Emotion understanding and performance during computer-supported collaboration

Ulises Xolocotzin Eligio *, Shaaron E. Ainsworth, Charles K. Crook

Learning Sciences Research Institute, University of Nottingham, Jubilee Campus, Wollaton Road, Nottingham NG8 1BB, United Kingdom

Abstract

Individuals collaborating around and through computers benefit from receiving information that helps them understand one another, which is often termed awareness. This article explores what collaborators understand about each other’s emotions and the potential benefits for performance that might come from raising this understanding. In Experiment 1 co-located collaborators judged each other’s emotions after playing a game that required cooperative data collection and analysis. Their judgements were largely inaccurate and based on their own emotions, suggesting limited emotion understanding. Experiment 2 explored if this could be overcome by making collaborators aware of each other’s emotions. Co-located and remote collaborators played a cooperative puzzle-solving game under conditions of awareness or no awareness. Awareness was manipulated by making collaborators share their self-reported emotions during key moments of their game play. Both remote and co-located collaborators improved their performance after sharing their emotions. However, unlike co-located collaborators, remote collaborators also improved their understanding of each other’s emotions and experienced more positive affect. We conclude by discussing the content of collaborators’ emotion understanding and the probable mechanisms underlying the observed effects of being made aware of a partner’s emotions.

1. Introduction

It is recognised that individuals collaborating around and through computers benefit from receiving information about each other, which is usually labelled awareness. Existing research, both in remote and co-located computer-supported collaboration, concentrates on studying awareness of behaviours (Janssen, Erkens, & Kirschner, 2011; Tobiasz, Isenberg, & Carpendale, 2009), knowledge (Engelmann, Dehler, Bodemer, & Buder, 2009), and social functioning (Guitton, 2012; Phielix, Prins, & Kirschner, 2010; Terken & Sturm, 2010). In contrast, the understanding of a partner’s emotions has received less attention. This neglects the evidence that shows the emotions of others can be highly influential for one’s own emotions and actions in a range of situations that are often involved in collaboration, such as cooperation and competition (see Van Kleef, De Dreu, Manstead, & Mark, 2010), negotiation (Van Kleef & De Dreu, 2010) or the collective generation of ideas (Van Kleef, Anastasopoulou, & Nijstad, 2010).

This paper explores what collaborators understand about each other’s emotions and the implications of sharing information about them. The research focuses on synchronous collaborations around computer games designed for learning and leisure. Playing collaborative computer games is intrinsically emotive and requires coordinated joint action, in which the emotions of others are thought to play a crucial role (Michael, 2011). Experiment 1 explores what collaborators understand about each other’s emotions. Experiment 2 assesses the potential benefits of making collaborators aware of each other’s emotions during co-located and remote interactions.

1.1. Emotion understanding and collaboration

It has been suggested that the conscious and unconscious processing of each other’s emotions facilitates the coordination of individuals who share a common goal (Michael, 2011). During collaborative activity the influence of a partner’s emotions can be subtle, as in cases of emotional contagion observed in situations such as working in groups (Barsade, 2002), playing team sports (Totterdell, 2000) or joint problem-solving (Conway, 2004). The process of emotional contagion may be unnoticed in these situations, but depending on its qualities (e.g., contagion of positive or negative affect), such process might be beneficial or detrimental to collaborators’ cooperativeness (Barsade, 2002) and individual performance (Totterdell, 2000). In other situations, individuals consciously try to understand and react to the emotions of a partner. For example, receiving feedback from a partner who is outwardly angry can increase or decrease one’s own creativity and willingness to cooperate during collaborative problem solving (Van Kleef et al., 2010).
During computer-supported collaboration, the demands and constraints derived from collaborating around or through computers might heavily influence what collaborators understand about one another's emotions. How accurate this understanding is remains an open question, one which is addressed in Experiment 1.

