EMOTION UNDERSTANDING DURING

COMPUTER-SUPPORTED COLLABORATION

by

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ABSTRACT

Affect has been neglected in computer-supported collaborative learning, which is unfortunate because emotions play important roles in collaborative learning and human-computer interaction. This thesis investigated affect in co-located and remote remote-synchronous collaboration, answering the question: *How does the task environment and interaction with a partner influence people's emotions during computer-supported collaboration?*

In Study 1, the collaborative tasks and affective features of a game provoked more goal-oriented emotions (e.g., challenge) than an open task in a concept-mapping tool. In both environments individuals assumed emotional similarity with a partner, which not necessarily was true. Some partners that reported similar emotions also interacted positively (e.g., with responsiveness and coordination). Study 2 investigated the dynamics of challenge around a collaborative game. Challenge was likely to change when the task environment included features like complexity or required coordination. Challenge increased if partners struggled, and decreased if they performed fluently. Moreover, partners influenced each other's actions in these situations. Probably this explained the similarity between partners' reported challenge and their tendency to assume such similarity when reasoning about the emotions of each other. In any case, partners rarely discussed emotions during their collaborative interaction.

Thus, Study 3 assessed the benefits of supporting affective awareness between partners during remote and co-located collaborations. Affective awareness facilitated enjoyable and productive interactions only during co-located collaborations, suggesting the remoteness highlighted the importance of an accurate understanding of a partner's emotions, precipitating a more effective response to the demands of the task environment.

The research shows that partners' emotions are under the influence of one another's actions, especially when the task environment requires them to solve collaborative tasks playing complementary roles. Moreover, collaborators assume emotional similarity with the partners. Thus, the process and outcome of collaboration might improve if the environment helps partners to have a better understanding of one another's emotions.

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LIST OF PUBLISHED PAPERS

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Chapter 1

Introduction

There is an increasing interest in the use of computers to support collaborative learning and the technological designs to do so are constantly appearing. Crook (1998b) proposed a (non-exhaustive) taxonomy of computer-based collaborative interactions: interactions *at* computers, interactions *around* computers, interactions *related to* computers, and interactions *through* computers. Interactions at, around, and related to computers typically refer to co-located collaboration. A typical example would be children using educational software seated together *at* a shared computer. In contrast, interactions *through* computers typically refer to collaborations at a distance. This can occur continuously, using 'chat' applications or videoconferencing, or asynchronously, as in e-learning environments.

This research investigates emotions and their implications for the processes and outcome of computer-supported collaboration in the co-located and remote-continuous formats. The results help to fill the gap about affect in the research about Computer-Supported Collaborative Learning (CSCL). In doing so, the thesis also contributes to the understanding of emotions in the general context of collaboration and in relation to more general aspects of learning. Three parts make up this introductory chapter. The first part presents a brief outline of co-located and remote-

continuous CSCL. The second part is an overview of the aims and methodology of thesis. The third part presents the structure of the thesis.

1.1 Co-Located and remote-continuous CSCL

This section outlines main features of the co-located and remote-continuous formats of CSCL, to give an overview of the area in which this thesis is developed. The co-located engagement is probably the earliest CSCL format. Crook (1998b) notes that during the 1980's, it was common for UK teachers to organize their students in pairs to use an educational application running in a shared *microcomputer*. More than the intention to promote collaborative learning, such practice obeyed economical imperatives. In those days computers were much more expensive than today and, therefore, schools' resources were insufficient to provide one computer for each student. Nowadays, computers are much cheaper and the educational value of collaborative learning is widely recognized. Therefore co-located CSCL is widespread and the technological designs to support it are constantly growing in number. For example, one early attempt to innovate co-located CSCL was the implementation of local networks to aid classroom collaboration (see for example, Scardamalia & Bereiter, 1994). More recent innovations include the usage of shared interfaces (Kerawalla, Pearce, Yuill, Luckin, & Harris, 2008), the development of software that supports social interaction in co-located cooperative learning (Belgiorno et al., 2008) as well as the utilization of tabletops (for a review, see Marshall, 2007) and handheld devices in classrooms (for a review, see Zurita, Nussbaum, & Sharples, 2003).

The continuous-remote one is also a widely used CSCL format, being the videoconference a traditional example. It is known that as long as the audio quality is reliable, collaboration through video-conference produces learning outcomes similar to co-located collaboration (Ertl, Fischer, & Mandl, 2006). The implementation of shared interfaces is another common method of remote-continuous CSCL. Learning

environments that follow this approach often combine a 'shared workspace' (e.g., a graphical tool) and a 'communication space' (e.g., a chat window). One example is the *Virtual Maths Team* (VMT) project, which is an online tool designed for small groups of learners to solve mathematical problems in remote collaboration. The VMT interface presents a shared whiteboard where learners can make visual representations to aid their problem solving (e.g., drawings or formulas) and a chat window (see Stahl, 2009).

Important advances have been made in the understanding of the social and psychological processes associated with co-located and remote-continuous CSCL. However, the majority of research has focused in cognitive factors, whilst emotions have received much less attention. For example, there is an abundant literature about one key issue of CSCL, namely knowledge construction, usually covered under labels such as *grounding* (e.g., M. Baker, Hansen, Joiner, & Traum, 1999) or *shared knowledge* (e.g., Roschelle & Teasley, 1994). It turns out that the affective aspects of knowledge construction have been traditionally neglected, which reflects on the current conceptualization of collaborative learning technologies: Designers and evaluators of CSCL technologies have usually attended the socio-cognitive aspects of collaborative learning, whereas attention to affective aspects is a fairly recent issue.

1.2 Aim and methodology

The general aim of this thesis is to advance the currently small understanding of how the technological environment and interaction with a partner influence people's emotions during co-located and continuous-remote collaboration. This aim is twofold. On the one hand, it is necessary to clarify how the technology participates in the generation and shaping of collaborators' emotions and their understanding of a partner's emotions. This is to highlight the meditational role of technology, which distinguishes CSCL from other forms of collaboration and collaborative learning. On

the other hand, it is necessary to identify the implications of people's emotions and their understanding of a partner's emotions for the processes and outcomes of collaboration.

Throughout this thesis, the *Appraisal Theory of Emotions* serves as a point of reference to conceptualize the nature of people's emotions. The empirical studies are conducted with persons organized in pairs (i.e., *dyads*), interacting around desktop collaborative technologies. The methodology combines statistical techniques suitable for interpersonal processes, labelled *dyadic analysis,* with qualitative video observations of collaborators' interaction and performance.

1.2.1 Dyadic analysis

The term dyadic analysis refers to statistical techniques that take the dyad as a unit of analysis and assess how the members of a dyad influence each other. This section describes the conceptual basis of the dyadic analyses employed in this thesis. The specific techniques are explained where it corresponds within the empirical chapters.

This thesis investigates emotions in computer-supported collaboration by analysing people during actual social interaction. In comparison to approaches such as vignette paradigms, the observation of social interaction generates data that, ideally, reflects the effects of interpersonal phenomena. There are several techniques to assess such effects in dyadic interaction (for a comprehensive review, see Kenny, Kashy, & Cook, 2006). This thesis employs techniques to assess interpersonal processes such as similarity between partners and interpersonal perception.

Similarity and interpersonal perception of emotions between collaboration partners are assessed with *dyadic indexes*, defined as correlations between variables (e.g., emotion intensity) measured in the members of a dyad. This logic underlies similar approaches to the assessment of interpersonal perceptions of emotions such as the

empathic accuracy paradigm. In the traditional employment of this paradigm, people are organized in dyads to perform a joint activity (e.g., to have a conversation or play a game). Right afterwards, dyad members make inferences about the partner's thoughts and feelings (e.g., by filling in a Likert scale). Then, their inferences are correlated with the thoughts or feelings actually reported by the partner (e.g., Hall & Schmid, 2007; Ickes, Robertson, Tooke, & Teng, 1986). In fact, the same logic is employed to investigate various social processes. For example, to assess the association between marital satisfaction and the similarity and understanding of marital ideas among members of close relationships (Acitelli, Kenny, & Weiner, 2001), and to compare the patterns of behavioural interaction displayed by dyads under conditions of cooperation and competition (Georgiou, Becchio, Glover, & Castiello, 2007).

1.2.2 Qualitative observations

This thesis also employs qualitative video analysis of partners' interaction and performance. In some parts of the thesis the video data was useful to extract illustrative examples directed to establish concrete connexions between the actual context (e.g., the interaction with a partner and the task environment) and the results of the statistical analyses. In other parts, the triangulation of qualitative and quantitative data permitted the identification of some of the features of the task environment and the interaction with the partner that were likely to influence the generation and shape of participants' emotions.

1.3 Structure of the thesis

The rest of this thesis is structured in five chapters:

Chapter 2 presents the review of the literature. The first four sections outline four topics: The appraisal theory of emotions, the relationship between emotions and

learning, the role of emotions in collaborative learning and affective factors in HCI and learning technology. The fifth section discusses the current state of the literature about affect in CSCL, and establishes the research questions of the thesis.

Chapter 3 presents Study 1, which investigates the role of design on people's emotions and their understanding of a partner's emotions. A comparison is made between collaborative learning environments with different features and underlying tasks: a concept-mapping tool and a collaborative educational computer game.

Chapter 4 presents Study 2, which investigates the changes of people's emotions and emotion understanding around a collaborative computer game, focusing on the affective state challenge. A microgenetic approach is employed to explore some factors likely to be associated with changes in the feelings of challenge, and the potential implications of these changes for the outcomes of collaboration.

Chapter 5 presents Study 3, which assesses the benefits of affective awareness. Two groups of dyads played a collaborative computer game co-locatedly or remotely. Half of the dyads were informed about the emotions of the partner. The comparative effects were assessed in four areas: understanding of a partner's emotions, collaboration quality, affective experience, and performance.

Chapter 6 presents the general discussion of the thesis. There are five sections. Section 1 integrates the findings of the studies to answer the main research question. Section 2 discusses how the thesis informs four areas: the Appraisal theory of emotions, the relationship between emotions and learning, the role of emotions in collaborative learning, and the design of CSCL technologies Section 3 discusses the methodological contributions of the thesis, covering the employment of dyadic analysis and qualitative video observations. Section 4 outlines the limitations of the methodologies employed. Finally, section 5 outlines future research that might extend the results of this thesis.

Chapter 2

Review of the literature

2.1 Introduction

Given that emotions are largely missing from the frameworks of CSCL (e.g., sociocultural theories and cognitive perspectives), this thesis borrows from the literature about affect in adjacent fields, such as Educational psychology, Social Psychology, Education and Human-Computer Interaction (HCI). Five parts compose this literature review chapter:

(1) The first section outlines the *Appraisal Theory* of emotions, which is frequently invoked throughout this thesis. The robustness of this theory and its usefulness in understanding affect in CSCL are discussed.

(2) The second section briefly reviews the research that postulates a relationship between emotions and cognitive processes recruited during learning. This is explained as one of the motivations to study emotions in CSCL.

(3) The third section outlines two significant issues about people's emotions during collaborative learning. The first refers to the relationship between emotions in the motivation to collaborate. The second refers to what

collaborators think about each other's emotions, and the resulting implications for the processes and outcomes of collaborative learning.

(4) The fourth section outlines the research about affect in HCI and learning technologies. It reviews attempts to theorize affect in HCI, as well as empirical studies that investigate people's emotions in relation to the usage of interactive technology in general, and learning technologies in particular.

(5) The fifth section discusses literature concerning affect specifically in CSCL, which leads to formulate the research questions addressed in this thesis.

2.2 Overview of the appraisal theory of emotions

This *Appraisal theory* of emotions is frequently referred in this thesis because its assumptions guide methodological decisions and the interpretation of results. The core idea of the appraisal theory is that people's emotions are provoked by their evaluative perceptions of the environment, termed *cognitive appraisals.* In other words, appraisals are the 'cognitive' links between people's emotions and the environment. The appraisal theory of emotions has a number of advantages. First, it permits the differentiation of emotions; therefore a wide range of emotions can be explained within its framework. Second, the assumptions of the theory are robust. Third, social factors that influence people's emotions can be incorporated in this theory. Therefore, the appraisal theory is useful to understand how contextual factors such as the technological environment and the interaction with a partner influence people's emotions in the context of computer-supported collaboration.

2.2.1 Outline of the appraisal theory

Appraisal theories provide a 'dimensional framework' to explain the experiential features that make emotions distinctive from each other. This framework can explain

a wide range of emotions, which is an advantage over other emotion theories, such as the *categorical theories* and the *dimensional theories.* Categorical theories claim that there is a set of basic emotions such as *anger* and *fear*, hard-wired by neurophysiologic processes. In turn, combinations of these basic emotions result in 'families' of secondary emotions (Ekman, 1992; Ortony & Turner, 1990). Appraisal theory is less restrictive in terms of how emotions are differentiated. Instead of relying in a-priori categorizations to define people's emotions in a given situation, appraisal theories imply that people's emotions are constantly transitional, depending on the transitions of people's appraisals of the environment. Appraisal theory is also different from the dimensional view of emotions, which suggests that emotions are explained in terms of the dimensions arousal and valence. In contrast, appraisal theory postulates that many more dimensions are necessary to differentiate between emotions. Thus, several dimensions of cognitive appraisals have been proposed to explain people's emotions. Although there is no consensus, Ellsworth & Scherer (2003) noted that various scholars agree that people's emotions are driven by their appraisals of pleasantness (valence), the extent to what they are engaged (goals/needs), their certainty about the situation outcomes (certainty) and their perceived control (agency) (see Table 2.1).

Table 2.1
Comparative overview of major appraisal dimensions as postulated by different theorists

	Frijda (1986)	Roseman (1984)	Scherer (1984)	Smith/Ellsworth (1985)
Novelty	Change Familiarity		Novelty Suddenness/ Familiarity	Attentional activity
Valence	Valence		Intrinsic pleasantness	Pleasantness
	Focality	Appetitive/ Aversive motives	Goal significance Concern relevance Outcome probability	Importance
Goals/needs	Certainty	Certainty		Certainty
Agency	Intent/Self-Other	Agency	Cause: agent Cause: motives	Human agency
Norms/Values	Value relevance		Compatibility with standards External Internal	Legitimacy

Source: Ellsworth & Scherer (2003, p. 573)

2.2.2 Robustness

A number of studies support the main proposition of appraisal theory that emotions are distinguishable in terms of their underlying cognitive appraisals. These studies employ a range of different methodologies and their results are mostly consistent, which indicates the robustness of the appraisal theory. One of the first studies that provided a comprehensive set of relationships between appraisals and emotions was conducted by Smith & Ellsworth (1985). They searched the dimensions underlying the appraisal themes used by people to rate a number of remembered experiences, and found that the appraisals themes could be grouped in six dimensions such as *Pleasantness, Responsibility/Control, Certainty, Attentional Activity, Effort* and *Situational Control.* Then, they found specific patterns appraisal dimensions for a number of emotions. For example, challenge and frustration were both experienced in

situations involving the achievement of a goal. However, people felt challenged when they were confident of success, and frustrated when they failed for unknown reasons.

Ecological validity is a main indicator of the robustness of the appraisal theory. The results about appraisal-emotion relationships found in laboratory settings have been replicated in a number of 'authentic' scenarios. For example, the aforementioned study of Smith & Ellsworth (1985) was carried out in a laboratory, and its results were largely replicated by these same authors (1987) in a naturalistic study. They tested appraisal-emotion relationships with students before an exam and after receiving their grades, and found distinctive patters of cognitive appraisals for a number of students' emotions. Moreover, the patterns of cognitive appraisal were 'sensitive' to the context. That is, different patterns of emotions and appraisals were observed before the exam and after receiving the grades. For example, students felt hope and fear more intensely before the exam than after receiving their grades. In turn, the variation in the cognitive appraisals associated and emotions was correlated with the variation in the students' exam scores.

More recently, Tong et al. (2007) made a-priori predictions about appraisal-emotion relationships on the basis of the results of laboratory studies. Then they found support for most of their predictions with a naturalistic study in which the participants (police officers) reported their emotions and appraisals continuously throughout a day. For their part, Nezlek, et al. (2008) conducted a longitudinal study in which participants reported their emotions and appraisals in naturally occurring situations. Their findings were consistent with the appraisal-emotion relationships described in an earlier laboratory study (C. A. Smith & Lazarus, 1993).

The robustness of the appraisal theory is also indicated by the consistency between self-report data and other methodologies. Traditionally, studies about appraisal-emotions relationships rely on self-report data. It has been suggested that the

participants responses to questionnaires could be distorted by stereotypical reactions (e.g., reporting they felt sad in a situation that typically provokes sadness, such as the death of a pet, without actually having felt sadness) (Parkinson & Manstead, 1992). However, recent evidence suggests that the basic assumptions of the appraisal theory hold when tested with implicit measures. For example, Siemer & Reisenzein (2007) used a reaction time paradigm to test whether emotion inferences were mediated by the inference of cognitive appraisals. First they found that emotion inferences were faster than appraisal inferences. Then they formulated and probed the hypothesis that emotion inferences were faster because they were based on automatised cognitive appraisals. For their part, Grandjean & Scherer (2008) operationalized cognitive appraisals in the form of tasks (e.g., goal conductiveness in the form of monetary gains, and novelty in the form of frequency and presentation of stimuli) and used an EEG to track participants' brain states while performing the tasks. Overall, they found the expected patterns of correlations between brain states and appraisals, and argued this was evidence of the automatic nature of cognitive appraisals.

2.2.3 Incorporation of social aspects

The appraisal theory is also helpful to explain how the social context influences people's emotions. For example, Parkinson & Hareli (2008) made an extensive review of the appraisal research about 'social emotions' such as shame, guilt, envy or pride. They concluded that social emotions are social because their underlying appraisals are heavily influenced by other people's thoughts, feelings and actions. This can occur during actually occurred interactions, or even if interactions are remembered, anticipated or imagined. For example, people feel anger when someone obstructs them achieving a goal (i.e., other-agent appraisal). People feel ashamed when they are under the judgement of others (i.e., other-agent appraisal), and guilty when they violate a social norm (i.e., self- agency appraisal).

Bieke, Kirby & Smith (2005) proposed the idea of appraisal as a social process. On the basis of an extensive literature review, they explained how, in spite of being 'internal states', emotions are very socialized, which must be accounted for within appraisal theories. They invoked literature on how people seek social support to deal with their emotions (e.g., anxiety), the practice of 'social sharing' (e.g., looking for opportunities to talk about a strong emotional experience) and the 'reality negotiation' (e.g., the use of excuses to reduce the perceived gravity of the norms violation).

2.2.4 Limitations

One downside of appraisal theory is that it does not explain the influence of high-level social structures in people's emotions. It is thought that *morality* and *culture* are powerful influences in the causality and consequence of emotions (e.g., Coulter, 1989; Harré 1989). From this point of view, the same sort of event could trigger different emotions because its moral content determines people's appraisals of the context. For example, being hurt by someone is usually a justified reason to feel angry and act accordingly (e.g., with an avoidance response). However, being hurt does not generate anger or avoidance responses under situations where it is 'morally' acceptable to be hurt, such as being hurt by a dentist (Harré, Clarke, & De Carlo, 1985, p. 5).

2.2.5 Concluding remarks on the appraisal theory of emotions

The aspects reviewed in this section indicate that the appraisal theory is an adequate framework for the empirical study of emotions, helpful in this thesis to make methodological decisions and interpret results. Furthermore, this will also help to test the robustness of the theory in a context where it has not been applied before. Lastly, methodological strategies have been employed to take into account the influence of culture on people's emotions, which deals with the limitations of this theory to take into account the cultural dimension of emotions.

2.3 Emotions and learning

A reason to study emotions in CSCL is the postulated relationship between emotions and learning. This section briefly summarizes the literature that suggests that emotions might influence a number of cognitive processes recruited during learning, such as memory and attention, as well as problem solving, transfer and metacognition. The relationship between emotions and learning is also investigated in other research lines. For example, in the Education literature, there is research about the impact of individual differences in 'affective variables' (e.g. emotion self-regulation) on academic performance (e.g., 2006; Pekrun, Elliot, & Maier, 2006). This literature is not reviewed here because both individual differences and academic performance are topics beyond the scope of this thesis.

2.3.1 The relationship between emotions, memory and attention

There are no studies that directly address the relationship between emotions and basic cognitive processes such as memory and attention during learning. However, learning depends on these processes. Therefore, if at a 'basic' level people's memory and attention are influenced by their emotions, this might reflect on their learning. Although the precise mechanisms that account for these relationships remain to be explained, a vast amount of research suggests that both memory and attention are susceptible to the influence of emotions.

The review of Kensinger & Schacter (2008) outlined three broad influences of emotions in *declarative memory* (i.e., conscious remembering): the quantity of events remembered, the subjective vividness of the remembered events, and the amount of details remembered about the events. In relation to *non-declarative memory* (i.e., unconscious memory that underlies conditioning and association mechanisms),

emotion modulates the impact of recent events for which there is no conscious memory (see the review of LaBar & Cabeza, 2006).

The literature describes a number of ways in which emotions influence attention. For example, emotionally loaded stimuli attract more attention than neutral ones. Moreover, the emotional state of individuals interacts with the content of the stimuli. For example, anxious individuals had slower reaction times to anxiety related words than non-anxious individuals (1998). People's emotions also influence the control of their attention. For example, individuals feeling positive affect are more able to effectively 'switch' the focus of their attention from previously relevant stimuli to a new relevant one (Dreisbach, 2006; Dreisbach & Goschke, 2004).

2.3.2 The relationship between emotions, problem solving, transfer and metacognition

Some evidence suggests that emotions influence reasoning mechanisms recruited during learning, such as problem solving, transfer and metacognition. These mechanisms obviously overlap during actual learning activities, but they are studied, and therefore reviewed, separately.

2.3.2.1 Problem solving

Individuals' emotions are closely linked to their problem solving capacity. It is known that under certain conditions, individuals' positive affect (e.g., 1999) and negative affect (e.g., 2003) might influence their problem solving performance. For example, Estrada, Isen, & Young (1997) reported that physicians inducted to feel positive affect made earlier accurate diagnoses than physicians in a control group (not affect inducted). Their positive affect helped them to be more open to the incorporation of new information, and less prone to distort or disregard disconfirming evidence. More recently, Frederickson and Branigan (2005) reported that emotions

can broad or narrow the scope of attention during problem solving. In comparison with people in a neutral affective state, people experiencing amusement and contentment gives a more 'global' view of a problem, rather than focusing on specific aspects, which implies that they can think of a wider array of solutions. On the other hand, anger and anxiety may not have any effect in the capacity to have a global view; but they can lead to a narrow account of solutions.

Contrary to the studies referred above, Spering, Wagener, & Funke (2005) found no influence of emotions on problem solving. However, they discussed that this was probably due to methodological issues.

2.3.2.2 Transfer

Transfer refers to the application of knowledge or skills in a specific situation after having acquired and practiced that same knowledge and skills in other different, but analogue, situation. It is the learning of algorithms and heuristics that permits the transfer of knowledge. It is known that emotions influence the preference to use a heuristic solution over an algorithmic one when making judgements and decisions (Izard, 1998). In relation to this, Brand et al. (2007) reported that positive affect facilitates, and negative affect hampers, the acquisition and transfer of problem solving algorithms. These authors found that individuals in a happy mood needed fewer repetitions to acquire mastering at solving the Tower of Hanoi (ToH) (a problem which solution requires a recursive algorithm) than participants in a negative mood. In turn, individuals in happy mood found it easier to solve tasks that required the same sort of recursive solution as the ToH, such as the missionary and cannibal problem. Moreover, individuals in a negative mood required more repetitions to learn the ToH and to perform the transfer tasks.

2.3.2.3 Metacognition

Emotions can also affect individuals' capacity of being conscious of their own cognition, which is commonly known as *metacognition*. Efklides & Petkaki (2005) induced positive and negative mood in learners before a maths problem-solving task, and measured the individuals' 'metacognitive experiences' (e.g., perceptions of difficulty and effort, and estimations of performance) in two ways: as expectation (before task) and as retrospection (after task). They found no effect of mood neither in problem solving performance or metacognitive expectations. However, positive mood was associated with positive metacognitive experiences in retrospection. This suggests that the relationship between emotions and metacognition resulted from the efforts to solve the task, and not from a-priori dispositions of the learners.

A number of studies illustrate the influence of emotions in learners' metacognition. For example, Eynde, Corte, & Verschaffel (2006) reported that during mathematics problem solving, students felt a wide range of negative emotions such as worry, frustration and anger. These emotions were associated with cognitive 'blocks', but also helped students to redirect their behaviour, looking for other strategies (e.g., solving the last part of a problem before the first part). This is consistent with the findings of Gomez-Chacon (2000), who reported that during mathematics problem solving, calmness relates with the approximation to a solution, confidence with understanding the problem, cheerfulness with achievement and helping others, *De abuty* (described as feeling 'just great') with having an idea that works, and 'blocked' with trying a strategy of trial and error.

2.3.3 Concluding remarks on the relationship between emotions and learning

The literature reviewed in this section strongly suggests that emotions might be a major influence during learning. This is a motivation for this thesis to investigate emotions in computer-supported collaboration and, in doing so; it will also help to expand the general understanding of the relationship between emotions and learning. Nevertheless, because emotions are intrinsically social, the emotions people feel during computer –supported collaboration might be highly susceptible to the influence of the interaction with a partner, which is explained in the following section.

2.4 Experience and understanding of emotions during collaborative learning

This section discusses how emotions might 'work' in the social environment of collaborative learning. This will be a background to explain emotions in computer-supported collaboration and, subsequently, in CSCL. Let us start by saying that emotions are social in a number of ways. People's emotions are often caused by other people (Ben-Ze'ev & Oatley, 1996) or by problems that affect them as members of relationships (e.g., friendship, marriage) or cultures (Keltner & Haidt, 1999). Emotions are also social in terms of experience. People have a strong tendency to *share* (i.e., disclose) their emotions with others (Pennebaker, Zech, & Rimé, 2001; Rimé, Philippot, Boca, & Mesquita, 1992). There are *group level* emotions, experienced because of the identification with a social group (Seger, Smith, & Mackie, 2009; E. R. Smith, Seger, & Mackie, 2007). Emotions are also sensitive to social ascriptions such as *power* (Langner & Keltner, 2008) and *leadership* (Sy, Côté, & Saavedra, 2005). Moreover, people can also 'align' their emotions with the expected reactions of others (Parkinson, 1996, 2005).

If people's emotions are interlocked with their social environment, how does this work during collaborative learning? This section integrates literature that suggests that people's emotions and what they understand about the emotions of others might play a key role during collaboration and collaborative learning. The first part offers a general overview of the interpersonal situation during collaborative learning. The second part explains the relationship between emotions and motivation during collaborative learning.

2.4.1 The interpersonal situation during collaborative learning

Several authors suggest that collaboration drives cultural development because it is a powerful way for people to transmit knowledge (e.g., Bruner, 1990; Tomasello, 2009; Vygotsky, 1978) This reflects on collaborative learning, a situation where individuals co-construct knowledge in order to arrive at the solution to a joint problem. In doing so, they think about (i.e., represent) their joint activity as a whole; while constantly updating their 'representation' of each other's perspectives (Tomasello, Kruger, & Ratner, 1999). Consider as an example the case of learners A and B solving a factorization problem. Together they might be thinking of the problem as a whole –what equations can we use to solve the problem? Additionally, they need to be aware of each other's perspective to solve the problem. In other words, A and B might think about one another's perspective - why does she think that that equation will be useful?

Participants in a collaborative learning activity not only need knowledge and experiences in common; they also need to 'know' that this common knowledge exists in each other. In other words, they need a 'mutual understanding', which depends on "*knowing (recursively) that the other knows what you know"* (Crook, 1998a, p. 241). For the case of A and B, let us suppose they know more or less the same range of equations relevant to the topic of factorization. Then they have a common

understanding of the problem, which is necessary, but not sufficient to collaborate successfully. They also need to create a state in which A knows what B knows about factorization and *vice versa*. In doing so, they constantly *mentalize* each other. That is, they infer what each other know employing a dual process in which they both express their own knowledge and take perspective of the other's knowledge.

Thus, the capacity to infer the mental states of others (i.e. to mentalize) is central to collaborative learning. In turn, studies in philosophy, and developmental and comparative psychology suggest that such capacity is in fact a primary requisite to collaborate. Therefore, it might be useful to review how mentalization operates during collaboration before explaining how it might operate during collaborative learning.

Bratman (1992) proposed a framework to conceptualize the dynamics of people's actions and 'intentions' during collaborative activities, which he describes as *shared cooperative activities* (SCA). From his point of view, in order to maintain the cooperative status of an activity, collaborators need to establish, by means of communication and actions, a mutual acknowledgement of *shared intentionality*[1]. Then, in order to maintain the cooperative status of their activity, collaborators must be *responsive* to the actions and intentions of one another, knowing that the other is similarly responsive. Consequently, they must help each other to play their role in a joint activity, showing *commitment with the joint activity* and *commitment to mutual support.* Extending Bratman's view, Tomasello (2009) explains that the commitment

[1] Some scholars describe this as acting in 'we mode', a notion often used to explain social conventions (Searle, 1995) and complex social scenarios (Tuomela, 2000). Also, there is a philosophical debate on whether intentions can be literally 'shared' in the sense of being experienced by more than one individual (see for example, Gilbert, 1990; Velleman, 1997). These aspects are distant to the main purposes of this research and, therefore, they are not covered in this literature review.

with the activity and with mutual support demand collaborators' attention both to matters concerning the common goal and to each other's individual perspective, leading to a process of *recursive mindreading*.

The importance of the mentalization capacity during collaboration is delineated by de Vignemont (2008) with a comparison of social interaction and social observation. She postulates that during social interactions where individuals 'have to know' the intentions of one another, as it occurs during collaboration, the capacity to ascribe mental states to others is 'interaction oriented'. Individuals regard one another as 'intentional agents' (i.e., ascribing mental states to one another) and not as instances of a class (i.e., without ascription of mental sates). Consequently, they conduct their interaction according to the mental sates (including emotions) that they ascribe to one another. In contrast, during social observation, the observer does not necessarily have to know the intentions of the observed. Therefore the observer can regard the observed either as an intentional agent or as an instance of a class.

The ascription of mental states (i.e., mentalization or mindreading) is important during collaborative learning activities because it is recruited for learners to create a shared understanding of the context, a process that carries employment and exchange of 'cognitive resources' (i.e., knowledge or skills). Joint problem solving is a good example because it requires collaborators to constantly represent each other's points of view. van Boxtel, van der Linden & Kanselaar (2000) tested in adults the effects of individual preparation before making joint explanations of electric phenomena with a poster or a concept map. They found that in general, participants who prepared individually before the activities asked each other more questions, especially whilst constructing the concept map because it required the explanation of abstract concepts (theoretical relationships between the elements). They argued that partners were not only reflecting on their own understanding, but also reflecting on the understanding of the partner; i.e., integrating their perspectives.

Another example of mentalization during collaborative learning is the study of Hausmann, Chi & Roy (2004), who compared three mechanisms of explanation during collaborative problem solving: *other-directed explanation, co-construction* and *self-directed explaination.* The results illustrated three forms mentalization.

- In other-directed explanation, the listener and the explainer represented the perspectives of each other. However, they represented each other's perspectives in 'parallel', not actively making a 'common ground' as described in Clark & Brennan (1991). This mechanism only benefited the listener, albeit modestly.

- In the self-directed explanation, the explainer did not represent the perspective of the listener, whilst the listener represented the perspective of the explainer in a 'third-person' perspective. With respect to previous discussion, this indicates that the listener was not preparing herself for any sort of collaborative interaction (de Vignemont, 2008). This mechanism produced the highest learning gains: much more for the explainer than the listener.

- In the co-construction, collaborators represented both the perspective of one another and the whole picture of their activity (Tomasello et al., 1999). This mechanism increased the problem solving performances overall.

In the other-directed explanation, the 'parallel' mentalization of collaborators generated a small benefit. In the self-directed explanation, the explainer benefited from not trying to represent the perspective of the listener -it is known that the effort to establish a common ground diminishes efficiency during cooperation (e.g., Brennan, Xin, Dickinson, Neider, & Zelinsky, 2008). In contrast, the listener benefited less because, even when she was representing the perspective of the explainer, she was doing so without social involvement, as an observer. Finally, co-construction illustrates how the mutual mentalization between partners might benefit the processes and outcomes of collaboration.

2.4.2 Emotion and motivation during collaborative learning

The examples presented above illustrate the role of mentalization during collaborative learning: it serves for collaborators to create a shared understanding of their knowledge. This is a key element in the cognitive processes of collaboration such as knowledge co-construction; and also carries a powerful affective tone. Crook (1998a, 1998b, 2000) commented that there might be 'something' motivating in the creation of shared understanding, which is in line with research suggesting that 'doing things together' is something that people are naturally motivated to do.

2.4.2.1 Shared understanding and the motivation to collaborate

Studies from developmental and comparative psychology suggest that young children (14-24 months old) are 'naturally' motivated to cooperate, and that the capacity to understand the mental states of others is an important part of this motivation. In Warneken & Tomasello (2007), children cooperated with adults in tasks that required actions not performable individually, such as making a wooden block bounce on a trampoline by holding it on opposite sites. Adults were instructed to quit the task suddenly. When they did so children made communicative attempts to re-engage the adult with the activity, many more times than would be expected by chance and even in the absence of reward, meaning it was not a conditioned response. One interpretation is that children were motivated by the activity simply because it was shared (Tomasello & Carpenter, 2007). Children seemed to employ an attitude of shared intentionality of the kind 'we intend to do *x* by means of you doing A and me doing B' (Searle, 1990), and attributed the same attitude to the adult. In turn, attempts to reengage the partner might represent a commitment with the activity and mutual support as described in Bratman's (1992) account of shared cooperative activities. From this point of view, the capacity to ascribe mental states must have been essential for children's motivation to cooperate, since assuming an attitude of shared

intentionality requires, by definition, the ascription of mental states (e.g., intentions) to the partner.

This argument is supported by other studies. Chimpanzees performing the same tasks as described in Warneken & Tomasello (2007) did not make attempts to re-engage the quitting partner (Warneken, Chen, & Tomasello, 2006). Referring back to the work of Premack & Woodruff (1978), it was suggested that chimpanzees lack the capacity to theorize about the mental states of others. This suggestion has been supported with further evidence, although the debate continues (Tomasello, Carpenter, Call, Behne, & Moll, 2005). Moreover, children with Autistic Spectrum Disorders (ASD), who are known to have problems ascribing mental states to others, also find it difficult to engage in cooperative activities (Liebal, Colombi, Rogers, Warneken, & Tomasello, 2006).

Thus, a sense of shared understanding seems to make collaborative activities 'naturally' attractive. Something similar has been suggested by Schwartz (1998, p. 8) in the context of collaborative learning. This author proposed that collaborative partners are motivated to achieve a 'shared meaning': "…*individuals want accurate representations of other people's thoughts, and individuals want other people to have accurate representations of their own thoughts*". In turn, whilst making an effort to understand each other, collaborators engage in the kind of interaction that 'produces' learning from collaboration, such as the constant making of a common ground (see for example, M. Baker et al., 1999).

The notion of 'agency' is central here. Recall that, in theory, individuals in collaboration regard the partner as an intentional agent (i.e., with ascription of mental states) and not as an instance of a class (de Vignemont, 2008). To emphasize the importance of agency in collaborative learning, Schwartz proposes that collaborative *artificial intelligence* (AI) companions would not pass a collaborative version of the

‘Turing Test’. People would not trust the cooperativeness of an AI partner because they would not attribute it ‘agency’. This resonates with the ‘plausibility problem’, which questions the credibility of AI engines ‘acting’ as if they were teachers (i.e., using tutoring strategies used by teachers in classrooms) (du Boulay & Luckin, 2001). Moreover, there is research that also illustrates the importance of perceived agency in a counterpart during collaboration. For example, people respond more affectively to the unfair offers of humans than to the unfair offers of computers in cooperation games (van’t Wout, Kahn, Sanfey, & Aleman, 2006). On the contrary, the assumption of Schwartz clashes with the research about *Anthropomorphism*, which shows that people tend to react towards computers as if they were human (Brave, Nass, & Hutchinson, 2005; Cliford Nass, Steuer, Tauber, & Reeder, 1994; Reeves & Nass, 1996). Anthropomorphism is reviewed in more detail later, whilst reviewing affect in the context of HCI.

2.4.2.2 Affect and motivation during collaborative learning

The above suggest that in theory, collaborative partners are naturally motivated to create a state of shared understanding because such a state is naturally enjoyable. This in turn might benefit the outcomes of their collaboration. For example, Buchs, Butera, & Mugny (2004) found that promoting the effort shared understanding prompted positive affect and useful social interaction during collaborative learning. They manipulated the interdependence between learners discussing Social Psychology texts. Learners collaborated with identical information (i.e., they just elaborated on the topic, with limited effort to create a shared understanding) or with complementary information (i.e., they had to create a shared understanding). Learners who discussed with complementary information had more positive affective reactions such as encouraging the partner and expressing understanding, and also made more explanations and questions for one another. This is consistent with Drolet & Morris (2000), who found that the establishment of mutual positivity and interest through

conversation (i.e., *rapport*) facilitates cooperation. For their part, Brand & Opwis (2007) found that collaborators in whom positive mood had been induced before solving a collaborative problem solving task (i.e., the Tower of Hanoi) had better performance in a subsequent transfer task (e.g., the missionary and cannibal problem).

The research on the effects of affinity during collaborative learning also illustrates the positive aspects of the relationship between shared understanding and affect. One early study reported that friends collaborating in a problem solving task showed more mutuality, social responsibility, positive affect and better performance than unacquainted partners and partners in competition (Newcomb & Brady, 1982). These kinds of results, in which friends outperform unacquainted partners, have been replicated in different conditions (e.g., individual, competition, unacquainted) and with a number of problem solving tasks such as looking for scarce resources (see the review of Zajac & Hartup, 1997). More recently, it has been found that friends in collaboration show more animated collaborations (e.g., including jokes or shared laughter) than unacquainted partners, although this does not necessarily results in better performance (Vass, 2002, 2007)

The examples presented above suggest that the positive affect associated with the achievement of a shared understanding might have positive implications for collaborative learning. Further research will have to explain with more detail the relationship between affect and shared understanding, which requires an investigation of what partners understand about the emotions of one another during collaborative learning.

