, 31	10.563	2.24	4.716*	0.132
Contrast 3	1, 31	10.563	1.014	10.416**	0.251
Perceived confidence in others					
Contrast 2	1, 31	1.563	0.304	5.132*	0.142
CS EMG					
Contrast 1	1, 30	12.327	0.589	20.936***	0.419
Contrast 2	1, 30	0.631	0.075	8.414**	0.225
SCL					
Contrast 2	1, 30	0.29	0.025	11.782**	0.282
SCR					
Contrast 1	1, 30	7.325	0.74	9.898**	0.248
Contrast 2	1, 30	0.907	0.195	4.639**	0.134

H = Hypothesis; Contrast 1 = task (routine/creative); Contrast 2 = valence (positive/negative); Contrast 3 = arousal (high/low); EMG = electromyography; CS = corrugator supercilii; SCL = skin conductance level; SCR = skin conductance response. Only statistically significant results are reported. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

versus low-arousal cues of group emotion (Contrast 3). The contrasts were orthogonal within the analyses of each dependent variable.

4. RESULTS

Descriptive statistics are presented in Table 1 and the results of contrast analyses are presented in Table 2

4.1. Self-report ratings

Positive cues of group emotion (pleasantly excited and pleasantly relaxed) elicited greater self-reported pleasure compared with cues of negative group emotions (depressed and nervous/stressed; see Fig. 1), for Contrast 2, $p < 0.01$, $\eta^2 = 0.23$ (*Hypothesis 1*).

In addition, planning tasks elicited higher self-reported pleasure and arousal compared with routine tasks (see Fig. 2),

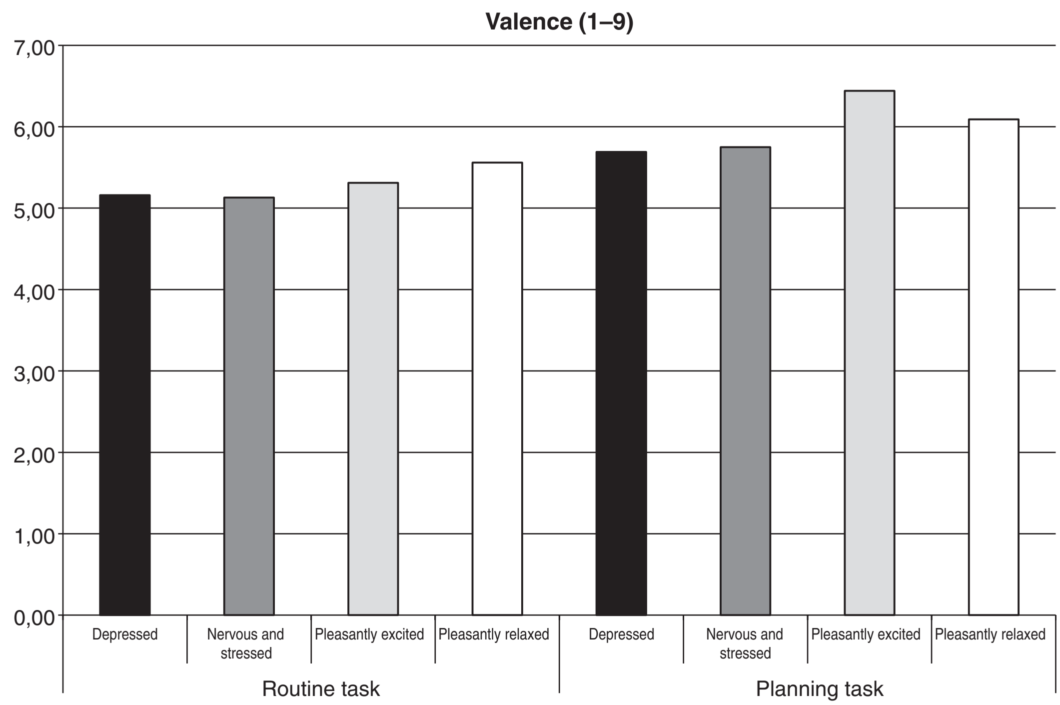

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Figure 1. Self-reported valence ratings for routine and planning tasks as a function of group emotion cue.