1.2. Emotion understanding and computer-mediated communication

People often collaborate remotely using computer-mediated communication (CMC), so entailing restricted communication that constrains social interaction. It has been suggested that under these constraints, knowing about the emotions of others and expressing one's own emotions acquires additional importance (Parkinson, 2008), and there is evidence to suggest that the communication of emotions might play a central role in the perception of “humanness” during CMC (Lortie & Guittion, 2011). Derks, Fischer, and Bos (2008) concluded that people using CMC expresses emotions frequently, using any channel available to do so. In fact, sometimes people prefer to express their emotions, especially negative ones, using CMC rather than face to face (Riordan & Kreuz, 2010). Moreover, people using CMC are likely to ‘catch’ the emotions of each other (Hancock, Gee, Giaccio, & Lin, 2008). In the case of remote computer-supported collaboration, there is evidence to suggest that collaborators often disclose their own emotions and look for information about the emotions of a partner (Johnson, Bettenhausen, & Gibbons, 2009; Michinov & Michinov, 2008; Stone & Posey, 2008). Moreover, research suggests that individuals collaborating remotely are likely to ‘catch’ each other’s emotions, even if these are expressed solely through text (Cheshin, Rafaeli, & Bos, 2011). However, no studies have specifically investigated whether making remote collaborators more explicitly aware of each other’s emotions benefits their performance, or whether these benefits differ in comparison to co-located collaborators interacting without communication constraints. This is addressed in Experiment 2.

2. Experiment 1

This experiment investigates what partners collaborating side-by-side around an educational computer game understand about each other’s emotions. The aim is to explore whether individuals are able to reason accurately about a partner’s emotions. This study is necessary to build foundational knowledge about the way in which the characteristics of computer-supported collaboration might influence individuals’ emotion understanding. This experiment focuses on two issues: Individuals’ accuracy at judging the emotions of a partner and the extent to which such judgements are based on their own emotions.

There is evidence to suggest that the accuracy at judging the emotions of a partner will be affected by people’s tendency to project their own mental states (Krueger & Clement, 1994; Ross, Greene, & House, 1977), especially since this tendency becomes stronger in situations that involve interdependence with others (Toma, Yzerbyt, & Cornille, 2010), as is often the case during collaborative activity. Moreover, people’s inferences about the mental states of others are more likely to show an egocentric bias when they face a concurrent task that is cognitively demanding (Lin, Keysar, & Epley, 2010) and when their incidental mood is positive (Converse, Lin, Keysar, & Epley, 2008). These two conditions are inherent to the experience of playing a computer game collaboratively since the game mechanics and the social interaction might demand cognitive effort and prompt a wide range of emotions. Consequently, we advance the following hypotheses:

**Hypothesis 1.** Individuals will misjudge the emotions of a partner.

**Hypothesis 2.** Individuals will judge the emotions of a partner using information about their own emotions.

2.1. Method

2.1.1. The collaborative game

Participants played Astroversity (Futurelab, 2004), a non-commercial prototype computer game designed to support learning in the domain of data collection and analysis. Participants played side-by-side sharing one computer and one mouse. Playing Astroversity involves situations commonly found in collaborative activities such as group identification, complementary roles, and argumentation. Players act as students in a spaceship academy invaded by invisible alien enemies. Their goal as a team is to find and rescue an injured fellow student. They have two tasks. The first one is to collect data. Players locate the injured student and identify the presence of alien enemies in the surrounding areas. In doing so they play complementary roles, since one player scans alien presence using a rover in the computer interface whilst the other player plots the areas with alien presence in a paper grid. During the second task, players discuss the data in order to trace an escape route that avoids the alien presence.

2.1.2. Participants

50 Unacquainted students from a range of departments at the University of Nottingham were recruited for the study (mean age = 21.6 years, 30 female). All participants were native English speakers and received £ 6 as inconvenience allowance. Given that Astroversity was developed as a non-commercial research prototype, previous exposure to it was unlikely and, therefore, no data regarding this issue was collected.

2.1.3. Questionnaires

Partners answered an Own Emotions questionnaire to report on themselves and a Partner Emotions questionnaire to report about the partner. Each questionnaire listed 15 emotions: happy, angry, sad, fearful, angry, bored, challenged, interested, hopeful, frustrated, contempt, disgusted, surprised, proud, ashamed, and guilty. Participants rated the intensity of these emotions with scales ranging from zero (not at all) to four (extremely). The listed emotions were selected from psychological research (Smith & Ellsworth, 1985) as this shows that individuals can distinguish them from each other and they have been found to be relevant to a range of experiences with diverse qualities. As such some of these emotions are more likely to be more relevant than others to the context of computer-supported collaborative games, and a secondary intention was to identify these.

2.1.4. Procedure

Participants were randomly assigned to dyads in three configurations: female (11), male (6) and mixed (8). On arrival, participants confirmed they were unacquainted and read the study information. Collaborative partners freely selected which side to seat and decided who used the paper grid or the computer. After 5 min of guided practice they were instructed to play Astroversity for 20 min with the goal of trying to proceed as far through the game as possible, without knowledge that they were going to report the emotions of each other. Immediately after playing participants ceased interaction and answered the questionnaires in the same room sitting back to back.