2.4.3 Understanding the emotions of a partner during collaborative learning

The literature about the interpersonal understanding of emotions during collaborative learning is scarce. However, a number of studies about collaboration suggest that thinking about the emotion of one's partner might play a key role during collaboration. Before reviewing this literature, it is useful to give a brief outline of how people understand the emotions of others.

2.4.3.1 Mechanisms and biases of emotion understanding

Mechanisms of emotion understanding

There are two complementary parts in the interpersonal understanding of emotions: understanding of others' emotions and expression of one's own emotions

Understanding others' emotions

The mechanisms underlying the understanding of others' emotions have been the object of numerous reviews (Nava, 2007; Preston & de Waal, 2003), theorizations (e.g., Blair, 2005; de Vignemont, 2004; Goldie, 1999; Thompson, 2001) and empirical studies (e.g., Decety & Jackson, 2004; Lamm, Batson, & Decety, 2007). Broadly speaking, the literature describes four general mechanisms of emotion understanding.

Emotional Contagion. This term is defined as "*The tendency to automatically mimic and synchronize expressions, vocalizations, postures, and movements with those of another person and, consequently, to converge emotionally*". (Hatfield, Cacioppo, & Rapson, 1993, p. 5). Emotion mimicry is a basic automatic process (see for example, McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006; Wild, Erb, & Bartels, 2001). Therefore, a person would not notice that she is 'catching' the emotions of others. Contagion is not sufficient to understand what the emotions of the

other are about because a person can ‘catch’ the emotions of other without catching the ‘object’ of the other’s emotions (Goldie, 1999). Emotional contagion is a precursor of sympathy and empathy.

Affective Perspective Taking. This mechanism implies understanding the emotions of others without using ‘emotional cues’. That is, in the absence of emotional expressions and using situational cues, (e.g., a vignette), or looking at a person in a situation that should generate an affective state (e.g., pain) but showing no emotion. This sort of emotion understanding prompts helping behaviour (Oswald, 1996) as well as emotional concern (Vaish, Carpenter, & Tomasello, 2009). However, it does not necessarily imply an affective reaction from the observer.

Empathy. Various accounts of empathy converge to define it as understanding the mental states and emotions of others in a way that involves some level of emotional engagement or distress for the observer, even when the observer is in a situation different to the situation of the observed. Empathy is often associated with helping behaviour and altruism (De Waal, 2008; Dovidio, 1984; Sturmer, Snyder, Kropp, & Siem, 2006), but also with egoistic behaviour (Lamm et al., 2007).

Sympathy. This is defined as an affective state in itself, implying concern and compassion about the emotions of others, especially if the other is in a suffering situation (Goldie, 1999; Preston & de Waal, 2003). It is different to empathy in that it does not imply feeling the same affective state of the one observed. There is evidence that empathy and sympathy work differently, being sympathy a mechanism less sensitive to the nature of the other’s conflict than empathy (Gruen & Mendelsohn, 1986).

Expression of one's own emotions

The social context strongly influences how emotions are expressed. For example, emotion imitation is influenced by social grouping effects (Mondillon, Niedenthal, Gil, & Droit-Volet, 2007) and the presence or absence of an audience determines whether emotions are expressed or not (Jakobs, Fischer, & Manstead, 1997; Kraut, 1982) Thus, emotion expressions are more than 'symptoms' of underlying mental states. They also play a communicative function. The 'relational' approach of Parkinson (1996, 2005) explains how people align their emotion expressions with the anticipated or imagined reactions of others, although the 'matching' between the expected and the actual response of others to the own emotions is not guaranteed.

Potential biases in the interpersonal understanding of emotions

The illusion of transparency and the *False consensus effect* are mechanisms that bias individuals' interpersonal perception, which might also influence the understanding of other's emotions during collaboration.

The illusion of transparency was described as the biased assessment of others' ability to 'read' one's own emotional states (Gilovich, Savitsky, & Medvec, 1998). It was explained as an incapacity of people to detach from their own 'phenomenological' experience in order to represent the perspective of others, which has had empirical support (Vorauer & Ross, 1999).

The false consensus effect has been described as people's tendency to "*see their own behaviours and judgements as appropriate to existing circumstances while viewing alternative responses as uncommon, deviant, or inappropriate*" (Ross, Greene, & House, 1977), implying an 'assumed similarity' between self and others. The effect was robust across a number of studies (see the reviews of Marks & Miller, 1987; Nickerson, 1999). However, methodological (Nickerson, 1999) and statistical

(Dawes, 1989) controversies challenged its typical explanation that people projected their motivations and opinions onto others.

Evidence of how egocentric biases might influence collaboration comes from research in economic games. People who derive more pleasure from selfishness than fairness assume that their counterparts will feel the same. Therefore, they tend to make more unfair offers. Conversely, people who derives more pleasure from fairness than selfishness assumes their counterparts will feel the same and, therefore, they make more fair offers because they think their counterparts will reject unfair ones (Haselhuhn & Mellers, 2005). Some evidence suggests that egocentric biases result from a process in which people first anchors their social perceptions on their own experience, and then they gradually adjust to the perspective of others (Epley, Keysar, Van Boven, & Gilovich, 2004).

2.4.3.2 The role of emotion understanding in collaborative learning

Although the mechanics involved in the understanding of a partner's emotions during collaboration have not been investigated, the literature suggests that it might play an important role in the processes and outcomes of collaborative learning. For example, it turns out that the mechanisms recruited to understand one's own emotions and the emotions of others overlap with the mechanisms recruited to understand the actions and mental states of others (see Gallese, Keysers, & Rizzolatti, 2004; Olsson & Ochsner, 2008). Clinical studies also suggest that mentalization and emotion understanding are interlocked. In comparison with typically developed children, children with ASD show less emotional responsivity (Scambler, Hepburn, Rutherford, Wehner, & Rogers, 2007) and rely more in actions than in mental states to understand the emotions of others (Dapretto et al., 2006). However, it has been noticed that the understanding of other's emotions should be different to the general understanding of other's minds, although the dissociation remains to be clarified (Blair, 2005).

Emotional similarity

Collaborative learners make constant efforts towards shared understanding, which requires recursive perspective taking. In this situation, they are likely to the sense each other's emotions. This would explain why people in collaboration tend to feel similar emotions. Lanzetta, Basil & Englis (1989) investigated the emotional responses (e.g., skin resistance, hear rate, electromyographic patterns) towards the emotion expressions of others (e.g., smiles, grimace) under conditions of cooperation and competition. Individuals expecting cooperation were more empathic than individuals expecting competition, and reacted to the emotional expressions of the other with a fairly similar affective expression. This sort of emotional similarity has been observed during collaborative learning. Barsade (2002) reported that students taking part in a group discussion 'catch' the mood of a confederate, suggesting an emotional contagion effect. The effect was robust and occurred similarly for positive and negative affect. Moreover, when partners similarly felt positive affect, they also showed less conflict and more cooperation and performance. This is consistent with research suggesting the importance of emotional similarity in groups. Members of the same group tend to feel similar emotions (Moons, Leonard, Mackie, & Smith, 2009; Seger et al., 2009; E. R. Smith et al., 2007), and people mimic more the emotions of members of their own group than the emotions of members of other groups (Mondillon et al., 2007).

Social regulation

Emotion understanding might also help collaborators to regulate the emotions of each other. It has been suggested that the emotional similarity between members of the same group serves to enhance their social regulation (Magee & Tiedens, 2006; Spoor & Kelly, 2004). In line with this, Smith, Seger and Mackie (2007) reported that behaviour tendencies beneficial for group activities such as in-group support and

solidarity were correlated with group-level emotions (i.e., emotions felt only because of the self-ascription to a social category, like membership of a university).

In collaborative learning, the emotional support between members of a team relates with their effectiveness. Effective teams focus on the 'desirable' aspects of the activity i.e., emotional support and belongingness, whereas ineffective ones focus in the 'undesirable' ones, e.g. boring teaching methods and little emotional support (Hijzen, Boekaerts, & Vedder, 2006). Järvenoja & Järvelä (2009) studied learners in collaborative learning tasks (discussion of educational psychology topics). They found that learners' main socio-affective challenges had to do with group matters such as mutual commitment and equality, whereas their personal priorities were less relevant. In turn, collaborators faced these challenges by regulating both their own emotions and the emotions of each other.

It is plausible that the participants in Hijzen, Boekaerts, & Vedder (2006) and Järvenoja & Järvelä (2009) recruited a mechanism of emotion understanding (e.g., empathy or affective perspective taking) in order to provide emotional support and regulate the emotions of each other. This would be in line with the fact that partners are constantly aware of one another during collaboration; as observed in authentic scenarios such as an emergency control center (Artman & Wærn, 1998) and several laboratory experiments (e.g., Brennan et al., 2008; Sebanz & Knoblich, 2009)

Support

Emotion understanding might also motivate collaboration partners to support each other. It is well established that empathy triggers helping and altruistic behaviour (see the early review of Dovidio, 1984), which is mediated by social grouping. People will help a member of her group more than a member of a different group (Sturmer et al., 2006). Moreover, the relationship between empathy and the tendency for altruism have been theorised as core mechanisms of collaboration (Tomasello, 2009). For

example, Batson & Moran (1999), reported that during a cooperation game (the prisoner's dilemma), people instructed to imagine the feelings of a cooperation partner in distress (after splitting a relationship) cooperated more than people instructed not to sympathize with the partner (Batson & Ahmad, 2001). Similar results have been reported in situations when the partner has cooperated inconsistently during longer-term interactions (A. Rumble, van Lange, & Parks, in press).

2.4.4 Concluding remarks on the experience and understanding of emotions during collaborative learning

We have seen that individuals in collaborative learning feel naturally attracted to understand one another. To do so they constantly 'think about' each other's 'mental states' (e.g., knowledge, ideas); which might be linked to their emotions and emotion understanding. But during CSCL, learners' emotions are also influenced by the technology, which is the content of the following section.

2.5 The study of emotions in HCI and learning technology

The previous section highlighted that the interaction with a partner is a powerful drive for people's emotions during collaborative learning. This of course should apply to CSCL. Nevertheless, in CSCL collaborators not only interact with each other. They also interact with the computer. There are no studies reported that address the issue of how the technology design influences emotions during CSCL. Therefore this section reviews the literature about emotions in the wider field of Human-Computer Interaction (HCI). The first part is a brief outline of two widely known attempts to conceptualize affect in HCI. The second part covers the topic of *Anthropomorphism* (treating computers as if they were humans) as a potential source of emotions during the usage of interactive technologies. The third part presents some examples of how the use of learning technologies might influence learners' emotions.

2.5.1 Conceptualization of affect in HCI

Two widely known attempts to conceptualize emotions in the usage of interactive technology are the concepts of *Emotional design* and *The Flow Experience.*

2.5.1.1 Emotional Design

Norman and colleagues (Norman, 2004; Norman & Ortony, 2006) postulated a framework to conceptualize how the properties of interactive technology might influence users' emotions. In their view, user's attachment with an interactive product is determined by its beauty, which works at three levels:

- *Visceral:* This is perceptually based and generates automated reactions (e.g., good or bad, safe or dangerous). At this level, emotional reactions to a given product result from subconscious conditioning mechanisms.

- *Behavioural:* At this level, user's emotional reactions to a given product are driven by their expectations about its controllability and usefulness. This level is also subconscious. Well functioning mechanisms give rise to positive affect, whereas a mismatch between expectations and actual functioning generates negative affect.

- *Reflective level.* At this level, user's emotional reactions towards a product result from prior experiences, individual preferences and self-image. These aspects conduct the evaluation of a product as pleasant or not.

From this view, any sort of interactive technology is capable of triggering affective reactions in the user, even if it has not been intentionally designed to do so.

2.5.1.2 The Flow Experience

The *flow experience* is defined as a mental state of extremely rewarding concentration that emerges in the space between frustration and boredom (Csikszentmihalyi, 1997). A balance between affective and cognitive elements is necessary for the flow experience to occur. The concept of flow was not originally developed within HCI, but it is widely used in the field. Webster, Trevino, & Ryan (1993) described flow as a playful and exploratory experience that a system can facilitate by providing with more user control. Computers can facilitate the experience of flow when used to write, play games, and read, (Pilke, 2004) and at using the web (H. Chen, 2006; Webster et al., 1993). *Enjoyment* of using a computer to perform a task and the *desire* for efficiency and productivity relate with the experience of flow (Sharafi, Hedman, & Montgomery, 2006). Chen (2006) reported that the 'symptoms' of flow, and the feeling of positive affect (e.g. *fun, relaxation, exciting* and *joy*) are not only correlated; flow indeed leads to the evocation of positive affect during the use of interactive technology (e.g., a website).

2.5.2 Affect and Anthropomorphism

The term *Anthropomorpism* refers to the tendency of people to attribute human properties (e.g., intentions, emotions and personality traits) to computers. People anthropomorphize computers even if they recognize that computers are nothing like humans, or if computers have no human-like features at all such as a regular desktop PC. In turn, anthropomorphism is a potential source of emotional reactions during the usage of interactive technology.

Nass, Steuer, Tauber, & Reeder (1994) were among the first researchers to report that people apply 'social rules' whilst interacting with machines. For example, they found people attributed friendliness to a computer if it praised others instead of itself.

Later on, Reeves & Nass (1996) coined the term 'media equation' to describe the kind of 'social relationship' that people establishes with artefacts -not necessarily computers. A number of affective responses to computers are triggered by anthropomorphism such as cohesion (Johnson & Gardner, 2007), reciprocity (Clifford Nass & Moon, 2000) and 'loyalty' (Sundar, 2004). Recently, Johnson & Gardner (2009) theorised that anthropomorphism is caused by people's 'mindlessness' while interacting with the computers. This means that while doing a computerized task, people start reacting socially because they forget they are interacting with a computer.

2.5.3 Affective features in the design of interactive technology

We have seen that computers can provoke emotions in the user even if they were not designed to do so. However, a relatively recent interest in HCI is the implementation of components intentionally designed to influence users' emotions.

2.5.3.1 Expressivity and aesthetics

Expressivity refers to use of affectively loaded information in the Graphic User Interface (GUI) of interactive technology. Examples of expressivity are *smileys, emoticons*, or media content (e.g., photographs, sounds or multimedia components) with 'affective connotations'. Expressivity is implemented to improve the communication between the user and the system (e.g., to inform about the 'state' of the system) or to make a more 'friendly' interface (Sharp, Rogers, & Preece, 2007).

GUI expressivity is closely related with its aesthetics. The early studies of Tractinsky and colleagues reported that systems with more aesthetic interfaces were also perceived as more usable (Tractinsky, 1997; Tractinsky, Katz, & Ikar, 2000). However, Wages, Grünvogel, & Grützmacher (2004) reported that in fact, the cosmetic features of an interface are more related with individual experience than with actual usability. Still, aesthetics are powerful in many ways. For example, realistic

graphics facilitate 'immersion' whilst playing computer games (D. Clarke & Duimering, 2006), and appealing aesthetics can be employed to prompt user's consumption in online shopping (Lim & Cyr, 2009).

2.5.3.2 Artificial expression of emotions

Human-like computer agents that express emotions are powerful means to influence user's emotions because they might be more believable (Bates, 1994), generate empathy (Paiva et al., 2004) and reduce frustration (Hone, 2006).

2.5.3.3 Emotion recognition

Tao (2008) outlined the most effective approaches to emotion recognition: cognitive emotion modelling, recognition of affect from speech, recognition of affect from facial expressions, and recognition of affect from multimodal information. The later has been emphasized as the most successful approach to emotion recognition (Zeng, Pantic, Roisman, & Huang, 2009). Nevertheless, emotion recognition systems are traditionally tested in laboratories, in scenarios that simulate real conditions, or with emotions 'posed' by actors. Therefore, a call has been made to test the accuracy of emotion recognition systems in naturalistic scenarios (Gunes, Piccardi, & Pantic, 2008). In line with this, recent approaches aim to recognize emotions from contextual information (e.g., Benţa, Cremene, & Todica, 2009).

2.5.3.4 Emotion communication

There is a brand of HCI devoted to enhance the user experience by taking advantage of the communicative functions of emotions. Boehner, DePaula, Dourish, & Sengers (2007) made a call to attend the social aspects of people's emotions in the design of interactive technologies. Sadat et al. (2008) compiled examples of this, including an analysis of the emotional content of slogans for persuasive HCI, the

study of emotional contagion in group settings, recognition and classification of emotional content in blogs, emotion recognition in multi-user environments and the measurement of group-level emotions in computer-mediated communication. Similarly, Gaver (2002) presented a number of technologies that enhance the communication of emotions between persons, increasing senses such as intimacy or affinity. One potential application of this approach is the development of 'social prosthetics'. One example is the development of 'wearable' technologies that help children with ASD to understand the emotions of others (see the review of El Kaliouby, Picard, & Baron-Cohen, 2006). Another application is social gaming. For example, Bernhaupt et al. (2007) developed 'Emotion Flowers', a game in which the emotional expressions of users were recognised with a video analysis tool, and then graphically represented as a flower in a public screen. Players interacted with one another by means of affecting each other's flowers (i.e., their emotions).

2.5.4 Emotions during the usage of learning technology

As a reference point to understand how the technology design might influence people's emotions during CSCL, this section briefly reviews the literature about emotions in relation to the individual use of learning technology.

Developers of Intelligent Tutoring Systems (ITS) study learners' emotions with the ultimate goal of building ITS capable to infer emotions and react accordingly. D'Mello, Craig, Sullins, & Graesser (2006) used an *Emote-Aloud* technique (i.e., an analogue to a think-aloud protocol) to study learners' emotions while using an ITS. They found that learners' confusion, frustration, and *eureka* state (a sort of affective state related to the realisation of an idea) were correlated with certain features of the dialogue between the learner and the ITS engine, such as the exchange of feedback and hints. These results were later replicated with an observational technique (D'Mello, Craig, Witherspoon, McDaniel, & Graesser, 2008). For their part, Porayska-

Pomsta, Mavrikis, & Pain (2008) presented a different approach to incorporate affect in the design of ITS. They observed the strategies taken by teachers to detect and react to students' emotions and then they modelled their strategies with an ITS, finding promising rates of accuracy in detecting learners' confidence, interest and effort.

Apart from the ITS area, affect has been investigated in relation to the use of other sorts of learning technologies, such as narrative-based learning environments for science education, (Mcquiggan, Robison, & Lester, 2008), e-learning environments, (Asteriadis, Tzouveli, Karpouzis, & Kollias, 2009; Mavrikis, Maciocia, & Leeb, 2007) and virtual environments (Mikropoulos & Strouboulis, 2004). Each of these investigations focused on specific learning environments. One attempt to have a wider view is reported by Baker, D'Mello, Rodrigo, & Graesser (2009). They analysed the incidence and persistence of learners' emotions while using three different learning environments: a Dialog Tutoring System, a problem-solving game and a problem-solving Intelligent Tutoring System (ITS). Across learning environments, boredom was very persistent and associated with lower learning, whereas frustration was not as persistent, and it was not associated with diminished learning. The most persistent emotions were concentration and confusion, in turn associated with learning improvement.

The study of the flow state is another form to study emotions in relation to the usage of learning technology. For example, Konradt, Filip, & Hoffmann (2003) documented the experience of flow during IT learning. They found that learners felt flow independently of their gender and attitudes towards computers. Moreover, flow was positively related with positive affect. Similarly, Shin (2006) found that, during the use of educational virtual environments, the flow experience was associated with enjoyment and feelings of 'vividness' and 'interactivity'. Although this author found this depended on individual differences rather than on instructional features in the environment. For their part, Davis & Wong (2007) found that in combination with

user's acceptance towards the system, the experience of flow is determinant for user participation and engagement with learning. Recently, Engeser & Rheinberg (2008) reported that the experience of flow facilitates both learning in formal academic activities (i.e., learning statistics) and performance during the usage of interactive technologies such as computer games.

Educational computer games intend to take advantage of emotions to facilitate learning. There is a wide range of genres such as *Drill and Practice, Simulations* or *Strategy* (for a review, see Squire, 2003). Computer games might generate engagement and make the learning more motivating (Conati & Maclare, 2004; Sim, MacFarlane, & Read, 2006). An educative game generates fun when it provokes new or unusual emotions in contexts that typically arouse none, or arouse emotions non-typically aroused in a given context (Carroll, 2004). But the extent to what educative games can actually ease learning needs to be clarified. Sim et al. (2006) found that fun and usability of educational games correlate, but that fun not necessarily supports learning. However, latest research reported by Ainsworth & Habgood (in press) suggests that computer games might foster both motivation and learning if the educational content is intrinsically integrated in the core mechanics of the game.

2.5.5 Concluding remarks on the study of emotions in HCI and learning technology

We have seen various ways in which interactive technology in general, and learning technology in particular, might influence people's emotions. Nevertheless, it in CSCL the computer not only offers an environment to interact with, but it also plays a meditational role. Thus, understanding its role in the affective experience of CSCL should be constructed in consideration of the social interaction around it. This view has leaded to the formulation of the research questions addressed in this thesis.

2.6 Research questions

We have reviewed a number of reasons to investigate affect in CSCL. Unfortunately, affect remains underexplored in CSCL. The relevant literature is discussed in the introductions to the empirical chapters. In this section, some studies are referred to introduce the research questions and hypothesis of this thesis.

Most of the research focuses on asynchronous collaborations (e.g., e-learning) (see for example, Gunawardena & Zittle, 1997; Kreijns, Kirschner, & Jochems, 2002), whereas research about the CSCL formats addressed in this thesis, co-located collaboration and continuous-remote collaboration, is still scarce and limited. Some studies give less importance to the role of technology, and focus on affective aspects of the interaction between learners, covering topics such as friendship (Vass, 2007), sources of emotions (Järvenoja & Järvelä, 2005), and emotion regulation (Järvenoja & Järvelä, 2009). Other investigations include both the technology and the interaction between partners, usually to present (without necessarily testing) an 'affective component' to be implemented in CSCL technology For example, Mentis, Reddy, & Rosson (2010) observed medical students in an emergency room and imagined technological ways to support their emotion expression, and Karlegren & Sins (2009) identified the benefits of affective tension during group work and proposed a tool to catalyse such benefits.

As representative of the current knowledge of affect in CSCL, these studies present three limitations. First, the role of technology in the affective experience of learner is often not clear, which is an unfortunate gap since the mediating role of technology distinguishes CSCL from other forms of collaborative learning and, as the reviewed literature suggests, there are several ways in which the technology can affect users' emotions. Second, current literature does not address the collaborators' understanding of one another's emotions. This is important because the understanding of a partner's

emotions is closely linked with the motivation to collaborate and several other processes such as emotional similarity, social regulation and mutual support. Third, the implications of using technology to enhance the mutual understanding of emotions between collaborators are unexplored.

Thus, the general question of the thesis is: *How does the task environment and interaction with a partner influence people's emotions during computer-supported collaboration?* This main question offers a number of sub-questions and hypotheses that guided the empirical work of three studies.

Study 1 explored the role of design in the affective experience of computer - supported collaboration. To do so, technologies with clearly different designs were compared. Thus, collaborations around a concept-mapping tool and collaborative educational computer game were analysed to answer the following research questions:

- How does using a concept-mapping tool and a collaborative educational game influence people's emotions?
- What do collaborators understand about their partners' emotions whilst using a concept-mapping tool and a collaborative educational game?
- What is the relationship between collaborators' emotion and the qualities of their interaction with a partner?

This initial study identified some aspects that might influence people's emotions and their understanding of a partner's emotions. But it could not tell about the way in which people's emotions and emotion understanding might have changed during the collaborative activity, or the factors associated with this changes and their implications for the outcomes of collaboration.

Thus, Study 2 employed a microgenetic approach to investigate the changes in people's emotions and emotion understanding around a collaborative computer game, focusing on the affective state challenge, to answer the following questions:

- How did peoples' emotions change as they played a collaborative computer game?
- How did affective similarity change as partners played a collaborative computer game?
- How did affective awareness change as partners played a collaborative computer game?
- What were some of the factors associated with changes in challenge?

This study identified features of the task environment and the interaction with a partner likely to influence collaborators' emotions and their understanding of a partner's emotions, as well as the potential implications for the outcomes of collaboration.

Given the importance of understanding the emotions of a partner, Study 3 tested the general hypothesis that providing collaborators with affective awareness support would generate benefits including:

- An overall improvement in the understanding of a partner's emotions
- A more positive affective experience
- Better interaction quality
- Performance improvement

Chapter 3

How design influences emotions during the usage of collaborative learning technologies

3.1 Introduction

This chapter explores the role of technology in the generation and shaping of emotions during the usage of collaborative learning technologies. A study is presented that compares collaborations around the concept-mapping tool *2Connect* and the collaborative educational computer game *Astroversity*. The comparison between learning environments is useful to distinguish how different tasks and design features might influence three affective aspects of the situation: Collaborators' emotions, their understanding of a partner's emotions, and the relationship between collaborators' emotions and their interaction quality.

3.2 How concept-mapping tools and collaborative educational games might influence people's emotions

Before describing the specific features of 2Connect and Astroversity, this section describes some of the main features of concept-mapping tools and educational

collaborative computer games, in terms of the *tasks* involved in their usage, and the *affective features* of their interaction design.

3.2.1 Tasks and technology during the usage of concept-mapping tools and collaborative educational computer games

Concept mapping tools and collaborative educational computer games aim to facilitate learning in different ways. Therefore collaborators around these learning environments perform tasks of different nature, employing different technological resources. This section describes these aspects and their possible implications for collaborators' emotions and their understanding of a partner's emotions.

3.2.1.1 Tasks and technology in the usage of concept mapping tools

It is thought that concept-mapping tasks are beneficial for learning. A concept map is a graphic structural representation in which nodes (i.e., boxes or circles) represent concepts, and lines that connect nodes represent relationships between concepts. It is though that by making a concept map, people learn by means of 'structuring' their knowledge (Novak & Cañas, 2008; Ruiz-Primo & Shavelson, 1996). Figure 3.1.presents a concept map that describes concept maps.

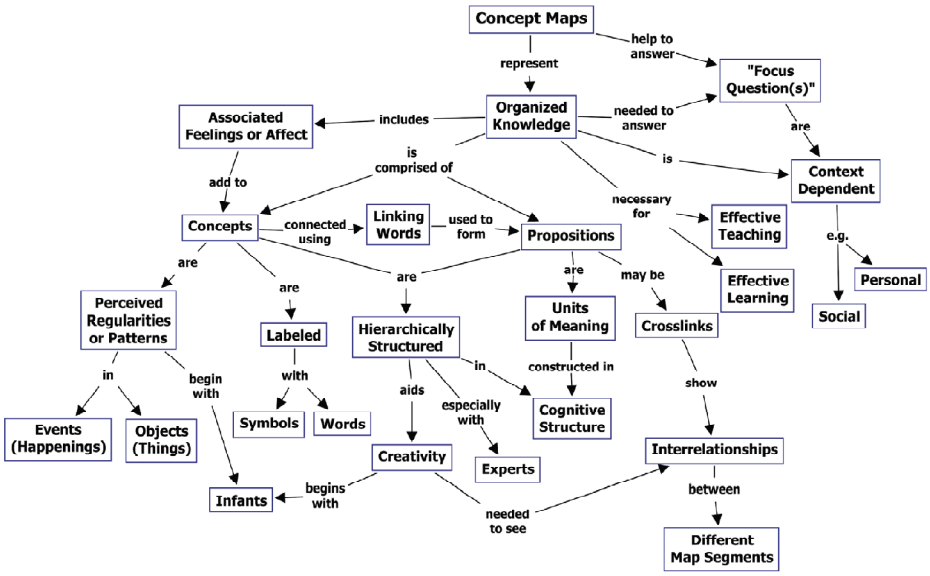


Figure 3.1. *A concept map showing the key features of concept maps (Cañas & Novak, 2006)*

Concept-mapping environments are fairly generic, consisting of tools for the user to manipulate text boxes, lines and graphs. Other features might include functionalities to incorporate audio and video, and the possibility to collaborate at-distance. A typical concept-mapping tool can be employed to support learning in different domains (e.g., electricity, genetically modified organism), using with different tasks (e.g., free discussion of a topic).

A collaborative concept-mapping task usually consists of an open-ended discussion. For example, participants may be asked to answer an open question by making a concept map. The final outcome (i.e., the characteristics of the concept map) can be undefined (Novak & Cañas, 2008) or relatively more specific. For example, learners can be asked to fill in a 'skeleton' concept map, or asked not to make more than one relationship per concept (Ruiz-Primo & Shavelson, 1996). In any case, the role of technology is to support the completion of he task, without any direct influence on how the task is set up.

In terms of the interaction between collaborators, learners making a concept-mapping task typically organize their interaction freely. That is, they do not play predefined roles to complete the task. However, some research suggests that structuring the interaction between learners might be beneficial. For example, engagement can be prompted if collaborators are asked to make a concept-map about a controversial topic (e.g., genetically modified organisms) defending opposite positions (Munneke, Andriessen, Kanselaar, & Kirschner, 2007). Moreover, learners' interaction can be structured by means of 'scripts', which are sets of instructions that indicate learners how to interact, for instance, in terms of sequence (e.g., if a learner brings an argument, the script will prompt the partner to state a counter-argument) or role allocation (e.g., after reading information, the script will ask one learner to make a summary, whilst the partner will have to listen) (Kollar, Fischer, & Hesse, 2006). Although scripting is expected to facilitate desirable qualities in collaborators' interaction (e.g., argumentation or mutual learning), it has also been noted that it may reduce the richness and 'fun' of collaboration (Dillenbourg, 2002).

Collaborations around concept mapping tools often imply the usage of a shared interface. In remote interaction, learners might share an interface employing their own terminal each. In co-located interaction, learners usually share one computer and its input device (e.g., a mouse). Recently, there has been increased interest in investigating other sorts of interfaces for collaborative concept mapping, such as digital tabletops, that permit learners to simultaneously manipulate the concept-map contents (Do-Lenh, Kaplan, & Dillenbourg, 2009).

3.2.1.2 Tasks and technology in the usage of collaborative educational computer games

Research about collaborative computer games as educational tools is still rare, especially considering the abundance of studies about educational computer games

that focus on individual game play (Kirriemuir & McFarlane, 2004). Briefly, collaborative computer games aim to facilitate learning by supporting the players' coordinated application of skills and knowledge in fixed collaborative tasks.

Clearly, collaborative educational computer games are different to concept mapping environments in many ways and in particular in terms of the relationship between technological features and their underlying task. The features of concept-mapping environments are generic across tasks and domains. In contrast, although collaborative educational computer games might be categorized according to genres (e.g., adventure, quest, role playing or first-person shooter), their specific core features (e.g., interface, storyline) are all different because they are designed according to the specific tasks that learners will be asked to perform. In turn, the design of these tasks is directed to promote learning in a specific domain.

Although educational computer games can be all different in terms of its tasks and technological features, they typically present specific goals and often allocate players to complementary roles. Presenting a specific goal to achieve, namely the 'win' state, is key for players of computer games to feel a satisfactory experience (Malone, 1981). Joiner et al. (2006) investigated the effect of having a goal in a ubiquitous game. They found that playing the game with a goal was more interesting than the same game without a goal. Furthermore, the goal version of the game also favoured cooperation between players, even when the game was not explicitly designed to do so.

The allocation of complementary roles is a feature of cooperative computer games that might be beneficial for collaborative learning. Salen & Zimmerman (2004, pp. 253-254) examined *Gaunlet,* a cooperative multiplayer co-located game in which players' task is to find and reach the exit of a series of mazes, employing the complementary skills of their characters (e.g., one character is physically strong whilst the other is a wizard). The complementary nature of the task prompts cooperative

work, discussions about fairness in the distribution of resources and a sort of 'useful' conflict between players while discussing strategies to escape the mazes. This is in line with Infante et al. (2009), who reported that the allocation of complementary roles was useful to prompt productive interaction amongst children playing a co-located educational collaborative computer game in the classroom.

Collaborative educational computer games might involve various sorts of tasks, such as going through quests, resolving puzzles, escaping mazes or collecting and analysing data. The tasks, environments, and tools provided, are usually designed with specific learning intentions. For example, in a game intended to support ecology teaching, players go through a number of quests, in which they have to complete different tasks such as acting cooperatively (e.g., approach the same object simultaneously) to eradicate dangerous species or heal infected animals (Susaeta et al., in press). Another example is *Prime Climb;* a game intended to support the learning of factorization in mathematics. Players have to cooperate to climb a series of mountains divided by numbered sections. The task of a player is to jump onto sections that share a factor with the section of her partner. This situation prompts the discussion of players to find out where to jump, in which the topic of factorization is ideally implicit (Dai, Wu, Cohen, & Klawe, 2003; Scott, Mandryk, & Inkpen, 2003).

Collaborative educational computer games can also take advantage of different sorts of interfaces. For example, there have been explorations in the employment of mobile devices in collaborative game-based learning outside the classroom (Facer et al., 2004), the usage of shared interfaces with multiple mice for multiplayer co-located game play (Infante et al., 2009; Scott et al., 2003; Susaeta et al., in press) and handheld devices (Margolis, Nussbaum, Rodriguez, & Rosas, 2006).

Lastly, it is important to mention that some characteristics of computer games may also be counterproductive for collaboration. For example, the tempo of the game can

be so fast that learners don't have time enough to discuss their strategies, or the amount and difficulty of the tasks to perform is so large that learners focus on playing a functional role rather than collaborating (Kiili, 2007).

3.2.1.3 How the task and technology might influence people's emotions during the usage of concept-mapping tools and collaborative educational games

It is possible to speculate that, during the usage of a concept-mapping tool or an educational collaborative computer game, learners' emotions might be influenced by the nature of the tasks that they are asked to perform.

During a typical collaborative concept-mapping activity, learners' task is to discuss a given topic, following an open-ended goal and interacting 'freely' (i.e., without normative rules such as role allocation). Learners use the concept-mapping tool to make a visual representation of a jointly developed idea. In doing so, they are required to understand one another's perspective. Referring back to Schwartz (1998), the effort to do so should be a major source of motivation (and affect) during collaborative learning. Thus, collaborators' emotions and their understanding of one another's emotions might be influenced by the qualities of their interaction. If their interaction is rich and productive, partners might feel positive affect, and think about the emotions of one another positively. The technology would have a secondary participation in this scenario because its role is limited to support the making of the concept map, without any influence on either the set up of the task or the interaction between learners.

In contrast, collaborative computer games have tasks with specific goals (e.g., resolve a quest, solve puzzles or climb mountains) and allocate players to complementary roles. One could speculate that, since the win state can only be achieved with an effective participation of both collaborators, the partner's actions

might be a major influence in the emotions of one another. For example, one collaborator might feel positive emotions if she and her partner are effectively playing their roles. In contrast, negative emotions might result if the partner does not play her role effectively. This context also permits speculations about the way that partners might understand the emotions of one another. For example, they could attribute more positive emotions to the partner who plays her role effectively, and negative emotions to a partner who is not. The technology would have a 'primary' participation in this scenario because the task determines features of the game such as the mechanics and the tools accessible to the players, as well as the dependency on each other.

3.2.2 Affective features in the design of concept-mapping tools and collaborative computer games

Features such as *appearance*, *functionality* and *anthropomorphism* are potential sources of affective reactions during the usage of interactive technologies. This section outlines how these features are implemented in concept-mapping tools and educational computer games. Norman's concept of Emotional Design (Norman, 2004; Norman & Ortony, 2006) explains how the appearance and functionality of interactive technologies influence user's emotions. This concept postulates three levels of 'processing' that provoke affective reactions to the user: *visceral, behavioural,* and *reflective.* The visceral level refers to the perceptual properties of a product, which depends on its appearance. The behavioural level refers to the feelings of control and understanding of a product, which depends on its functionality. The reflective level refers to aspects such as users' personal history and self-image. This level is not covered because is beyond the scope of this chapter. Finally, anthropomorphism refers to people's tendency to treat computers as if they were humans, which is a potential source of affective reactions.

3.2.2.1 Appearance

The first level in Norman's (2004) model of emotional design is the visceral one. This level refers to how the perceptual properties of a product generate basic and automatic affective reactions in the user. This includes, for example, basic judgements such as good or bad, ugly and pretty. The perceptual properties of a product are mostly concentrated in its appearance. *Expressivity* and *aesthetics* are features that differentiate the appearance of concept mapping tools and educational computer games.

Expressivity refers to the use of graphics and animations that make direct reference to emotion conventions (e.g., emoticons) (Sharp et al., 2007). Concept-mapping tools can present emotionally loaded icons. However, expressivity is not a main characteristic of concept-mapping tools. In comparison, it is a common feature in the GUI of educational computer games.

Aesthetics are a common concern in GUI design. Cosmetic properties such as colour and elaborated fonts are elements that can be exploited in order to *embellish* an interface. Although the content included by users in a concept map might have aesthetic properties or the concept map itself might have a nice layout, the GUI of a concept-mapping tool in itself is typically not 'pretty'.

In contrast with concept-mapping tools, appealing aesthetics are a common component in the GUI of computer games. It has been explained that graphics are important for affective aspects such as players' immersion and 'sensory appeal'(Padilla, Gonzalez, Gutierrez, Cabrera, & Paderewski, 2009; Wages et al., 2004). For example, changes in the light tone of a game's GUI might increase or decrease the quality of players' experience and performance (Knez & Niedenthal, 2008). However, sophisticated graphics might also have negative effects. Animations and eye-catching colours engage players, but this might affect the functionality of the

game menus (Johnson & Wiles, 2003). Moreover, Clarke & Duimering (2006) reported that regular players of computer games regard eye candy/good graphics as irrelevant if the game is not enjoyable, suggesting that the enjoyment of the game is relatively independent to the graphics quality. Figure 3.2 displays examples of expressivity and aesthetics in concept-mapping tools and educational games.