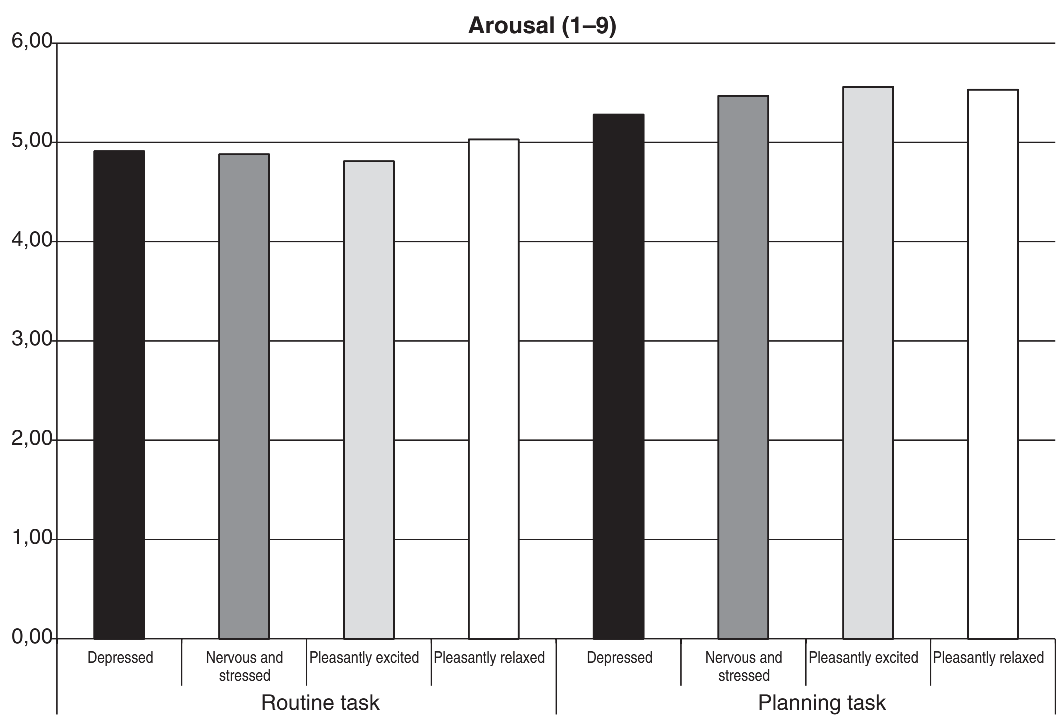

Figure 2. Self-reported arousal ratings for routine and planning tasks as a function of group emotion cue.