2.2. Results

The understanding of a partner’s emotions was measured with a technique based on the empathic accuracy paradigm. In this
paradigm an observer attributes thoughts and/or feelings to a target, and these attributions are compared with the thoughts and/or feelings reported by that target. Accuracy is assessed with a test of association between observer and target. This paradigm has proven useful to assess interpersonal inferences in non-structured dyadic interactions, and is independent of personality traits in empathic ability (Ickes, Stinson, Bissonnette, & Garcia, 1990). Data analysis focused on six emotions with normally distributed data across questionnaires. Three of these emotions were positive: happy, interested, challenged, and the other three negative: hopeful, frustrated, and bored. Other emotions showed floor effects and were therefore excluded from further analysis. The six selected emotions were analysed separately with multiple regressions including the following variables:

Dependent variable: Scores in the Partner Emotions questionnaire, representing the judgements made about the partner’s emotions.

Independent variable 1: Partner’s scores in the Own Emotion questionnaire. A positive and significant effect of this variable would suggest that individuals judged the emotions of their partners accurately.

Independent variable 2: Individuals’ scores in the Own Emotions questionnaire. A positive and significant effect of this variable would suggest that individuals used knowledge about their own emotions to judge the emotions of their partners.

Table 1 shows the results of the regression analyses. The results show that individuals’ judgements of their partner’s emotions were not related to what their partners actually reported (IV1), for any emotion except interest. Individuals attributed more interest to their partners when their partners also reported more interest. Overall, this set of results suggests that individuals’ understanding of their partners’ emotions was mostly inaccurate.

The regression analysis also revealed that for all the reported emotions, individuals’ judgements of their partners’ emotions were related in significant and positive ways to their own emotions (IV2). That is, the more intensely they felt an emotion, the more strongly they attributed this emotion to their partner. This effect was stronger for the cases of hope and frustration than for happiness, interest, challenge and boredom. Overall, this suggests that individuals used information about their own emotions to report the emotions of their partners.

2.3. Discussion

Consistent with Hypothesis 1, the associations between the intensity attributed to the emotions of the partner and the intensity of participants’ own emotions was positive and significant for all emotions. This suggests that individuals judged their partners’ emotions as more or less intense according to the intensity of their own emotions, regardless of what their partners actually reported.

There are at least two explanations for these findings. One is that whilst playing the game, participants were not concerned about their partner’s emotions and, therefore, when asked to judge them had no knowledge other than their own emotions. Another explanation is that participants did care about the emotions of the partner, but prioritised their efforts to deal with the demands of the game, and/or to understand mental states other than emotions that they considered to be more directly linked with the game (e.g., ideas that resolved the tasks). Consequently, they lacked the resources to attend and process information about their partner’s emotions and therefore relied on what they knew about their own emotions. This would be consistent with evidence from research about mental-state reasoning. It is known that people use their own mental states as default information to infer the mental states of others (Epley, Keysar, Van Boven, & Gilovich, 2004): an egocentric bias that increases in the presence of a concurrent task (Lin et al., 2010).

The findings may also indicate that individuals assumed emotional similarity with the partner. This reasoning, which turned out to be inaccurate on most occasions, is consistent with the tendency to project one’s own attributes and mental states to others increases during situations that involve cooperation (Toma et al., 2010). Thus, emotional similarity with the partner probably seemed natural for individuals after having shared a cooperative task such as playing a game collaboratively.

The findings of this experiment suggest that individuals collaborating around a computer game are largely unaware of their partners’ emotions. However, this oversight may be unwise given that understanding of others’ emotions could influence the process and outcomes of computer-supported collaboration. Influencing partners’ emotions is just as likely to occur without awareness, as a product of automatic mechanisms such as contagion, than as a product of effortful and accurate reasoning. The following experiment explores whether making collaborators aware of each other’s emotions could facilitate this kind of reasoning, assessing the extent to which this is beneficial for the process and outcomes of their joint activity.