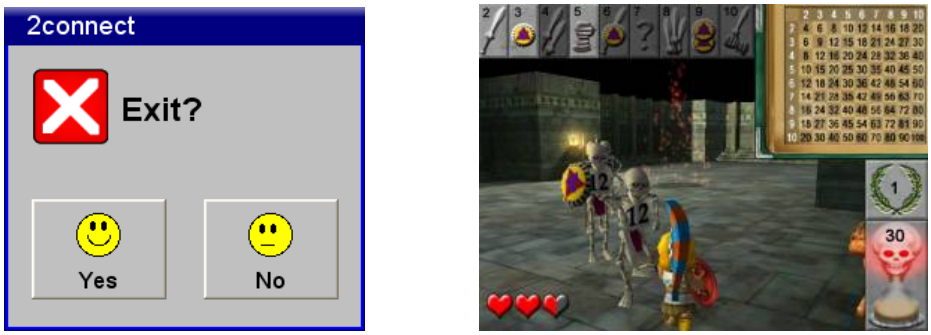


Figure 3.2 *Expressivity and aesthetics in the concept- mapping tool 2Connect and the educational game Zombie Division (Habgood, Ainsworth, & Benford, 2005)*

3.2.2.2 Functionality

The second level in Norman's (2004) concept of emotional design is the behavioural one. At this level, user's emotional reactions towards an interactive product are linked to the functionality. Positive affect emerges when the user feels control and understanding of a product. *Feedback* and *complexity* differentiate the functionality of concept-mapping tools and educational computer games.

Concept-mapping tools offer very basic feedback (e.g., editing or saving functions). In contrast, educational computer games offer feedback about the learner's performance, which is known to have beneficial effects (Rosas et al., 2003). For example, feedback that indicates progress in a game provokes positive emotions (Jones & Issroff, 2007).

The complexity of concept-mapping tools is not a potential source of emotions. This kind of learning technology provides learners with simple to use tools that often

resemble more mundane technology such as paper and pencil. In comparison, the interaction design of educational computer games is more complex. The number and complexity of tools and rules is often abundant, which might facilitate engagement and motivation, but can also overburden learners. For example, players of computer games like having multiple levels and a varied story line; but dislike having to make precise manoeuvres in large and slow to learn scenarios (D. Clarke & Duimering, 2006).

3.2.2.3 Anthropomorphism

Anthropomorphism refers to the tendency of people to regard computers as persons. That is, attributing to them qualities like motivations, emotions or personality. Anthropomorphism can be the consequence of both the perceptual and functional properties of software. Animated agents or messages in first person can intentionally trigger affective reactions derived from anthropomorpism. In fact, the implementation of human-like features such as animated companions has proven to be beneficial in computer-supported learning. For example, Maldonado et al (2005) found that the implementation of a co-learner that expresses emotions helped e-learners to have a better performance and feel better (i.e., not alone, praised and supported). Similarly, Morishima et al (2004) found that cooperating with an agent that expresses emotions increases positive affect (e.g., cooperativeness, trustworthiness and warmth).

It can be said that concept-mapping tools do not have interface elements nor do they interact with users in a way that can be regarded as 'human-like'. In comparison, the use of animated characters and messages that imitate humans are common features of computer games. Moreover, anthropomorphic features are beneficial for the player experience. For example, AI animated characters that exhibit realistic human-like behaviour such as unpredictability and mistakes are well appreciated (D. Clarke &

Duimering, 2006). Prendinger, Mayer, Mori, & Ishizuka (2003) reported that the implementation of an empathic character decreased the stress of users in a mathematical game; although this had no impact on players' performance.

3.2.2.4 Comparative summary of concept-mapping tools and collaborative educational computer games

Table 3.1 compares the typical underlying tasks and affective features of concept-mapping tools and educational collaborative computer games. During collaborations around concept-mapping tools, learners' task is to discuss a topic and elaborate a graphical representation to structure the results of such discussion. The outcome is open ended and learners interact 'freely'. In contrast, collaborative educational computer games may imply a wide range of tasks with specific goals that allocate partners to complementary roles. Clearly, computer games outnumber concept-mapping tools in terms of elements that can directly generate emotional reactions.

Table 3.1 *Underlying tasks and affective features of concept-mapping tools and collaborative educational computer games*

	Concept-mapping tools	Collaborative computer games
	Underlying tasks	
Intended learning outcomes	Learning by means of argumentation, reflection, and structuring of jointly constructed knowledge	Learning by applying knowledge and/or practicing skills. This recruits cognitive demands such as planning and reasoning.
Specific tasks	The typical task is to discuss a topic and make a graphical representation of the jointly elaborated knowledge (i.e. a concept map).	Task depending on the learning intentions (e.g., to solve quests to learn about ecology, to resolve puzzles to learn mathematics)
Goals	Open ended (e.g. answer an open question)	The specific goal is to achieve the 'win-state' (e.g., finishing a mission)
Interaction with a partner	Learners interact 'freely' (i.e., without pre-defined roles)	Players are allocated to play pre-defined complementary roles
	Affective features	
Appearance	Colourful and aesthetically pleasing interfaces are not common	Aesthetics are important for engagement
	Expressivity can be implemented in icons and menus	Expressivity is a common feature in different aspects of the interface, e.g., avatars and characters
Functionality	The interfaces of concept-mapping tools tend to be fairly simple and most of them work upon the same principles. They can be used in a very intuitive manner.	Educative games are quite diverse in terms of interface and mechanics. Their functions can be complex and often demand effort.
	Concept-mapping tools do not give feedback	In educative games, feedback is common and often used as a resource to promote reflection
Anthropomor-phism	Animated characters or first person messages are not a common feature	The use of animated agents or 'persona' is common
	Concept-mapping tools are unlikely to be regarded as with human-like attributes	The characters of the game can provoke emotional reactions

3.2.3 Underlying tasks and affective features in the usage of 2Connect and Astroversity

This section makes an overall description of 2Connect and Astroversity, also explaining how the tasks around these learning environments were set for the presented study. To do that is necessary to mention that participants were organized in pairs. The characteristics of the participants and their organization in the experimental design of the study will be fully described in the Methods section. Figure 3.3 shows screenshots of Astroversity and 2connect.

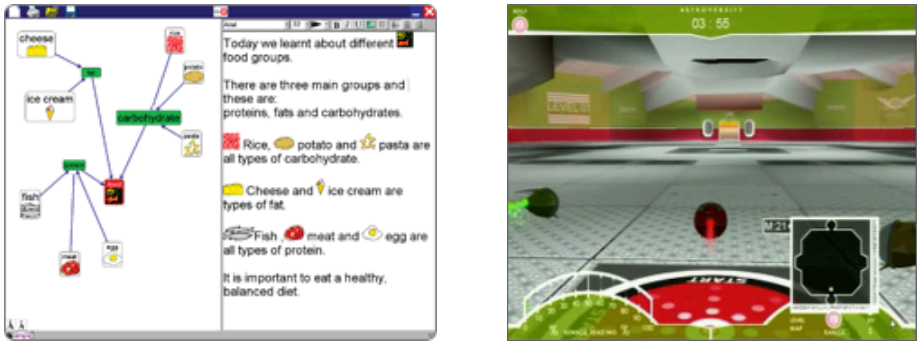


Figure 3.3 *Screenshots of Astroversity and 2Connect*

2Connect is a typical concept-mapping tool developed for children. Its interface offers only basic functionalities such as tools to draw nodes and lines with different colours. Other functionalities include a predefined collection of images and the capacity to record and insert audio. In the study, participants were introduced to the functionalities of 2Connect and were asked to make a concept-map to outline the pros and cons of the student life in the University of Nottingham No predefined features for the concept map were requested, and participants were free to include any kind of content other than text (e.g., images or audio). Participants used 2Connect sharing one computer with one mouse as input device, and autonomously (i.e., without direction of the experimenter) determined who was going to be in charge of the computer to control the mouse and type with the keyboard.

Astroversity was designed to support the learning of data gathering and interpretation skills. Astroversity is the name of a spaceship academy invaded by invisible aliens. The first part of the game explains the mission: to find an injured student and trace the safest route for a rescue vehicle to save her. In the second part, a series of animated characters give advice to approach the mission. In the third part, players use a rover to find the injured student and detect invisible aliens using sensors. They plot the areas with alien presence in a paper grid. This is the data collection task. In the fourth part, players use the data plotted in the paper grid to trace the route with less alien presence in a map. Then, the rescue vehicle follows the route traced by the players and rescues the injured student. In the fifth part, players receive feedback on the amount of damage the student received due to alien presence. This is the data interpretation task. Players pass to the next level or not depending on how much damage the student received. There are three levels of increasing difficulty.

In its networked implementation, Astroversity allows up to three players, each one in a different terminal. However, in the presented study, dyads shared one computer using the one player mode. In this configuration, players shared the control over the computer and autonomously adopted the role of controlling the rover or plotting in the paper grid. This configuration conserves the shared goal of Astroversity and the complementary nature of the collaborators' roles. The configuration was used to have dyadic data, easier to handle than data from triads. Table 3.2 compares the tasks (as defined in the presented study) and the affective features of 2Connect and Astroversity. Although these learning environments might support collaborative learning effectively, they might influence collaborators' emotions in different ways. Astroversity is more likely to produce intense emotions related to the achievement of goals, and the interaction with various affective features. 2Connect might generate emotions related to the content of the partners' discussion, but there are almost no technological features that can potentially generate emotions.

Table 3.2 *Affective features and collaboration support the design of 2Connect and Astroversiy*

	2Connect	Astroversity
	Underlying task	
Intended learning outcomes	2connect is a typical concept map tool designed to support leaners as they acquire and structure their knowledge s.	Astroversity supports the acquisition of skills for collective data gathering and interpretation.
Setting	Participants shared one computer running 2Connect, with one mouse as input device	Participants shared one compute to play Astroversity, with one mouse as input device. They were also given a paper grid complementary to the game, in which they had to plot some data during the game play.
Specific task	Participants' task was to discuss the pros and cons of their student experiences and make a concept map.	Whilst playing Astroversity, participants performed number of specific tasks such as data search and collection, strategy planarization, and data interpretation.
Goals	Open ended. Participants were not told which aspects of their student experience to discuss, and no predefined characteristics for the concept map were requested.	Participants' goal was to get as far as they could, and were told there were 3 levels of Astroversity.
Interaction with a partner	Partners were not allocated specific roles. However, they organized themselves to control the computer	Partners were not allocated specific roles. However, they organized themselves to either control the computer or to use the paper grid.
	Affective features	
Appearance	2connect was designed for children. Therefore, its interface uses bright colours and emoticons in the menus	Astroversity has a sophisticated 3-D design and presents characters with emotional expressions
Functionality	The interface of 2connect is straightforward. It presents only a few basic commands represented by easy to recognize icons and provides with no feedback.	In Astroversity, players are embodied in a 'rover' controlled with keyboard arrows. Users have to use a paper-pencil plot to help themselves.
Anthropomorphism	In 2 connect, animated characters are implemented in menus, but their participation is limited and they do not interact with users.	Astroversity's interface is populated by characters with anthropomorphic features

3.3 Study 1

3.3.1 Overview of the study

The study answers exploratory research questions, rather than testing specific hypotheses. There are also methodological investigations, such as the selection of emotions that could be more relevant to the CSCL experience and an assessment of whether using both intensity and frequency in self-report of emotions could bring valuable information.

This study focused on co-located collaborations in order to make a fair comparison between learning environments. A comparison of remote vs co-located collaborations around 2Connect and Astroversity would have required a complicated setting to guarantee comparability across conditions; which was beyond the exploratory ambitions of the study.

3.3.2 Research questions

This study addresses three research questions.

3.3.2.1 RQ1: How does using a concept-mapping tool and a collaborative educational game influence people's emotions?

Two aspects about the usage of 2Connect and Astroversity are studied to answer this question. First, the effects of using 2Connect and Astroversity on collaborators' emotions are compared. Different CSCL activities might generate different sorts of emotions, which is clear with the comparison between the tasks and technological affective features of computer games and concept-mapping tools. It is expected that using Astroversity would generate more intense emotions than 2Connect, but no

specific predictions are made about which emotions could differentiate these collaborative learning environments.

Second, the sources of collaborators' emotions during the usage of 2Connect and Astroversity are explored. This is to distinguish the relevance of three main 'actors' in the scenarios of dyadic CSCL: the activity, the self, and the partner. No specific predictions are made, but it is expected that collaborators will refer differently to these aspects as sources of their emotions whilst using Astroversiy and 2Connect.

3.3.2.2 RQ2: What do collaborators understand about their partners' emotions while using a concept-mapping tool and a collaborative educational game?

Two aspects are studied to answer this question. First, if collaborators feel similar emotions during the use of 2Connect and Astroversity. Second, whether partners 'think about' the emotions of one another differently while using these learning environments. Two mechanisms are investigated: the collaborators' accuracy at judging the emotions of their partners (affective awareness) and the extent to what they judge their partner's emotions on the basis of their own emotions (affective projection). No specific predictions are made, but differences are expected because the tasks of 2Connect and Astroversity may influence the interpersonal understanding of emotions in different ways.

3.3.2.3 RQ3: What is the relationship between collaborators' emotions and the qualities of their interaction with a partner?

This question was formulated to address the importance of collaborators' emotions beyond the individual level, looking at how it affects the quality of the interaction with a partner. An assessment was made of the relationship between partners'

emotions and their judgements about the quality of their interaction. Additionally some illustrative cases are presented to explore the relationship between emotional similarity and some qualities of collaborators' interaction.

3.3.3 Method

3.3.3.1 Participants

50 unacquainted native English speakers participated in this study. Their mean age was 21.6 years. Recruitment and organization of participants was balanced to control for gender, although gender analysis was not an objective of the study. 60% of the participants were female and 40% male. They were randomly assigned to dyads in three configurations: female (11), male (6) and mixed (8).

3.3.3.2 Design

A within-participants experimental design was used to explore whether the differences in the design of 2Connect and Astroversity influenced collaborators' understanding of their own emotions and the emotions of their partners. *Learning Environment* was the experimental factor with two counterbalanced conditions. In the condition '2Connect', participants outlined the pros and cons of their student experience in the University of Nottingham using 2connect for 20 minutes. In the condition 'Astroversity', participants played Astroversity for 20 minutes, with the instruction to reach as far as they could.

3.3.3.3 Questionnaires

Participants answered four questionnaires during the study: *Prior Emotions, Own Emotions, Partner emotions* and *Interaction Quality*. The first three questionnaires collected data about the participants' emotions and their judgements of their partners' emotions. These questionnaires included a list of 15 emotion words: *happy, angry,*

sad, fearful, angry, bored, challenged, interested, hopeful, frustrated, contempt, disgusted, surprised, proud, ashamed and *guilty.* These emotions were selected because they have two properties relevant for this study. First, their underlying dimensions of cognitive appraisal make them clearly different from each other. That is, people makes different associations between these emotions and aspects such as the *pleasantness, certainty* or *control* they perceive in the context (Reisenzein & Hofmann, 1993; C. A. Smith & Ellsworth, 1985) Therefore, these words are adequate to describe affect in terms of discrete emotions. Second, the selected words include emotions that have been previously studied in the study of learning technologies e.g., *anger, boredom, frustration, contempt, disgust* and *surprise* (D'Mello et al., 2006; Graesser et al., 2006).

Appendix A shows the questionnaires answered by participants. The questionnaires were employed as follows:

- *Prior Emotions.* Participants answered this questionnaire to report the emotions they felt during the 20 minutes prior to their arrival for the study.

- *Own Emotions.* Participants answered this questionnaire to report the intensity and frequency of their own emotions during the usage of 2Connect and Astroversity, and the extent to which their emotions had to do with *the activity, themselves* and *their partners.*

- *Partner Emotions.* This questionnaire was identical to the Own Emotions questionnaire, except that participants reported the emotions of their partners. Unlike in the Own Emotions questionnaire, participants did not report whether the emotions of their partners had to do with *the activity, themselves* and *their partners.*

- *Interaction quality.* This questionnaire presented three questions for the participants to assess the quality of their interaction. The questionnaire presented the assertion *while my partner and I were using 2Connect/Playing Astroversity, we…* followed by the sentences: 1) *understood each others' ideas and opinions,* 2) *were thinking alike* and 3) *were cooperating equally.* Participants used a 4-point Likert scale anchored in *not at all* and *to a great extent,* to rate their agreement or disagreement with these sentences.

3.3.4 Procedure

Participants were recruited by advertisement and mailing list in several schools of the University of Nottingham. Once registered, participants were paired with no knowledge of who would be his/her partner. Each dyad was randomly assigned to one of two orders of counterbalance: 2Connect-Astroversity or Astroversity-2Connect. Once in the experimental room, participants confirmed they did not know each other. Then they were introduced to the study, read the information, signed the consent form and answered the Prior Emotions questionnaire. Also, all participants agreed to be videoed. The recording captured partners' interaction (frontal view), but not the computer screen.

Then, participants were asked to do their first activity, either play Astroversity or use 2Connect, depending on their assigned counterbalance order. After completion of their first activity, participants answered the Own Emotions questionnaire, the Partner Emotions questionnaire and the Interaction Quality questionnaire. After a 5 minutes break, participants were asked to perform their second activity. After completion, they answered again the Own Emotions questionnaire, the Partner Emotions questionnaire and the Interaction Quality questionnaire. Collaboration partners answered the questionnaires in the same room, sitting back to back so they could not see each

other's answers. The sessions lasted approximately 70 minutes and finished with a debriefing.

3.3.5 Data screening

3.3.5.1 Overall distributions

A histogram screening was carried out to examine the data collected with the Interaction quality questionnaire, the Own Emotions questionnaire and the Partner Emotions questionnaire. The histograms are shown in Appendix B.

The screening of the Own Emotions questionnaire data focused on the scales of frequency and intensity, excluding the scale where participants reported the extent to what their feelings had to do with their own actions, the actions of their partners and the activity. The histograms of the scales of intensity and frequency are virtually identical. In both cases, there are floor effects in the reports of the emotions *contempt, sad, guilty, fearful, angry, ashamed* and *disgusted*. Other emotions with less extreme skew are *hopeful, frustrated, bored, surprised* and *proud.* Emotions with no skew are *happy, interested* and *challenged.*

The histograms of the frequency and intensity scales of the Partner Emotions questionnaire are virtually identical to the histograms in the Own Emotions questionnaire.

There are at least three explanations for the floor effects and extreme skews in the Own Emotions questionnaire and the Partner Emotions questionnaire. One is that the questionnaire was not sensitive enough to capture a subtle feeling of these emotions. A second explanation is that participants were reluctant to report these emotions. This would be consistent with other studies showing that 'negative' emotions, e.g., anger, sadness, fear, guilt and shame, are reported with less frequency and intensity than

other, more 'positive' emotions (Carstensten, Pasupathi, Mayr, & Nesselroade, 2000; Nezlek et al., 2008; Tong et al., 2007). A third explanation is that some of the emotions represented by these words are simply not part of the average CSCL experience (e.g. disgust), or occur with low frequency (e.g., surprise).

Consequently, further analysis focused on the emotions *happy, interested, challenged, hopeful, frustrated* and *bored.* The rationale for this selection was to have two positive emotions (happy and challenged), two emotions that imply both positive and negative attributes (challenged and hopeful) and two negative emotions (frustration and bored). Although bored showed a noticeably skew, it was included to maintain the balance. Other emotions with similar distributions as bored, such as *surprised* and *proud,* were not included because they were positive.

The histogram of the interaction quality questionnaire shows no extreme skews. Therefore, all the data collected with this questionnaire was retained for analysis.

Further analysis located missing values and outliers. In the Own Emotions questionnaire, 4 data points were missing and 6 participants gave outlier scores in at least three emotions, and were excluded or substituted in further analyses.

3.3.5.2 Correlations between frequency and intensity

The questionnaires Prior Emotions, Own Emotions and Partner Emotions, included scales of frequency and intensity. If the data showed a clear differentiation between intensity and frequency, this would indicate that participants could distinguish these 'dimensions' when reporting their emotions.

Correlation and difference were the criteria to determine whether frequency and intensity were distinguishable. Table 3.3 shows that the correlations between the scores of frequency and intensity in the Own Emotions questionnaire and the Partner Emotions questionnaire, in relation to the use of 2Connect and the use of Astroversity,

are all positive and strong ($r > .70$). This suggests that participants increased or decreased their scores of intensity and frequency at the same time almost all the time.

Table 3.3
Correlations between frequency and intensity in the Own Emotions questionnaire and the Partner Emotions questionnaire, during the use of 2Connect and Astroversity

	Own Emotions questionnaire		Partner Emotions questionnaire	
	2Connect (n=44)	Astroversity (n=44)	2Connect (n=44)	Astroversity (n=44)
Happy	.88**	.79**	.84**	.90**
Interested	.72*	.88**	.70**	.76**
Challenged	.92**	.77*	.77**	.73**
Hopeful	.96**	.87**	.65**	.92**
Frustration	.83**	.79**	.92**	.88**
Boredom	.96**	.89**	.94**	.95**

*p <0.05, **p < 0.01

Table 3.4 shows that the differences between the frequency scores and the intensity scores in the Own Emotions questionnaire and the Partner Emotions questionnaire, during the use of 2Connect and Astroversity. Overall, are all very small (< 1.0).

Table 3.4
Means and SD of the average differences between frequency and intensity scores in the Own Emotions questionnaire and the Partner Emotions questionnaire

	Own Emotions questionnaire		Partner Emotions questionnaire	
	M (n=44)	SD (n=44)	M (n=44)	SD (n=44)
2Connect	.39	.28	.41	.35
Astroversity	.53	.23	.44	.24

The strong and positive correlations between frequency and intensity and the small differences between their means indicate that these attributes were not differentiated by participants. Therefore, the analysis of frequency and intensity would be

redundant. Consequently, the analysis focuses upon the scales of intensity since this is more commonly used than frequency in emotion research (see for example, Feldman, 2004; Gray & Watson, 2007; C. A. Smith & Ellsworth, 1985; Tong et al., 2007).

3.3.6 Results

The results are sorted in three sections, one for each research question.

3.3.6.1 Effects of using 2Connect and Astroversity on collaborators' emotions

To answer RQ1: *How does using a concept-mapping tool and a collaborative educational game influence people's emotions?,* Analyses were made to test the emotional intensity of participants in 2Connect and Astroversity, as well as the differences in what participants attributed as sources of their emotions.

Effects on emotional intensity

The analysis consisted of a *doubly* MANCOVA including the learning environment as within-participants factor with two levels (2Connect/Astroversity), counterbalance order as between participants factor with two levels (2Connect-Astroversity/Astroversity-2Connect) and the prior emotion scores as covariates.

Table 3.5 shows the Mean and SD of the participants' intensity scores for the emotions *happy, intensity, challenged, hopeful, frustrated* and *bored*. There were no effects of the participants' emotions previous to the study [F (18, 108) = .42, *ns*) or the counterbalance order [F (6, 34)= 1.53, *ns*]. The main effects of learning environment indicated that participants felt more intense emotions whilst using Astroversity than whilst using 2Connect [F (6, 34)= 12.93, $p< .001$, $\eta_p^2= .69$). This effect was not general to all the analysed emotions. Participants felt equally, happy, interested and bored across learning environments, but using Astroversity made them feel more

challenged [F (1, 39) = 41.29, *MSE*=.65, *p*< .001, η_p^2=.51), hopeful (F [1, 39] = 33.60, *MSE*=.55 *p*< .001, η_p^2=.46) and frustrated (F [1, 39] = 41.73, *MSE*= .98, *p*< .001, η_p^2=.52). The effects are illustrated in Figure 3.4

Table 3.5
Means and SD of the intensity scores of the emotions happy, interested, challenged, hopeful, frustrated and bored

	2Connect (*n=44*)		Astroversity (*n=44*)	
Emotion	*M*	*SD*	*M*	*SD*
Happy	1.61	1.06	1.48	1.00
Interested	1.74	1.08	1.77	1.05
Challenged	0.86	1.03	1.98	1.05
Hopeful	0.25	0.58	1.18	1.08
Frustrated	0.55	0.82	1.93	1.19
Bored	0.68	1.03	0.70	1.05

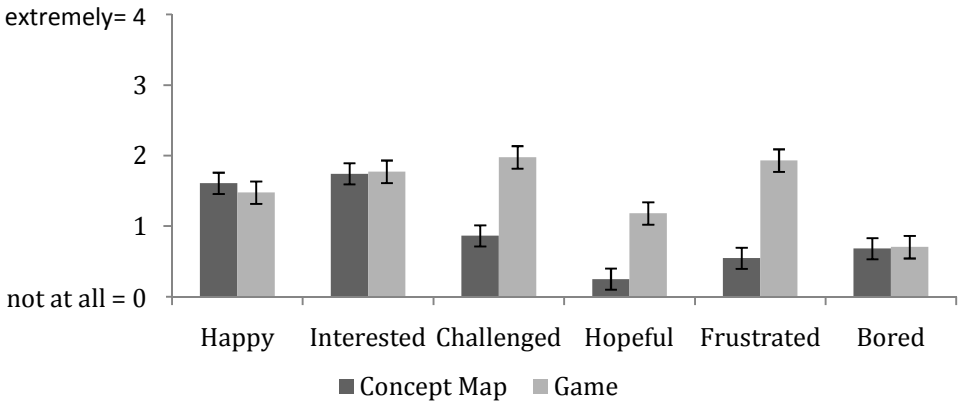


Figure 3.4 *Mean intensity scores of the emotions, happy, interested, challenged, hopeful, frustrated and bored during the usage of 2Connect and Astroversity*

Sources of emotions

This analysis investigated how participants referred to their partners, themselves or the activity as sources of their challenge, hope and frustration. The analysis focused on these emotions because they were reported more intensely in relation to Astroversity than in relation to 2connect. This helped to reduce data complexity and also to highlight the differences between learning environments. Table 3.6 shows the means and SD of participants' scores on the scales of attribution to the *partner, self* and *activity* as sources of their challenge, hope and frustration.

Table 3.6
Means and SD of the participants' attribution scores for the partner, self and the activity as sources of challenge, hope and frustration, in 2Connect and Astroversity

		2Connect		Astroversity	
Emotion	Source	*M*	*SD*	*M*	*SD*
Challenged (*n*=44)	Partner	.82	.99	1.50	.95
	Self	.93	1.20	1.53	.89
	Activity	1.36	1.63	3.14	1.25
Hopeful (*n*=44)	Partner	.39	.87	1.07	1.04
	Self	.48	1.06	1.16	1.07
	Activity	.48	1.17	1.89	1.61
Frustrated (*n*=44)	Partner	.57	.87	1.32	.98
	Self	.63	.96	1.48	1.13
	Activity	1.02	1.48	2.89	1.52

The attribution scores were analyzed with a 4-way ANOVA including order as between-participants factor with two levels (2Connect-Astroversity/Astroversity-2Connect) and three within-participants factors: source (Partner/Self/Activity), emotion (Challenge/Hope/Frustration) and learning environment

(2Connect/Astroversity). Table 3.7 shows the results, which indicate no significant main effects of order and significant main effects for the three within-participants factors. Further analyses consisted of Bonferroni pairwise comparisons.

In relation to specific emotions, the sources of challenge and frustration were rated higher than the sources of hope (respectively: *Mean Dif*= .64 $p < .001$, *Mean Dif*= .41 $p < .001$), whilst the sources of challenge and frustration were rated equally (*Mean Dif*= .21, *ns*). In relation to the learning environment, the three emotion sources were rated higher for the usage of Astroversity than for the usage of 2Connect (*Mean Dif*= 1.04 $p < .001$). Lastly, in relation to the source, participants gave higher rates to the activity as an emotion source than to the partner (*Mean Dif*= .76, $p < .001$) or themselves (*Mean Dif*= .85, $p < .001$). The difference between the partner and the self as emotion sources was significant but relatively small (*Mean Dif*= .09 $p < .05$).

Table 3.7
Effects table for the 2 (Order) x 2 (Source) x 3 (Emotion) x 2 (Learning Environment) mixed ANOVA over the attribution scores

Effect	$df_{(effect,\ error)}$	*MSE*	*F*	η_p^2
	Between-participants main effects			
Order	1,42	7.46	1.69	.03
	Within-participants main effects			
Source (S)	2, 84	.73	75.32***	.64
Emotion (E)	2,84	2.22	12.25***	.22
Learning Environment (L)	1,42	3.04	70.09***	.62
	Interactions[a]			
SxL	2,84	.57	35.45***	.46
SxE	4,168	.30	11.67***	.22
ExL	2,84	2.50	.33	.00
SxExL	4,168	.27	1.77	.03

[a]Interactions with Order were all not significant. For readablity, they are not included in the table

The significant interactions Source x Learning Environment and Source x Emotion, were interpreted with graphs and simple effects analysis. As for the Source x Learning Environment interaction, simple effects of source within each learning environment indicated that the differences between partner, self and the activity as sources of emotions (i.e., attribution scores for each source averaged across emotions) were smaller in 2Connect [$F(2, 86)= 13.70$, $MSE= 1.58$, $p<.001, \eta_p^2 = .24$)] than in Astroversity [$F(2, 86)= 75.27$, $MSE= 24.65$, $p<.001, \eta_p^2 = .63$)]. Hence Figure 3.5 shows that the activity was more emphatically referred as an emotion source during Astroversity than during 2Connect.

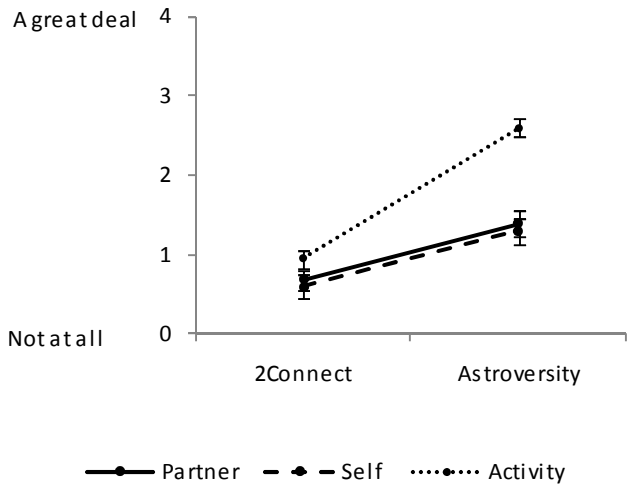


Figure 3.5 *Attribution scores for the partner, self and the activity as sources of emotions as a function of learning environment.*

As for the Source x Emotion interaction, simple effects of source within emotions (i.e., attribution scores averaged across learning environments) indicated significant but relatively small differences between the participants' attributions to the partner, themselves and the activity as sources of hope [$F(2,86)=19.47$, $MSE=.13$, $p<.001, \eta_p^2 = .31$]. In contrast, participants made clearer differentiations between the sources of challenge [$F(2.86)=60.19$, $MSE=.27$, $p<.001, \eta_p^2 = .58$] and frustration [$F(2.86)=49.18$, $MSE=.27$, $p<.001, \eta_p^2 = .53$]. Figure 3.6 shows that participants gave a relatively equal importance to the partner, themselves and the activity as sources of hope, whereas they gave clearly more importance to the activity than to the partner or themselves as a source of challenge and frustration.

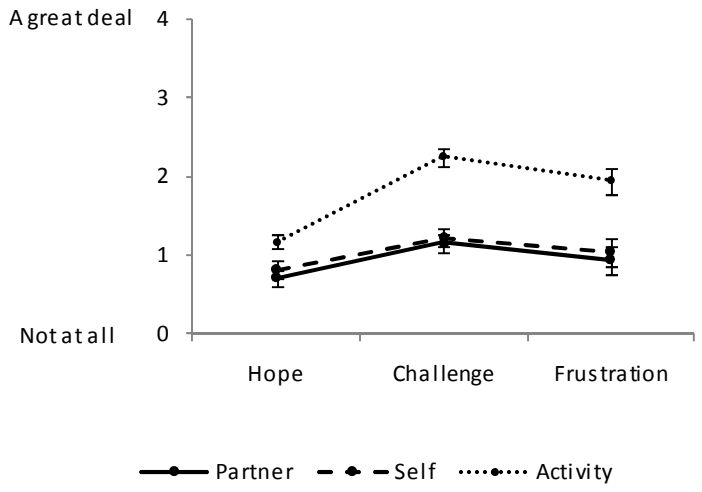


Figure 3.6 *Attribution scores for the partner, self and activity as a function of emotion.*

These results indicate that participants identified the sources of their emotions differently depending on the learning environment and specific emotion. Participants made little differentiation between the partner, themselves or the activity as sources of their hope, challenge and frustration whilst using 2Connect. In contrast, the activity was more strongly attributed as an emotion source during the usage of Astroversity, more in relation to challenge and frustration than in relation to hope.

3.3.6.2 Assessment of emotion understanding

To answer RQ2: *What do collaborators understand about their partners' emotions while using a concept-mapping tool and a collaborative educational game?,* two analysis were made that tested the emotional similarity between partners while using Astroversity and 2Connect, as well as the accuracy at judging the emotions of a partner.

Similarity between partners' emotions

First, the overall similarity between partners' emotions was tested against a by-chance baseline. Secondly, the affective similarity between partners' using 2Connect and Astroversity was assessed separately.

The difference between partners' emotions was measured with a variable labelled *affective similarity index.* In the first analysis, the affective similarity index was defined as the correlation between the dyad members' answers to the Own Emotions questionnaire (considering only the emotions happy, interested, challenged, hopeful, frustrated and bored) across learning environments (n=12 for each dyad, made of 6 emotions x 2 Learning Environments). This index was contrasted with the affective similarity index of a *nominal dyad.* That is, a dyad made out of persons in the same learning environment (using 2Connect or Astroversity) but paired randomly post-hoc. The SD's were as large as the Mean in the affective similarity index of the actual dyads (M=.33, SD=*.34)* and actually larger than the mean in the nominal dyads (M=.22*,* SD=.34). Therefore, a *Mann-Withney* test was used to compare between these indexes. The results indicated no significant differences between the actual dyads and the nominal dyads (Z=-.81, p=*.41*)2.

The second analysis tested the affective similarity on each learning environment. Affective similarity indexes in relation to the use of 2Connect and Astroversity were

[2] It is known that the sampling distribution of the Pearson correlation (r) is not normal. Therefore, transformation with Fisher's formula is recommended when using correlation coefficients as data (e.g, Kenny et al., 2006). However, results obtained with untransformed correlation coefficients are presented throughout this thesis. These results do not differ significantly from those obtained with transformed data, and are preferred because its interpretation is more straightforward.

calculated for each dyad. These indexes were defined as the correlation between the dyad members' answers to the Own Emotions questionnaire (n=6 for each dyad, made of 6 emotions). Table 3.8 shows the *Means, Medians, SD*'s and *Mean ranks* of the affective similarity indexes of actual dyads and nominal dyads. As in the first analysis, the SD's are larger than the means and therefore, the data was analyzed with Mann-Withney tests. There were no differences between the affective similarity indexes of the actual dyads and the affective similarity indexes of nominal dyads, neither in 2Connect, (Z=-.98, p=.32) or Astroversity (Z=-.91, p=.36).

Table 3.8
Means, SD and Mean rank of the affective similarity indexes of actual dyads and nominal dyads in relation to the use of 2Connect and Astroversity

	Actual (n=25)				Nominal (n=25)			
	M	*Med*	*SD*	*Mean Rank*	*M*	*Med*	*SD*	*Mean Rank*
2Connect	.30	.37	.44	27.53	.13	.21	.55	23.48
Astroversity	.28	.31	.49	27.38	.08	.20	.56	23.62

These results indicate that in general, the emotions reported by participants were not more similar to the emotions reported by their partners than would be expected by chance. However, these results are inconclusive given the large variation in the data. Figure 3.7 shows that actual dyads had a tendency to have higher affective similarity indexes than the nominal dyads, but the large dispersion of the data (i.e., large standard errors) diminished the effect of this tendency, making it not significant.

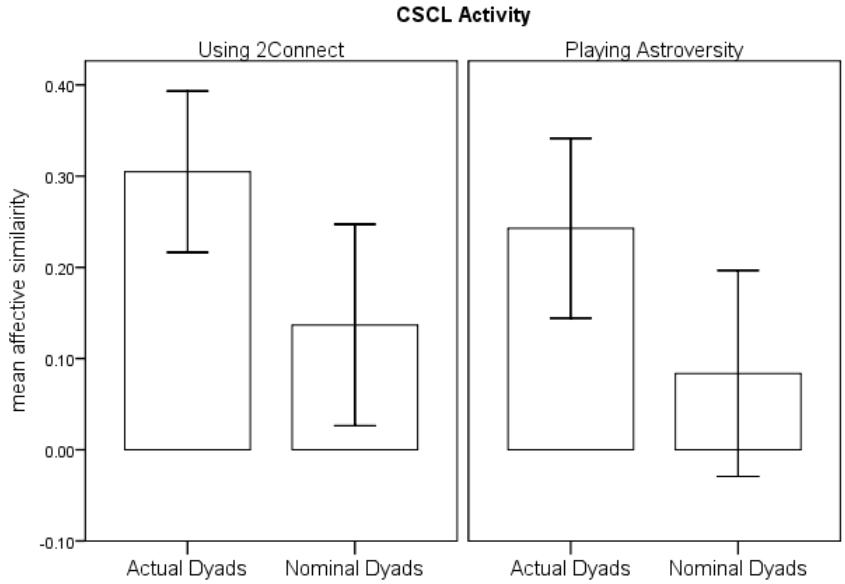


Figure 3.7 *Means and standard errors of the affective similarity index of actual dyads and nominal dyads in the use of 2Connect and Astroversity*

Judgements of a partner's emotions

An assessment was made of collaborators' affective projection and affective awareness. The affective awareness referred to the accuracy of collaborators at judging the emotions of their partners. The affective projection referred to the extent to which the collaborators judged their partners' emotions on the basis of their own emotions. The data were the participants' answers to the Own Emotions questionnaire and the Partner Emotions questionnaire. Table 3.9 shows the Means and SD's of these questionnaires in relation to the use of 2Connect and to the use of Astroversity.

Table 3.9
Means and SDs of the participants' answers to the Own Emotions Questionnaire and the Partner Emotions questionnaire in 2Connect and Astroversity

	2Connect				Astroversity			
	Own Emotions (n=50)		Partner emotions (n=50)		Own Emotions (n=50)		Partner emotions (n=50)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Happy	1.72	1.1	1.46	.95	1.52	1.01	1.52	.99
Interested	1.86	1.08	1.90	.84	1.82	1.06	1.98	.96
Challenged	1.04	1.08	.92	1.07	2.04	1.04	1.98	.915
Hopeful	.28	.67	.36	.75	1.24	1.08	1.18	1.14
Frustrated	.58	.86	.60	.92	1.88	1.20	1.34	1.20
Bored	1.86	1.08	.80	1.03	1.82	1.06	.82	1.00

The data was arranged in a dataset of n= 50. To analyse all the dyads, the outliers found in the data screening were substituted with the overall mean in each learning environment. There were columns for the participants' answers to the Partner Emotions questionnaire and the Own Emotions questionnaire, as well as columns for their partners' answers to the Own Emotions questionnaire.