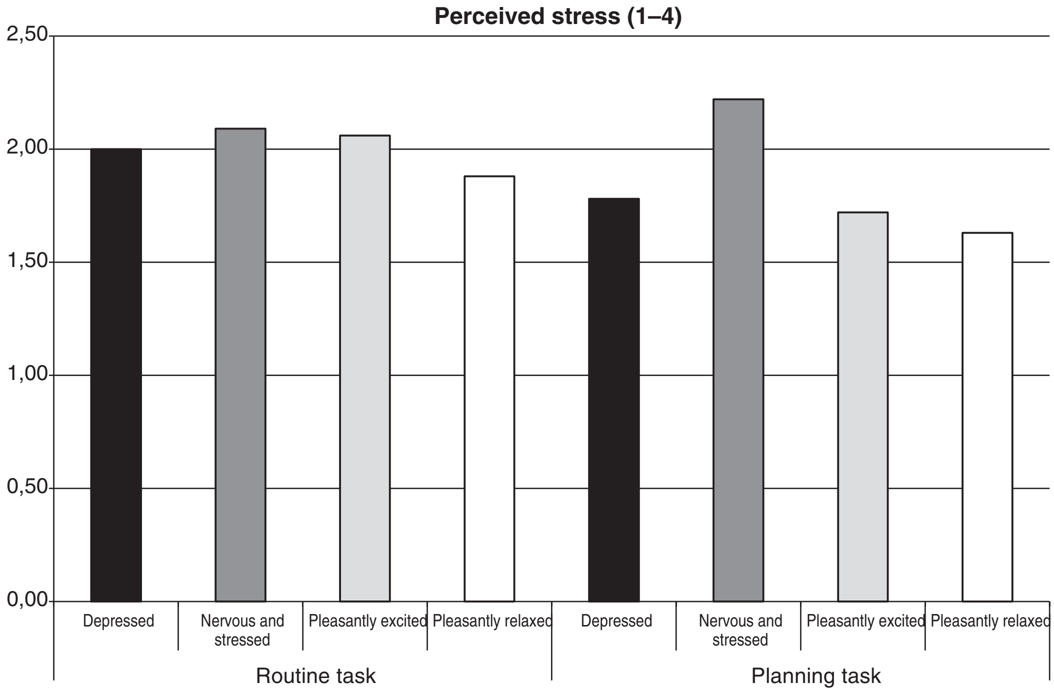

Figure 3. Self-reported stress ratings for routine and planning tasks as a function of group emotion cue.

for Contrast 1, p's < 0.05 for both and η^2s $= 0.17$ and 0.13, respectively (*Hypothesis 6*).

When predicting perceived stress, both Contrast 2 and Contrast 3 were significant, $p < 0.05$, $\eta^2 = 0.13$ and $p < 0.01$, $\eta^2 = 0.25$, respectively. Perceived stress was particularly high when the group emotion cue indicated that the group was nervous and stressed (*Hypothesis 3*, see Fig. 3).

In addition, positive cues of group emotion elicited higher perceived confidence in the other group members compared with cues of negative group emotions (see Fig. 4), for Contrast 2, $p < 0.05$, $\eta^2 = 0.14$ (*Hypothesis 4*).

4.2. Psychophysiological measures

4.2.1. Facial EMG

Negative cues of group emotion elicited higher corrugator supercilii EMG activity during the tasks compared with cues of positive group emotion (see Fig. 5), for Contrast 2, $p < 0.01$, $\eta^2 = 0.23$ (*Hypothesis 1*). Corrugator supercilii activity was also higher during routine tasks than during planning tasks, for Contrast 1, $p < 0.001$, $\eta^2 = 0.42$ (*Hypothesis 6*).

4.2.2. EDA

NS.SCR frequency was higher during planning tasks than during routine tasks, for Contrast 1, $p < 0.01$, $\eta^2 = 0.25$ (*Hypothesis 6*). In addition, outside the hypothesis, it was observed that negative cues of group emotion elicited higher SCL and NS.SCR frequency. (non-specific skin conductance response frequency) during the tasks compared with cues of positive group emotion (see Figs 6 and 7), for Contrast 2, $p < 0.01$ for both, η^2s $= 0.28$ and 0.13, respectively.

5. DISCUSSION

5.1. Effect of the group's emotional state on individual

Hypothesis 1 was confirmed: the subjects scored lower (more negative) self-ratings of valence when they were informed that the group was feeling negative valence emotions ('Depressed' or 'Nervous and stressed') than when the group was informed to feel positive emotions ('Pleasantly exited' or 'Pleasantly relaxed'). Thus, it is suggested that the reported emotional valence of the (in reality non-existent) group was contagious to the individual subject's self-ratings. In addition, *Hypothesis 1* was supported by one psychophysiological finding; the activity of corrugator supercilii (frowning muscle) was higher during the reported negative valence group states than during the positive valence group states. No group emotion evoked differences in zygomatic major (cheek muscle) activity were observed.

Hypothesis 2 was not confirmed: there were no statistically significant differences between high-arousal (pleasantly excited and nervous/stressed) and low-arousal (depressed and relaxed) group emotions either in the arousal self-rating or in EDA. It is possible that emotional valence is more contagious than emotional arousal in such a distributed setting. Perhaps the