3. Experiment 2

This experiment explores the extent to which facilitating awareness of a partner’s emotions benefits co-located and remote
computer-supported collaborations around a computer game. Benefits would be expected for co-located and remote collaborators, but there is evidence to suggest that remote collaborators might benefit more. Stone and Posey (2008) compared remote and co-located teams resolving a fixed-goal task. Only amongst remote teams was it observed that those who asked more about the emotions of their partners also performed better. Knowing about a partner’s emotions might also improve the affective experience of remote collaborators. Michinov and Michinov (2008) found that blended-learning students used more socio-emotional expressions (e.g., disclosing intimate information, providing emotional support) after face-to-face meetings. They probably tried to improve the affective quality of remote interactions, which is often reported to be inferior than the quality of face-to-face interactions (e.g., Johnson et al., 2009).

In this experiment partners shared their emotions in key moments of their game play, the effects of which were assessed in four areas: emotion understanding, own emotions, interaction quality, and performance. We expected positive main effects of sharing emotions, as well as interactions consisting of larger positive effects amongst remote collaborators.

Performance: Recent research suggests that collaborators’ participation and effectiveness is likely to improve with awareness of certain affective components such as friendliness (Phielix, Prins, Kirschner, Erkens, & Jaspers, 2011) and mutual trust (Fransen, Kirschner, & Erkens, 2011). These findings motivated the following hypothesis:

**Hypothesis 1.** Collaborators, especially those interacting remotely, will perform better after sharing emotion information.

**Emotion understanding:** Emotions can vary in seconds (Kuppen, Oravecz, & Tuerlinckx, 2010) especially whilst playing computer games (Baker, D’Mello, Rodrigo, & Graesser, 2009). Therefore, participants in this experiment would be wrong to conclude that the emotions of their partner will remain unchanged following emotion sharing. To accurately understand the emotions of a partner, individuals will have to integrate the emotion information shared by the partner with other cues available during game play, hence the following hypothesis.

**Hypothesis 2.** Sharing emotion information will improve the understanding of a partner's emotions, especially amongst remote collaborators.

**Own emotions:** A substantial amount of evidence suggests that sharing emotions with others improves the quality of one’s own emotions (see Pennebaker, Zech, & Rimé, 2001; also Rimé, 2009). Therefore, we formulated the following hypotheses:

**Hypothesis 3a.** Exchanging emotion information will increase positive affect, especially amongst remote collaborators.

**Hypothesis 3b.** Exchanging emotion information will decrease negative affect, especially amongst remote collaborators.

**Interaction quality:** Processing the emotion of others is known to facilitate positive behaviours during social interaction, e.g., helping (Hoffman, 2008), and sharing emotions facilitates affiliation (Rimé, 2009). This led to the following hypothesis:

**Hypothesis 4.** Collaborators, especially those interacting remotely, will assess their interaction more positively after sharing emotion information.

### 3.1. Method

#### 3.1.1. The collaborative game

Participants played the commercial game Lego Star Wars II (Lucas Arts & TT Games, 2006). In this game players collaborate to resolve puzzles embedded in an adventure storyline. Players control characters that share basic capabilities such as pushing boxes and pulling levers, but also have different complementary skills. For example, one character can manipulate objects at a distance but cannot climb, while the other character can climb but cannot manipulate objects at distance. Not all puzzles force players to cooperate, but all puzzles are more efficiently resolved with cooperation.

#### 3.1.2. Participants

48 Female undergraduates from the University of Nottingham participated in the study; their mean age was 22.3 years. Only females were invited to avoid the controversy of gender differences regarding the interpersonal understanding of emotions (Baron-Cohen & Wheelwright, 2004; Ickes, Gesn, & Graham, 2000). All participants had an occidental background and were either native or fluent English speakers. They all reported not having played LSWII before. Each participant received £6 as inconvenience allowance.

#### 3.1.3. Questionnaires

Participants answered five questionnaires designed for the purposes of this experiment. They were presented electronically in counterbalanced order with randomized items.

**Game Playing Habits:** Composed of three items with Likert scales for participants to report their interest for computer games: How interested in video games and/or computer games are you? (4-points scale anchored with Not interested at all and Very interested), and frequency of game play: How much time did you spend playing video games/computer games last month? (4-points scales: 0 h, <5 h, 5–10 h, and >10 h).

**Own Emotions:** Self-reported intensity of emotions such as happy, interested, hopeful, excited, challenged, frustrated and annoyed, rated with Likert scales ranging from 0 (not at all) to 8 (extremely).

**Partner Emotions:** Identical to the Own Emotions questionnaire except that participants reported the emotions of their partners.