Within each learning environment, there were separated analyses for each emotion: happy, interested, challenged, hopeful, frustrated and bored. These analyses consisted of multiple regressions including the following variables.

- Dependent variable: The participants' answers to the Partner Emotions questionnaire (what they thought about their partner's emotions)

- Independent variables:

- The participants' answers to the Own Emotions questionnaire (what they were feeling). The effect of this variable would be the 'indicator' of the participants' affective projection. If significant, this would suggest that participants based their judgements of their partner's emotions on the basis of their own emotions.

- The answers to the Own Emotions questionnaire of the partner (what the partner was 'actually' feeling). The effect of this variable would be the indicator of the participants' affective awareness. If significant, this would mean that participants made an accurate judgement of their partners' emotions, suggesting that during the use of 2Connect and Astroversity, they paid attention to aspects such as the emotional expressions of the partner, or that they accurately identified the events that affected their partner's emotions.

Appendix C presents the extensive summaries of the analyses. To ease the interpretation, Table 3.10 includes only the Beta (*B*) coefficient of each independent variable. There were 24 tests and, therefore, a risk of type I errors. A conservative approach would be to make Bonferroni corrections to lower the alpha value employed as criteria to determine significance. However, the n (50) is not vast and the application of Bonferroni corrections would lower the alpha value to a rather harsh level ($p<.002$), which increases the risk of type II errors. Therefore, an alpha value of $p<.01$ was used as criterion for significance.

Overall, the participants' affective awareness was very low. In both learning environments and in most emotions, the participants' reports of their partners' emotions (their answers to the Partner's Emotions questionnaire) were not associated with the emotions actually reported by their partners (the partner's answers to the Own Emotions questionnaire), hence the non significant *B* values.

In contrast, participants showed a strong affective projection. They had a strong tendency to judge their partners' emotions on the basis of their own emotions, especially during the use of 2Connect. In this activity, the *B* values of the participants' scores in the Own Emotions questionnaire are significant for all emotions except frustration. Although with less strength, the same tendency is observable in relation to the use of Astroversity. For all emotions, the participants' own emotions were marginally or significantly associated with their judgements of their partners' emotions.

Table 3.10
Beta values of the participants' own emotion scores and their partners' own emotion scores as predictors of their judgements about each other's emotions

	2Connect		Astroversity	
	Own emotions	Partner's own emotions	Own emotions	Partner's own emotions
Emotion	*B*	*B*	*B*	*B*
Happy	0.52**	0.17	0.36*	0.25
Interested	0.40**	0.04	0.30[1]	0.32*
Challenged	0.52**	0.003	0.24[1]	0.16
Hop eful	0.56**	-0.13	0.58**	0.18
Frustrated	0.33[1]	-0.07	0.52**	-0.02
Bored	0.58**	0.20	0.30[1]	0.12

[1]$p<.05$, *$p<.01$, **$p<.005$

3.3.6.3 The relationship between collaborators' emotions and their interaction quality

To answer RQ3: *What is the relationship between collaborators' emotions and the qualities of their interaction with a partner?* One analysis was made that assessed the correlations between joint measures of partners' emotions and their perceived

interaction quality. Additionally, the examples of some dyads are presented to illustrate different ways in which the relationship between emotions and interaction quality could occur .

The relationship between collaborators' emotions and their perceived interaction quality

Dyad level measures of partners' emotions and their perceived interaction quality were composed. Then, the correlations between these measures were calculated in relation to the use of 2Connect and Astroversity. The analysis was made with a dyad-wise dataset (n=25). There were 25 rows, one for each dyad, and columns for each dyad member (e.g., emotion intensity of dyad member *a,* and emotion intensity of dyad member *b*). The measurement of emotion intensity at the dyad level was defined as the sum of the dyad members' answers to the Own Emotions questionnaire. Thus, there was a dyad level measure for each emotion happy, challenged, hopeful and frustrated. The use of sum to make dyad-level variables is common in CSCL studies (e.g., Do-Lenh et al., 2009).

As for the measurement of interaction quality, a *perceived interaction quality* variable was defined as the averaged items in the interaction quality questionnaire. The reliability of this questionnaire was marginally acceptable in the concept map (*Cronbach's alpha*= .61) and good in the game (*Cronbach's alpha*= .84). The perceived interaction quality of dyad members was summed to make a dyad-level measure.

Table 3.11 shows the correlations between the dyad level measures of perceived interaction quality and the dyad level measures of happiness, interest, challenge, hope, frustration and boredom. Regardless of the learning environment, those who rated their collaboration quality higher also enjoyed more (i.e., reported more happiness and less boredom). Only difference between learning environments was that only during

Astroversity, those who felt more frustrated also made lower ratings of their interaction quality. The rest of the emotions did not significantly correlate with the perceived interaction quality.

Table 3.11
Correlation coefficients of the dyad level measures of perceived interaction quality and emotions

	Dyad level emotion intensity (n=25)					
Dyad level PIQ	Hap	Int	Cha	Hop	Fru	Bor
2Connect	.40*	.28	-.02	-.12	-.33	-.46*
Astroversity	.47*	.27	-.14	.14	-.40*	-.49*

*p<.05

Illustrative examples of the relationship between emotions and interaction quality

The results presented above suggest that people's emotions are associated with their interaction quality. When partners reported more happiness and less boredom they also rated their interactions more positively, regardless of the learning environment. Only in Astroversity, partners reported more frustration when they rated their interaction negatively. This complements other results, which indicate that individuals reported positive emotions (e.g., interest, happiness) in 2Connect and Astroversity, but they reported more challenge, hope and frustration in Astroversity (Section 3.3.6.1), and that some collaborative partners reported more similar emotions than others (Section 3.3.6.2).

The video data of partners' interaction was employed to illustrate these results. Some examples are presented of dyads in which the partners reported more similar or more different emotions whilst interacting around 2Connect and Astroversity. The examples show how the emotions of some collaborators might have been associated

with their interaction with the technology (e.g., reactions to the interface, execution of a collaborative task) and a partner (e.g., responsiveness). The aim is to aid the interpretation of the quantitative results with some examples. However, although the video data showed the partners' interaction, not recordings of the computer screen were taken and therefore, observations of their performance in the learning environments could not me made. Thus, the features described in the example dyads were selected as mere illustrations instead of systematically determined with inferential analysis and, therefore, generalisation to other dyads is not possible.

Selection

On each learning environment *(2Connect/ Astroversity),* the dyads were classified in terms of high affective similarity (dyads in the 4th quartile of the affective awareness index) and low affective similarity (dyads in the 1st quartile of the affective similarity index). For each activity, two dyads with low affective similarity and two dyads with high affective similarity were randomly selected to make a total of eight dyads. Table 3.12 show the affective awareness indexes and the pseudonyms assigned to the members of the selected dyads.

Table 3.12
Affective similarity level, affective similarity index and pseudonyms of the partners in the example dyads

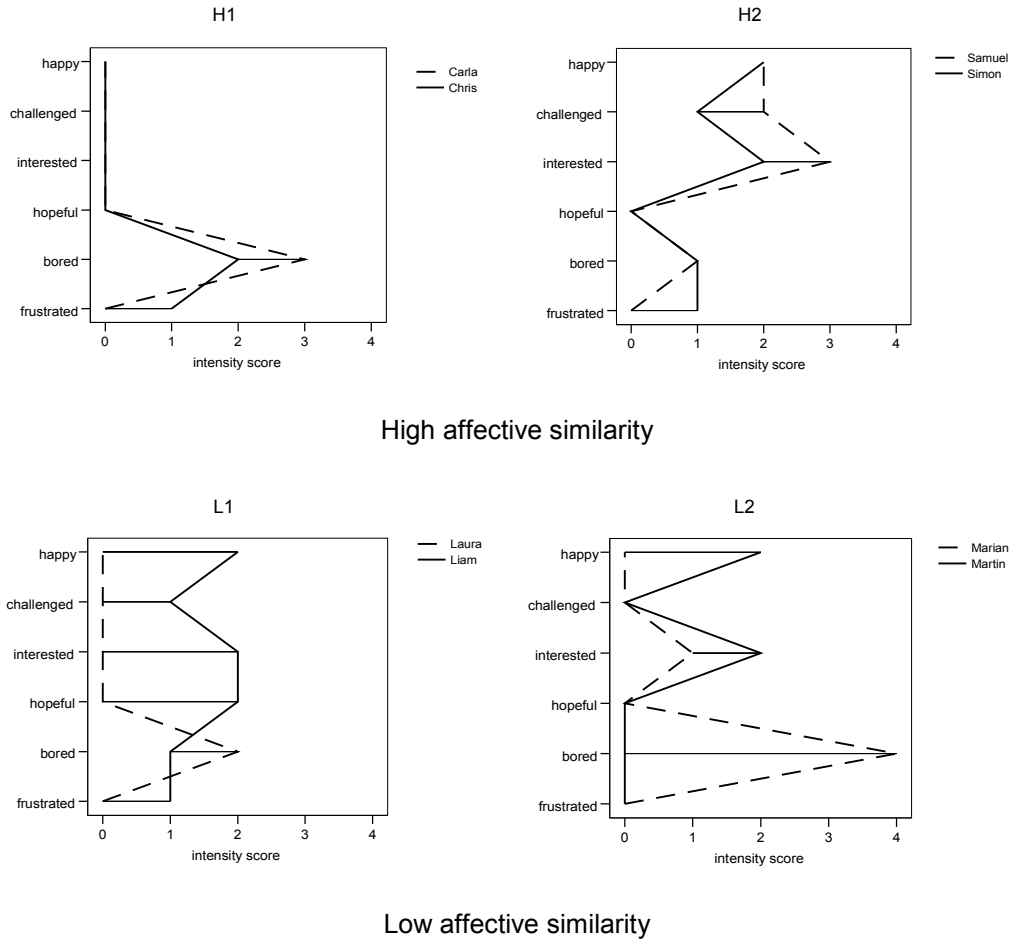
Learning environment	Affective similarity level	Dyad ID	Affective similarity index	Pseudonyms
2connect	High	HS1	.88	Chris and Carla
		HS2	.80	Samuel and Simon
	Low	LS1	-.16	Martin and Marian
		LS2	-.44	Laura and Liam
Astroversity	High	HS1	.60	Paola and Peter
		HS2	.75	Nora and Natalie
	Low	LS1	.21	Arthur and Armand
		LS2	-.72	Sophie and Sarah

Examples of collaborations around 2Connect

Emotion profiles

Figure 3.8 shows the emotion profiles of the dyads collaborating around 2connect. It shows that collaborators with high affective similarity were either equally bored or equally enjoying the activity. The profile of Chris and Carla (H1) show a 'flat' emotional intensity except for boredom. Conversely, the profile of Samuel and Simon (H2) shows that both of them enjoyed the task -they felt happy, challenged and interested with moderate to a lot of intensity, and felt less bored, frustrated and hopeful.

In dyads with low affective similarity, in the case of L1, Liam reported more happiness, interest, hope and frustration than Laura, who did not report these emotions at all. In the case of L2, the difference was that Martin was moderately happy and not bored, whereas Marian was not happy at all and extremely bored.



Intensity score: 0= not at all, 1 = slightly, 2= moderately, 3= a lot, 4 = extremely

Figure 3.8 *Emotion profiles of dyads with high affective similarity (H1, H2) and low affective similarity (L1, L2) during the use of 2connect*

Interaction quality

Affective expressions. Individuals rarely showed positive or negative affective expressions, at least not in a clear manner (e.g., they did not laugh or made jokes). Although partners in dyad L2, Chris and Carla, equally bored, yawned and explicitly commented about the dullness of the activity.

Responsiveness. One key feature of collaborators' interaction, that probably reflected their emotion profiles, was the responsiveness with the partner. For example, in Dyads L1 and L2, the individuals who reported less happiness, challenge and interest (Laura and Marian) responded to the ideas of the partner, but this was not

reciprocal. For example, in dyad L2, Laura reported more boredom and less interest than Liam. She proposed ideas and also complemented the ideas proposed by Liam. In contrast, Liam proposed ideas but did not complement or request Laura's ideas. Often, he responded to Laura's questions with elaborated accounts of his own student experiences without asking hers. For example:

```
Laura: and then, are you travelling for the summer?
Liam: ehm… I am going to [long list of places] and then to
   Australia
Laura: [turning to him, smiling] jesus, all in the summer?
Liam: yeah, with my friends and then to Australia with my
   family
Laura: and you are in what year?
Liam: first year
Laura: Psychology?
Liam: Chemistry
```

Responsiveness between partners was also relevant in dyads H1 and H2. For example, partners of dyad H1 felt equally bored and not happy or interested at all. In this case, Carla was usually more responsive than Chris. Chris frequently added topics to the concept map without saying anything to Carla or typed whatever she proposed, not asking for more nor complementing her ideas. Sometimes, Carla asked Chris what he was typing but his responses were short. For example:

```
Chris: [silently typing]
Carla: what are you putting?
Chris: ehm, excellent… [pause] I do not know what I am trying
   to say [pause] how good the teach is
Carla: excellent teaching, I guess…
```

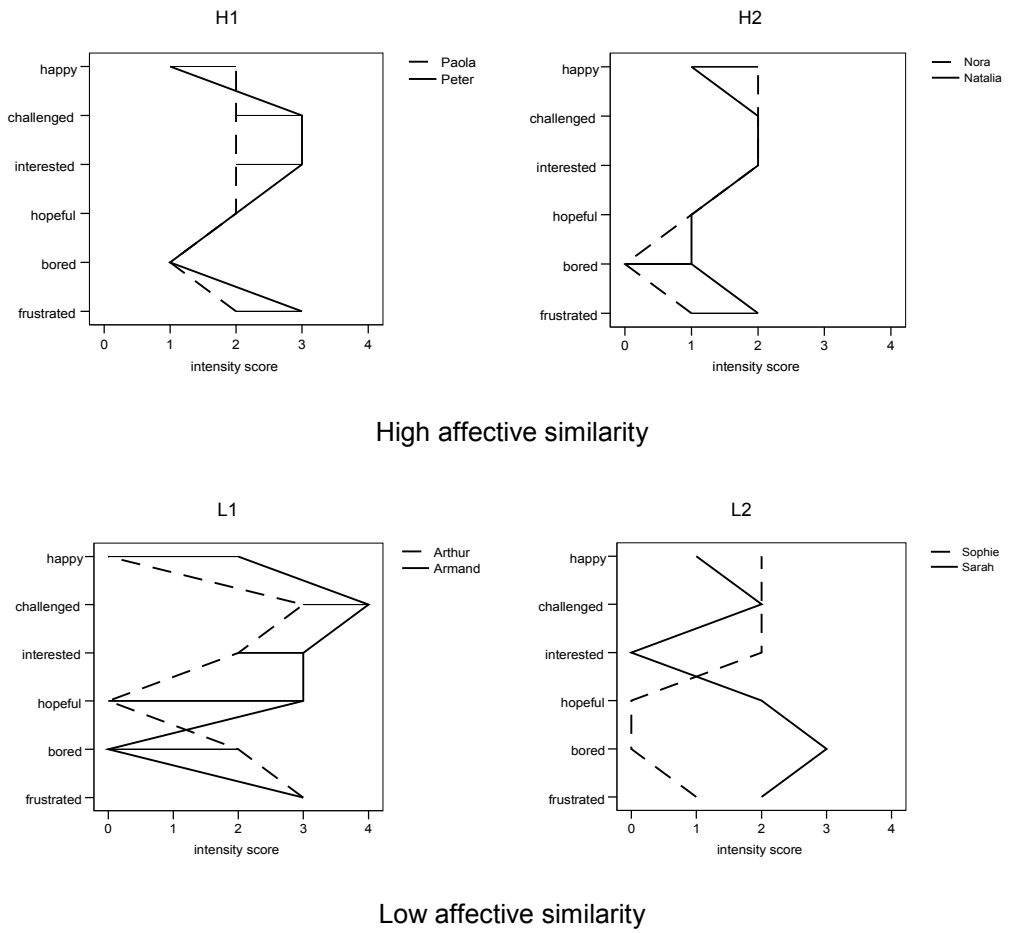
Differently, partners in dyad H2 reported similar happiness and interest. In this case, they were usually responsive to the propositions of one another. For example, in the following extract, Samuel is proposing a topic to include in the concept map. Simon responds with further information on the topic and Samuel responds back:

```
Samuel: [proposing a pro of their university] good rank
   international
Simon: what is our rank international?
Samuel: 73 or something
Simon: is not bad... currently we are in the 20 something in
   the UK
Samuel: is sixth
Simon: sixth?
Samuel: yeah...
```

Examples of collaborations around Astroversity

Emotion profiles

Figure 3.9 shows the emotion profiles of dyads playing Astroversity. Members of dyads with high affective similarity were 'emotionally' engaged with the activity. Paola and Peter (H1) and Nora and Natalie (H2), reported low boredom, moderate happiness, interest, challenge, hope and frustration. In contrast, in dyads with low affective similarity, one partner showed more engagement. In L1 Armand reported more happiness and hope and in L2 Sarah reported more interest, frustration and hope.



Intensity score: 0= not at all, 1 = slightly, 2= moderately, 3= a lot, 4 = extremely

Figure 3.9 *Emotion profiles of dyads with high affective similarity (H1, H2) and low affective similarity (L1, L2) during the use of Astroversity*

Interaction quality

Affective expressions. Partners in dyad L2 reported similar intensities of happiness and interest, but Sarah reported less interest and, in general, more negative emotions such as hope, boredom and frustration. Nevertheless, neither Sarah nor Sophie showed affective expressions. In Dyad L1, partners reported similar challenged and interest, but Arthur reported more happiness and negative emotions and showed more affective reactions than Armand.

Partners in dyads H1 and H2, who reported positive emotions similarly (e.g., more challenge and interest than boredom), frequently showed positive affective expressions. Partners displayed simultaneous affective reactions towards Astroversity, especially when animated characters gave them recommendations and feedback with expressive elements. For example, in H1, Peter and Paola made make jokes about the feedback of the game, as in the following extract:

```
Peter: [reading the interface and smiling] ok, brain damage but
   stable
Paola [smiling]: but he's all right
Peter: [smiling] what!?
Paola [reading the interface and smiling]: you need more
   practice as a team!
Peter: [laughs]
Paola: [laughs]
```

Also, the conversations of Paola and Peter (H1) and Nora and Natalie (H2) usually included jokes and/or affective expressions. In the following extract for example, Peter is listing coordinates while scanning alien presence. Paola is plotting and then, joyfully expressed that they were making progress.

```
Peter: N18 is zero
Paola: awesome, N18 is zero... ok we seem to have some sort of
   progression
Peter: N17 is also zero
Paola: [cheers]
```

Responsiveness. Partners in dyads H1 and H2 usually asked and proposed ideas to one another. For example, in dyad H1, when Peter was telling the coordinates with highest alien presence for Paola to plot them in the grid, she often proposed other coordinates to look at. Accordingly, Peter responded and scanned these coordinates. Conversely, when Paola listed the more secure coordinates for Peter to trace the safest route, he noticed that some of the coordinates listed by Paola were actually dangerous and proposed alternative routes. Similarly, in dyad H2, Natalie and Nora displayed more responsiveness with the passing of time. Their communication evolved from short exchanges combining silence, monologue and backchannel, to a sort of interaction in which they asked, proposed or elaborated about each other's ideas and opinions. In the following extract, Nora and Natalie show responsiveness while scanning alien presence:

```
Natalie: But, [the alien presence] is also high this side maybe
   we can try this area
Nora: yeah but this is a long...
Natalie: [backchannels] thus
Nora: It can't be trouble through it, as long as you go round
   on it, is that a good idea?
Natalie: I am not to sure
Nora: because in that case we can go over here, somewhere
   [laughs]
Natalie: [backchannels] yeah...
Nora: like… to G15
Natalie: [goes to plot]
```

Partners in dyads L1 and L2 showed less propositions and requests of ideas to one another. For example, Arthur and Armand regularly proposed ideas, but their responses were often limited to a minimal backchannel. It was usually Armand, the one who enjoyed the activity more, who was feeding the conversation while Arthur just complemented. The following extract illustrates some of these forms of response. Armand is scanning alien presence and Arthur is plotting in the paper grid.

```
Armand: R5?
Arthur: mhmm
[silence]
Arthur: we are in...
Armand: no... [mumbling]
[silence]
Arthur: That's high isn't it?
Armand: yeah...
```

```
Arthur: [so where is the...]
Armand: [we are at R5.] which is here... which wasn't that bad
Arthur: yeah...
```

Similarly, Sophie and Sarah usually responded with backchannel but with no further elaboration to one another's ideas, as in the following extract:

```
Sarah: [scanning] ok, so now this route is no longer safe
Sophie: [backchannel] mhh...
[…]
Sarah: the entrance is no longer safe
[…]
Sarah: where is the middle part?
Sophie: [backchannel] erm…
[…]
Sarah: [monologue, reacting to the interface] what?
Sophie: erm...
```

Coordination. Dyads H1 and H2 usually did the collaborative tasks of Astroversity with a clear role assignation, which helped them to coordinate their actions during the collaborative task of Astroversity. For example, in dyad H1, when Peter and Paola were scanning alien presence, Peter controlled the rover telling the coordinates with high or low alien presence to Paola, who plotted them in the grid using a constant backchannel. Conversely, when tracing the safest route for the student to be rescued, Paola told the coordinates she plotted in the grid while Peter traced the route in the computer and used backchannel. Dyad H2 organized similarly. The following extract is taken from a moment when Nora and Natalie were tracing the safest route for the student to be rescued:

```
Nora: [points to the screen] right, say...that one?
Natalie: yeah... I20
Natalie: [backchannel] I20... I19
Nora: I19, got it
Natalie: yeah... N19
Nora: N19?
Natalie: M19
Nora: M?
Natalie: yeah
Nora: got it
```

Dyads L1 and L2 organised differently to make the collaborative tasks of Astroversity. For example, in Dyad L1, Armand, who reported more positive emotions, controlled the computer for detecting alien presence while Arthur plotted in the paper grid. Conversely, Arthur controlled the computer and Armand suggested

coordinates in the part for tracing the safest route. In the case of Dyad L2, partners were more disorganised. For example, in the part of Astroversity where the dyad LS2 was scanning the spaceship to detect alien presence, Sarah scanned the screen while Sophie was supposed to be plotting in the paper grid. The next task consisted of tracing the safest route to escape, avoiding the alien presence plotted in the paper grid. Sophie was supposed to tell the coordinates for Sarah to trace the route, but Sophie did not plot while Sarah was scanning and consequently, they failed the trial.

Integrative summary of dyad examples

The presented examples revealed some features of the interaction with the task environment and with the partner that might be related to the individuals' emotions, and the similarity of emotions between partners in this study.

It was common for individuals under different circumstances not to show affective expressions, as it occurred in the four dyads using 2Connect, or in dyads who reported dissimilar emotions around Astroverstity. The expression of positive emotions was common in partners who reported similar emotions whilst playing Astroversity (Paola and Peter; and Nora and Natalie). They laughed or made jokes as a response to features of Astroversity such as the characters that give feedback, or as part of their ongoing interaction whilst resolving the collaborative tasks of the game.

The partners' response to one another also seemed to be related to the partners' emotions. Individuals whose partners showed little responsiveness (e.g., did not ask for, or elaborated on, the ideas of the other) also reported less positive emotions, as it occurred to Laura and Marian whilst using 2Connect, or to Armand whilst playing Astroversity. Furthermore, partners in dyads feeling more similarly positive emotions around Astroversity (Paola and Peter; and Nora and Natalie) and 2Connect (Simon and Samuel) were also more responsive with one another.

Finally, the sort of organisation displayed by partners whilst playing Astroversity might have also been related to their emotions. This aspect was not observed in the examples of dyads around 2Connect, presumably because partners did not have to execute any sort of organised interaction (in the sense of action coordination in a specific task). Thus, Paola and Peter; and Nora and Natalie; who similarly enjoyed Astroversity, displayed an effective coordination during collaborative tasks (e.g., searching alien presence), based on a clear role assignation. In contrast, collaborators who felt different emotions showed different organisations, such as Arthur and Armand swapping the control of the computer and the paper grid, or Sarah and Sophie being unable to clarify roles to play.

3.3.7 Discussion

This study compared collaborations around the concept-mapping tool 2Connect and the collaborative educational computer game Astroversity to explore how the usage of these technologies affects collaborators' emotions. This discussion integrates the results. First, the methodological findings are explained. Then, the results are discussed to answer the research questions.

3.3.7.1 Methodological findings

There were two methodological aims related to the usage of questionnaires for collaborators to report their emotions. The first was to select emotions relevant to the CSCL experience. The second was to assess whether the inclusion of scales for frequency and intensity would help to obtain fruitful data about collaborators' emotions.

No studies were found that reported a list, or a 'survey' of the emotions people feel during CSCL. Therefore, one methodological aim was to select the emotions relevant to the use of 2Connect and Astroversity. Initially, 15 words that refer to emotions

differentiable in terms of their underlying cognitive appraisals were included in the questionnaires: *happy, angry, sad, fearful, angry, bored, challenged, interested, hopeful, frustrated, contempt, disgusted, surprised, proud, ashamed* and *guilty.*

There were extreme floor effects for contempt, sad, guilty, fearful, angry, ashamed and disgusted. Presumably participants did not report these emotions because they are negative. It has been found that 'negative' emotions, e.g., anger, sadness, fear, guilt and shame, are reported with less frequency and intensity than other, more 'positive' emotions (Carstensten et al., 2000; Nezlek et al., 2008; Tong et al., 2007). However, other explanation is that some of these emotions are simply not part of the average CSCL experience, (e.g. disgust), or probably occur with low frequency, (e.g., surprise).

Thus, the study focused on the emotions happy, interested, challenged, hopeful, frustrated and bored. The rationale for this selection was to have two positive emotions (happy and challenged), two emotions that imply both positive and negative attributes (challenged and hopeful) and two negative emotions (frustration and bored).

The second methodological aim was to explore whether participants could differentiate between the intensity and the frequency of their emotions. That could have been useful to detail the collaborators' emotions more. However, the high correlations and small differences between the scores of frequency and intensity showed that participants did not differentiate between these aspects of their emotions. Therefore the study focused on intensity, as is common in emotion research.

3.3.7.2 How does using a concept-mapping tool and a collaborative educational game influence people's emotions?

The Introduction section explained the differences between the collaborative usages of 2Connect and Astroversity in terms of their underlying tasks and the

affective features of their designs. This served as a framework for the analyses that assessed the differences between the emotions reported by collaborators around these learning environments and what they referred as the sources of their emotions

Activities around Astroversity and 2Connect were equally pleasant and engaging, provoking equally mild levels of happiness and interest, as well as low levels of boredom. However, playing Astroversity provoked more intense 'goal-oriented' emotions such as challenge, hope and frustration.

Although with similar intensity, 2Connect and Astroversity might have prompted pleasantness and engagement in different ways. Collaborators used 2Connect to make a concept map about their student experiences. 2Connect has very few affective elements (e.g., expressivity, anthropomorphism) and therefore it should have had little influence on collaborators' emotions. Also, partners were not allocated to predefined roles, no specific characteristics for the concept-map were requested and no other materials (e.g., paper and pencils) were provided.

Probably the interaction with a partner was the key for the pleasantness and engagement in 2Connect. Partners probably felt positive affect (e.g., more interest and happiness) if they showed motivation to understand each other (Schwartz, 1998). Some illustrative examples are in line with this. Partners who were mutually responsive (i.e., asked and elaborated on the ideas of the other) also reported similar happiness and interest (Samuel and Simon), whereas partners who were not reported equal boredom (Chris and Carla) and those who interacted with an unresponsive partner reported low enjoyment (Laura in L1 and Marian in L2).

Pleasantness and engagement might have appeared differently in Astroversity. Partners resolved tasks with specific goals (e.g., scan alien presence), playing complementary roles (e.g., plotting on the paper grid whilst the partner scans alien presence on the computer) and employing supplementary materials (e.g., paper and

pencil). These aspects were embedded in an environment with affective features such as expressivity, aesthetics and anthropomorphised feedback. In this context, partners' probably felt positive affect as they were effectively playing their roles, successfully resolving the tasks, and interacting with the affective features of the game (e.g., feedback), as observed in some illustrative examples. For instance, partners who reported similarly positive emotions around Astroversity (H1 and H2) were also more responsive to one another and coordinated effectively to resolve the tasks, and laughed and joked about the animated characters that gave them feedback.

However, even when both learning environments provoked equal pleasantness and engagement, participants did felt more intense feelings of challenge, hope and frustration whilst playing Astroversity. To complement this result, the analysis turned to what collaborators identified as sources of these emotions.

Participants made a significant but small differentiation between the partner, themselves and the activity as sources of their challenge, hope and frustration whilst using 2Connect. The small differentiation is probably related to the fact that partners felt these emotions with low intensity, (lower than other emotions such as happiness and interest). In contrast, during Astroversity, participants made clear differentiations when rating the sources of these emotions. They attributed more emphatically to the activity than to themselves or their partner as an emotional source, more in relation to challenge and frustration than in relation to hope.

This suggests that making effort to achieve the specific goals of the tasks, playing of complementary roles, and interacting with the affectively loaded GUI of Astroversity, were main sources of challenge and frustration. Moreover, all these aspects are absent in 2Connect, which probably explains the difference in the intensities of these emotions across learning environments. Moreover, in the illustrative examples, partners around Astroversity showed coordinated action and

played complementary roles to resolve tasks like scanning alien presence, a sort of interaction not observed in the cases around 2Connect.

Research on cognitive appraisal and emotions is helpful to further interpret these results. It is not surprising that whilst playing Astroversity, the activity was the main source of challenge, hope and frustration, and that these emotions were more intensely reported than whilst using 2Connect. Challenge, hope and frustration are emotions associated with situations that demand high *effort* and *attentional activity* (Reisenzein & Hofmann, 1993; C. A. Smith & Ellsworth, 1985), as it was required to resolve the tasks of Astroversity. For example, whilst scanning alien presence, collaborators have to act quickly and collect as much data as they can. However, the task requirements might not be the only source of challenge, hope and frustration. Probably the affective features also played a key role. For example, frustration could have been triggered when collaborators received the feedback about their performance from expressive characters, denoting some form of anthropomorphism.

However, although challenge, frustration and hope are similarly associated with the appraisals of effort and attention, there are other appraisals that differentiate them. Challenge and hope are opposites in the appraisal dimension of *certainty.* Challenge is experienced when a person is certain about the outcome of a situation, whereas hope is associated with situations with an uncertain outcome. Some parts of Astroversity are 'intentionally' designed to generate uncertainty. For example, when players have to scan invisible alien presence or wait for feedback.

Challenge and frustration are opposites in the appraisal dimension of *perceived situational control*, which ranges from self-agency to other–agency. Challenge is associated with the sense of self-agency, which implies the control over the situation. In contrast, frustration is associated with the sense of other-agency, which implies that the situation is controlled by another 'agent', a person or, as in the case of this study, a

computer program (i.e., Astroversity). On the one hand, collaborators had control of their own actions whilst playing Astroversity. This could have generated a sense of self-agency and the subsequent feeling of challenge. In contrast, the feelings of frustration could have been generated by the fact that collaborators could not control neither the actions of the partner or the structure of the game. A sense of 'other-agency' in relation to the partner might have aroused because in order to achieve the win state, collaborators largely depended on each other. A sense of 'other-agency' in relation to the computer might have aroused because collaborators had to follow the rules 'imposed' by Astroversity with no control over its mechanics.

3.3.7.3 What do collaborators understand about their partners' emotions while using a concept-mapping tool and a collaborative educational game?

The study also explored what collaborators understand about the emotions of a partner. Two aspects were analysed: the similarity between partners' emotions and their judgements about the emotions of one another.

Similarity between partners' emotions

The affective similarity between collaborators was not higher than would be expected by chance, neither in the overall assessment across learning environments, nor in the separate tests of 2Connect and Astroversity. One interpretation is that collaborators' emotions were unrelated because they depended on the emotions they felt before the study. But this interpretation is not supported since the multivariate relationship between collaborators' prior emotion scores and their emotion scores during 2Connect and Astroversity was not significant [$F(18, 108) = .42$, *ns*)].

Apparently, the statistical test of the emotional similarity between partners was not significant because some partners reported very similar emotions, and others did so

very differently, as indicated by the large SD's of the affective similarity index. At least two explanations are possible for this.

One explanation is that the 5-point Likert scale used by collaborators to report their emotions was too short and collaborators made a 'forced choice'. This could have increased both the measurement error and the probability that collaboration partners selected different options to report their emotions.

The other explanation is that the large differences between dyads' affective similarities were due to within-dyad factors. That is, some dyads were different to others in a way that affected their affective similarities. The illustrative cases showed that some partners showed different interaction qualities, probably related with the similarity of their reported emotions. For example, partners who reported similar emotions also showed more responsiveness, around 2Connect and Astroversity, and only around Astroversity also showed more coordination and positive affective expressions.

Accuracy at judging the emotions of a partner

Affective awareness was measured as the accuracy of collaborators at judging the emotions of their partners; taking the emotions reported by the partner as 'true' reference. The measurement of affective projection referred to the degree in which collaborators based their judgements of their partners' emotions on their own emotions.

In general, collaborators' affective awareness was rather low, both during the use of 2Connect and during the use of Astroversity. One interpretation is that whilst interacting around these learning environments, collaborators did not pay attention to the emotional expressions of their partners, or to the particular events that could have affected their emotions. However, it is also possible that the inaccuracy at reporting

the emotions of the partner is the result of having only one opportunity to do so at the end of each activity. Probably the participants could have been more accurate if they had more occasions to report the emotions of their partners.

It was found that in general, collaborators showed a tendency to 'project' their own emotion onto their partners. This suggests that collaborators based their understanding of their partner's emotions on their own emotions. Probably collaborators did so to avoid effort at reporting the emotions of the partner. Or probably they did put effort at reporting the emotions of the partner but felt they lacked information to do so.

This is consistent with the bias in interpersonal perception known as the 'false consensus effect'. That is, a person will think that others in the same situation have the same opinion (for a review, see Marks & Miller, 1987). This tendency was lower during the use of Astroversity than during the use of 2Connect. Probably, when using Astroversity, collaborators projected less because the partner expressed emotions more emphatically, or because the game mechanics and narrative generated situations that could be clearly identified as sources of the partner's emotions. However, even when collaborators showed less affective projection during Astroversity, this did not imply that they were more aware about the emotions of the partner.

Importantly, these results were calculated with control of the emotional similarity between partners. A number of multiple regression analyses were employed to predict' the collaborators' judgements about the emotions of their partners. These included both the participants' own emotions and the emotions felt by their partners as dependent variables. In this way, the individual predictive power (i.e., the beta coefficients) of these variables has been calculated controlling for their relationship (i.e., the emotional similarity between partners). A high relationship could have provoked 'collinearity', reflected on very large standard errors and, consequently, a reduced significance for most of the beta coefficients. However, the results show that

the beta coefficients of the participants' own emotions were fairly high (≅ .50) and that overall, the standard errors are not extremely large (≅ .10). Thus, the analysis is reliable and 'conceptually' valid. It is recognised that feeling in the same way as the partner is a potential influence on the understanding of a partners' emotions. However, the results suggest that the similarity with the partner is relatively independent of both the collaborators' tendency to project their emotions onto their partners and of their low affective awareness.

3.3.7.4 What is the relationship between collaborators' emotion and the qualities of their interaction with a partner?

The relationship between collaborators' emotions and their perceived interaction quality was assessed with joint measures of emotion intensity and perceived interaction quality. In the case of collaborators' emotions, the joint measure was the sum of the emotion intensity scores of both partners. In the case of perceived interaction quality, the joint measure was the sum of the perceived interaction quality scores of both partners.

Both in 2Connect and Astroversity, the joint measure of interaction quality was positively correlated with the joint measure of happiness, and negatively correlated with the joint measure of boredom. Recall that collaborators reported similarly mild levels of happiness and low levels of boredom around the two learning environments. Altogether, these results suggest that collaborators' enjoyed more if they thought they were thinking alike, understanding each other and cooperating equally; irrespective of the tasks and affective features of the technology. The qualitative examples illustrated this. Individuals who felt more positive emotions also had partners who asked and responded more to her ideas. Moreover, in the cases of partners who reported similarly positive emotions around Astroversity, the two partners were responsive to

one another. Furthermore, the partners around 2Connect that only reported boredom rarely responded to one another.

In Astroversity, but not in 2Connect, the dyads' joint measure of perceived interaction quality was negatively correlated with their joint measure of frustration. Recall that frustration was one of the emotions that collaborators reported more intensely during Astroversity than during 2Connect. Probably the collaborative tasks of Astroversity prompted, but did not guaranteed, a sort of interaction quality that helped partners to increase their control of the situation and reduce uncertainty, leading to a reduced frustration. Again, this is illustrated in the dyad examples. Those who reported similarly positive emotions (e.g., happiness) and less negative emotions (e.g., frustration) around Astroversity, often took clearly defined roles to solve the collaborative tasks. In comparison, those dyads in which at least one partner felt frustration played less fluently, and the role assignation between partners was unclear and/or one of the partners did not play her role effectively. This sort of relationship between interaction quality and emotions was not observed around 2Connect, presumably because partners did not have to execute fixed task that required coordinated action.

Finally, the dyads' joint measure of perceived interaction quality was not correlated with their joint measures of interest, challenge and hope. This suggest that collaborators' assessed the quality of their interaction with a partner independently of the attention they put in the activity (interest), the positive aspects of their engagement (challenge) or their expectations about the activity (hope).

3.3.8 Conclusions

This study compared the affective effects of collaborations around clearly different collaborative learning environments such as the game Astroversity and the concept-mapping tool 2Connect. Partners reported more goal-oriented emotions (e.g.,

challenge and frustration) in relation to the collaborative tasks of Astroversity. But there were no differences in terms of emotion understanding since partners showed a tendency to assume similarity, which was not necessarily true. This indicated that partners had little awareness about the emotions of the partner. In turn, emotions seemed to be associated with interaction quality, which probably suggests that partners influence each other's emotions during collaborative interaction; and idea illustrated by dyad examples (e.g., partners who showed mutual responsiveness also reported more positive emotions).