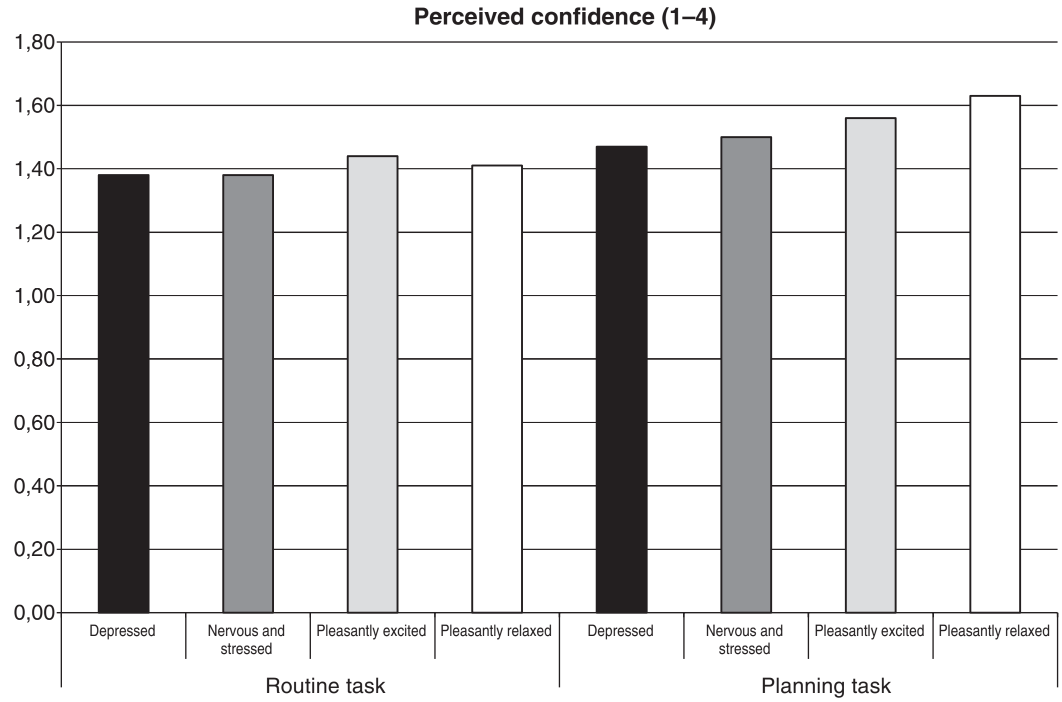

Figure 4. Self-reported confidence in the other group members for routine and planning tasks as a function of group emotion cue.

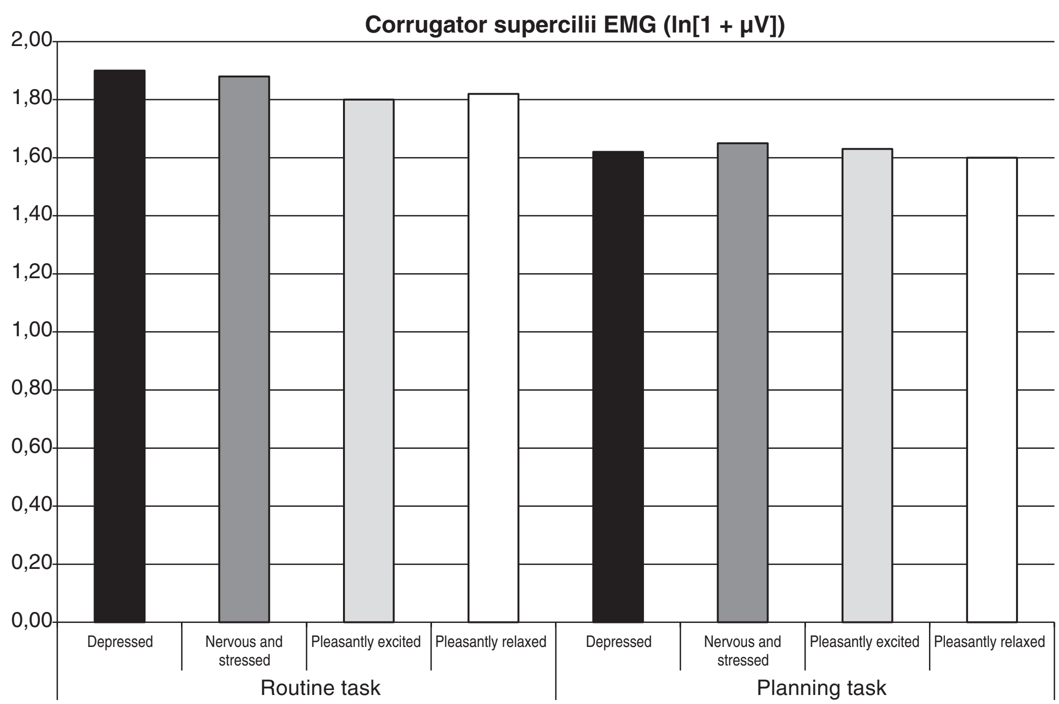

Figure 5. Mean values of ln +1 normalized corrugator supercilii activities for routine and planning tasks as a function of group emotion cue.