**Interaction quality:** Composed by two scales:

- **Individual appraisal:** Composed of six items covering individuals’ perceptions of their own and their partners’ provision of support, expression of ideas, and interest concerning the other’s ideas; rated with Likert scales ranging from 0 (never) to 8 (all the time).
- **Dyad appraisal:** Composed of seven items covering individuals’ views about qualities of their interaction such as equality of contributions, understanding of one another’s ideas and overall performance; rated with Likert scales ranging from 0 (totally disagree) to 8 (totally agree).

#### 3.1.4. Design

Dyads were randomly formed and assigned to one of four conditions in a 2 (Awareness/No Awareness) × 2 (Remote/Co-located) between-participants design with 12 individuals/6 dyads in each cell. Awareness was operationalized as making partners share their answers to the Own Emotions questionnaire (awareness) or not (no awareness). Location was operationalized as interacting side by side (co-located) or in different rooms communicating through an audio channel (remote).

#### 3.1.5. Procedure

All participants answered the questionnaires in laptops in separated rooms. Those in the awareness conditions looked at the
partner’s answers to the Own Emotions questionnaire on monitors connected to the partner’s laptop. In the remote condition partners played LSWII in separated rooms, communicating through a high-fidelity audio channel wearing noise-cancelling headphones. In the co-located condition collaborators played in the same room sitting side-by-side.

On arrival participants confirmed they were unacquainted and read the study information. Unlike those in the no awareness condition, those in the awareness condition learned that their answers to the Own Emotions questionnaire were to be disclosed to the partner. After reading the study information participants answered the questionnaires Game Play Habits and Own Emotions, the latter to report their emotions during the last 20 min. Then, those in the co-located conditions joined in the same room and those in the remote conditions remained in separated rooms. In all conditions, participants freely decided which side to sit (co-located) or which room to use (remote).

Sessions lasted 60–70 min. Before the experimental trials, participants learned how to play LSWII by solving the two initial puzzles with guidance and received a handout with reminders and hints. There were three trials:

**Trial 1:** Participants played for 10 min and then answered the questionnaires Own Emotions, Partner Emotions, and Interaction Quality. There were no differences between the awareness and no-awareness conditions at this stage.

**Trials 2–3:** Immediately after answering the questionnaires in the previous trial, those in the no awareness conditions reactedivate their game play for another 10 min without looking at the partner’s answers. In contrast, those in the awareness conditions saw a histogram-like representation of the partner’s answers to the Own Emotions questionnaire (Fig. 1) before reactivating their game play for another 10 min. Finally, participants in both the awareness and no awareness conditions answered the questionnaires again.

### 3.1.6. Measures

**Performance:** To measure performance, the steps required to solve the puzzles in LSWII were classified by two independent researchers as simple, rewardable and interdependent (Kappa = 0.80, p < .001). Each of these step types was assigned a score depending on the extent to which its mechanics demanded collaboration between players. Table 2 shows the definition of the step types and its score value.

Participants played mission 2 of LSWII. Maximum possible scores during this mission were defined as the score that each character could achieve after executing all the steps required to resolve the puzzles, excluding those steps only executable by the other character. Excluding the initial puzzles used in the game induction, the maximum possible scores were 78 for character A and 87 for character B. The participants’ performance score was then defined as the score obtained by an individual in Trials 2 and 3 divided by the maximum possible score of her character.

**Emotion understanding:** The measure of emotion understanding was the correlation between participants’ answers to the Partner Emotions questionnaire and their partners’ answers to the Own Emotions questionnaire. Data from Trial 1 (prior to any emotion sharing) indicated no differences between awareness and no awareness conditions and, therefore, it was discarded from further analysis. Consequently, indices of emotion understanding were calculated with data from Trial 2 and Trial 3. To confirm that these indices were not biased by stereotypical responses, we compared them with indices calculated with a nominal partner – someone in the same experimental group but different to the actual partner, paired randomly post hoc (Kenny, Kashy, & Cook, 2006). As expected, indices of actual partners (M = .57, SD = .36) were higher than indices of nominal partners (M = .42, SD = .44), t (47) = 2.51, p < .02 (one-tailed).

**Positive Affect and Negative Affect:** The scores from the Own Emotions questionnaire showed positive and significant intercorrelations (not reported) between positive emotions (happy, interested, hopeful, excited and challenged) and between negative emotions (frustrated and annoyed). The positive emotions scores were averaged to compose the variable Positive Affect. This same procedure was applied to the negative emotion scores to compose the variable Negative Affect. Descriptive analyses indicated floor effects for Negative Affect and, therefore, further inferential analyses focused on Positive Affect only.