These findings suggest that the resolution of collaborative tasks with fixed goals and complementary roles are features of collaborative games that might facilitate joyful and productive collaborations. However, whether this occurs or not, seemed to depend on the interaction with a partner. It is also important to recognise the limitations of the study. Partners reported their emotions and the emotions of their partners in one occasion, at the end of each activity. Therefore, moments of especially intense emotions could not be identified. Moreover, because there were no screen recordings, it was not possible to link emotions or emotion understanding with performance. Also, participants' collaborative tasks were fairly short, leaving uncertain whether collaborators' emotions might change over time.

The findings and limitations motivated Study 2, which investigates they way people's emotions and emotion understanding change during extended computer-supported collaboration, the factors associated with these changes and its potential implications for the process and outcome of collaboration.

Chapter 4

The dynamics of challenge around a collaborative digital game

4.1 Introduction

Study 1 compared collaborations around a concept-mapping tool and a collaborative computer game. Around the game, participants reported more challenge, frustration and hope, and referred to the activity more than to themselves or their partners as the main source of these emotions. There were no differences in emotion understanding. The partners inaccurately estimated the emotions of one another because apparently, they thought they felt same. However, in some specific cases, partners feeling similarly positive emotions whilst playing Astroversity were also more responsive to one another, showed more positive affective reactions and organised themselves with role assignment to resolve the collaborative tasks.

These results motivated an interest to investigate in more detail the way in which people's emotions change during during collaborative learning, and how these emotions relate to their performance. These issues are addressed in this chapter, which studies the changes in people's emotions and their understanding of a partner's emotions during extended collaborations around the collaborative game *Lego Star*

Wars 2 (LSW2). Emphasis is placed on the factors associated with the dynamics of the affective state *challenge* and its implications for the process and outcome of collaboration.

4.1.1 Variation in emotions and emotion understanding

The study of emotions in CSCL needs to consider the dynamic nature of affective factors such as emotion experience and emotion understanding. It is well documented that one's own emotions are not stable and show meaningful fluctuations over different time-spans (e.g., minutes, hours, days). Moreover, as in the case of one's own emotions, the understanding of others' emotions is also highly variable.

Early studies of emotional variability reported that people's emotions vary in different forms (e.g., in terms of frequency, intensity or duration) (Larsen, 1987; Zevon & Tellegen, 1982). More recent studies suggest that the fluctuation of emotions might be associated with individual differences in such aspects as self-regulation capacity (Hemenover, 2003) or coping strategies (Tong et al., 2009). However, individual differences are not sufficient to explain variations in the intensity and duration of emotions, and other more general factors might also be important. For example, the variability of emotional intensity (self-reported or physiologically indicated) can be accurately explained with three parameters: steepness at onset, skewness, and number of peaks. These parameters are different across emotions and relatively independent of individual differences (Sonnemans & Frijda, 1995; Verduyn, Van Mechelen, Tuerlinckx, Meers, & Van Coillie, 2009).

Verduyn et al. (2009) reported that the durations of emotions such as joy, sadness and gratitude was more strongly associated with situational features (e.g., physical or mental contact with the eliciting source, importance of the situation and intensity at the onset) than with personality traits (e.g., neuroticism, agreeableness); whereas the duration of anger was more strongly associated with personality traits than with

situational features. Verduyn et al. (in press) replicated the associations between emotional duration and situational features, and also found a strong association between emotional duration and the processing of the eliciting episode (e.g., responding to an episode of sadness with a positive thought, or sharing an emotional experience).

The social environment is another factor that might have a strong influence on the fluctuation of people's emotions and their understanding of others' emotions. For example, the emotions of friends and romantic partners tend to converge and become similar over time, supposedly because the development of a shared history makes partners incorporate each other's ways of reacting to environmental stimuli. (Anderson, Keltner, & Oliver, 2003; Gonzaga, Campos, & Bradbury, 2007). Moreover, in the case of romantic partners, the development of a shared history might also facilitate their understanding of each others' emotions. For example, husbands can distinguish the emotional characteristics of their wives from those of other females (although this understanding does not apply from wives to husbands) (D. D. Clarke, 1997). In turn, the increased emotional similarity and enhanced emotion understanding of romantic partners might have important implications for their relationship. For example, the degree of emotional similarity between partners predicts their longer-term satisfaction with the relationship (Gonzaga et al., 2007), and the emotions of a closely related person (e.g., a romantic partner) become as important as one's own emotions for decision making (Parkinson & Simons, 2009). What is more, Gottman & Notarius (2000) indicate that the future of a marriage can be predicted by the affective behaviours and talk displayed by partners during episodes of interaction (e.g., natural conversations) observed months earlier. Negative patterns of affective communication predict divorce, and positive affect during a discussion predicts satisfaction.

The variability of emotions and emotion understanding is also relevant in other sorts of social situations, not necessarily involving a romantic relationship. For example, the empathy of medical students declines over time, which is relevant because empathy is recognised as an important aspect of the physician-patient relationship (Bellini & Shea, 2005; D. Chen, Lew, Hershman, & Orlander, 2007). More resonant with this thesis, it has been found that over time, group work members become more sensitive to 'catch' the emotions of one another (Ilies, Wagner, & Morgeson, 2007), and that the their trust on each other grows in parallel to their willingness to cooperate (Wilson, Straus, & McEvily, 2006).

4.1.2 Affective variability during computer-supported collaboration

The previous section presented some factors associated with the variability of emotions and emotion understanding, as well as the potential implications of such variation for the outcomes of social relationships. Studies addressing these aspects in CSCL are small in number and scattered across different formats of CSCL, but they are helpful to illustrate the importance of the topic.

For example, some studies suggest a connection between emotional change and performance during collaborative learning. Azmitia,(2000) observed collaborative problem solving activities, and noticed that individuals disengaged or engaged with collaboration depending on the increase and decrease of their frustration. She suggested that taking time-out from collaboration helped the partners to regulate their own frustration, which reflected on positive interaction when collaboration was reactivated. Brand & Opwis (2007) reported that learners induced to feel a positive mood during a joint learning phase transferred their knowledge more effectively than learners who went through the learning phase individually or feeling a negative mood. From this result, one could speculate that some moments of a CSCL activity are more

favourable to acquire and transfer knowledge than others, depending on the variations in the quality (positive or negative) of individuals' emotions.

Vass (2002) studied the effects of friendship on collaborative writing in a school IT suite. When comparing friends with acquaintances, the discourse of friends was more 'reflective' (i.e., partners generated content through mutual elaboration of each other's ideas), which was accompanied by affective loaded interactions (i.e., partners giggled and joked whilst generating content). Probably the interaction between friends was more reflective and affective because it was sustained in affective qualities that evolve over time; such as the emotional convergence associated with long-term friendship (Anderson et al., 2003; Gonzaga et al., 2007) and the increased trust that emerges from collaborative learning (Wilson et al., 2006).

Other studies have indicated that the motivation of collaborators engaged in programs of 'blended learning' (i.e., a form of computer-supported learning that combines co-located and remote interactions) tend to oscillate over time, which has been associated to the way in which the group employs strategies of social regulation (Järvelä, Järvenoja, & Veermans, 2008; Michinov & Michinov, 2008). Probably the changes of people's motivations are linked to changes in their emotions, as it occurred in the collaborative learning activities described by Järvenoja & Järvelä (2005).

4.1.3 Challenge and collaborative learning computer games

The present study explores the ways in which people's emotions might change during a computer-supported collaborative activity such as playing the digital game LSW2. The study will focus on the affective state *challenge* because the literature highlights its importance in the experience of educational technologies such as computer games. A In particular, a digital game might be pragmatically defined as an 'interactive challenge', different from a film because it is interactive, and also

different from a toy because it has a prescribed challenge (Habgood & Overmars, 2006).

Malone (1981) listed challenge as one of the three factors (along with fantasy and curiosity) that a learning environment must include in order to be intrinsically motivating. He suggested that a challenging learning environment provide goals with uncertain outcomes. Goals have to be personal and obvious, and feedback has to be given about their attainment. Uncertainty might be given by variable difficulty level, multiple level goals, hidden information and randomness. The challenges presented by a game must be in balance with the skill of the player. When the challenges exceed the skills of players, this might reduce the game play flow (Engeser & Rheinberg, 2008). Other studies also suggest that the feelings of challenge might not only be reflected in people's performance, but also linked to other sorts of affective reactions such as anxiety (Rani, Sarkar, & Liu, 2005).

It is clear that challenge is relevant in the experience of playing an educational computer game. However, current research focuses on individual game play (Engeser & Rheinberg, 2008; Rani et al., 2005) or treats challenge as competition (e.g., Sheese & Graziano, 2005; Wingrove & Bond, 1998) and, therefore, the factors associated with challenge in the context of collaborative game play are still relatively unknown. In this context, there are two potential sources of challenge. One would be the interaction with the technological environment and the task design, as it has been outlined by Malone (1981). The other one would be the interaction with a partner. It is thought that collaborative learners face various challenges that emerge at the social level (e.g., working more or less cooperatively) (Järvenoja & Järvelä, 2009), and teams whose members feel challenge rather than stress tend to perform better and make more positive accounts of their interaction qualities (e.g., coordination, mutual credibility) (Pearsall, Ellis, & Stein, 2009).

Finally, there is a gap in the understanding of factors associated with the feeling of challenge whilst paying a collaborative learning game. The importance of doing so is illustrated by two findings of a literature review on educational computer games (Kirriemuir & McFarlane, 2004). First, many educational games have failed because they focus on creating fun and attraction, paying less attention to the generation of challenge (e.g., their underlying tasks are too simplistic, repetitive or lack progression). Second, the potential of collaborative computer games as learning tools has not been explored enough because most educational games are designed for individual game play.

4.2 Study 2

4.2.1 Overview of microgenetic analysis

This study investigates how people's sense of challenge changes whilst playing a collaborative computer game. The study can be described as microgenetic as it tries to give a very detailed account of a changing process. Microgenetic studies have been useful to study other aspects of collaborative learning. For example, Taylor & Cox (1997) found that collaborators who label and externalize their knowledge are more successful during mathematical problem solving, and Donato (1994) reported that collaborators in language learning give each other the sort of 'scaffolding' that adults give to children. More recently, Iiskala, Vauras, Lehtinen, & Salonen (in press) found that learners' metacognitive strategies change according to the demands of the task during mathematical problem solving

There are also microgenetic studies of technology-enhanced learning. Schoenfeld, Smith III, & Arcavi (1993) studied how the knowledge of one student changed during repeated interactions with a learning environment in the domain of algebra. Knowledge changed substantially, but not as smoothly as it was expected. Learner's

prior knowledge, correct and incorrect, was highly resilient and 'filtered' her interpretations of the learning environment (e.g., she misinterpreted the graphs). Another study reported that learners exhausted their own and their partners' knowledge before employing the tools offered by technology whilst making of a text in second language learning (Cekaite, 2009).

This study is in line with the main characteristics of microgenetic analysis, as listed by Lavelli et al. (2005):

- The changing *individual* is the unit of analysis
- Observations are conducted *before, during* and *after* a period in which rapid change occurs
- There is an elevated *density* of observations within the transition period
- Observations are *intensely* analysed

These characteristics permit a real-time detailed account of changing processes, difficult to obtain with other methodologies (e.g., cross-sectional studies). But there is a trade-off. As is the case of this study, microgenetic studies often employ small or single-n designs to economise the intensive analysis of various observations and therefore, the results are difficult to generalise.(Flynn & Siegler, 2007; Siegler, 2006). Moreover, microgenetic analyses are usually about cognitive change, whereas affective change has received less attention.

4.2.2 Overview of the study

This study presents micro-genetic analyses of six dyads playing LSW2 during four sessions, each of 15-20 minutes, over the span of two weeks. Immediately after each session, participants watched a recording of their game play in segments of 2-3 minutes and used Likert scales (0-8) to rate their emotions, their perceptions of their

partner's emotions, and their appraisals of the game play. These ratings were matched with their performance as showed in the game play recording.

Dyads were made to play under different circumstances of experience with LSW2 and one another (e.g., playing with experience of the game but not of one another, with experience of one another but not of the game, or with both experience of the game and one another). First, a graphical analysis is employed to distinguish the dynamics of challenge from other emotions such as happiness and frustration. Then quantitative and qualitative data are triangulated to investigate the factors likely to be associated with the increase and decrease of challenge.

The study focused on co-located collaborations because the data collection procedure was difficult to implement remotely. To collect detailed data, participants were asked to make a 'prompted' retrospective account. This technique required controlled conditions difficult to implement with participants in remote locations. Although the results of this study should not be generalized to remote CSCL, they are useful as an exploration of the dynamics of challenge in CSCL.

4.2.3 Research questions

Four research questions were formulated to address different aspects of the affective variability for the case of challenge, such as the general patterns of change, the changes in affective similarity and affective awareness; as well as the factors likely to be associated with the variation of challenge. The questions are phrased in past tense to emphasise they are about the reported emotions of the participants of this study, and their answers should not be generalised.

4.2.3.1 RQ1 How did peoples' emotions change as they played a collaborative computer game?

A first step in the understanding of challenge was to explore the features of its variation. To do that, the variation patterns in the participants' reports of challenge were compared with their reports of other emotions. Happiness and frustration were selected to do that because appraisal studies (e.g., 1985; C. A. Smith & Lazarus, 1993) suggest that the cognitive appraisals that underlie these emotions are clearly different from those of challenge.

4.2.3.2 RQ2 How did affective similarity change as partners played a collaborative computer game?

The partners' reports of challenge may have diverged, converged, remained stable, or oscillated between similarity and dissimilarity. This is important to know for two reasons. First, Study 1 suggested that in some cases, the emotional similarity between partners could have been associated with positive features of their interaction (e.g., mutual responsiveness). Second, emotional similarity changes over time, and some studies suggest that this might be related with aspects such as satisfaction in social relationships (e.g., friendship) (Anderson et al., 2003) and trust between partners in group work (Wilson et al., 2006). Although these studies cover a longer period of time than deployed in this study, they do suggest that it might be useful to know whether the similarity between the challenges of partners in this study changed over time.

4.2.3.3 RQ3 How did affective awareness change as partners played a collaborative computer game?

Participants' accuracy at judging the emotion of their partners may have increased, decreased, remained stable, or oscillated between accurate and inaccurate. Again, this is important to know for two reasons. First, Study 1 suggested that collaborators tend

to make inaccurate judgements about the emotions of their partners. Second, the understanding of others' mental states changes in the short term (e.g., minutes) because to move from egocentrism (a default), an adjustment is necessary that requires effort and time, and that is sensitive to environmental demands (e.g., time pressure) (Epley et al., 2004; Lin, Keysar, & Epley, 2010). Probably the demands of LSW2 prompted changes in the partners' emotion understanding. Moreover, although covering longer time-spans, other studies have documented changes over time in emotion understanding. For example, it improves between romantic partners, especially husbands (D. D. Clarke, 1997); and decreases for physicians with respect to their patients (Bellini & Shea, 2005).

4.2.3.4 RQ4 What were some of the factors associated with changes in challenge?

Challenge is recognised as a core aspect of the motivation and engagement that learning technologies aspire to generate, but the factors that might favour or inhibit challenge during collaborative game play are still unknown. This question addresses this issue, and to answer it, a broad range of factors that might have been associated with increases and decreases in the partners' challenge were explored, including: *experience (with LSW2 and/or with the partner), magnitude of the change, similarity, awareness, perception of the context, game situation (the tasks and structure of LSW2), social situation (the interaction with the partner)* and *performance.*

4.2.4 Method

4.2.4.1 The collaborative puzzle solving game

The commercial game LSW2 was selected for the study for four reasons: (1) The game is ethically appropriate because it lacks sexist or violent content (2) It is easy to learn and play. In a pilot study, non-expert players learned the basic skills of the

characters and understood the general game mechanics in a 5-minutes induction. This was important because otherwise, the participants' emotions would be mostly driven by aspects such as the usage of the gamepads for controlling the characters, or the need to learn how to play LSW2. (3) The mechanics of LSW2 support and reward collaboration. Players need to resolve puzzles with collaborative tasks in which the players use characters that complement each other. For example, one of the characters can control objects at–distance but it cannot climb, whilst the other character can climb using an anchor but it cannot manipulate objects at distance. Importantly, LSW2 allows collaborators to solve a good number of puzzles without cooperation, but at the cost of time and effort. In contrast, players can solve the puzzles more efficiently if they collaborate. For example, they can distribute the steps needed to solve a puzzle, or complement the skills of their characters. (4) Lastly, the number and complexity of the puzzles of LSW2 varies constantly, which is useful to sustain participants' engagement.

4.2.4.2 Participants

Participants were 12 unacquainted female students with a mean age of 20.3 years, recruited through mailing lists across various departments in the University of Nottingham. All of them declared to play computer games rarely or occasionally and described themselves as non-expert players. All declared not having played LSW2 before.

4.2.4.3 Study Design

Dyads were organized to play either all sessions collaboratively, two sessions individually then two collaboratively, or two collaboratively then two individually. This organisation was to investigate different situations of experience such as more or less game experience with and without collaboration. The six dyads were organised as shown in Table 4.1

Table 4.1
Organization of the dyads

C-C-I-I	I-I-C-C	C-C-C-C
A, B	C, D	E, F

I: individual playing, C: collaborative playing

- *C-C-I-I*: Dyads in this group played collaboratively in the four sessions, acquiring both experience with the game and of one another.

- *I-I-C-C:* Dyads in this group played individually the first two sessions and collaboratively the last two sessions. In the last two sessions, their members played with experience of the game but not of one another.

- *C-C-C-C:* Dyads in this group played collaboratively the first two sessions and individually the last two sessions. In the first two sessions, their members played with little experience of the game and one another.

4.2.4.4 Setting and procedure

The study was implemented in the room design depicted in Table 4.1. Regardless of playing individually or collaboratively, all participants played LSW2 on a laptop PC with gamepads attached (1C). The laptop was input for a DV recorder in the central section (2A), which recorded collaborators' game play. In turn, the DV recorder was input for televisions in the lateral sections (1A and 3A). This served for participants to watch the recording of their game play whilst answering the questionnaires, which were presented in tablet PCs (1B and 3B).

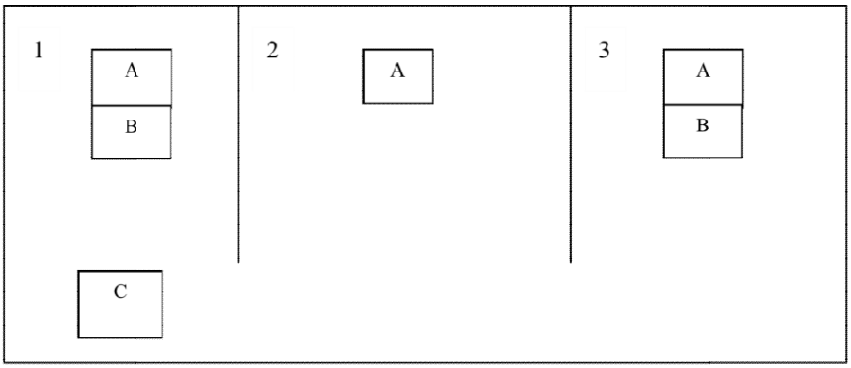


Figure 4.1 Experiment room

On each session and at their arrival to the experimental room, participants answered the Own Emotions questionnaire to report the emotions they felt during the 20 minutes prior to the study. Participants who played collaboratively answered the questionnaire in different sections of the experimental room. In general, sessions lasted 60 - 70 minutes, and followed similar procedures with adjustments. At arrival to the experimental room for Session 1, all participants confirmed they were unacquainted and they were then presented with the study information.

For all participants, the information assured confidentiality for the answers to all questionnaires. However, the information was different depending on the group. For those in the C-C-C-C group, the information indicated they would be playing LSW2 collaboratively during the four sessions. For those in the groups I-I-C-C and C-C-I-I, the information indicated that they would be playing LSW2 in 2 sessions individually and 2 sessions collaboratively.

Then, participants played LSW2 for 15-20 minutes, depending on the mission and their performances (i.e., mission 2 had more complicated puzzles than mission 1, and some dyads played more effectively than others). To avoid extreme frustration, all participants received a handout with a reminder of the button-action relationship to control the characters, a short explanation of the goals in each puzzle and some hints.

The computer screen was recorded during participants' game play to capture their performance.

Right after their game play, participants made a retrospective account of their play using the questionnaires Own Emotions, Partner Emotions and Contextual Appraisal. Participants watched the video recording of their performance. The recording was stopped on five occasions, or *trials.* In each trial, participants answered the questionnaires in relation to the content of the video. The time between trials varied between 2-3 minutes, depending on the length of their game play. When the game play was longer than 20 minutes, the participants were presented with the last 15 minutes of their game play.

In collaborative sessions, participants answered three questionnaires: Own emotions, Partner emotion and Contextual appraisal. In individual sessions, participants answered two questionnaires: Own emotions and Contextual appraisal. Participants playing collaboratively answered the questionnaires in separated rooms.

4.2.4.5 Questionnaires

Participants answered three questionnaires presented electronically, with randomised items and counterbalanced order. Dyad members answered these questionnaires in separated rooms.

- *Own Emotions.* This questionnaire presented a 9-point Likert scale ranging from 0 to 8 and anchored by not at all and extremely. Participants reported how intensely they felt the emotions *happy, interested, challenged, frustrated, hopeful, ashamed, guilty* and *angry*. The emotions happy, interested, challenged, frustrated and hopeful were selected because study 1 demonstrated its relevance during collaborations around collaborative learning technologies.

Other emotions used in study 1 were not included because; either they produced floor effects (e.g., *sad, fearful, contempt, and surprised*), or because they were just conceptually opposite to other emotions (as the case of *bored*, being the opposite of *interested*).

The emotions *ashamed*, *guilty* and *angry* were selected because, even though they generated floor effects in Study 1, they are closely related with social situations

- *Partner Emotions.* This questionnaire was identical to the Own Emotions questionnaire, except that participants used it to report their partners' emotions.

- *Contextual Appraisal.* This questionnaire presented a 9-point Likert scale ranging from 0 to 8 and anchored in *not at all* and *extremely* for the participants to appraise their game play context. There were 6 appraisal themes. Four of them, *certainty, effort, ability* and *understanding* were selected because previous investigations of appraisal-emotion relationships report they are associated with the emotions analysed in the study. For example, perceiving certainty and understanding of the situation are positively related to the feelings of happiness and challenge, whereas the lack of certainty and control of the situation are associated with the feelings of anger and frustration (Ellsworth & Scherer, 2003; C. A. Smith & Ellsworth, 1985; Tong et al., 2007)

The theme computer agency was included because anthropomorphism is a potential source of emotions in HCI (e.g., Gong, 2006). The theme 'interface problems' was included because, although LSW2 is easy to play, participants were not expert players. Therefore it was important to assess the extent to which their emotions were influenced by their problems at controlling the characters of the game.

4.2.4.6 Data screening

Data from the Contextual Appraisal questionnaire on Sessions 1 and 2 of Dyad C was not collected due to an error. The rest of the data was collected completely and reliably. The questionnaire data were screened in order to detect major anomalies (e.g., floor or ceiling effects).

Appendix D shows the histograms for the questionnaires Own Emotions, Partner Emotions and Contextual Appraisal. Most participants rated with very low intensities the emotions angry, ashamed and guilty in the Own Emotions questionnaire and the Partner Emotions questionnaire. This indicated floor effects and, therefore, the data concerning these emotions were excluded from further analysis.

In the Contextual Appraisal questionnaire, most of the questions showed distributions without extreme skews. However, the appraisal theme computer agency (... *I feel the computer was controlling the situation* was rated with extremely low intensity most of the time and therefore, its data were excluded from further analysis.

4.2.4.7 Performance measurement

The participants' performance was measured with a *Performance score*. Only the performance in collaborative sessions was scored, discarding the performance in individual sessions. The performance score assessed individual performance and rewarded collaboration, which matches the mechanics of LSW2.

The puzzles of LSW2 are resolved by means of executing a number of essential steps, embedded in game play scenes that included other irrelevant steps and abundant expressive details (e.g., random characters, coins, sounds). All steps are similarly easy in technical control, but they vary in how the mechanics reward or demand cooperation. To account for this variation in the measurement of performance, the steps were classified in three types. Each step type was scored depending on how it

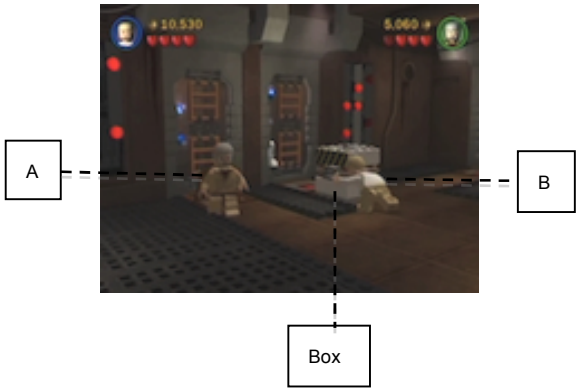
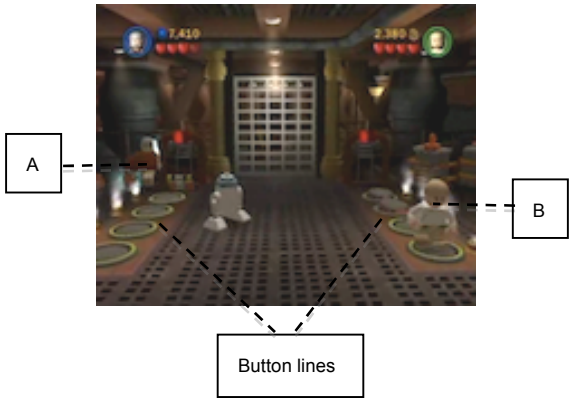
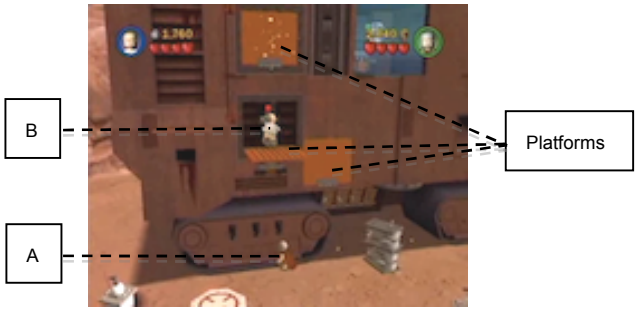
rewarded or demanded the cooperation between partners. Table 4.2 shows the definition, values and typical examples of the step types defined for the measurement of performance.

In LSW2, the two characters can make a similar number of essential steps; hence they can achieve a similar maximum score. Maximum score refers to the highest possible score that a character can make by executing all the essential steps in the puzzles, except those that only the other character can make. In mission 1, the maximum possible scores were 38 for character A, and 39 for character B. In mission 2, the maximum possible scores were 78 for character A, and 87 for character B.

In order to match the participants' performance score with their answers to the questionnaires, the performance score was calculated for each of the video sections employed to prompt the participants answering of the questionnaires, and divided by the number of minutes of the video section, in order to control for the different lengths of the video sections (between 2 – 3 minutes).

The performance score fits the collaborative mechanics of LSW2 and, importantly, considers individual performance and also reflects collaboration. In a hypothetical situation, one player scored much higher than her partner because she executed the steps exclusive to her character and various other steps, while her partner executed only those steps exclusive to her character and just a few other steps.

Table 4.2 *Definitions, values and typical examples of the step types defined to score performance in LSW2*

Type of step		
Simple (value = 1)	Rewardable (value = 2)	Interdependent (value = 3)
The step requires a basic action by only one character. Example:  Character B pushes a box. It does not make any difference whether character A also pushes de box.	The step can be executed by one character only, but cooperation is the most efficient solution. Example:  Players need to stomp two button lines and they organize to stomp one line each. One character could do the two button lines, but this would require more time and effort.	The step is tied to the execution of a previous step than can only be done by the other character. Example:  Character B grapples onto a platform previously opened by character A using its special skill. In the following step, A needs B to open the lower platform. Players need to do this recursively to solve the puzzle.

4.2.5 Results

The results are presented in four sections. The first section describes how participants' reports of challenge, happiness and frustration varied over sessions, and how such patterns of variation could be different between individuals. The rest of the sections focus on challenge because this emotion is of great interest in technology-enhanced learning but has never been investigated in the usage of collaborative environments. The variation of affective similarity and affective awareness in the case of challenge is covered in the second and third section respectively. The fourth section analyses the factors associated with the increase and decrease of challenge.

4.2.5.1 Variability of happiness, frustration and challenge

RQ1 asked *How did peoples' emotions change as they played a collaborative computer game?* This question was answered with a graphical analysis of the participants' self-reports of happiness, challenge and frustration of every participant on every trial of the sessions[3]. These emotions were selected to have one positive emotion, one negative and challenge, which implies both positive and negative aspects[4]. The cognitive appraisals associated with happiness are mostly positive (e.g.,

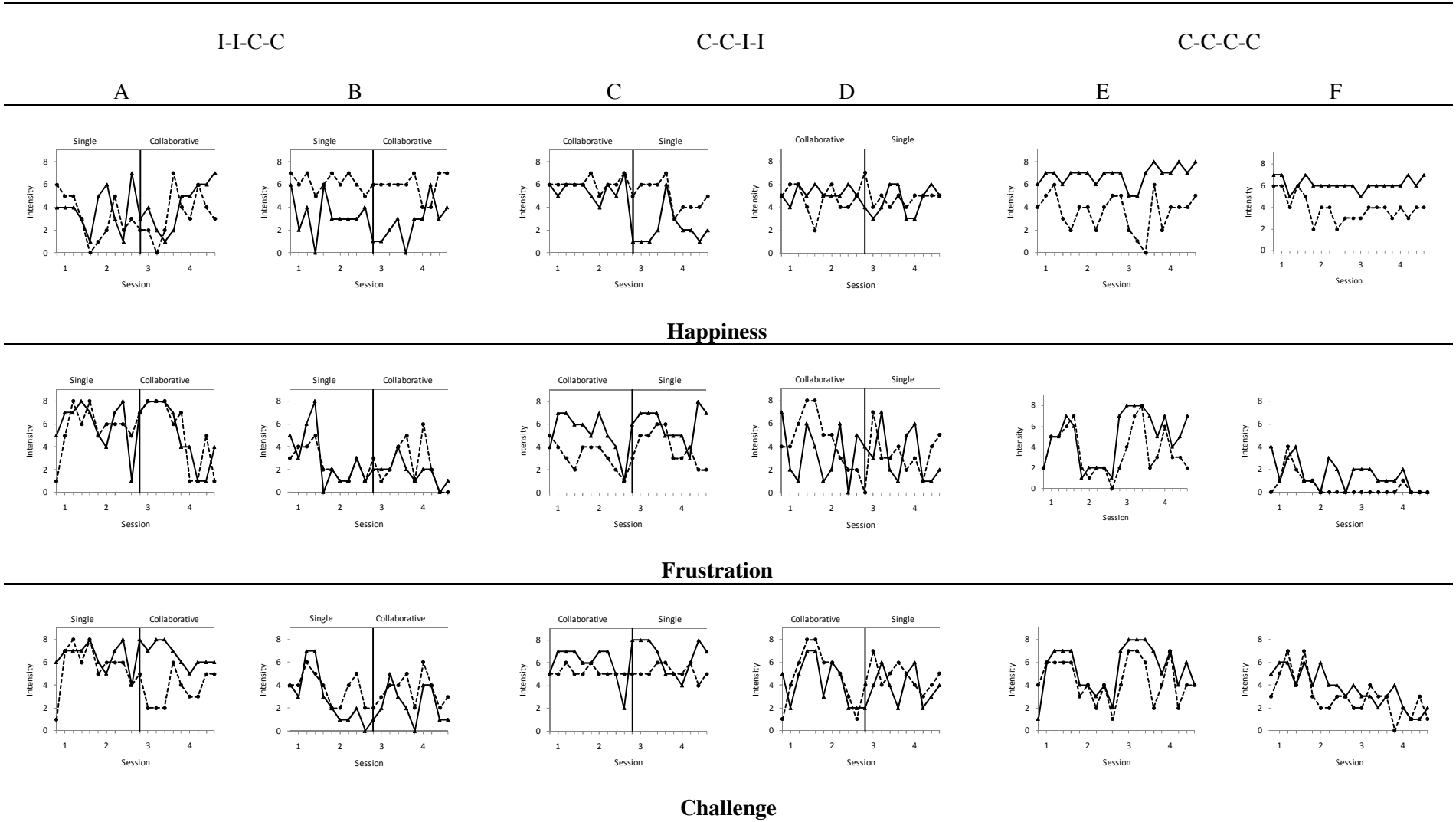
[3] The individual's scores prior to the session were not plotted to reduce complexity. However, the histograms of these scores (Appendix E) show that the participants varied in their prior happiness, but no extreme cases were observed. The ratings of prior frustration tended to be lower. In the case of challenge, most participants across sessions reported their prior feelings of challenge as not at all or with a low intensity.

[4] Interest and hopeful were not analysed because they are 'positive' emotions. Additionally, they were highly correlated with happiness across participants. Frustration and challenge were also correlated but as explained, frustration is totally negative and challenge has both negative and positive components. Correlations between emotions are shown in Appendix F.

pleasantness, control of the situation and little effort and certainty); whereas those associated with frustration are mostly negative (e.g., unpleasantness, lack of control, extreme effort and uncertainty). Challenge combines negative appraisals like low pleasantness and high effort with positive ones such as control of the situation and certainty (C. A. Smith & Ellsworth, 1985; C. A. Smith & Ellsworth, 1987; Tong et al., 2007).

Figure 4.2 shows the self-reports of happiness, challenge and frustration of the individuals on the six dyads across the four sessions. There is a wide range of variation patterns. Especial attention was put on the individuals' variation over time, and in the similarity between the variation patterns of dyad partners.

Happiness. Two dyads did not vary. In one case partners usually reported similarly high and stable levels of happiness, playing together or individually (D). Partners in other case constantly reported different levels of happiness, even collaborating all the time (F). Other dyads varied more, and most of the times the partners reported different emotions, regardless of playing individually or collaboratively (B, E). Changing from individual to collaborative mode seemed to change the happiness in two dyads. In one case the partners increased their reports of happiness gradually with move from individual to collaborative mode (A), and in other case the partners reported less happiness after moving from collaborative to individual mode (C). Thus, happiness could vary in various ways or vary very little. Moreover, partners often reported happiness differently. This suggests that for some individuals, enjoyment of the game could be relatively independent of changes in the game situation.



Note: Legends are not included in the graphs to simplify the layout. On each dyad, the solid line represents Member 1, and the dotted line represents Member 2. For example in Dyad A, the solid line is A1 and the dotted line is A2.

Figure 4.2 *Self-reported happiness, frustration and challenge.*

Frustration. The variation and intensity of frustration gradually decreased in one of the dyads that collaborated all the time (F), whereas partners in the other dyad that also collaborated all the time (E) oscillated frequently, and except in some trials, partners often increased or decreased their reports of frustration together. In some dyads that played some sessions singly and others collaboratively (A, B, and C), partners usually expressed similar frustration whilst playing collaboratively, although not always in a consistent manner Finally, Dyad D was the only case when partners' frustration varied in dissimilar ways in most occasions across sessions. This suggests that frustration varied more than happiness, which probably means that frustration was more linked to the game play events.

Challenge. Partners in dyads E and F collaborated all the time and partners reported similar increases and decreases of challenge across sessions, but in E partners oscillated whereas in F the challenge decreased over time. In dyads A and B, moving to the collaborative mode did not make the similarity between partners more consistent, because they could report similar levels of challenge in individual and collaborative sessions. In dyads C and D, the similarity between partners was more consistent before moving to the individual mode. That challenge varied substantially probably indicates that the changes of this emotion were linked to the changes in the game play, and that these changes were likely to be shared with a partner.

Thus, the main feature that seemed to distinguish challenge is that it varied more than happiness. Challenge did not necessarily vary more than frustration, but partners' challenge went increased or decreased together in a more consistent way.

4.2.5.2 Changes in the similarity of challenge

RQ2 asked *How did affective similarity change as partners played a collaborative computer game?* This question was answered with a graphic analysis of partners' affective similarity in the case of challenge. It has been explained that challenge is the

main interest of the study because of its theoretical importance in technology-enhanced learning. Therefore, other emotions are not covered, which also reduces complexity. The previous section showed that the similarity between partners distinguished challenge from happiness and frustration. Figure 4.3 shows this more directly by plotting the dissimilarity between partners' reported challenge in collaborative sessions.

There were no apparent effects of time for any dyad. That is, their similarity did not grow as they collaborated more. Not even dyads E and F, that collaborated in the four sessions. Instead, the dissimilarity between partners was regularly small (<2), and rarely varied more than two points, suggesting that partners felt similarly challenged in most of occasions, although there are some atypical cases.

For example, partners in Dyad A reported challenge differently during Session 3 (their first collaborative session), but then converged in Session 4. In other dyads, occasions when partners reported challenge differently were rare, for example, Dyad D in the very beginning of Session 1, Dyad E in the last part of Session 3 and Dyad F in the beginning of Session 2 and the end of Session 3.