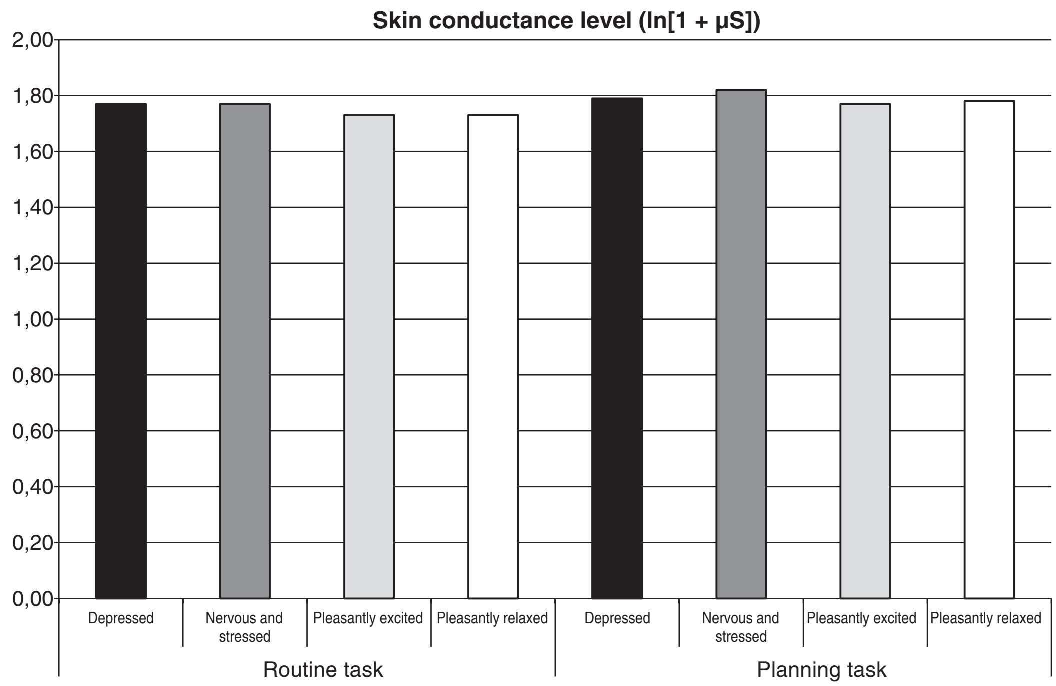

Figure 6. Mean values of ln +1 normalized SCL values for routine and planning tasks as a function of group emotion cue.