**Interaction Quality:** Descriptive analysis indicated that across trials and conditions, participants used only the highest part of

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**Fig. 1.** Representation of their partner’s answers to the own emotion questionnaire.

<table>
<thead>
<tr>
<th>Happy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Interested</td>
<td>X</td>
</tr>
<tr>
<td>Hopeful</td>
<td>X</td>
</tr>
<tr>
<td>Excited</td>
<td>X</td>
</tr>
<tr>
<td>Challenged</td>
<td>X</td>
</tr>
<tr>
<td>Frustrated</td>
<td>X</td>
</tr>
<tr>
<td>Annoyed</td>
<td>X</td>
</tr>
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</table>
the rating scale to answer the questions in the Interaction quality questionnaire, indicating little variability. These data was therefore excluded from further analysis.

3.2. Results

3.2.1. Game playing habits

To assess whether individuals’ interest in computer games and game playing habits (e.g., frequency of computer game play) could influence the results of the study, the answers to the Game Play Habits questionnaire were tested with a 2 (Awareness/No Awareness) × 2 (Remote/Co-located) doubly multivariate ANOVA. As expected, no significant difference was found for the multivariate effects of awareness [F (3, 42) = 0.53, p = .66, η²p = .03], location [F (3, 42) = .81, p = .49, η²p = .05] or the awareness × location interaction [F (3, 42) = 1.40, p = .25, η²p = .09]; indicating that individual differences in game play habits did not influence the results.

3.2.2. Performance

The performance scores were analyzed with a 2 (Awareness/No Awareness) × 2 (Remote/Co-located) ANOVA. The location main effect indicated that remote collaborators performed better [F (1, 44) = 8.26, MSE = 53.05, p < .01, η²p = .15], and the awareness main effect showed that those who shared emotion information performed better [F (1, 44) = 5.43, MSE = 53.05, p < .05, η²p = .11]. The awareness × location interaction was not significant [F (1, 44) = 1.24, MSE = 53.05, p > .05, η²p = .02]. Fig. 2A illustrates these results.

3.2.3. Emotion understanding

The emotion understanding indices were analysed with a 2 (Awareness/No Awareness) × 2 (Remote/Co-located) ANOVA. The main effect of location was not significant [F (1, 44) = 0.02, MSE = 0.11, p = .87, η²p < .01]. A marginally significant main effect of awareness indicated a tendency of those in the awareness conditions to have a more accurate understanding of a partner’s emotions [F (1, 44) = 3.48, MSE = 0.11, p = .06, η²p = .07]. There was a significant awareness × location interaction [F (1, 44) = 4.42, MSE = 0.11, p = .04, η²p = .09]. Bonferroni post hoc tests revealed that sharing emotion information facilitated the understanding of a partner’s emotions amongst remote collaborators (p < .005) but not amongst co-located collaborators, as Fig. 2B illustrates.

3.2.4. Positive affect

Positive affect was analysed with a 2 (Awareness/No Awareness) × 2 (Remote/Co-located) ANCOVA including the scores of prior positive affect as covariates. The covariation with prior positive affect was not significant [F (1, 43) = 2.31, MSE = 1.24, p > .05, η²p = .05] indicating that the participants’ prior emotions did not influence their emotions during the experiment. The location main effect was marginally significant, indicating that remote collaborators tended to report more positive affect than co-located collaborators [F (1, 43) = 3.85, MSE = 1.24, p < .06, η²p = .08]. A significant main effect of awareness indicated that those in the awareness condition reported more positive affect [F (1, 43) = 4.30, MSE = 1.24, p < .05, η²p = .09]. This main effect was due to a significant awareness × location interaction [F (1, 43) = 5.31, MSE = 1.24, p < .05, η²p = .11]. Bonferroni post hoc tests revealed that sharing emotion information increased positive affect amongst remote collaborators (p < .05); but not amongst co-located collaborators, as illustrated in Fig. 2C.

3.3. Discussion

The data permitted testing hypotheses about performance, emotion understanding, and positive affect, but not hypotheses about negative affect (which was at floor) and self reported interaction quality (which was at ceiling). The results partially supported our predictions. Concerning performance (Hypothesis 1) both remote and co-located collaborators performed better after sharing emotion information, although unexpectedly, this effect was not larger amongst remote collaborators. In areas such as emotion understanding (Hypothesis 2) and positive affect (Hypothesis 3a); sharing emotion information benefited remote collaborators only. It seems like remote collaborators were more able to take advantage of the information about each other’s emo-

![Fig. 2. Performance (A), emotion understanding (B) and positive affect (C) as a function of awareness and location.](image-url)
tions than co-located collaborators. Below we discuss each area to explain how this might have occurred.