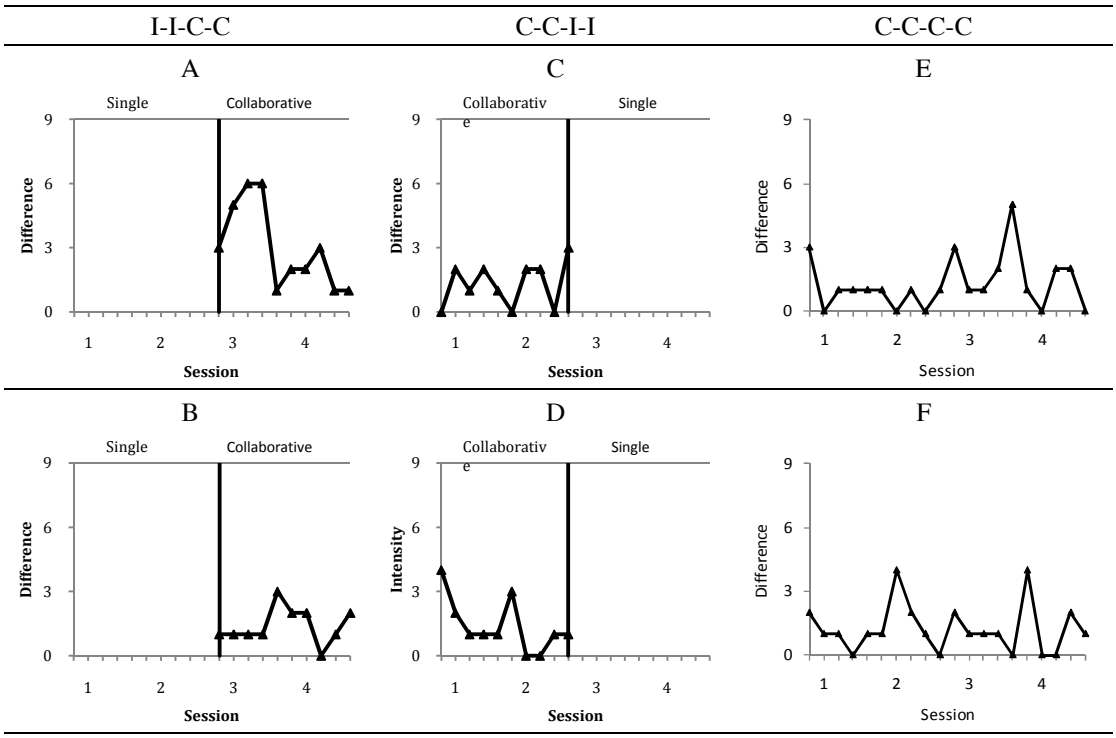


Figure 4.3 *Dissimilarity between partners' challenge in collaborative sessions*

4.2.5.3 Changes in the awareness about the challenge of a partner

RQ3 asked *How did affective awareness change as partners played a collaborative computer game?* Again, the analysis that answered this question focused on challenge, and it consisted of a graphic analysis of the partners' *inaccuracy* at estimating the challenge of a partner. That is, the difference between the estimations made about the challenge intensity of a partner and the challenge actually reported by that partner.

Figure 4.4 shows the individuals' *inaccuracy* at estimating how challenged their partners felt. Lower differences mean more accuracy, interpreted as more awareness concerning the challenge of the partner. As in the case of similarity, there are no apparent effects of time. Awareness did not grow for any individual. Among those who collaborated with experience of the game but not with the partner (I-I-C-C), the individual game play (common previous experience) did not facilitate the mutual

awareness between partners. Those who collaborated on every session (C-C-C-C) did not grow their awareness over time.

Partners' inaccuracy typically overlapped, or was very close, to the similarity with the partner. Partners' inaccuracy was typically low, it rarely increased and if it did, the dissimilarity also increased. This suggests that individuals consistently thought they felt as challenged as their partners, which happened to be an accurate estimation as partners tended to make similar reports of challenge. There was one atypical case. In dyad A, during Session 3, partner A2 is more inaccurate when she and A1 were more dissimilar. In other words, she seemed to be more aware about the challenge of A1 when they felt differently challenged.

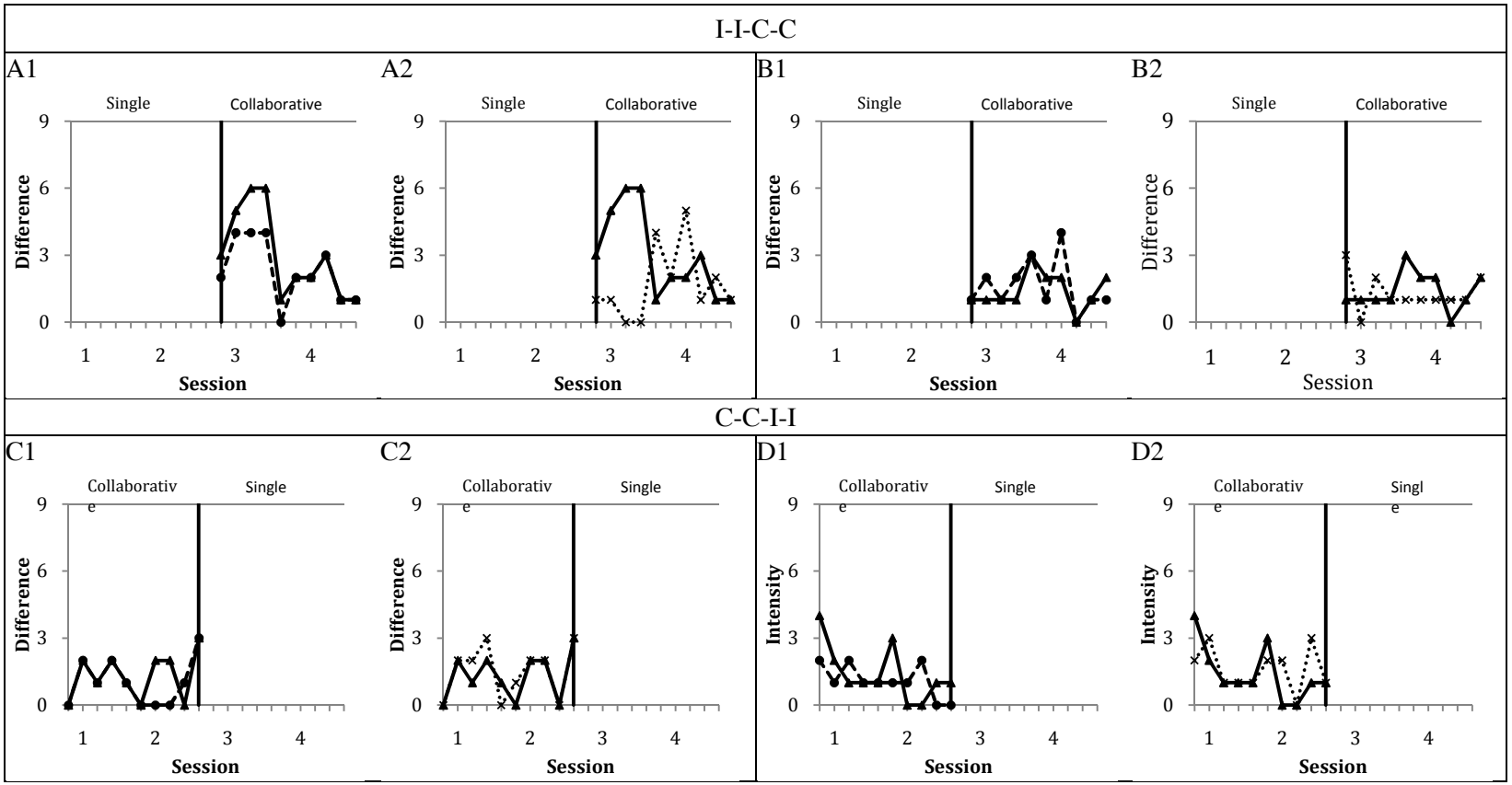


Figure 4.4 *Inaccuracy of the individuals' estimations about the challenge of a partner, compared with the emotional dissimilarity between partners (solid line) (continues in next page)*

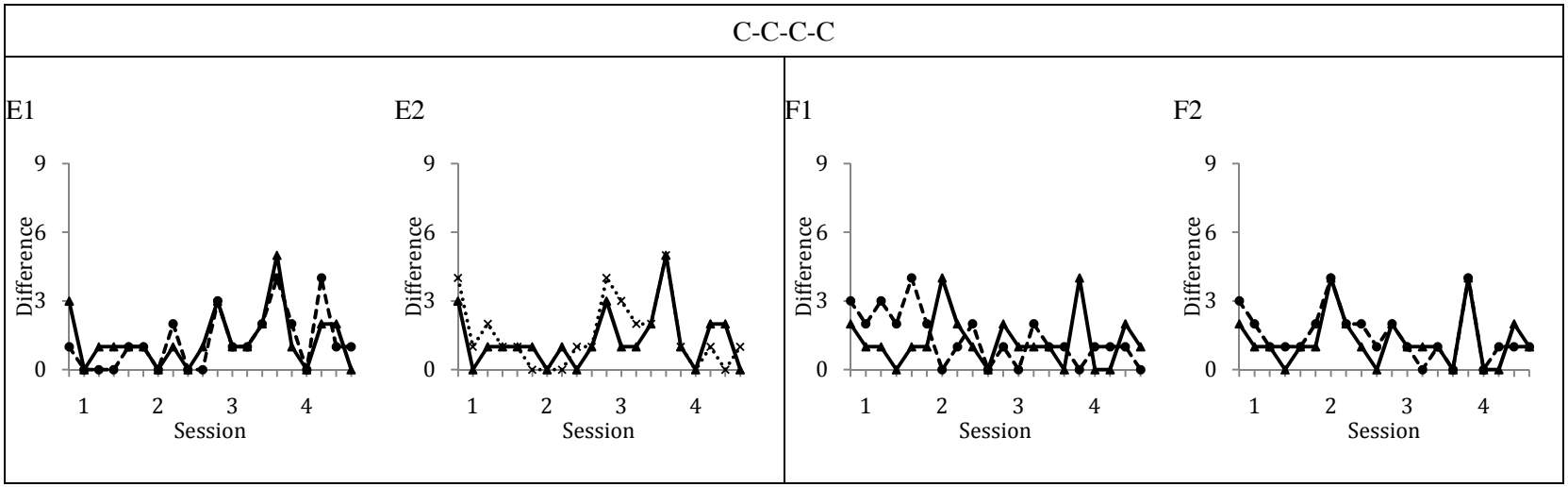


Figure 4.5 (Cont.) *Inaccuracy of the individuals' estimations about the challenge of a partner*

4.2.5.4 Factors associated with challenge variability

RQ4 *asked what were some of the factors associated with changes in challenge?* In previous sections we have seen different patterns of variation in the individuals' reported challenge. One main aspect is that the variation of challenge was often similar between partners of a dyad. This similarity was accompanied by an accurate estimation about the emotions of a partner, based on a consistent tendency to estimate the emotions of a partner on the basis of their own emotions. This section searches for some game play factors that might change from moment to moment, and that could potentially be associated with the increase and decrease of challenge.

A sample of moments when challenge increased and decreased more were selected and analysed intensively, focusing on the following factors and research questions:

- *Experience:* in which session did the increase or decrease of challenge occur, and how much experience of the game and/or the partner did they have?
- *Intensity and change:* How much did the challenge intensity of partners' change?
- *Similarity:* Did partners' challenge reports become similar or dissimilar as a consequence of the change?
- *Awareness:* Did partners become more or less accurate at estimating the challenge of one another?
- *Context perception:* How did partners appraise the game situation?
- *Game situation:* What is going on in the game?
- *Performance:* How well were the players playing the game?
- *Social situation:* How were partners interacting?

Data selection

The analysis focuses on trials when collaborators played together. In total, dyads played 16 collaborative sessions (4 dyads played 2 collaborative sessions each, and two dyads played all four). A game play session had 5 trials of 2-3 minutes. Consequently, a sample of trials with the largest increasing and decreasing changes in challenge was selected for analysis. The measure of change was the difference between the summed scores of partners' challenge in a trial (t) with respect to a previous trial (t_{-1}). The first trial on each session was discarded because it had no change reference, leaving a pool of 64 collaborative trials suitable for analysis (16 sessions x 4 trials).

For each dyad, the two trials with the largest challenge increase and the two trials with the largest challenge decrease were selected as cases for detailed analysis. Thus, 24 trials were selected, representing 37.5% of the data pool. This approach of sampling 30% of the data is consistent with other studies (e.g., Järvenoja & Järvelä, 2005) in that it helps to economize the analysis of computer-supported collaborative learning activities with video data whilst hopefully still retaining a large enough sample for analysis.

Experience

In which kind of session did the increase or decrease of challenge occur? Table 4.3 shows that the increases tended to occur more in the beginning of the game play. Most cases of increase occurred in Session 1. No increases occurred in Session 2, and similar increases occurred in Session 3 and Session 4.

Partners who collaborated with experience of the game but not of each other (I-I-C-C) increased in both Session 3 and Session 4. The magnitude of these changes was different depending on the dyad. Dyad A had smaller increase than Dyad B.

Partners who collaborated without experience of the game and one another (C-C-I-I) increased only in Session 1, although Dyad D increased more than Dyad C. Amongst dyads who played with both experience of the game and one another (C-C-C-C), Dyad E increased in Session 1 and Session 2, and Dyad F increased only in Session 1.

Challenge decrease tended to occur most frequently in Session 2. Amongst partners who collaborated with experience of the game but not of one another (I-I-C-C), the challenge decreases occurred similarly in Session 3 and Session 4. Amongst partners who collaborated without experience of the game and one another (C-C-I-I), challenge decrease occurred in Session 2 only. Amongst dyads that played with both experience of the game and one another (C-C-C-C), Dyad E increased in Session 2 and Session 4, and Dyad F decreased in Session 1 and Session 2.

To summarize, it seemed like the largest changes in challenge, both in terms of increase or decrease, occurred during the beginnings of the game play. This might be in part due to players only limited experience with the game and/or with their partner. It seemed that having more experience with the game, although not necessarily with the partner, helped to reduce the felt impact of a potentially challenging situation, hence challenge change during Session 3 and Session 4 was not concentrated in one individual session.

Table 4.3 Challenge change as a function of the type of session (Individual or Collaborative)

		Session 1	Session 2	Session 3	Session 4	Total
				Increase		
I-I-C-C	A			3	2	5
	B			4	8	12
	Total			7	10	17
C-C-I-I	C	3				3
	D	9				9
	Total	12				12
C-C-C-C	E	7			5	12
	F	8				8
	Total	15			5	20
Grand Total		27		7	15	49
				Decrease		
I-I-C-C	A			-4	-2	-6
	B			-2	-5	-7
	Total			-6	-7	-13
C-C-I-I	C		-5			-5
	D		-7			-7
	Total		-12			-12
C-C-C-C	E		-5		-8	-13
	F	-5	-2			-7
	Total	-5	-7		-8	-20
Grand total		-5	-19	-6	-15	-45

Challenge intensity and change

How much did the challenge intensity of partners' change? In moments of challenge increase, all individuals reported moderate or high challenge intensity (>=4), which often resulted from a small increase (1 to 3, 15 cases) usually shared with the partner, except for atypical cases when the partner did not change from the previous trial (A1-4,4; C2-1,2 and C1-1,3), increased more than usual (A2-3,5; D2-1,3; E1-1,2 and B1 and B2-4,2) or minimally decreased (A2-3,5).

In the moments of challenge decrease, most participants reported either small (<=3, 12 individuals) or slightly moderate (4 or 5, 11 individuals) challenge. The majority of

participants had small decreases (-1 to -3, 18 cases) usually shared with the partner, except for atypical cases when the partner did not change from the previous trial (B-3,4; C-2.4; C-2,5 and F-2,3), decreased more than usual (E2-4,3) decreased but remained highly challenged (A1-3,2) or increased but still reported little challenge (E1-2,5).

To summarize, at the selected moments of increased challenge, individuals reported moderate or high challenge levels, whereas the challenge reported in moments of decreasing challenge was moderate or low. Moments of increased and decreased challenge typically involved small changes (increase or decrease), often shared between partners. Only a few individuals did not change, or changed atypically.

Similarity

Did partners' challenge intensity become similar or dissimilar as a consequence of the change in their reports of challenge? In the trials with challenge increase, all dyad partners reported challenge similarly (dissimilarity =<2). However, this similarity resulted from different configurations of change. In most cases (10) the dissimilarity between partners decreased or increased a little, or remained as it was in the previous trial. In one atypical case (Dyad A-3,5), the dissimilarity increased more than usual (change=5).

In the trials with challenge decrease, all dyad partners reported challenge similarly (dissimilarity =<2). In most cases (11) the dissimilarity decreased or decreased a little, or did not change at all. In one atypical case (Dyad A-3,5) the dissimilarity between partners increased more than usual.

To summarise, the challenge reported by partners in the same dyad was typically similar, both in moments of increased or decreased challenge. Often, partners were already similar in the previous trial.

Awareness

Did partners become more or less accurate at estimating the challenge of one another? In moments of challenge increase, most individuals made accurate estimations about the challenge of their partners (inaccuracy <=2). The inaccuracy of 20 individuals increased or decreased a little (difference = 1 to 2, or -1 to -3) or did not change. The rest were atypical cases when individuals were more inaccurate than usual (B1-4,2 and F1-1,5), and when dyad partners changed asymmetrically and one was much more accurate than the other (A-3,5).

In moments of challenge decrease, most individuals made accurate estimations about the challenge of their partners (inaccuracy <=2). The inaccuracy of 21 individuals increased or decreased a little (diff= -2 to -1 and 1 to 2) or did not change. Atypical cases were individuals who became more inaccurate than usual (A1-3,2; A2-4,2; E1-4,3).

It was also interesting to investigate the relationship between partners' similarity and awareness. Amongst the cases of increased challenge, the inaccuracy of 21 individuals was small (0 to 2) when the dissimilarity with the partner was also small (0 to 2). Only three individuals (A2-3,5; B1-4,2 and F1-1,5) had relative larger inaccuracy when their dissimilarity with the partner was small.

In cases of decreased challenge, the inaccuracy of 20 individuals was small (0 to 3) when the dissimilarity with the partner was also small (0 to 3). Two atypical individuals (E1-4,3; A2-4,2) were more inaccurate when the dissimilarity with the partner was small. Other two atypical cases come from the same dyad (Dyad A, 3,2), partners were more dissimilar and one was more accurate than the other.

To summarise, most individuals made accurate estimations about the emotions of their partners, both in moments of increased and decreased challenge. Most

individuals were already accurate in the previous trial, and their accuracy was closely related with the similarity with the partner. These results are consistent with the graphical analysis of the general variability of affective similarity presented in section 4.2.5.2.

Context perception

How did partners appraise the game situation? Medium to high appraisals of effort and ability, as well as minor interface problems, were typical amongst cases of increased challenge. Other appraisals were reported differently depending on the increase or decrease of challenge. Typically, the uncertainty reported by individuals was medium to high in moments of increased challenge, and low in moments of decreased challenge. Also, high understanding was typically reported in moments of challenge decrease, whereas in moments of challenge increase, there were no typical responses.

Effort. Most individuals reported medium to high effort (>=4) in moments of increased 5 (19 cases) and decreased challenge (20 cases). Partners were usually similar, except for one dyad amongst cases of increased challenge (Dyad D-1,4) and four dyads amongst cases of decreased challenge (A-3,2; E-2,5; F-1,4 and F-2,3).

Ability. Most individuals reported medium to high levels of understanding, both in moments of increased (14 cases) and decreased challenge (20 cases). Partners were usually similar, except for three dyads in cases of increased challenge (D-1,3; F-1,4 and F-2,3), and three dyads in cases of decreased challenge (A-3,2; B-3,4 and F-1,4).

[5] For Dyad C, the moments of increased challenge selected for analysis occurred in Session 1. The data about their appraisals was not collected in this session due to an error. Therefore, in this section, the maximum number of cases of increased challenge with data about individuals' appraisals is 20, and not 24 as in the cases of decreased challenge.

Interface problems. Most individuals reported few problems controlling their characters (<=3), both in moments of increased (13 cases) and decreased challenge (18 cases). Partners were usually similar, except for 4 cases of decreased challenge (A-4,4; A-3,5; D-1,3; and E-4,2) and 3 cases of decreased challenge (A-4,2, A-3,2; and D-2,3).

Uncertainty. During moments of challenge increase, most individuals (12) reported medium to high uncertainty, and partners were usually similar, except for three cases (A-3,5; D-1,3; F-1,5). In comparison, during moments of challenge decrease, most individuals (15) reported little uncertainty and partners were usually similar, except for three cases (A-3,2; C-2,4; D-2,4; and F-2,3).

Understanding. During moments of challenge increase, an almost equal number of individuals reported medium to high (9) or little (11) understanding. Partners were usually similar, except for some atypical cases (A-35, B-3,3, D-1,3). During moments of challenge decrease, most partners (18) reported high understanding, and partners were usually similar, except for one case (C-2,5).

Game situation, performance and social situation

What is going on in the game?, How well were the players playing the game?, and How were partners interacting? To answer these questions, the 24 video sections of 2-3 minutes of game play that corresponded with the sampled trials of increased and decreased challenge were analysed qualitatively.

Because the trials were purposefully selected as instances of increased and decreased challenge, the analysis was directed to explain why challenge changed, abstracting the key features of each case rather than trying to find general principles across cases. This sort of approach is common and useful to study computer-supported collaborative learning. For example, Hmelo-Silver et al. (2007) selected

portions of video recordings of six successful peer-learning groups and observed each portion intensively to abstract the key features of the social interaction and usage of the technological tools.

Analysis procedure

First, each video episode was summarised in terms of:

- *Game situation*. The mechanisms of LSW2 that partners faced in the episode (e.g., features of a puzzle and key game events)
- *Performance*. The fluency with which partners responded to the mechanisms of the game in order to resolve the puzzles and keep advancing (e.g., effective execution of the steps, focus on relevant steps, systematic strategies). This analysis complemented with the quantitative performance score described in section 4.2.4.7
- *Social situation*. The way in which partners interacted with one another (e.g., proposing ideas, explanations, using backchannels)

The summaries of these features are included in the trial profiles, along with the quantitative information about partners' emotions, affective similarity, affective awareness and perception of the context (Appendix G).

Second, each case profile was reviewed in order to abstract key situations likely to increase or decrease challenge, conserving the particularities of each case. Another researcher who had both experience with qualitative analysis of CSCL data and with LSW2 also carried out this procedure. Finally, the interpretations of the researchers were integrated through discussion and revisiting the data as necessary (Robson, 1997). Below, the situations likely to have increased or decreased challenge are presented in separate sections.

Cases of increased challenge

Disruptions in the fluency of collaborators' performance were typical in these cases. But these disruptions were prompted by different game mechanisms depending on particular cases. In terms of the social situation, constantly silent interaction was observed in only one case (A-3,5). Partners in the rest of the cases occasionally interacted silently or using only backchannel, but only whilst fluently making routine activities like walking around, shooting enemies, or manipulating blocks or levers. Typically, partners talked more when their performance was less fluent, which occurred in three situations likely to provoke feelings of challenge:

(1) *Lacking 'insight'* when confronting puzzles with *hidden elements* (2 cases) or *complex rules* (3 cases)

(2) *Overt confusion* when the game situation included a *key game event* (3 cases) or during a puzzle that required *routine activity* (2 cases)

(3) *Ineffective game play* when a puzzle required *coordinated action* (2 cases).

Lacking insight

In five cases, the fluency of partners' performance was disrupted because they struggled to figure out a puzzle with hidden elements or complex rules. They recognized what to do, but spent most of the episode or all of it struggling to figure out how to do it.

Lacking insight in puzzles with hidden elements. In two cases, partners' struggled to figure out a puzzle because the key elements were hidden.

In one case (A-4,4) the partners had to assemble a bridge using blocks only accessible by jumping onto a stone, which involves interdependence because only one

of them can do that. They seemed to recognise they needed a bridge but struggled to figure out how to make it, although their interaction included positive features such as explanations and support. Finally they found the blocks incidentally. For instance, in the following segment partners approach the stone where the hidden blocks are. A2 accurately explains the mechanics of this step to A1; but none of them seems to know the blocks are there:

```
[Trying to jump onto the stone, only A2 can do that]
A2: [jumping onto the stone] so, yeah…
A1: [jumping] ok…
A2: now, jump up
A1: [as she falls in the gap] I can't
A2: (inaudible) the double jump
A1: [tries to jump and falls]…
A2: [jumping off the stone] If you can't do it means it won't
   be able to be done… so maybe that's not possible
```

The following segment shows that A1 spotted the blocks incidentally and quickly realised how to use them, which prompted A2's actions:

```
A1: [standing near the stone]  can you jump in the other side?
A2: [jumps onto the stone, near the hidden blocks]   probably
   not without you, but let's have a look
A1: I think those (the blocks) are the things to build the
   bridge
A2: [moving the blocks, making the bridge]  yeah... ahh… yes…
```

In the other case (B-4,2), partners had to find a panel to try and cross a swamp, which is an interdependent step because they have to walk together to do so. They realised they needed a panel, but not that the panel was hidden and instead of looking for it, engaged with distracters or walked together in the wrong places exchanging explanations and suggestions that not necessarily leaded to the solution. In the following example, partners' interaction includes positive attributes such as the explanations of B1, responded with actions and suggestions of B2. However, their discussion does not help them to gain insight about the hidden nature of the panel they need:

```
B1: so this (a panel) can definitively be only activated by him
   (the droid)
B2: [goes and gets the droid]
```

```
B1: [standstill] yeah... but he can't jump (there is a step
   that impedes the droid to reach the panel)
B2: [standing in the step] try and move him a bit
B1: [goes to move the droid] ok…
B2: [as the droid does nothing] no… is not the right way
```

Lacking insight in puzzles with complex rules. In three cases, the partners struggled to figure out puzzles where the key elements are visible but the rules for using them may not have been apparent. These puzzles consist of only simple steps or sometimes combinations of simple and interdependent steps.

In one case (B-3,3), partners had to liberate a droid by pushing a turnstile that controls a vacuum, which takes the droid out of a cage. Only simple steps are required (e.g., pushing the turnstile, operating panels). At first they silently manipulated the elements of the puzzle without an apparent strategy, and often engaged with distracters (e.g., a useless box). Partners figured out some key mechanisms (e.g., the relationship between the turnstile and the vacuum, how to operate the vacuum) by trial and error, exchanging practical suggestions and communicating with backchannel. For instance in the following segment, partners manipulate the turnstile without discussing their actions or the mechanics of the puzzle when B2 incidentally makes insight about the relationship between the turnstile and the panel, and tells B1 what to do without explaining her why:

```
B1: [goes to push] maybe I should push more [pushes the
   turnstile and then the panel gets blocked again]
B2: [notices the panel blocks] uh, right, push again… it needs,
   is, this…
B1: which way?
B2: [stands in from the panel] back that way, a little bit
B1: [pushes]…
B2: [panel is liberated] that's right, stop... oh it's r2d2
   (the droid), right
```

In other two cases, partners had to use a crane to pass the droid across a gap, and to do that they needed to use the crane to eliminate some enemies and free a lever. This involved simple (e.g., jumping and operating panels) and interdependent steps (e.g.,

one partner uses the crane whilst the other controls the robot). All elements were already visible and partners realized they needed the crane, but failed to figure out how to use it. In one case (D-1,4), partners spent all the episode solving this puzzle, and accompanied their parallel manipulations of the crane and other irrelevant elements with occasional brief explanations, together with overt misunderstanding. In the following segment partners accompany their manipulations of the crane and the elevator (a distracter) with explanations about the sort of things the crane does; which is positive but does to help them to gain insight of what to do:

```
D2: [jumps into the crane]...
D1: [approaching a useless elevator] I though I can be...
   what's this thing?
D2: [moving the crane] I can go left and right
D1: [standing in the elevator] but you can't go forwards and
   backwards
D2: that's ... I need to know
```

In other case (Dyad F, trial 1,5), partners' talk included expressions of misunderstanding that reflected their struggle to figure out the puzzle, as in the following segment:

```
D1: [stands next to the crane]
D2: [walks around] no idea what to do...
D1: I just can't do anything!
D2: I do not know... not very easy
```

But they also exchanged suggestions to coordinate their actions in organised, but useless, strategies. For instance, in the following segment the partners have not gained insight of how to solve the puzzle, and focus on implementing a useless strategy:

```
D1: [switches to droid and flies] oh, oh, oh... he can like,
   fly!
D2: [laughs]
D1: [flies on the gap and falls] I think you can pick me up
   like that! If I fly into the middle
D2: that's right let me get back [jumps into the crane]
```

Ineffective game play

In two cases, the partners' performance was disrupted because one of them had problems controlling her character. This occurred in game situations where the requirement of rewardable and interdependent steps or the shared screen, highlighted the need for coordinated game play. They seemed to know what to do and how to do it, but could not do it because a partner was unable to do her part effectively.

Ineffective game play when coordinated action was required. In one case (E-4,2), partners tried to cooperate in a rewardable step. There were two levers and they tried to pull one each, but one partner could not do that because of control problems. They remained standstill in front of the levers, or walked around, unable to keep advancing. In the end, one partner pulled the two levers. They offered practical suggestions and ideas to resolve this situation. In the following segment, E1 suggests coordinated action to pull the levers down, but E2 is unable to participate because she has problems with her character and requests and receives practical advice from E1:

```
E2: [tries to pull the lever but her character not responding]
   c'mon
E1: maybe we have to do it at the same time. 1, 2, 3 [pulls the
   lever down]
E1: now go.
E2: [walking around] no… 2 (the button to press)?
E1: 2
E2: [moaning] oh…
…
E1: [breaking things around, then pulls the right lever]
E2: [standing in front the right lever, unable to pull it], no…
E1: [pulls the right lever, then runs to the left lever and
   pulls it down. The door opens, completing the puzzle]
E2: [cheers]
```

In the other case (A-3,5), partners had to jump across platforms to reach the top of a building, which required interdependent steps. For example, one partner uses her special ability to open a platform so the other partner can jump onto it and vice versa. In this case, one partner had problems to do her part, which stops the other partner who is also unable to move away because of the shared screen. The partner with control problems kept trying whilst the other one stood still. Interestingly, partners did

not talk about this. In fact, this is an atypical case, since is the only one in which partners interacted almost silently during most of the trial.

Overt confusion

There were five cases in which partners were overwhelmed by the game situation and acted in disconcert, denoting overt confusion that disrupted their performance. This occurred in a puzzle that required simple steps but also included a key game event and in a puzzle that required simple steps in routine activity. Partners seemed to be uncertain about what to do.

Overt confusion during a key game event. In three cases (D-1, 3; E-1, 2 and F-1,2), partners showed overt confusion in a corridor where they find the droids for the first time and one character leaves the scene for no apparent reason. This puzzle is resolved with simple steps (i.e., using the droids to operate panels and cross the corridor). However, partners reacted to this situation in a disorganised manner. They switched from robot to character randomly, or walked back searching for the missing character. Their interactions denoted confusion and included explanations and practical suggestions about how to control the droids.

Overt confusion is illustrated in the following segment from case F-1,2. F1 was controlling the character that left for no apparent reason, and openly queries about it; to which F2 responds offering some explanations that seem to diminish the worries of F1:

```
[One character leaves for no apparent reason]
F1: [walks around] oh wait... where?
F2: I think you are now me and now I'm the robot
F1: where is me? [laughs]
F2: [laughs] you are runaway and he (the droid) is going to
   follow us [walking back towards the boxes room] is ok. Just
   stay like this
F1: ok, [laughs] I like you now. Strange world
```

The following segment shows a similar form of overt confusion in a different case (E-1,2). E1 was controlling the character that left and questions about it, to which E2 responds with an explanation:

```
E1: wait, where has my character gone?
E2: now I am this one [she has gained control of r2d2)
E1: wait, whare's my character gone?
E2: [laughs]
```

Overt confusion during routine activity. In two consecutive episodes of the same dyad (C-1,2 and C-1,3), partners showed confusion in a puzzle where they had to cross a corridor doing simple routine steps like shooting enemies and crossing doors. In fact, they just had to cross a door to complete the puzzle. Instead, they engaged with distracters (e.g., useless levers) and walked back to puzzles already resolved. Their talk consisted of commentaries that accompanied their manipulations of irrelevant elements or elements that they had already used. As in the following segment, C2 wonders if they have done all the necessary steps, and repeats some actions already done whilst C1 just walks around:

```
[In a previously solved puzzle, a corridor with levers]
C2: have we pulled down all the levers?
C1: mmhh
C2: [trying to pull down a lever already done] is not
   working...
C1: [walking around]...
```

They also expressed confusion and, moreover, this confusion was increased when they misinterpreted the hints. For instance:

```
C2: [reading hints that apply for a different puzzle] boxes
   with yellow stripes
C1: [walking around] I do not understand...
C2: [walks forward, towards the door]
C2: [in a distracter window] can we get back there or
   something? [to the previous puzzles]
C1: [walking back]...
C1: I thought it meant to be boxes.
```

Interestingly, this was one of the two cases amongst all the analysed cases (both of increased and decreased challenge) in which participants showed off-task talk, referring to the overall intentions of the study, presumably a consequence of spending

almost two complete trials (aprox. 6 minutes) in a situation where they thought they could not do anything:

```
C2: I think is done on purpose, to get us angry... is not
   working on purpose (walking around)
C1: [laughs]
C2: oh, he (experimenter) is recording this don't he?
C1: [laughs]
C2: recording how terrible we are…
```

Cases of decreased challenge

Fluent performance was typical in these cases, but it was displayed under different game situations. In terms of the social situation, extended sequences of verbal interaction were rare. Only in one case the partners showed a constantly abundant verbal interaction (F-1,4). The typical verbal interaction consisted of brief and dispersed exchanges of various sorts (e.g., backchannel, commentaries, suggestions) that accompanied collaborators' fluent game play. This occurred during three situations likely to decrease challenge:

(1) *Making insight* in puzzles with *hidden elements* (1 case) or *complex rules* (4 cases)

(2) *Effective game play* in puzzles with *hidden elements* (1 case), *complex rules* (1 case) or *routine activity* (1 case)

(3) *Completion* of a puzzle that required *complex rules* (3 cases) or highlighted *coordinated action* (1).

Making insight

In five cases, partners rapidly figured out the mechanisms of a puzzle and sustained an effective game play that permitted them to keep advancing in the game. This occurred in game situations when a puzzle included hidden elements or complex

rules. Partners seemed to know what to do and how to do it. Some of these cases involved puzzles also seen in cases of increased challenge.

Making insight during puzzles with hidden elements. Partners in one case of increased challenge (A-4,4) struggled to solve a puzzle that requires assembling a bridge using blocks only accessible by jumping onto a stone, which involves interdependence because only one partner can do it. Partners in one case of decreased challenge (B-4,4) were faster resolving this puzzle because their understanding of the game and coordination helped them to rapidly find the blocks. For instance, in the following segment, B2 recognises that B1 might be the one who can jump onto the stone, showing understanding of the characters' complementarity. Then she prompts B2, who responds effectively and once upon the stone, quickly makes insight about the blocks and uses them effectively:

```
B2: [trying to jump onto the stone and failed because this for
   B to do] mhh… I think is for you
B1: ok [walks towards the stone]
B1: ups… oh… [jumping onto the stone]
B1: [building the bridge with the blocks] ups, I built us a
   bridge
B1: great (walking towards the bridge)
B2: that's handy
```

Making insight during puzzles with complex rules. In four cases, partners resolved, in a relatively rapid manner, puzzles where the key elements are visible, but the rules to resolve the puzzle are not apparent.

Two of these cases involved a puzzle that partners in one case of increased challenge (B-2,3) struggled to resolve. The objective is to liberate a droid by pushing a turnstile that controls a vacuum, which takes the droid out of a cage. Partners in the decreased challenge cases quickly figured out the usage of the turnstile and fluently

executed the remaining steps. Then they continued with the following puzzle or even further.

In one case (A-4,2) the partners briefly engaged with distracters until one of them figured out how to use the turnstile, and executed most of the remaining steps whilst the other partner followed her, exchanging only some requests for advice and commentaries. The following segment illustrates that partners seemed to rapidly gain insight. First A1 realised the relationship between the turnstile and the panel, then A2 seemed to 'know' what to do –operate the panel- and did so promptly, requesting and receiving advice from A1:

```
A1: [puts the vacuum upon the cage, unblocking the panel that
   activates the vacuum]...
A2: all right...
A2: ... what do I press? (In reference to the button she needs
   to press for controlling the droid that operates the panel)
A1: [standing] press 1
A2: [operates the panel, taking the droid off the cage]...
A2: [cheers]
A1: [standing]...
```

In the other case (E-4,3), partners focused on the manipulation of the key element of the puzzle, namely the turnstile, communicating with backchannel and short commentaries. This sort of minimal communication seemed to accompany moments when they gained insights of the puzzle together. In the following segments E1 and E2 seem to gain insight of the relationship between the turnstile and the panel, and express this understanding with short incomplete sentences.

```
E1: [pushes the turnstile and puts the vacuum upon a cage,
   unblocking the panel that controls the vacuum] hold on… oh
   we need to… oh I see [keeps pushing and the panel is blocked
   again]
E2: [standing] oh no no… yea yeah that's…
…
E2: when this comes off is when… (about the unblocked panel)
E1: …over his this… [pushes the turnstile towards the cage]
E2: [standing in front of the panel]
E1: [puts the vacuum upon the cage and unblocks the panel] is
   moving over his like, cage…
E2: yeah, yeah... oh I see [operates the panel and the vacuum
   takes the droid off the cage] yeah...
```

In other two cases, partners quickly figured out a puzzle not observed in cases of increased challenge. They had to open a series of doors making simple steps such as operating panels or pulling levers. The solution is to figure out is that the doors open sequentially. In one case (C-2,4) partners rapidly figured out the puzzle and, although they showed little problems controlling the droids, their mutual suggestions helped them to perform fluently. The following segment illustrates how partners acted as if they knew what to do (i.e., having made insight). C1 seems to know she needs to operate a panel, but she can't and makes C2 aware of it, and in turn, C2 reacts promptly:

```
C1: [tries to operate the panel, she can't because she needs
   the other droid] I am not making anything
C2: oh wait here with that one [switches to the droid that
   opens the panel]
C1: him?
C2: yeah [operates panel]
```

In the other case (D-2,4), partners also figured out the puzzle rapidly, and fluently manipulated the elements in the puzzle with barely any talk, except for occasional request for advice. The following segment illustrates that the partners' insight might have reflected on their fluent game play, usually accompanied by short exchanges and backchannel:

```
D2: how do you get through the door? (the blocked panel in door
   3)
D1: press 2?
D2: ... no (tries to operate the panel and she can't)
D1: ...
D2: ... (switches to droid and operates panel)
D1: ... (goes into room 1)
D2: ... go (gets into room 1)
D2: ... (trying to pull the lever)
D1: do we have to ... (in reference to the lever)
D2: yeah ... (gives way to D1)
D1:  ... (operates the lever)
```

Effective game play

In 3 cases, the partners showed an effective game play that could benefit performance if applied to elements useful to solve a puzzle, but it can also disturb it if applied to

irrelevant elements and actions. Effective game play was observed in three different situations for each case, in puzzles that included routine activity, hidden elements or complex rules. Partners not necessarily had to know what to do to resolve the puzzle

Effective game play during puzzles with hidden elements. In one case, partners had to walk together to find a panel that dries a swamp. Partners in a case of increased challenge (B-4,2) could not figure out the panel was hidden. In the case of decreased challenge (B-3,4), partners did not find the other panel either so their performance was not better. However, they showed an effective execution of procedural steps (e.g., assembling blocks, grappling) that were irrelevant for solving the puzzle. Whilst doing so, they exchanged brief commentaries about their actions. The following segment illustrates the effective but useless game play of the partners. B1 has rapidly approached a grappling point, which is a sort of element that might be potentially useful in other puzzles, but not in this one. Moreover B1 requests for the participation of B2, who responds promptly and effectively. In any case, their actions did not help them to find the hidden panel:

```
B1: [standing on the grapple point] ehm.. oh, this is other
   thing [an anchor that only B can manipulate with her
   ability]
B2: [does the anchor]...
B1: [uses the anchor to grapple upon a rock, which is useless]
   now
```

Effective game play during puzzles with complex rules. This case (Dyad F, trial 1,4) is atypical because partners talked much more (30.33 $wpm_{MemberA}$ and 23.55$wpm_{Member\ B}$) than partners in the other cases of decreased challenge (Med= 16.55 wps). Partners struggled to solve a puzzle where they had to use a crane to pass a droid across a gap; the same as they and other players did in cases of increased challenge (F-1,5; D-1,4). Their performance was diminished because they could not figure out the rules of the puzzle. Instead of making the correct steps to solve the

puzzle, they displayed an effective execution of incorrect strategies, exchanging practical suggestion as well as expressions of overt confusion, as in the following segment:

```
F1: what happens if I try [inaudible]
F2: I tried to push it towards the edge and didn't do anything
F1: oh yea...[walks around] I'm really confused
F2: me too, I don't actually understand
```

Effective game play during routine activity. In one case (E-2,3), partners had to walk across a corridor, making simple routine steps like shooting enemies and assembling blocks. They fluently executed the necessary steps in an almost silently manner and briefly engaged with a distracter, which was the moment when they talked to each other more. The following segment illustrates the sort of effective game play displayed by partners. In this case partners quickly disregard a distracter:

```
E1: ... (trying to operate the panel in the distracter door)
E2: maybe we need to be ...
E1: I don't' think it is... is that a picture? ... and it says
   only stormtroopers (in the distracter door)
E2: ok what do we do (as she walks away from the distracter
   door)
E1:…
```

Completion

In four cases, partners performed fluently because they had already figured out the key aspect of a puzzle, and only had to complete the remaining procedural steps. This occurred in two situations, when a puzzle required complex steps or highlighted coordination. Partners knew what to do and how to do it

Completion of puzzles with complex rules. There were three cases in which partners completed puzzles after having figured out complex rules.