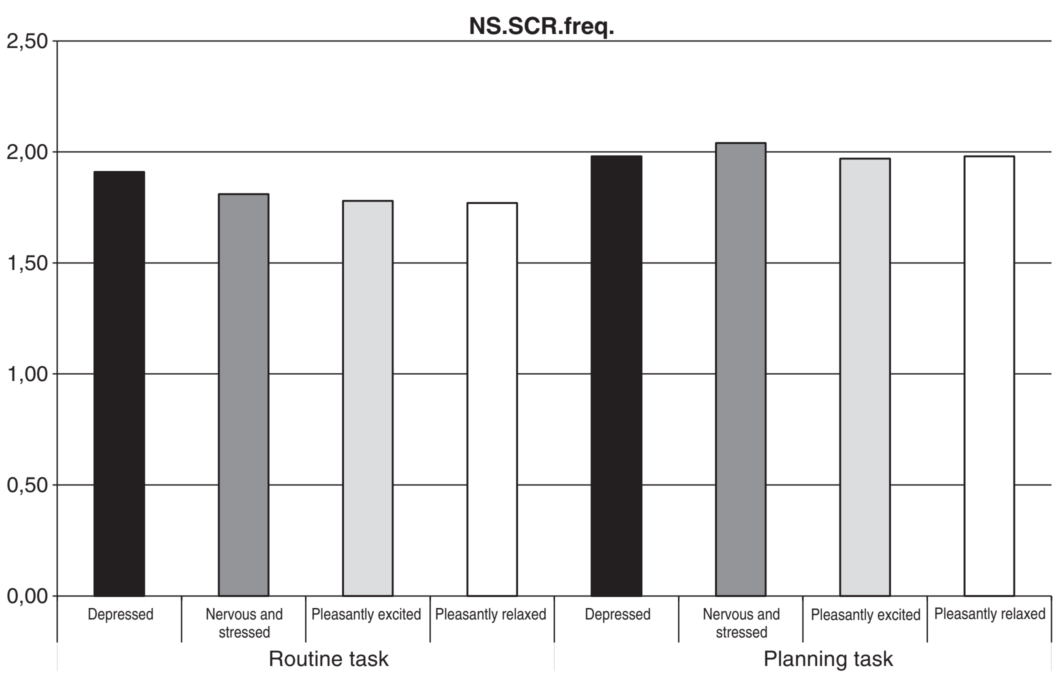

Figure 7. Mean values of ln +1 normalized skin conductance response values for routine and planning tasks as a function of group emotion cue.

participants felt constant arousal level through the whole experiment and consciously or unconsciously ignored arousal-related cue information of group emotional state. Another possible explanation is that information about the group's emotional valence was perceived more important and it overrode the information about the group's emotional arousal.

Hypothesis 3 was confirmed: cue of high nervousness and stress in the group led to increased perceived stress. It is suggested that information about the stress of other group members performing the same task acted as a contagious warning signal. The detrimental effects of stress on an individual are well studied and documented; a common finding is that stress usually increases the quantity and decreases the quality of performance (Kerr and Tindale, 2004). On a group level, a moderate stress level can even enhance effectiveness, but high stress levels lead to degraded performance (see for example, Adelman *et al.*, 2003).

Hypothesis 4 was confirmed: during positive emotion group states, the subjects reported higher confidence in other group members versus during negative emotion group states. This result is plausible; emotions and trust are strongly connected in three different ways: the experience of trust embodies affect, judgments of trustworthiness are affected by the feeling toward the judged person; in addition, one's current affective state may affect the experience of trust and the way judgments of trustworthiness are made; and thirdly trust is built partly on emotional expectations (see Jones and George (1998) for a review).

Hypothesis 5 was not confirmed: there were no statistically significant differences in the perceived task performance between different group emotional statuses. It is possible that the used setting was such that it was not utterly important for the participant to perform well in the tasks. With more pressure for good performance, the emotional contagion could have stronger effect, but this remains to be solved in future studies.

Taken together, *Hypothesis 1* was confirmed, *Hypothesis 2* was not confirmed, and *Hypotheses 3* and *4* were both confirmed and *Hypothesis 5* was not confirmed. In addition, we observed that the SCL and the number of skin conductance responses were higher when the group was reported to experience negative valence emotions than when the group's valence was positive. This effect could index that both the high- and low-arousal negative valence states (stressed and depressed) were interpreted as threatening cues and that the task was difficult and failure was possible. This threat increased physiological arousal.

5.2. Effects of task type

Hypothesis 6 was confirmed: more positive valence and higher arousal emotional self-ratings were given after planning tasks versus after routine tasks; it is suggested that the routine tasks were perceived as boring and thus less pleasant and arousing. In the routine tasks, the subject had to do the same task for the whole period, whereas in the planning tasks some planning was required in addition to the typing. The corrugator supercilii activity was higher during routine than during planning tasks. It is possible that in the current experimental setting corrugator activity reflected attentional processes, in addition to emotional valence. Corrugator activity may increase during effortful attention (e.g. Cohen *et al.*, 1992) and the employed routine task, grammar checking, possibly increased this sort of attention. In addition, planning tasks evoked higher number of skin conductance responses compared with routine tasks. This was expected; the routine task were possibly perceived as boring whereas the planning task required more personal involvement from the subject and this might have led to increased arousal. However, it must be remembered that the self-report emotional valence ratings support the interpretation of increased corrugator activity as an index of negative emotional valence in the present context. The role of corrugator activity in tasks requiring attention and evoking emotions still needs to be studied more thoroughly in future studies. In such studies, the use of electroencephalogram could be used to determine the subject's attentional state between different conditions.