3.3.1. Performance

The main effect of location on performance indicated that remote collaborators played more effectively than co-located collaborators. This might suggest that playing the game imposed more taxing demands for co-located collaborators, who interacted both inside and outside the game, processing an abundant stream of visual and non-visual information in order to interact with each other whilst also responding to the individual and social requirements of the game. In contrast, remote collaborators interacted only in the virtual space of the game whilst processing auditory information only. Another compatible explanation is that given the conditions of virtual collaboration, remote partners interacted more frequently, which might have facilitated their performance. Although we did not collect this data our strong impression was that this was not the case. If anything, remote collaborators seemed to talk less to each other than co-located collaborators.

The main effect of awareness on performance showed that in spite of the apparently different demands that individuals responded to in each condition, both remote and co-located collaborators played more effectively after sharing emotion information. However, this effect seems more robust in the case of remote collaborators, for whom the improvements in performance were accompanied by improvements in emotion understanding and positive affect. It appears that interacting through an audio channel in the virtual space of the game not only helped remote collaborators to perform better, such conditions probably made them more able or willing to consciously process and take advantage of the shared emotion information.

3.3.2. Emotion understanding

The non-significant main effects of location indicate that having visual access to the partner did not facilitate the emotion understanding of co-located collaborators. This result is in contradiction to that of Hall and Schmid (2007), who reported that having visual and non-visual cues facilitated more accurate inferences about others’ emotions. One plausible explanation for this discrepancy might be the taxing demands faced by co-located collaborators: recall the reliability of mental-state reasoning decreases in the presence of a concurrent tasks (Lin et al., 2010). This might also explain the awareness \times location interaction. Co-located collaborators probably found it harder to integrate emotional information available in visual (e.g., facial expressions), auditory (e.g., voice tone, discourse) and contextual (e.g., game events) sources with the information shared by the partner. In contrast, for remote collaborators it might have been easier to consciously process such information to integrate it with the available auditory cues, which in turn helped them to infer the partner’s emotions more accurately.

A complementary explanation is that remote collaborators were more aware that they did not have access to as rich a source of emotion expression as co-located collaborators. This may have led them to accord greater significance to the provided emotion information.

3.3.3. Positive affect

The non-significant main effect of location on positive affect indicate that, contrary to the results of some previous studies (e.g., Johnson et al., 2009), remote collaborators felt as positively as co-located collaborators. Moreover, the awareness \times location interaction indicated that with awareness of a partner’s emotions, remote collaborators reported more positive affect that co-located collaborators. It is plausible that remote collaborators valued the sharing of emotions more than co-located collaborators. This would be consistent with prior studies in which remote collabora-tors show more interest about the emotions of their partners than co-located collaborators (e.g., Stone & Posey, 2008). Consequently, sharing positive emotions probably helped remote collaborators to capitalise upon them, enhancing their own and their partner’s current level of positive affect, which is a documented consequence of sharing positive emotions with others (for a review, see Rimé, 2009).

3.3.4. Conclusions

Being aware of each other’s emotions helped both remote and co-located collaborators to improve their performance. Amongst remote collaborators this was also associated with increases in emotion understanding and positive affect. Accurately inferring each other’s emotions probably eased collaborators’ coordination (Michael, 2011), and feeling positive affect may have facilitated their problem-solving ability (Brand & Opwis, 2007). In contrast, amongst co-located collaborators sharing emotion information facilitated performance without affecting emotion understanding or positive affect.

We conclude that supporting awareness of a partner’s emotions is likely to benefit performance in remote and co-located computer-supported collaborations, albeit the mechanisms underlying such improvement remain unclear and appear to be different. Future studies should be directed towards explaining the nature of these differences.

4. General discussion

Facilitating awareness is important for remote and co-located computer-supported collaboration because it aids the understanding of collaborators in relation to each other and their activity. This research represents an initial step in the study of collaborators’ understanding of each other’s emotions, of which we know only little in comparison to cognitive and social factors. Therefore our interpretation of the results will remain speculative. Consequently we end by discussing the results in relation to what appears to be the content of collaborators’ emotion understanding, and considering what the implications of making collaborators aware of each other’s emotions might be.