In two cases (C-2,5 and F-2,5), partners had to use the droids to operate panels to open doors. This puzzle has been mentioned before, in other cases of decreased

challenge when partners were making insight. But in these cases, partners had already figured out that they need to open the doors, and fluently resolved the remaining simple procedural steps to do so. Finishing this puzzle implies a key game event, which is the finalization of mission 1.

In these cases partners accompanied actions with short commentaries and some exchange of practical advice and explanations. For instance the following segment is form case C-25, C1 and illustrates the sort of fluency displayed by partners as they completed the puzzle fluently. C1 goes into one room and C2 tries to follow her but she can't and requests for advice from C2, who responds promptly.

```
C1: [in the room with pool] oh, this water?
C2: [laughs, jumps off the water and operates the lever] oh,
   cool
C1:  how did you get up there?
C2: ah, press 3
```

In other case (F-2,3) partners had to use a crane to pass a droid across a gap, and to do that they need to eliminate some enemies and free a lever. This puzzle provoked increased challenge in themselves and other partners (see cases F-1,5; and D-1,4). But in this case, partners have figured out how to use the crane and fluently executed the remaining steps, after which they entered another puzzle made of fairly simple steps (e.g., shooting enemies and assembling blocks). Their interaction is composed by frequent and brief exchanges, in which they just commented their actions to the partner, for instance:

```
F1: [jumps into the crane and takes the droid across the gap]
   does someone needs to be him (the droid)?, are you him?
F2: yeah I'm him, so it's ok [operates the pannel and door
   opens]
```

Completion of a puzzle that emphasises coordination. In one case (A-3,2) the partners completed a puzzle after having resolved a coordination problem. They had to jump onto a box and cross a gap, but one of them did so effectively and the other one struggled. The shared screen impeded the advancing partner of going further and

also made it more difficult for the other partner to jump onto the box. After some moments of silence, they resolved the situation with an exchange of practical suggestions. The following segment illustrates how partners resolved the demands for coordination of the shared screen; A1 expresses her trouble, prompting in A2 explanations and actions to resolve the problem:

```
A1: something is pulling me... (pushed by the screen)
A2: Is because of the screen,
A1: [laughs, tries to jump onto the box but falls]
A2: maybe if I come back a bit [walking back]
A1: we can try [now she can jump onto the box]
```

Then, these partners just made the simple steps of the next puzzle fluently, talking only occasionally.

Summary

In the situations likely to influence challenge, it was observed that certain mechanisms of LSW2 could prompt either increase or decrease of challenge, depending on the way in which the partners reacted to them. This could be observed in the fluency of partners' performance and some features of their social interaction.

Game situation

The mechanisms of LSW2, per se, did not distinguish between the situations likely to provoke challenge form the situations likely to decrease it. First, different sorts of puzzles were observed amongst the cases of increased and decreased challenge, indicating important differences between cases. Second, various puzzles observed in cases of increased challenge were also observed in cases of decreased challenge. This suggests that some mechanisms of LSW2 had the potential to influence challenge. However, the direction of this influence, increase or decrease, depended on the players' responses.

Rules and structure: Puzzles with hidden elements or complex rules seemed to demand insight from the partners. Struggle figuring out these puzzles increased the feelings of challenge (5 cases), whereas rapidly making insight decreased it (10 cases).

Coordination requirements: Mechanisms such as rewardable steps, interdependent steps or the shared screen could increase the need for partners to coordinate their actions. Challenge increased when coordinated action was required and one partner played ineffectively (2 cases), and decreased when partners rapidly resolved coordination problems (1 case).

Key game events: There were various key game events in LSW2 (e.g., finishing a mission). One of them, when partners find the droids for the first time and one character leaves for no apparent reason, was likely to increase challenge because it provoked confusion (3 cases).

Routine: Various parts of LSW2 required routine actions with no complexity such as pulling levers, operating panels, etc. These parts provoked challenge increase in atypical situations of misunderstanding (2 cases) and challenge decrease due to effective game play (1 case).

Performance

Partners were usually 'doing something', even if just walking and manipulating things around. Typically, partners in cases of increased challenge showed a disrupted performance and were unable to keep progressing, whereas partners in cases of increased challenge performed more fluently and progressed rapidly. This is consistent with the performance score per minute, which was about 1 SD lower in cases of increased challenge (M=0.88, SD=1.04) than in cases of decreased challenge (M=2.7, SD=1.34).

Typically, challenging situations slowed down the game play progress. A common situation involved puzzles that required insight (5 cases). The typical approach to these puzzles was a trial-and-error strategy, and only some partners employed systematic strategies. Other partners reacted in disconcerted and disorganised game play to the first encounter with the droids (a key game element). In one atypical dyad (2 cases), partners misunderstood a routine part of the game, and engaged with distracters and walked back and forth. Finally, some partners played ineffectively in parts of the game that emphasised coordination (2 cases). In one case, one of the partners did all the work, and in other case one partner just stood still waiting for the ineffective partner.

Typically, situations that decreased challenge also implied a fluent game play progress. One situation involved puzzles that required insight (5 cases). The common approach to these puzzles was to focus on the main elements of the puzzle, and effectively making the necessary steps. Most partners played 'together' focusing in the same activities and only in one case, one partner did most of the work. In other situations, partners played effectively (3 cases) showing an effective manipulation of the elements of the game. But not in all cases the partners focused on elements actually useful to resolve a puzzle. In these cases, effective game play decreased the feelings of challenge without performance improvement. Finally, other partners completed a puzzle after having made insight, or resolved a coordination problem (4 cases). Typically, these partners made rapid execution of procedural steps

Social situation

Verbal interaction seemed to be related to the game play fluency. The typical interaction during moments likely to provoke challenge included abundant exchange of practical suggestions and explanations, altogether with expressions of confusion and misunderstanding. When challenge decreased, the typical interaction between

partners was likely to include frequent but short exchanges, including brief commentaries about their actions, presumably to 'update' the communication with the partner, and to a lesser extent, practical advice and explanations. Overall, the social verbal interaction focused on concrete aspects of the task (i.e., actions to do) and more abstract aspects like general game mechanisms were less discussed. Except for expressions of confusion and misunderstanding, partners did not talk about affective states, or not even about other 'mental' states like ideas or opinions (e.g., partners did not directly ask or contended a partner's idea).

Summary of factors associated with challenge change

This section aimed to identify some factors that could be possibly associated with the increase and decrease of individuals' reported challenge.

In terms of experience, the increase of challenge seemed to be more likely to occur in the beginning of the game. Amongst dyads that played with little experience of the game and the partner (C-C-I-I) and dyads who played with a growing experience of the game and one another (C-C-C-C), the increases of challenge occurred only during Session 1; whereas the challenge of partners who collaborated with experience of the game and one another (I-I-C-C) increased in Session 3 and Session 4.

The decrease of challenge could occur in almost any session, depending on the dyad. For those playing with little experience with the game and the partner (C-C-I-I), the largest decreases occurred in Session 2. However, in the rest of the dyads, the largest decreases occurred in different sessions. Probably the lack of experience with the partner and the game was one of the factors associated with challenge increase. However, the role of experience for the partners' challenge decrease seemed to be less clear.

Individuals typically reported a challenge of medium or high intensity in moments of increased challenge, and medium or little challenge during moments of decreased challenge. The change of individuals' challenge was usually modest. Also, the reports of challenge made dyad partners often increase or decrease together, leading to a small dissimilarity that changed very little. Something similar occurred in terms of affective awareness. The estimations about the challenge of a partner were typically accurate; which changed very little and was often associated with the similarity with the partner.

In moments of increased or decreased challenge, most partners reported high levels of effort and understanding, and little problems controlling the character. However, most of them also reported more uncertainty during increased challenge than during decreased challenge. During challenge decrease, most partners reported high understanding, but not necessarily less understanding during challenge increase. As with reported challenge, the appraisals made by dyad partners were usually similar.

These perceptions of the game play were probably reflected in aspects such as the game situation, performance and social situation. Features of the game such as rules and structure, coordination requirements, key game events and routine were likely to prompt changes in individuals' challenge. However, whether such influence was for increase or decrease, depended on how the partners responded. In most cases, individuals' seemed to increase their reports of challenge when their performance was less fluent, and decreased their reports of challenge when they performed fluently. It was also common to observe that partners gave more advice and explanations to one another during increased challenge, whereas their communication was more minimal during decreased challenge.

4.2.6 Discussion

The topic of emotional change during computer-supported collaboration has not been touched upon previously on the literature. This is an unfortunate gap because change is an inherent feature of people's emotions and their understanding of others' emotions, which has important implications for individuals and their relationships with others (e.g., in terms of satisfaction or group work interaction and outcomes). This study addressed this topic, focusing on the affective state *challenge* during collaborations around the collaborative game LSW2. The focus on challenge responded to its recognized importance in the use and design of learning technologies.

4.2.6.1 Advantages and limitations of the methodology

The study applied some principles of the microgenetic method: individuals were the unit of analysis, a large number of observations in short periods of time were made, and intensive analysis was applied to analyze individuals' data. A rich view about the particularities of each individual and/or dyad in terms of their emotions, their emotion alunderstanding and performance whilst playing LSW2 was possible because abundant quantitative (e.g., various self-reports matched with a performance score) and qualitative (i.e., game play video recording) data of fine granularity (i.e., periods of 2-3 minutes) was collected. But there is a trade-off since the findings cannot be widely generalized, given the small n.

One advantage of the method was that participants were asked about their emotions immediately after having played LSW2, in relation to short periods of time (2-3 minutes), and while looking at a recording of their game play. Hopefully, this procedure helped to reduce memory biases and stereotypical responses. The variation of the data indicates that this was probably the case. For example, participants seemed to differentiate their emotional states during different moments of their game play.

Also, some parts of the game were associated with high challenge for some individuals and with low challenge for others, which probably indicates that participants did not rely much on stereotypes to report their emotions. Moreover, similar methodologies have proven useful to investigate the understanding of thoughts and feelings (Ickes et al., 1986) and affective changes during computerized problem solving (D'Mello, Person, & Lehman, 2009).

Also, this study overcame some limitations of Study 1, in which participants reported their own emotions and the emotions of their partners in a 'single shot', and their usages of 2Connect and Astroversity were not recorded. Therefore, specific moments with high or low emotional content could not be identified, and emotions and performance could not be linked. In this study, the game play recordings were employed as a prompt for participants to make various reports of their emotions and the emotions of their partners, and these reports were matched with their performance.

4.2.6.2 How did peoples' emotions change as they played a collaborative computer game?

Early studies of emotional change documented that emotions vary in different manners depending on their qualities (e.g., in terms of valence, see Larsen, 1987; Zevon & Tellegen, 1982). Therefore, the first step was to explore the ways in which the participants' reports of challenge varied over time, looking also at the variation of other emotions such as happiness and frustration.

One aspect to note is that most participants' did not change their reported emotions gradually. It would not be surprising to find that some participants reported gradually less happiness, frustration or challenge as a result of their increased experience with the game. However, none of the participants showed a gradual increase or decrease in happiness and frustration; and only in one dyad, the partners showed a gradual

decrease on their reports of challenge. Probably the changes of people's emotions were more related with events occurring during the game play and/or with particularities of the interaction with the partner, rather than with the mere passing of time.

Instead of gradual changes, the graphical analysis showed different forms of variation in the reports of happiness, challenge, and frustration, probably reflecting that these emotions were linked with different aspects of the game play. Another aspect that distinguished the variations of happiness, challenge and frustration was the similarity between partners.

The many different forms of variation and stability observed in the reports of happiness suggest that the specific events of the game play were not always important for individuals to enjoy LSW2, and that such enjoyment was not necessarily shared with the partner. Some individuals varied, but others reported a constantly mild happiness. Although some individuals seemed to enjoy LSW2 more in collaborative sessions than individually, some others reported happiness in the same way during individual and collaborative sessions. Thus, most individuals seemed to enjoy LSW2, albeit in different ways. Moreover, it was common to see that dyad partners showed different patterns of variation during collaborative sessions (e.g., one oscillated and the other remained stable).

In comparison to the reports of happiness, there were more individuals who showed substantial and frequent variation in their reports of frustration –although some of them did not vary much. This probably suggests that individuals linked their frustration with specific game play events. It is thought that people feel frustrated when something impedes them to achieve a goal (see for example, C. A. Smith & Ellsworth, 1985). In this study, individuals' implicit goal was to achieve the win state of LSW2, and they probably faced different sorts of situation that impeded them from

doing that easily (e.g., the difficulty to figure out the mechanics of a puzzle). Nevertheless, it seems like individuals could have reported frustration for different reasons. In various cases and occasions (trials), partners collaborating reported frustration differently. For example, one increased whilst the other one decreased or remained stable. What is more, playing individually or collaboratively did not seem to change the way in which individuals' reported their frustration.

The variations of challenge indicate that this emotion is closely linked to specific events, as well as often shared with the partner. Most individuals showed frequent and substantial variation, although some of them did not vary much. This suggests that participants' challenge was linked with specific events, the same as frustration. Challenge and frustration are both associated with high effort and a strong desire to achieve a goal. However, frustration also implies negative appraisals like uncertainty and lack of control; whereas challenge implies positive ones such as certainty and control (C. A. Smith & Ellsworth, 1985).

Apparently, challenge was more likely to be shared with the partner than happiness or frustration. Partners playing collaboratively usually made similar reports of challenge (e.g., increasing and decreasing together), depicting patterns of variation that distinguished between dyads. For example, partners in one dyad showed a constantly similar decrease in their reports of challenge, whereas partners in other dyads oscillated constantly. What is more, in most cases the similarity between partners seemed to be more consistent during collaborative sessions, which is interesting because it did not occur with the reports of frustration or happiness, suggesting that challenge was probably more likely to be shared. The similarity between partners' challenge is discussed in the following section.

4.2.6.3 How did affective similarity change as partners played a collaborative computer game?

It has been documented that the emotional convergence between people over time occurs and has important implications for the relationships between friends (Anderson et al., 2003), romantic partners (Gonzaga et al., 2007) and teammates (Wilson et al., 2006). Moreover, in Study 1, it was observed that in some cases, the similarity between partners' emotions was associated with positive aspects of the interaction with a partner. Therefore it was interesting to investigate if an emotion such as challenge was likely to be shared by partners playing LSW2 during relatively extended periods of time, developing experience of this game/and or the partner.

A graphic analysis revealed that the similarity between partners did not increase or decrease gradually over time for any of the six dyads. One could expect that by having more experience with the game and/or with one another, partners could develop an increasingly growing similarity. Probably the period of observation of this study was too short (2 weeks) to observe this sort of incremental change observed in studies that cover months or years (Anderson et al., 2003; Gonzaga et al., 2007).

Instead of showing gradual increases or decreases, the similarity between partners showed little variation. Most of the time, partners playing LSW2 collaboratively reported similar intensities of challenge (the dissimilarity between their scores was usually <=2). The only atypical case was Dyad A, in which partners reported different levels of challenge in their first collaborative session but then they converged.

Thus, it seems like challenge was an emotion likely to be shared. Probably the partners' reports of challenge had more to do with their situation as a 'team' that with their situation as individuals. Recall effort and control are cognitive appraisals associated with challenge and, whilst playing LSW2, the effort of each individual was

important to succeed as a dyad, and the partners shared the control of the situation. The structure of the tasks and the mechanics of LSW2 might have generated a situation of 'mutual influence'. Partners used characters with complementary abilities in a shared screen, a situation in which the individual actions were likely to influence both the actions of the partner and the outcome of the dyad (e.g., the success at resolving a puzzle).

Partners shared the common goal of achieving the win state of LSW2, by means of achieving smallest goals such as resolving puzzles. Probably the feelings of challenge of an individual depended more on the way in which she and her partner faced the puzzle than on their individual actions. For example, if partners struggled to resolve a puzzle because one of them was having problems to control her character, the situation could have been challenging for both partners, but frustrating only for the partner who had control problems. Recall that in the previous section, it was discussed that in most of the dyads the similarity between the partners' reports of frustration seemed to be less consistent than the similarity between their reports of challenge.

To conclude, it seems like playing LSW2 collaboratively was an activity in which partners were likely to feel similarly challenged. Probably because of the allocation of complementary roles and the shared interface created a situation of mutual influence.

4.2.6.4 How did affective awareness change as partners played a collaborative computer game?

It is known that people changes what they understand about others' mental states changes might change in the short term (Epley et al., 2004), and that the understanding of others' emotions might also change depending on the social context and the passing of time (Bellini & Shea, 2005; D. D. Clarke, 1997). Moreover, Study 1 suggested that collaborators tend to make inaccurate judgements about the emotions

of their partners. Therefore, it was important to know how the individuals' understanding about the challenge of their partners changed whilst playing LSW2 collaboratively over a relatively extended period of time, developing experience of the game and/or one another.

The graphic analysis revealed that individuals in this study did not get better or worse at estimating the challenge of their partners over time. One could expect that the partners' awareness about the emotions of the partner increased in parallel with the increase of experience with the game and/or with the partner. But probably this study was too short to observe the sort changes in emotion understanding reported in other studies, such as the more accurate recognition of spouses by husbands (D. D. Clarke, 1997) or the decline in the empathy of medical students (Bellini & Shea, 2005).

The accuracy of the partners at estimating the challenge of one another showed little variation. Most of the times, partners playing LSW2 collaboratively made accurate estimations about the challenge of their partners (their inaccuracy was usually <=2). For most partners, the variation of accuracy followed the same pattern as the similarity with the partner, except for the atypical case of individual A2.

Apparently, the individuals' accuracy at estimating the emotions of their partners was closely related with their emotional similarity. This could reflect the fact that the partners referred to their own feelings as a reference in order to reason about the challenge of their partners, which happened to be accurate because they reported similar levels of challenge. This would be consistent with the documented tendency of people to see their own opinions or behaviours as more common and appropriate than they could be (Krueger & Clement, 1994; Ross et al., 1977), especially in cooperation (Toma, Yzerbyt, & Corneille, 2010).

In the specific case of challenge, assuming that the partner felt the same as you was not necessarily an erroneous reasoning. The previous section discussed that, probably, the partners reported challenge in a similar way because this feeling had more to do with their situation as a team than with their individual situations and actions. Probably the partners were actually aware of the shared nature of their challenge, and therefore they reported the emotions of the partner on the basis of their own. In fact, it is known that under certain circumstances, referring to the self can actually lead toone reason about someone else's mental states in an accurate manner (e.g., Gendolla & Wicklund, 2009; Hoch, 1987).

However, this finding must not be generalised, neither to other situations nor to emotions other than challenge. Apart from the small n, it is possible that the situation of playing LSW2 offered an ideal context for challenge to be shared, and for partners to be aware of such sharedness. More research will tell if this situation can be replicated in other situations (e.g., around other sorts of collaborative technologies). Also, partners collaborating reported challenge similarly, but their reports of other emotions such as happiness and challenge were not as similar (at least from a visual inspection). Therefore, if partners used their own feelings as a reference to report the happiness and frustration of their partners, it is likely that their estimations were erroneous. What is more, some emotions such as happiness are known to reduce the ability to think about others accurately (Bodenhausen, Kramer, & S¸sser, 1994; Converse, Lin, Keysar, & Epley, 2008).

4.2.6.5 What were some of the factors associated with changes in challenge?

It is known that learning technologies such as educational computer games need to provoke challenge in order to successfully facilitate learning. But so far, most of the

research has focused on individual game play and therefore, little is known about the factors that influence challenge during collaborative game play. In response to this, a detailed exploratory analysis was made of the factors that might have increased and decreased people's challenge whilst playing LSW2.

Following principles of the microgenetic method, the moments when the participants changed their reports of challenge more were analysed intensively, employing a wide range of quantitative and qualitative data. This section integrates and discusses the nine factors explored: *Experience*, *change*, *similarity*, *awareness, context perception, game situation, performance* and *social situation*.

Experience. It seems that the game play events impacted more amongst individuals when they had little experience with the partner and/or the game, especially in terms of challenge increase.

Individuals in the groups C-C-I-I and C-C-C-C registered their largest increases of challenge in Session 1. Probably the limited experience with the game and the partner magnified the impact of situations likely to increase challenge in this part of the game (e.g., finding the droids for the first time and/or facing a their first puzzle with complex rules). Individuals in the group I-I-C-C registered their largest increases of challenge in Session 3 and Session 4. Probably their experience with the game (but not with the partner) reduced the impact of situations likely to increase challenge in the second part of the game (e.g., various puzzles with hidden elements or complex rules).

Amongst individuals in the group C-C-I-I, the largest decreases of challenge concentrated in Session 2, when they had a little more experience with the partner and the game, and after having reported the largest increases of challenge in Session 1. The largest decreases of challenge of individuals in the groups C-C-I-I and C-C-C-C

could occur in almost any session. Probably, having more experience with the game (although not necessarily with the partner) reduced the impact of the events likely to decrease challenge.

Intensity, similarity and awareness. In most cases, the increase and decrease of challenge resulted from modest changes, and only atypical individuals changed their reports of challenge abruptly. This suggests that the game play situations likely to influence challenge demanded a gradual processing, rather than a sudden reaction. For example, a puzzle with complex rules could have prompted an increase in challenge after the partners spent more time solving it than other puzzles.

Also, the moments of largest increase or decrease of challenge typically involved similarity between partners and an accurate judgement about the challenge of one another, reflecting these were general features of the variation of challenge. In sections 4.2.6.3 and 4.2.6.4, it was suggested that probably the partners reported more or less challenge depending on their situation as a dyad, leading to report similar intensities of this emotion, and prompting them to use their own challenge as a reference to judge the challenge of the partner. Probably the complementary roles and the shared inference established a situation of mutual influence between partners, hence the same event was equally challenging for both of them, with relative independence of their individual situation. This interpretation seems to be consistent with the analysis of the game situation, performance, and social situation, which shows that partners were often engaged in a joint effort to resolve the puzzles in LSW2, albeit in different ways and situations depending on specific cases, which will be discussed later on this section.

Context perception. Typically, dyad members reported a similar perception of the context, in terms of effort, ability, understanding, uncertainty and problems controlling their characters. These appraisals were selected to investigate the

perceptions of the context because other studies pointed at them as relevant for goal-oriented emotions such as challenge (C. A. Smith & Ellsworth, 1985; C. A. Smith & Ellsworth, 1987). Recall that partners typically reported similar rates of challenge. It was discussed that they did so because their feelings of challenge were probably linked with their situation as a 'dyad' rather than to their individual situations. Probably this implied that partners perceived the context in a similar way. For example, partners who struggled to resolve a puzzle with hidden elements might have equally lacked understanding and felt uncertainty.

However, it seems like the increase and decrease of reported challenge was not necessarily accompanied by changes in all the appraisal themes. Typically, individuals reported high effort both in moments of increased and decreased challenge. Probably they were not discouraged during moments of increased challenge, nor disengaged when LSW2 was less challenging, suggesting this game successfully sustained the sort of 'intrinsic motivation' desirable for educational computer games (Malone, 1981). Also, individuals typically thought they had the ability to play the game and reported few interface problems, regardless of having increased or decreased their reports of challenge, suggesting that in this study, participants could have perceived LSW2 as challenging but not necessarily difficult to play.

Typically, individuals reported more uncertainty during moments of increased challenge. This is in line with Malone (1981), who listed uncertainty as one factor likely to prompt challenge in educational games. In the case of LSW2, the uncertainty might have been generated by elements such as the hidden elements or complex rules of some puzzles. Also, high understanding was typically reported in moments of challenge decrease. Probably, participants felt less challenged when they found it easier to identify what to do and how to do it. However, in moments of challenge increase, similar numbers of individuals reported low and medium or high

understanding. Probably understanding the game situation helped participants to reduce the challenges of LSW2, but the lack of understanding did not necessarily meant more challenge.

To conclude, partners seemed to have similar perceptions of the game play context. It seems like the features of LSW2 sustained their effort, and made it challenging but not necessarily difficult. The uncertainty seemed to be an important aspect of what made LSW2 challenging, and better understanding of the game seemed to reduce the individuals' challenge. In the following section, we discuss some situations likely to have influenced challenge, which also illustrates their perceptions of the context.

Game situation, performance, and social situation. The analysis of the game play recordings revealed that the moments of increased challenge usually involved disruptions in the dyads' performance, whereas the moments of decreased challenge usually involved a fluent performance.

These findings suggest that LSW2 successfully sustained the productive engagement of the players, as reflected on their constantly reported effort and their actual performance during game play. This seemed to be driven by an interaction between the structure of LSW2 and the interaction with the partner.

Some of the mechanisms of LSW2 that participated in the changes of challenge have been listed by Malone (1981) as desirable to prompt challenge in learning environments (e.g., hidden information and randomness provoking uncertainty). But other components had not been listed before, such as rules and structure and moments of routine game play. Moreover, other components apply exclusively for the context of CSCL, such as coordination requirements (e.g., sharing the interface, interdependence). Additionally, LSW2 also presented various other components such as distracters, enemies and expressive elements (e.g., coins, doors), that could have

helped to sustain engagement but sometimes also made it difficult for the partners to interact with one another.

But the features of LSW2 were not sufficient to increase or decrease challenge. This depended on the way in which partners faced them. For example, some partners approached one puzzles with complex rules using a trial and error and spent more time trying to resolve it, whereas others resolved the same puzzle focusing on the manipulation of the key components and resolved it more quickly.

During the situations likely to increase challenge, most participants had an abundant exchange of ideas or advice. In moments of decreased challenge, most partners interacted with brief commentaries or back channel, which in certain occasions helped them to coordinate their actions. It is relevant that partners rarely talked about something that was not an action directed to resolve a puzzle. They rarely talked about the mechanisms of a puzzle in 'abstract' terms, and only in some cases the partners took time to discuss before acting. This sort of 'concrete' interaction (i.e, based on actions) lacked of any sort of 'high' level social process documented in studies of collaborative learning, such as 'shared' metacognition (Iiskala et al., in press) or social regulation of emotional challenges (Järvenoja & Järvelä, 2009). What is more, partners almost never expressed their feelings verbally (except for the moments of overt confusion).

4.2.6.6 Conclusion

This study investigated the way in which the challenge reported by individuals playing LSW2 changed over relatively extended periods of time. The study applied some principles of the microgenetic method such as making an intensive analysis of various observations in a small number of individuals. As such, the results cannot be too freely generalised, either to other persons, or collaborative technologies. But

hopefully, the findings will be useful as exploratory knowledge about the many ways in which people's emotions might change during computer-supported collaboration.

The study focused on the emotion challenge because of its theoretical importance in the study of technology-enhanced learning, and offered a rich view about the way in which the challenge of a small number of persons might have changed as they played LSW2. Although the momentary demands of the game could prompt challenge change, whether this emotion increased or decreased depended on partners' collective performance. Moreover, partners usually reported similar increases or decreases of challenge, and assumed such similarity. These aspects could be the result of a situation of mutual influence between partners, generated because LSW2 allocated partners to play complementary roles and often required cooperation.

Although these findings cannot be generalised to other individuals, collaborative environments and emotions, they open an interesting issue not attended in the literature of CSCL. If partners can influence each other's emotions and performance, it seems interesting to know what would happen if they could know what the partner is feeling; can this improve their emotions and performance? One way to know is by probing that partners' emotion understanding can be supported, and that there are potential benefits of doing so. This is investigated in Study 3, which assesses the potential benefits of helping partners to be more aware about the emotions of each other whilst playing LSW2.

Chapter 5

The benefits of affective awareness support during remote and co-located collaborations

5.1 Introduction

The findings of Study 2 cannot be generalised but illustrated how the collaborative environment (LSW2) and interaction with a partner might influence emotions and emotion understanding, affecting the collaboration outcomes. Challenge changed depending on the collective response to momentary demands of LSW2 (e.g., complex tasks, coordination requirements or key game events), it increased when partners struggled, and decreased when they performed fluently. In any case, partners' actions could influence each other's emotions (e.g., whilst using the characters' complementary abilities, by gaining insight through other's actions, or when the problems of one partner disrupted collective performance). This mutual influence could explain the similarity between partners' challenge, something relevant because, as in Study 1, partners assumed such similarity, even if they rarely talked about their emotions whilst playing LSW2.

If partners' actions and emotions can be mutually influential, and they assume affective similarity, it might be useful to know whether helping collaborators to

accurately understand one another's emotions could be beneficial for the outcomes of their collaboration. This chapter presents a study designed to assess the potential benefits of helping collaborators to be more aware about the emotions of a partner, which has been termed *Affective Awareness Support.* More than proposing a design solution, the study informs about the potential benefits of supporting affective awareness during CSCL.

There have been attempts to improve CSCL environments with elements to support collaborators' awareness of social aspects such as collective participation (Kreijns, Kirschner, Jochems, & Van Buuren, 2004) or the influence of minorities in large group work (Buder & Bodemer, 2008). However, the specific topic of affective awareness remains unattended. There is potential in doing so. For example, research in clinical settings indicates that affective awareness support is useful for people diagnosed with disorders in the autism spectrum to have a better interpersonal understanding of emotions (El Kaliouby et al., 2006)

The study presented in this chapter assesses the effect of affective awareness support in co-located and remote-continuous collaborations. This contrast is made because it will permit the observation of the effects of technological mediation; which needs to be addressed in the implementation of affective awareness support.

5.2 The importance of understanding the emotions of a partner during collaboration

Section 2.4 of Chapter 2 reviewed literature about the experience and understanding of emotions during collaborative learning. This is further discussed to introduce the study of this chapter, focusing in two mechanisms that might recruit emotion understanding during collaboration: Motivation to collaborate and social regulation.

5.2.1 Motivation to collaborate

The advances in developmental and comparative psychology suggest that humans have a natural enjoyment of joint activities, which drives the motivation to collaborate. Such enjoyment has been attributed to the capacity to make inferences about the 'mental states' of others (Moll & Tomasello, 2007; Tomasello et al., 2005). In line with this, Schwartz (1998) theorized that during collaborative learning, partners are motivated to construct a 'shared meaning'. That is, they make efforts to understand the partner, and also to be understood by the partner. Thus, Crook (2000) postulated that the positive affect associated with the 'sense' of a shared understanding drives the motivation to collaborate during collaborative learning.

In other words, collaborative partners are expectedly motivated to create a state of shared understanding because such a state is naturally enjoyable. One could speculate that some 'portion' of the motivation to collaborate might depend on whether collaborators sense, or not, a shared or complementary affective experience. Sensing a different or non-complementary affective experience should diminish collaborators' motivation. In comparison, collaborators' awareness of a similar or complementary emotional experience should indicate the achievement of a shared understanding and/or the effort to do so.

5.2.2 Social regulation

Understanding the emotions of the partner might also be useful for collaborators to regulate the emotions of one another. Järvenoja and Järvelä (2009) found that during collaborative learning, the main social affective challenges arise from the perceptions of commitment and equality of the participants (i.e., group work) and the making of a shared understanding (i.e., collaboration). In comparison, challenges related with individual concerns (i.e., personal priorities) are significantly less important.

Collaborators face these affective challenges using both individual and social regulation mechanisms.

Mutual support could be one of the mechanisms employed by partners to regulate the emotions of one another. This is in line with Bratman (1992), who postulates mutual support as one of the key theoretical features of the interpersonal situation during *shared cooperative activities*. In turn, the literature suggests that the provision of mutual support during collaboration is closely linked to the understanding of a partner's emotions. On the one hand, is well known that one of the functions of empathy is to trigger helping and altruistic behaviour (see the review of Dovidio, 1984). On the other hand, both the tendency to behave altruistically and the capacity to empathize seem to be core mechanisms of collaboration (see the review of Tomasello, 2009). This is in line with research about cooperative behaviour in the context of cooperation games, which indicates that people cooperate more when they empathize with their counterpart (Batson & Ahmad, 2001; Batson & Moran, 1999; A. C. Rumble, Van Lange, & Parks, 2010).

5.3 Technological mediation and affective awareness during remote and co-located collaboration

Technological mediation permits collaborations to occur remotely, either in asynchronous or continuous fashion. While asynchronous remote collaboration occurs mainly through text (as in e-learning environments), continuous-remote collaboration often implies audio and/or video communication. The study presented in this chapter compares the effects of supporting affective awareness among partners interacting in co-located collaboration and remote-continuous collaboration mediated with an audio channel.

Computer mediated communication (CMC) constraints social awareness, which has been recognized as a major disadvantage of computerized joint activities such as computer-supported collaborative work (CSCW) (Schmidt, 2002). It is true that the provision of more media spaces (e.g., video and audio channels) is part of the solution to remedy the lack of awareness in remote collaborations. For example, it is known that communication channels increase trust in CMC (Bos, Olson, Gergle, Olson, & Wright, 2002). However, Schmidt (2002) remarked that the provision of more media spaces is only one part of the solution to remedy the lack of awareness in remote collaboration. It is also important to investigate the information that collaborators employ to be aware of one another, how they use it and what is the optimal form to represent and transmit such information. In turn, investigations about awareness of a partner's emotions (i.e., affective awareness) are rare, and mostly focus on text-based interaction. However, they suggest that understanding the emotions of a partner plays a functional role during remote collaboration and that this role might be more important than in co-located collaborations.

One of the obstacles that CMC imposes for remote collaboration and that probably also influences affective awareness is the diminished sense of *Social Presence*. Short, Williams & Christie (1976) coined this term in reference to the extent to which communication media can transmit social and emotional cues in a way that users perceive one another as 'physically present'.

The channel constraints represent a disadvantage for emotion communication in CMC. In co-located interaction, there is access to a complete set of information about the emotions of a partner, including both visual information (e.g., facial expressions, gestures) and audio information (e.g., verbal content, voice intonation). In comparison, during CMC, there is a substantial loss of visual and verbal social information. As a consequence of this information loss, two forms of emotion

miscommunication during CMC have been suggested. One occurs when people overestimate the readability or transparency of their emotion expressions. This is indeed a 'natural' bias of interpersonal perception (Gilovich et al., 1998) that might be stronger during CMC. The other is the miscalibration that occurs when people adjust their emotional expressions to the inaccurate readings of the other's reactions (Parkinson, 2008).

CMC used to be regarded as 'emotionless' because of the diminished social presence. But the evidence says that in fact, CMC is a rich context for emotional communication, even if based on text only (Derks, Fischer, & Bos, 2008). Moreover, there is evidence that affective factors are key in CMC. For example, Feng, Lazar and Preece (2004) reported that people interacting online through text with a conversational partner who shows both empathic accuracy and support, reports more trust than people interacting with non-empathic or non-supportive conversational partners.

It is known that in remote CSCL, satisfaction with learning depends on the degree of perceived social presence (Gunawardena & Zittle, 1997), and that enhancing the social presence with audio and video channels increases the perceived easiness and naturalness of CMC (Yamada, 2009). Moreover, Pauchet et al. (2007) found that remote-continuous collaboration can be as effective as co-located collaborations if adequate communication resources are provided (e.g., video communication and shared interfaces). Nevertheless, users will focus more on the task and bother less about the other during remote collaborations because of the diminished sense of social presence, which in turn affects the quality of collaborator's experience.

Few studies have addressed the relationship between social presence, technological mediation and the understanding of emotions during collaboration. Michinov & Michinov (2008) assessed the effects of introducing a session of co-located interaction

in the middle point of an e-learning program. They found that the 'socio-emotional interaction' (i.e., expression of the one's own emotions, and asking about others' emotions) increased after the co-located session. This made no differences in the overall quality of the participants' affective experience. However, the authors argued that people expressed more emotions in the subsequent CMC sessions in order to sustain the social presence created by the co-located session.