Overall, there were no statistically significant differences in zygomaticus major activity between the different conditions of group emotional state or between the two task types. This might be due to limited social aspect in the study setting. There were no other persons in the same room with the participant to communicate, verbally or non-verbally, with. It has been suggested that in social situations, valence may have a stronger effect on activity over zygomaticus major (Larsen *et al.*, 2003). On the other hand, Larsen *et al.* also showed that corrugator and zygomaticus index emotional state differently. In their study, they found that positive and negative affect have reciprocal effects to the activity of corrugator supercilii but not to the zygomaticus major. They observed that, when using emotional pictures and sounds as stimuli, increases in positive affect potentiated activity of zygomaticus major, but increases in negative affect had little effect in the opposite direction. It is thus possible that in the present study corrugator supercilii managed to capture both the extremities of emotional valence dimension more reliably than did zygomaticus major and this could explain why there were statistically significant results for corrugator but not for zygomaticus.

5.3. General discussion

It is notable that the emotional contagion occurred in the current study even when the group was such loosely structured and the experimental subject was not familiar with the other group members (in reality, there were no other group members, only the subject who was connected to the electrodes). There was practically no communication between the group members, only the aggregated group emotional state was shown as a verbal description. In addition, the subject was not aware of how the other group members proceeded in the task, and he was only told that all the group members were performing the same task simultaneously and that in the end the responses would be discussed with the whole group. In his classic works, Tajfel (1970, 1974) studied the minimal conditions that are required for there to be discrimination between groups. In numerous experiments, he showed that even meaningless distinctions to define groups can lead to a tendency to favor own group versus the other group. In the present study, there was only one group and thus no between-group comparison was possible for the participant. Still, one possible explanation for the observed emotional contagion is that simply because the participant was categorized as a group member, he or she unconsciously desired to feel similar emotions with the group.

Emotional contagion has not been previously studied within a group that is distributed and as loosely formed as in the experiment described here. Barsade (2002) reported on a laboratory experiment with managerial decision-making task, where the emotional contagion was induced by a trained person who was acting the different mood conditions. Thus, the contagion occurred in a face-to-face situation. Emotional and other forms of social contagion have also been studied in more distributed settings, namely in a mediated negotiation context (e.g. Thompson and Nadler, 2002; Van Kleef *et al.*, 2004a). In an e-mail negotiation situation (e.g. Thompson and Nadler, 2002), the interacting partners are actually communicating through quite a rich communication channel. The main difference between the current study and the previous research is the limited information the individual had of the other group members. Emotional contagion occurred even when the subject was provided with only the aggregated emotional state of the group and no communication was allowed between the group members. Given that this effect was observed in a limited communication setting like this, it remains for the future studies to validate whether the effect persists also within real groups with members actively interacting to reach shared goals.

5.4. Practical implications

Since the emotional contagion was observed on the self-report data as well as on the psychophysiological indices, it is suggested that both these signals could be considered useful in future software applications for collaborative knowledge work. Experiencing positive emotional contagion has been shown to lead to improved cooperation, decreased conflict and increased perceptions of task performance (Barsade, 2002). On the other hand, conveying of information about the group's negatively valenced emotional state could lead to detrimental effects, although there is evidence from experiments on individuals suggesting that there might be some linkage between negative mood and more systematic information processing (e.g. Forgas, 1990). Depending on the task and the situation, this could result in positive outcomes. More recently, Guillory *et al.*, (2011) reported on an experiment where, surprisingly, negative emotional contagion in a group using CMC led to increased performance. The type of work, organizational structure and culture must be known when predicting the possible outcomes of providing affective feedback to the group. In some cases, negative feedback might even be used as a strategic tool to gain better economic outcomes in a negotiation situation (Sinaceur and Tiedens, 2005; Van Kleef *et al.*, 2004a, b). Belkin *et al.*, (2006) suggested that with mediated communication, the impact of a 'tough' negotiator might be even stronger than in a face-to-face situation because of the lack of non-verbal cues that might provide additional information of the other partner. In addition, when the emotional information is mediated by some technical system (i.e. self-reported or psychophysiologically recorded), the deception is easier than in face-to-face situation and this could change the whole interaction situation when compared with the more traditional ways of mediated communication, such as phone calls.