4.1. What collaborators understand of each other’s emotions

Experiment 1 showed that collaborators’ understanding of each other’s emotions was very limited, and Experiment 2 showed no difference between the emotion understanding of collaborators interacting remotely and that of collaborators interacting side-by-side. This suggests that in general, collaborating around and through computers is an activity in which individuals are largely unaware of each other’s emotions. This might be a consequence of the subtle nature of emotions in combination with the demands inherent to collaborating around and through computers. There might be situations in which the emotions of a collaborative partner are evident and inevitable to notice. For example, when the partner expresses emotions in an unusually intensive manner, when her emotions are ostensibly different to one’s own, or radically inappropriate for the current situation (e.g., expressing anger for no apparent reason). However, people often experience emotions without overtly expressing them and subtle changes in the emotional state of a partner can easily be unnoticed, especially considering that collaborating around and through computers imposes multiple demands, such as individual effort, joint planning and coordinated action.

More research is necessary to identify the implications of having limited understanding of a partner’s emotions. One issue that deserves further investigation is whether the emotions of a partner
require conscious processing and understanding to influence one's own emotions and actions. It is known that the automatic transmission of emotions, i.e., emotional contagion, has important implications for the process and outcomes of collaboration (Barsade, 2002; Totterdell, 2000), but this topic has received little attention in the specific case of computer-supported collaborations (e.g., Cheshin et al., 2011; Hancock et al., 2008).

4.2. Awareness and understanding of a partner's emotions

The limited awareness of each other's emotions showed by collaborators in Experiment 1 motivated Experiment 2, which investigated the potential benefits of facilitating such awareness. The results suggest that receiving information about each other's emotions can be useful for remote and co-located collaborations, albeit in different ways and extents. Here we discuss theoretical, practical and ethical implications of these findings.

In terms of theory, this research draws attention to mechanisms underlying the effects of emotional awareness. After sharing emotion information co-located collaborators improved their performance, but not their emotion understanding. It might be that they used the information shared by the partner to interpret her behaviour, but not to develop a more accurate understanding of her emotions. Another explanation would be that looking at the emotions of the partner triggered behaviours that facilitated social interaction during subsequent collaboration (e.g., helping), regardless of what the partner did. It appears that the benefits of emotional awareness are not necessarily tied to an improved understanding of each other's emotions. However, as observed amongst remote collaborators, there might be conditions in which emotional awareness facilitates more accurate emotion understanding, with parallel benefits in performance and positive affect. In future, it would be helpful to understand how emotional awareness works in co-located and remote collaborations, so as to determine the extent to which better understanding of a partner's emotions is necessary to achieve such benefits.

This research also has a number of practical and ethical implications. Using computers to support collaboration offers possibilities to incorporate the awareness of others' emotions in ways not possible in traditional forms of collaboration. Participants in Experiment 2 were instructed to report the intensity of their emotions, which in turn was disclosed to the partner. There are other ways to implement emotional awareness, perhaps in more unobtrusive ways. Current advances show that emotions can be reliably recognised using a variety of sources, e.g., visual, auditory or multimodal information (Calvo & D'Mello, 2010). Another issue to think about relates to the way in which the emotions of a collaborative partner ought to be presented. The representation of emotions is an expanding area of research in fields such as Human–Computer Interaction (e.g., Beale & Creed, 2009), but it remains unexplored in computer-supported collaboration. Finally, we would like to highlight the ethical implications of supporting emotional awareness. In this research, participants voluntarily agreed to disclose their emotions to others. People in other circumstances, e.g., at work or in a learning community, might feel uncomfortable with this kind of emotional sharing.

4.3. Limitations

This research was based on dyads collaborating around computer games designed for learning and leisure. These are common forms of computer-supported collaboration; however, future research should aim to replicate the results here presented in other collaborative situations, for example, studying larger groups and other species of collaborative technology. Also, this research focused on synchronous collaborations; studies would be welcomed that investigate emotion understanding and emotional awareness in asynchronous computer-supported collaboration.

4.4. Concluding remarks

We conclude that it is worth investigating what partners in computer-supported collaboration understand about each other's emotions. This is important in theoretical terms since emotions and the understanding of others' emotions are largely missing from current frameworks of computer-supported collaboration. In practical terms, the evidence that emotional awareness might benefit collaborators performance adds to the increasing interest for improving the process and outcomes of computer-supported collaborations by making collaborators aware of each other and their activity. More research in these directions is likely to generate insights to advance our current understanding of computer-supported collaboration as means of doing things with others.

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