It can be questioned whether actual (knowledge) workers would bother to rate their emotional state daily or several times during the day. Obviously, the system for self-rating and mediating the emotional information must be made such that it requires as little effort as possible, optimally as parts of existing tools and applications (e.g. an e-mail client software or a side bar on computer desktop). Instead of requiring users to input their emotional state, it could also be interpreted from psychophysiological signals. Automatically collected psychophysiological signal would allow continuous monitoring of the emotional state of the user. Psychophysiological methods have been used, for example, in the monitoring of mental workload (Freude and Ullsperger, 2000) and alertness (Gundel *et al.*, 2000). In knowledge work, however, the tasks may vary greatly during the day and it could be difficult to tell what actions of the user caused the psychophysiological reactions. For example, heart rate could be difficult to interpret, since it is not univocally attributable to any single source (Ravaja, 2004) and heart rate changes could be caused also by mere physical activity (e.g. Armstrong and Bray, 1991). Of course, for example, the heart rate in itself could be a useful signal, even if the source of its variability would remain unclear to the users. Seeing one's teammates, animated heartbeat might prove to be a strongly affective signal.

5.5. Limitations of the study and ideas for future research

In the current study, EDA was measured from the medial phalanges of the ring finger and the little finger of the non-dominant hand. None of the subjects complained after the experiment that the electrodes would have interfered with the typing. It is possible, however, that the typing actions caused some artifacts to the EDA signal. It is also possible that typing pace and rhythm as well as the general amount of keyboard use were dissimilar between the routine and planning tasks. This difference could have, at least in theory, affected the EDA results that were obtained for the task difference; more skin conductance responses were observed during planning tasks versus routine tasks and it may well be that the planning tasks involved more active typing. Typing artifacts cannot, however, explain all the EDA results, as there were results showing differences between different group emotional states, regardless of the task. That is, negative cues of group emotion elicited more physiological arousal (as indexed by SCL and NS.SCR freq.) during the tasks compared with cues of positive group emotion. Considering this, it is suggested that EDA may turn out to be a valuable tool in assessing psychological arousal during knowledge-work tasks. For the future studies, other electrode placement might also be considered; for example, the plantar surface of the feet has been used in some experiments (Fowles *et al.*, 1981).

One apparent limitation of this study was the lack of measurement for the participant's actual performance in the experimental tasks. There were no statistically significant differences between experimental conditions and group emotional states to the self-report item about succeeding in the tasks. Experiencing positive emotional contagion has been previously shown to lead to improved cooperation, decreased conflict and increased perceptions of task performance (Barsade, 2002). However, it is possible that these effects are stronger for emotional contagion that has happened during face-to-face communication or it is possible that a longer period of emotional contagion would be required.

One interesting area of research in the future would be to study the effects of different ways of mediating the group's emotional state. Different kinds of textual descriptions could be compared with visual elements of software applications, for example, emoticons or more subtle features like color changes in the visual interface of the working environment. Even some more exotic options could be considered, for example, sense of touch has been studied for conveying emotional information (Mathew, 2005). For the detection of the emotional state of an individual also automatic methods other than psychophysiological measurements could be studied in a group-work context. For example, facial expression analysis and vocal expression analysis could provide information about emotions unobtrusively (e.g. Pantic and Rothkranz, 2003).

Another topic worth studying in the future is the individual differences in the susceptibility to emotional contagion by cues of group status. Doherty (1997) has suggested that personality, genetics, gender and early experiences contribute to individual differences in susceptibility to emotional contagion. However, it is possible that different personality dimensions affect susceptibility to computer-mediated emotional contagion rather than face-to-face emotional contagion. For example, extraversion/introversion dimension could have a differential effect in mediated versus non-mediated interaction.

6. CONCLUSIONS

In the present study, we have shown that emotional contagion happens also in a distributed setting, within a group where the participant does not know the other members previously. The effects of emotional contagion were visible in self-ratings and in the psychophysiological indices. As previous studies have suggested that positive emotional contagion may lead to favorable effects in a working team, it is suggested that adding emotional cues to future groupware and communication applications could prove to be fruitful.

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