Functions related to aspects other than social presence have been found for the communication of emotions during remote joint activities. Maloney-Krichmar & Preece (2005) found that emotion communication is a significant component of the sociability and evolution of an online community. They found that in the shared spaces of the community (e.g., the website forums), the communication exchanges with socioemotional content (e.g., showing solidarity, dramatization and agreement) constituted 31% of the total number of exchanges, in comparison to 66% of task oriented exchanges and 2.5% of negative exchanges. Moreover, they also found that the community members used the social affordances of the community website to show empathy with one another (e.g., they offered 'virtual' snacks and shared common experiences with each other).

Functions like these indicate the importance of understanding the emotions of a partner during remote collaborations. Although the issue has not been directly assessed, some evidence suggests that the understanding of emotions might be more important during remote collaborations than during co-located collaborations. Stone & Posey (2008) compared the performances of groups making a judgmental task (i.e., solving an open-ended problem) and an intellective task (i.e., solving a murder mystery) under conditions of text-based CMC and co-located interaction. The groups in the CMC condition showed more explicit coordination, help and inquiry than the co-located groups, especially in the intellective task. Among other behaviours such as

clarification, planning or support, the expression of one's own emotions and the understanding of others' emotions were important mediators of these results. The expression of one's own emotions predicted the perceived performance in the CMC condition, but not in the co-located condition. Similarly, asking the feelings of the partner predicted the actual performance in the CMC condition, but not in the co-located condition. This indicates that both the expression of one's own emotions and interest in the emotions of others are relevant for the process and outcomes of collaboration. The expression of one's own emotions enhances the individual satisfaction with the activity (perceived performance), while the interest for the emotions of others generates an actual improvement in the collaboration outcome (actual performance).

It is important to recognize that these investigations were not, as the study presented in this chapter, directed to specifically assess the effects of affective awareness support. Therefore, its methodologies did not attend to important issues in the investigation of emotions at the interpersonal level. For example, neither Michinov & Michinov (2008) nor Stone & Posey (2008) controlled the affinity between participants, which is important since familiarity can strongly influence the interpersonal understanding of emotions, especially in collaboration (see for example, Vass, 2007). Nevertheless, the results of these investigations are consistent with the theoretical importance of emotion understanding because they suggest that the exchange of affectively loaded information is instrumental for the process and outcomes of collaboration. This instrumentality seems to be sensitive to the meditational effects of communication technology during remote collaborations. Moreover, emotion understanding seems to play a more important role during remote collaborations than during co-located collaborations.

5.4 Study 3

5.4.1 Overview of the study

The reviewed literature indicates that the understanding of a partner's emotions plays a key role in two mechanisms: the motivation to collaborate and the social regulation of emotions. This is solid background to speculate about the potential benefits of helping collaborators to be more aware about the emotions of their partners (i.e., affective awareness support). Moreover, if affective awareness support brings benefits for collaboration, these benefits might be more important during remote collaborations than during co-located collaborations. This could be expected as an effect of affective awareness support compensating the disadvantages that CMC generates in remote collaboration.

However, no previous investigations have been specifically directed to empirically assess the benefits of affective awareness support; either during remote collaborations or during co-located collaborations. This study contributes to filling this gap. The effects of receiving affective awareness support are assessed among participants playing the collaborative computer game LSW2, co-locatedly or remotely using headsets to communicate. Affective awareness support is operationalized as the provision of information about the emotions of a partner. There are four areas of assessment: emotion understanding, affective experience, perceived interaction quality, and performance.

In spite of the threats that CMC imposes for emotion communication, which also represent potential threats for affective awareness, the comparison between remote and co-located collaborations presented in this study is a fair one.

First, the remote collaborations implemented in this study will be continuous. That is, collaborators playing LSW2 remotely will interact in real time, as collaborators playing LSW2 co-locatedly will do. This is important because a number of limitations for social interaction during remote collaboration are associated with discontinuity. For example, asynchrony is a major obstacle for fluent argumentation in CSCL, which is expressed in aspects like the collaborators' tendency to ignore the contributions of one another (Carell & Herrmann, 2009). Second, the use of an audio channel to operationalize remote collaboration permits the conservation of verbal information. This is important because there is evidence that when inferring feelings, people pay special attention to verbal cues (discourse content) and nonverbal vocal cues (voice intonation) (Hall & Schmid, 2007). In turn, people react more intensely to the negative emotions of others in vocal co-located interaction than in text-based CMC during an emotionally engaging interaction, namely conflict resolution (Sasaki & Ohbuchi, 1999). Moreover, it is known that as long as the audio quality is reliable, collaboration through video-conference produces learning outcomes similar to co-located collaboration (Ertl et al., 2006).

Thus, the effects of affective awareness support during remote collaborations will be independent of major limitations of CMC in terms of social interaction (asynchrony) and emotion understanding (loss of verbal information). This will permit a fair comparison with co-located collaborations and a straightforward interpretation of the effects of affective awareness support. There are three general expectations:

1. Affective awareness support will have an overall positive effect in all the assessed areas; regardless of whether the collaborators play LSW2 remotely or co-locatedly. This is expected as the result of affective awareness support helping collaborators in two ways. First, affective awareness support will prompt the motivation to collaborate.

Collaborators will use the information about the emotions of the partner to interpret her intentions and actions. This will facilitate the ’sense’ of shared understanding that, in theory, drives the motivation to collaborate. Second, affective awareness support will facilitate the social regulation of emotions. Collaborators will use the information about the emotions of a partner to identify her needs and concerns, in order to give her adequate support.

2. Collaborators playing LSW2 remotely will be inferior to collaborators playing LSW2 co-locatedly in all assessed areas; regardless of receiving affective awareness support or not. This is expected because remote collaborators will not have access to the facial expressions and gestures of the partner. This will diminish the sense of social presence of the partner, hindering their communication and coordination.

3. For all the assessed areas, it is expected that affective awareness support will have a more powerful positive effect among collaborators playing LSW2 remotely than among collaborators playing LSW2 co-locatedly. This is expected as a result of the affective awareness support helping collaborators to compensate the disadvantages of remote collaborations.

Following these general expectations, five specific hypotheses about the effects of affective awareness support during remote and co-located collaborations are formulated.

5.4.2 Hypotheses

5.4.2.1 Hypothesis 1: Emotion understanding

The first hypothesis is related to whether affective awareness support actually helps collaborators playing LSW2 to have a better understanding of a partner's emotions. The testing of this hypothesis will be helpful to check whether the operationalization of affective awareness support was successful. Moreover, it will be helpful to determine whether providing information about the emotions of the partner is a useful way to improve the interpersonal understanding of emotions, which is important because there are no antecedents of this issue in the current CSCL literature. This hypothesis makes three predictions:

- H1: First, supporting affective awareness will improve emotion understanding overall. Second, overall, emotion understanding will be lower during remote collaborations than during co-located collaborations. Third, affective awareness support will generate a larger improvement in emotion understanding during remote collaborations than during co-located collaborations.

5.4.2.2 Hypothesis 2: Positive affect

The effects of affective awareness support in the participant's positive affect are expected to work as follows. Among collaborators with different levels of positive affect, it is expected that the collaborator with higher levels of positive affect will give support and encouragement to the partner. Consequently, the level of positive affect of the partner will increase.

Among collaborators with similar levels of positive affect, the realization of a shared positive affective experience will reinforce and/or increase the positive affect. For partners whose positive affect tends to be high, this tendency will be reinforced.

For partners whose positive affect tends to be low, this tendency will be reverted with, for example, more mutual support. Three predictions are made:

- H2: First, affective awareness support will increase the positive affect overall. Second, overall, the positive affect will be lower during remote collaborations than during co-located collaborations. Third, affective awareness support will generate a larger increase in positive affect during remote collaborations than during co-located collaborations.

5.4.2.3 Hypothesis 3: Negative affect

The effects of affective awareness support in the participant's negative affect are expected to work as follows. Among collaborators with different levels of negative affect, it is expected that the partner who feels more negative affect will receive support and encouragement from the partner who feels less negative affect. Among collaborators with similar levels of negative affect, the realization of a shared negative affective experience is expected to reduce the negative affect. For partners whose negative affect tends to be high, this tendency will be reverted with more mutual support. For partners whose negative affect tends to be low, this tendency will be sustained. Three predictions are made:

- H3: First, affective awareness support will decrease the negative affect overall. Second, overall, the negative affect will be higher during remote collaborations than during co-located collaborations. Third, affective awareness support will produce a larger decrease in negative affect during remote collaborations than during co-located collaborations.

5.4.2.4 Hypothesis 4: Perceived interaction quality

The fourth hypothesis makes predictions about the effects of affective awareness support in the participants' perceived interaction quality. In general, it is expected that with affective awareness support, collaborators will make more positive assessments about the quality of their interactions, measured in terms of perceived mutual support and perceived mutual understanding. Three predictions are made:

- H4: First, affective awareness support will increase the perceived quality of the interaction overall. Second, the perceived interaction quality will be higher during co-located collaborations than during remote collaborations. Third, affective awareness support will generate a larger improvement in the perceived interaction quality during remote collaborations than during co-located collaborations.

5.4.2.5 Hypothesis 5: Performance

The fifth hypothesis makes predictions about the effects of affective awareness support on the participants' performance. In general, it is expected that with affective awareness support, collaborators will be more motivated to collaborate and more easily coordinate with the partner. This will be useful for them to perform better while playing LSW2. Three predictions are made:

- H5: First, affective awareness support will improve the collaborators' performance overall. Second, the performance will be, in general, better during co-located collaborations than during remote collaborations. Third, affective awareness support will generate a larger improvement in performance during remote collaborations than during co-located collaborations.

5.4.3 Exploratory research question

One exploratory research question complemented the testing of the hypotheses listed above:

- EQ: To what extent are the understanding of a partners' emotions and understanding and performance related, and how is this relationship influenced by affective awareness support?

5.4.4 Method

5.4.4.1 The collaborative puzzle solving game

Participants played the mission 2 of LSW2. The structure of the game has been explained in detail in Chapter 4 (section 4.2.4.1). Briefly, this game implies the solution of collaborative puzzles embedded in an interface loaded with affective features such as expressivity and aesthetics. The game is playable in 2-player cooperative (coop) mode (i.e., collaboratively). Players control characters with complementary abilities. That is, characters share general basic capabilities (e.g., pushing boxes, pulling levers), but also have different specific skills that complement each other (e.g., one character can manipulate objects at distance but it cannot throw anchors to climb; while the other character can throw anchors to climb, but it cannot manipulate objects at distance).

Importantly, LSW2 rewards collaboration without forcing it, which is a recommended principle for the design of cooperative games (Habgood & Overmars, 2006). That is, collaborators can solve the puzzles without cooperation, but they will have to make more individual effort and invest more time. In contrast, the puzzles are more efficiently resolved if players cooperate.

5.4.4.2 Participants

Participants were 48 females with a mean age of 22.3 years recruited through advertisement and mailing lists across various departments in the University of Nottingham. There is an ongoing controversy regarding gender differences in interpersonal understanding of emotions (see for example, Baron-Cohen & Wheelwright, 2004; Ickes, Gesn, & Graham, 2000). To reduce biases given by gender differences, only females were invited for this study. In order to reduce biases given by cultural differences, 34 participants were native English speakers and the rest were fluent English speakers with an occidental cultural background. Only participants who did not know LSW2 were selected for the study. To control for affinity, participants were paired with someone from a different department to increase the probability of the dyad members to be unacquainted.

5.4.4.3 Questionnaires

Participants answered five questionnaires during the study. These questionnaires were presented electronically with randomized items and counterbalanced order. Dyad members answered them in separated rooms.

- *Game Play Habits*. Self reported interest for video/computer games, online computer games and frequency of game play. The data from this questionnaire was employed to assess the influence of individual differences in game play habits on the effects of the experimental manipulations of the study.

- *Own Emotions.* This questionnaire presented a 9-point Likert scale ranging from 0 to 8 and anchored by *not at all* and *extremely* for the participants to report the intensity of the emotions *happy, interested, hopeful, excited, challenged, frustrated* and *annoyed.* Some of these emotions are different to the emotions included in the questionnaires of Study 1 and Study 2. Excited and annoyed are now included because during the debriefing of Study 1 and Study 2, various participants referred to them as emotions not included in the questionnaires, that could have been appropriate to describe their affective experiences. Also, emotions used in Study 1 and Study 2 were not included in this study because they showed floor effects (e.g., ashamed, guilty, disgusted).

- *Partner Emotions.* This questionnaire was identical to the Own Emotions questionnaire except that participants were asked to report the affective states of their partners.

- Interaction quality. This questionnaire was composed by two scales:

  Individual appraisal. This scale was for the participants to assess the quality of the own and the partners' interaction quality as individuals. It consisted of six items to be answered in a 9-point Likert scale ranging from 0 to 8, anchored in *never* and *all the time*. The items covered the themes support, expression of ideas and interest for the ideas of the partner.

  Dyad appraisal. This scale was for the participants to assess their interaction quality as members of a dyad. It consisted of seven items to be answered with a 9-point Likert scale anchored in *totally agree* and *totally disagree.* These items covered the themes equality of contributions, understanding of one another's ideas and overall performance.

- *Interpersonal Reactivity Index.* This is a measure of individual differences in dispositional empathy. In this study, it is used to control for individual differences in the assessment of the effects of affective awareness support in the participants' understanding of a partner's emotions (H1). This is important because personality traits are highly influential in empathic ability. The interpersonal reactivity index (IRI) includes four scales: *perspective taking, empathic concern, personal distress* and *fantasy* (M. H. Davis, 1983).

5.4.4.4 Experimental Design

Dyads were randomly assigned to one of four conditions in a 2x2 between-participants design with 12 individuals/6 dyads in each cell. The manipulated factors were: *Awareness (*A) and *Location* (L). The operationalization of Awareness consisted on presenting the participants (awareness) or not (no awareness) with the scores of the partner in the Own Emotions questionnaire. Location was operationalized as playing LSW2 side by side (co-located) or in different rooms using an audio channel to communicate (remote). The design is illustrated in Table 5.1.

Table 5.1
Experimental design

	Factor A: Awareness	
Factor L: Location	A+: Awareness	A-: No Awareness
L+: Co-located	A+ L+	A- L+
L-: Remote	A+ L-	A- L-

5.4.4.5 Setting and procedure

Approval was obtained from the ethics committee in the School of Psychology in the University of Nottingham. The study was run in a room with three sections as depicted in Figure 5.1. Participants answered the questionnaires in tablet PC's (1C and 3C). Those in the awareness conditions looked at their partners' answers to the Own

Emotions questionnaire in a monitor (1D and 3D). Those in the co-located condition played LSW2 in rooms 1 and 3, using televisions (1A and 3A) and gamepads (1B and 3B) connected to the central laptop running LSW2 (2A). The participants in the co-located condition played LSW2 in the room 1, with the television (1A) and gamepads (1B) connected to the central PC running LSW2 (2A).

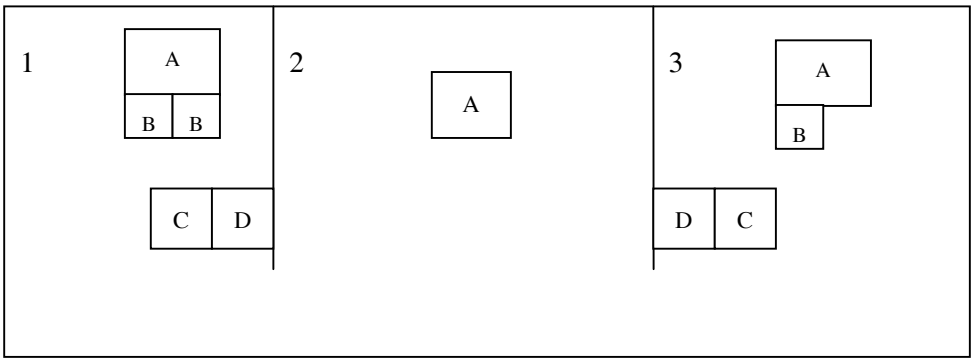


Figure 5.1 *Experiment room*

Participants confirmed they were unacquainted and then they were presented with the study information. For those assigned to the awareness condition, the information clarified that their answers to the Own Emotions questionnaire, but not their answers to any of the other questionnaires, were to be presented to the partner. Conversely, for those in the no awareness condition, the information assured confidentiality for the answers to all questionnaires.

After reading the study information and signing the consent form, participants answered the Game Play Habits questionnaire and the Own Emotions questionnaire to report their emotions during the 20 minutes before their arrival to the experimental room. Participants answered these questionnaires in separated rooms. Following this, those in the co-located conditions were asked to join in the same room; while those in the remote conditions remained in separated rooms during the rest of the session.

The procedure consisted of four steps with adjustments according to the experimental manipulations:

1. Induction to the game: Dyads were introduced to the game in 10 minutes of guided game play. They were trained in the control of their character and the general objectives and mechanics of LSW2 while solving the first two puzzles of the mission 2. After the induction, all dyads were left in the same point of the game with the instruction to get as far as they could. All dyads were given a handout which content included a reminder of the button-action relationship to control the characters, clarification of the goal in each puzzle and some hints.

2. Trial 1: This trial followed the induction to the game. After 10 minutes of game play, participants answered the questionnaires Own Emotions, Partner Emotions, and Interaction Quality. In this trial, there was no differentiation between those in the awareness conditions and those in the no awareness conditions.

3. Trial 2: This trial started the differentiation between the conditions awareness and no awareness. After finishing the previous trial, those in the no awareness condition just restarted their game play for another 10 minutes. In comparison, those in the awareness conditions were presented with the scores given by the partner in the Own Emotions questionnaire during the previous trial. This consisted of a histogram-like representation of the partner's scores as located in the scale range of the questionnaire (see Figure 5.2). After looking at the partner's emotion scores, participants continued with their game play for another 10 minutes.

   Following the 10 minutes of game play participants in all conditions answered for the second time the questionnaires Own Emotions, Partner Emotions, and Interaction Quality.

This part of the study will help you and your partner to improve your collaboration in the next part of the game.

Below you can see the emotions your partner felt during the last period of game play. Please look at them carefully.

When you are ready to continue with the game, press the grey button labelled CALL in the white box located at your right and wait for the experimenter"

1. How intensely YOU felt the following emotions during the last period of game play?									
	not at all (0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	extremely (8)
Happy						x			
Interested						x			
Hopeful					x				
Excited					x				
Challenged						x			
Frustrated	x								
Annoyed	x								

Figure 5.2 *Representation of the partner's answers to the Own Emotion questionnaire employed to operationalize affective awareness support*

4. Trial 3: This trial followed the same procedure as the trial 2 with additional answering of the IRI questionnaire at the end of the trial.

After finishing Trial 3 participants were debriefed, thanked and received their inconvenience allowances. Sessions lasted 60 - 70 minutes.

5.4.4.6 Measures

Affective awareness index

The participants' understanding of a partner's emotions was measured with the *affective awareness index*. As in Study 2, this index was defined as the correlation between the participants' answers to the Partner Emotions questionnaire and their partners' answers to the Own Emotions questionnaire. A higher affective awareness index would indicate that collaborators made an accurate judgment of their partners' emotions that approximates to what the partner reported. To do so, collaborators might have paid attention to the emotional expressions of their partners, and/or made

inferences about the emotions of a partner on the basis of the events occurring during game play. Data from Trial 1 was excluded because in this trial, no differentiation was made between the conditions awareness and no awareness. Thus, the affective awareness index was calculated for each participant in a dataset that included the data collected with the questionnaires Own Emotions and Partner Emotions during Trial 2 and Trial 3. For each participant, there were 14 rows (7 emotions x 2 trials) and 2 columns. One column contained the scores in the Partner Emotions questionnaire and the other column contained the scores in the Own Emotions questionnaire of the partner. The affective awareness index was the correlation between these columns.

The reference value to interpret the affective awareness index is a nominal value. That is the affective awareness index in relation to a person different to the actual partner but from the same experimental group, assigned randomly post hoc. Overall, participants' affective awareness index in relation to the actual partner (M=.57, SD= .36) was higher than in relation to a nominal partner (M= .42, SD= .44), $t(47)=2.51$, p= .01 (two-tailed). This indicates that overall, participants' judgments of their partner's emotions were more accurate than what would be expected by chance. Therefore, the affective awareness index is a valid measure to assess the interpersonal understanding of emotions in this dataset.

Positive Affect and Negative Affect

As is common in emotion research (e.g., Langner & Keltner, 2008) data were separated in terms of valence. Table 5.2 shows the intercorrelations between the scores of the emotions listed in the questionnaires Own Emotions and the Partner Emotions. In both questionnaires, there are positive and significant correlations between the positively valenced emotions (happy, interested, hopeful excited and challenged) and between the negatively valenced emotions (frustrated and annoyed). Following this, the data from the Own Emotions questionnaire and the Partner

Emotions questionnaire were reduced into variables of positive affect and negative affect. The variables *own positive affect* and *partner positive affect* were defined as the summed scores for the emotions happy, interested, hopeful, excited and challenged. The variables *own negative affect* and *partner negative affect* were defined as the summed scores for the emotions frustrated and annoyed.

Table 5.2
Averaged intercorrelations between the emotion scores of the questionnaires Own Emotions and Partner Emotions across experimental trials

	Int	Hop	Exc	Cha	Fru	Ann
			Own emotions			
Hap	.61**	.56**	.54**	.26	-.38*	-.52*
Int	--	.50**	.60**	.45*	-.36*	-.39*
Hop	--	--	.52**	.39*	-.19	-.15
Exc	--	--	--	.45*	-.20	-.34*
Cha	--	--	--	--	.014	-.03
Fru	--	--	--	--	--	.76**
			Partner emotions			
Hap	.65**	.60**	.76**	.46**	-.26*	-.30*
Int	--	.66**	.71**	.55**	-.15	-.17
Hop	--	--	.65**	.46*	-.12	-.03
Exc	--	--	--	.45**	-.29	-.26*
Cha	--	--	--	--	.12	.09
Fru	--	--	--	--	--	.82**

Hap= Happy, Int=Interested, Hop=Hopeful, Exc=Excited, Cha=Challenged, Fru=Frustrated, Ann=Annoyed
**p<.01, *p<.05

Interaction Quality

The dyad appraisal scale showed good internal consistency across the three trials (α=.89, .90 and .95); the same as the individual appraisal scale (α= .80, .84 and .91). The items for each scale were averaged to form the variables *dyad appraisal* and

individual appraisal. Differently to the scores in the emotion questionnaires, the average was used to aggregate the interaction quality items instead of the sum because these items are part of theoretically homogeneous constructs.

Performance score

The variable *performance score* was defined to measure participant's performance, using the same scheme as in Study 2. The steps in LSW2 are classified in three types: simple, rewardable and interdependent. Each type of step has a score value that depends on the extent to which the mechanics reward or demand the coordination between players. Table 5.3 shows the definition of the type of steps and its score value.

Table 5.3 *Definition and score value of the puzzle solving steps in LSW2*

Step type	Definition	Example	Value
Simple	The step is to be executed by one character	Building a block, jumping across a gap, breaking a tie	1
Rewardable	The step can be executed by one character only, but the mechanics allow for the step to be more efficiently executed in coordination with the other character	Pulling levers simultaneously, distributing the pressing of a 4 buttons line in 2 buttons each	2
Interdependent	The step is tied to the execution of a previous step than can only be done by the other character	Character A grapples onto a platform previously open by character B using its special ability	3

In the present study, participants played only the mission 2 of LSW2; which has 13 puzzles whose solution requires the execution of a variable number of steps. Maximum possible scores during the mission 2 of LSW2 were calculated for each character. The two initial puzzles used in the induction to the game (procedure Step 1)

were not included. The maximum possible score was defined as the score that a character could make by executing all the steps necessary to succeed in the mission, excluding those steps only executable by the other character. The maximum possible score was 78 for character A and 87 for character B. The performance score was then calculated for each participant. It was defined as the participant's score obtained during trials 2 and 3 divided by the maximum possible score of her corresponding character. The score in Trial 1 was excluded because in this trial there was no differentiation between awareness and no awareness; hence the score was not suitable for comparison across experimental conditions.

5.4.5 Results

The results are presented in seven sections. The first section contains analysis directed to rule out the influence of individual differences in factors that might affect the results of the study, namely game play habits and interpersonal reactivity. Sections 2 to 5 present analyses that assess the effects of the experimental factors awareness and location on the participants' emotion understanding, positive affect, negative affect, interaction quality and performance. Section 6 presents analyses that answer the exploratory question 1.

5.4.5.1 Assessing individual differences in game play habits and interpersonal perception

Game playing habits

It was necessary to rule out that individual differences related to the participants' interest for computer games and game play habits did not bias the results of the study. To do so, a 2x2 doubly multivariate ANOVA with awareness and location as between-participants factors was run over the scores in the three questions of the Game Play Habits questionnaire. As expected, multivariate analysis indicated no main

effects neither for awareness [$F(3,42)=.53$, $p= .66$, $\eta_p^2= .03$] nor location [$F(3,42)= .81$, $p= .49$, $\eta_p^2= .05$]. The Awareness x Location interaction was also not significant [$F(3,42)= 1.404$, $p= .25$, $\eta_p^2= .09$]. This indicates that individual differences in interest for computer games and game play habits were not influential for the results of the study.

Interpersonal reactivity

It was important to check that the affective awareness index was not correlated with the scales in the IRI. A significant correlation between these variables could compromise the results of the study. For example, had the analysis indicated that affective awareness support actually helped collaborators to better understand their emotions of their partners, this would apply only to those with a tendency to have a 'high' interpersonal reactivity as measured with the IRI, and not applicable to those who had a 'low' interpersonal reactivity.

Table 5.4 shows low and non-significant correlations between the affective awareness index and the personality dispositions measured by the IRI. This indicates that individual differences did not influence the measurement of emotion understanding.

Table 5.4
Mean and SD of the IRI scales and its correlation with the affective awareness index

Scale	M	SD	r[1]
Fantasy	28.35	5.35	-.20
Empathic Concern	32.70	4.35	-.15
Perspective Taking	26.12	5.35	-.24
Personal Distress	21.60	4.67	-.23

[1]Correlation with the affective awareness index

Note: All r's $p>.05$, all cells N=48

5.4.5.2 Awareness and location effects on the affective awareness index

Two analyses were made to test the predictions made in H1 about the effects of affective awareness support in the understanding of a partner's emotions. The first one analyzed the effects of awareness and location; the second analyzed the effects of awareness and location controlling for individual differences in interpersonal perception. The first analysis consisted of a 2x2 MANOVA with awareness and location as between-participants factors over the participants' affective awareness index. There was a trend for the main effect of awareness indicating a tendency of those in the awareness condition to have higher affective awareness indexes than those in the no awareness condition [$F(1, 44)= 3.87$, $MSE=0.11$, $p=.06$, $\eta_p^2= .07$]. The main effect of location was not significant [$F(1, 44)= 0.02$, $MSE=0.11$, $p=.87$, $\eta_p^2= .01$].

The Awareness x Location interaction was significant [$F(1, 44)= 4.42$, $MSE=0.11$, $p=.04$, $\eta_p^2= .09$]. Table 5.5 shows the means and SD of the affective awareness index as a function of awareness and location. Tukey HS comparisons indicated that those in the Awareness/Remote cell had significantly higher affective awareness indexes than those in the No awareness/Remote cell ($p<.05$), but not significantly higher than those in the rest of the cells.

Table 5.5
Means and SD of the affective awareness index as a function of awareness and location

	Remote		Co-located	
	M	*SD*	*M*	*SD*
Awareness	0.76	0.34	0.57	0.25
No awareness	0.37	0.42	0.59	0.32

Note: all cells N=12

These results indicate that affective awareness support had null effects during co-located collaborations. In contrast, affective awareness support largely increased collaborators' affective awareness index during remote collaborations, which explains the trend in the awareness main effect. This is illustrated in Figure 5.4

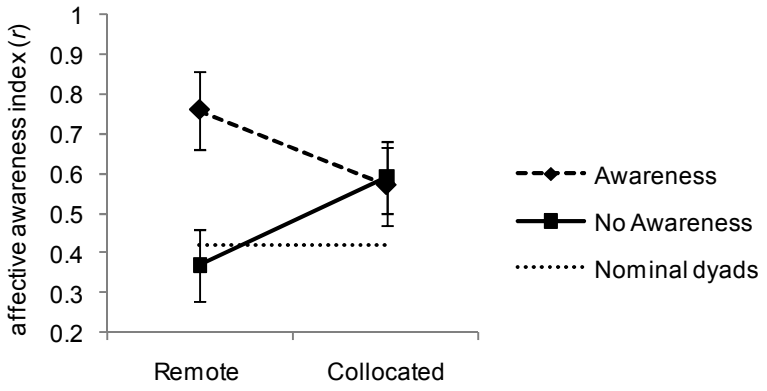


Figure 5.3 *Affective awareness index as a function of awareness and location*

The second analysis was to take into account the individual differences in interpersonal understanding. It consisted of a MANCOVA with awareness and location as between-participants factors over the affective awareness index, including the scores in the IRI scales as covariates. There were no significant covariations with any of the IRI scales: *fantasy* [$F(1, 40)= 0.14$, MSE=0.11, p=.60, η_p^2 <.01], *empathic concern* [$F(1, 40)=0.01$, MSE=0.11, p=.98, η_p^2= .001], *perspective taking* [$F(1, 40)= 0.62$, MSE=0.11, p=.43, η_p^2= .01] and *personal distress* [$F(1, 40)= 2.00$, MSE=0.11, p=.16, η_p^2= .04].

In this analysis, the effect of awareness was not significant [$F(1, 44)= 1.88$, MSE=0.11, p=.17, η_p^2= .04] the same as the location effect [$F(1, 44)= .16$, MSE=0.11, p=.68, η_p^2< .01]. Nevertheless, the Awareness x Location interaction remained significant [$F(1, 40)= 5.25$, MSE=0. 11, p=.04, η_p^2= .10]. These results indicate that

the individual differences in interpersonal perception were not strong enough to diminish the increase in the affective awareness index generated by affective awareness support among those who collaborated remotely.

To summarize, the first prediction of H1 was that affective awareness support would improve the participants' emotion understanding overall. This prediction was not supported. The first analysis indicated a trend for the main effect of awareness, but this was explained by the Awareness x Location interaction. Moreover, in the second analysis, this trend vanished after controlling for the individual differences in interpersonal perception. The second prediction was that, overall, the participants' emotion understanding would be lower during remote collaborations than during co-located collaborations. This prediction was not supported since there was no significance for location in any of the analyses.

The third prediction was that awareness support would generate a larger improvement of participants' emotion understanding during remote collaborations than during co-located collaborations. This prediction was supported. In both analysis, the affective awareness support increased the affective awareness index only during remote collaborations; and had no effects during co-located collaborations.

5.4.5.3 Awareness and location effects on positive affect

Two analyses were made to test the predictions made in H2 about the effects of affective awareness support in participants' positive affect. The first one analyzed the effect of awareness and location. The second one analyzed the effects of awareness and location controlling for the prior positive affect.

The first analysis consisted of a 2x2x2 MANOVA with trial as within-participants factor and awareness and location as between-participants factors over the own positive affect of Trial 2 and Trial 3. The results indicated no main effects of trial

[$F(1,44)=.03$, $MSE=8.47$ $p=.86$, $\eta_p^2= .01$). Those in the awareness condition reported more positive affect than those in the no awareness condition [$F(1,44)= 4.97$, $MSE=64.19$, p=.03, $\eta_p^2= .10$]. Similarly, those in the remote conditions reported more positive affect than those in the co-located conditions [$F(1,44)=5.19$, $MSE=64.19$, $p=.02$, $\eta_p^2=.10$).

The Awareness x Location interaction was significant [F(1,44)=6.04, $MSE= 64.19$, $p=.02$, $\eta_p^2= .12$]. Table 5.6 shows that in Trial 2, those in the Awareness/Remote cell reported higher positive affect than those in the Awareness/Co-Located cell. In Trial 3, those in the Awareness/Remote cell reported higher positive affect than those in all the other conditions.

Table 5.6 *Mean and SD of positive affect in Trial 2 and Trial 3 as a function of awareness and location*

	Awareness				No Awareness			
	Remote		Co-Located		Remote		Co-Located	
	M	SD	M	SD	M	SD	M	SD
Trial 2	33_{aa}	5.46	26.75_{bb}	4.64	27_{ab}	6.87	27_{ab}	5.70
Trial 3	35.16_{aa}	4.38	25.96_{bb}	6.44	25.83_{bb}	6.72	26.41_{bb}	7.32

Means in the same row which two subscript terms are different differ at $p<.05$ in the Tukey honestly significant comparisons

These results indicate that affective awareness support largely increased the positive affect during remote collaborations, but had a null effect during co-located collaborations. Therefore, the Awareness x Location interaction explains the main effects of awareness and location. This is illustrated in Figure 5.4.

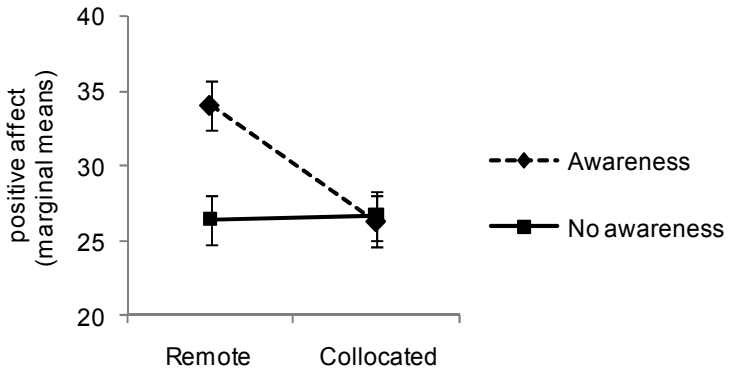


Figure 5.4 *Marginal means of positive affect as a function of awareness and location*

The second analysis was to take into account collaborators' prior positive affect. If prior positive affect had a significant influence on the positive affect during the experimental trials, the interpretability of the awareness and location effects would be compromised. For this analysis, a 2x2x2 MANCOVA with the prior positive affect scores as covariates, trial as within-participants factor and awareness and location as between-participants factors, was run over the positive affect scores.

The results indicated non-significant covariation of the prior scores of positive affect with the scores of positive affect during Trial 2 and Trial 3 [$F(1,43)= 2.31$, $MSE=62.32$, $p=.13$, $\eta_p^2= .05$]. The main effects of trial were also not significant [$F(1,43)= .43$, $MSE= 8.45$, $p=.51$, $\eta_p^2= .01$]. Positive affect was significantly higher in the awareness condition than in the no awareness condition [$F(1,43)= 4.33$, $MSE= 62.32$, $p= .04$, $\eta_p^2= .05$). Similarly, positive affect was higher in the remote condition than in the co-located condition ($F(1,43)=3.85$, $MSE= 62.32$, $p=.05$, $\eta_p^2= .09$). The Awareness x Location interaction was significant ($F[1,43]= 5.31$, $MSE= 62.32$, $p= .02$, $\eta_p^2= .02$). These results indicate that the prior positive affect did not influence the positive affect during the experimental trials. Therefore, the increase of positive affect as a function of affective awareness support during remote collaborations is fully attributable to the experimental manipulations of the study.

In summary, the first prediction of H2 was that affective awareness support would increase the positive affect overall. This prediction was not supported. The main effects of awareness were significant in both analyses, but this was a product of the Awareness x Location interaction.

The second prediction of H2 was that, overall, the positive affect would be lower during remote collaborations than during co-located collaborations. This prediction was not supported. In the two analyses, the main effects of location indicated more positive affect during co-located collaborations. However, this was a product of the Awareness x Location interaction.

The third prediction of H2 was that affective awareness support would generate a larger increase of positive affect during remote collaborations than during co-located collaborations. This prediction was supported. In both analysis, the affective awareness support generated a large increase of positive affect during remote collaborations; and had no effects during co-located collaborations.

5.4.5.4 Awareness and location effects on the own negative affect

Two analyses were made to test the predictions made in H3 about the effects of affective awareness support on the negative affect. The first one analyzed the effect of awareness and location. The second one analyzed the effects of awareness and location controlling for the prior negative affect.

The first analysis consisted of a 2x2x2 MANOVA with trial as within-participants factor and awareness and location as between-participants factors over the own negative affect of Trial 2 and Trial 3. There were no significant main effects either of trial [$F(1,44)=.18$, $MSE=6.83$, $p=.67$, $\eta_p^2= .04$], awareness [$F(1,44)= 0.52$, $MSE= 30.48$, $p=.47$, $\eta_p^2= .01$)] or location $F(1,44)= 2.24$,

MSE=30.48 p=.14, η_p^2= .04]. The Awareness x Location interaction showed a trend [F(1,44)= 4.97, MSE= 30.48, p=.06, η_p^2=.07]. Table 5.7 indicates no differences in the negative affect means across experimental conditions in Trial 2. However, in Trial 3, those in the Awareness/Remote cell reported less negative affect than those in the Awareness/Co-Located cell.

Table 5.7
Mean and SD of negative affect in Trial 2 and Trial 3 as a function of awareness and location

	Awareness				No awareness			
	Remote		Co-Located		Remote		Co-Located	
	M	SD	M	SD	M	SD	M	SD
Trial 2	3.16_{aa}	4.08	5.66_{aa}	3.72	6.25_{aa}	4.53	5.75_{aa}	4.37
Trial 3	2.41_{aa}	4.10	7.50_{bb}	4.62	5.61_{ab}	4.17	4.83_{ab}	4.83

Means in the same row which two subscript terms are different differ at p<.05 in the Tukey honestly significant comparisons

These results indicate that the affective awareness support minimally decreased the negative affect during remote collaborations, and had no effect in co-located collaborations. This is illustrated in Figure 5.5.

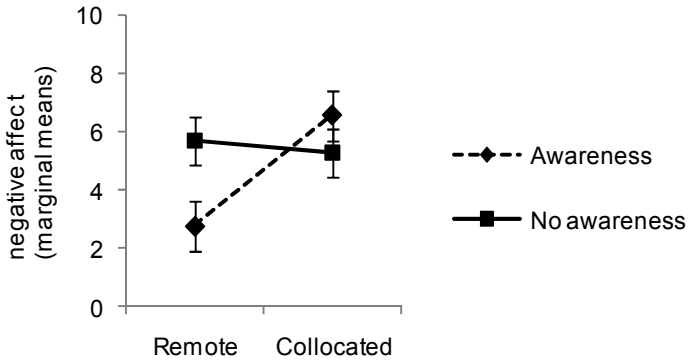


Figure 5.5 *Marginal means of negative affect as a function of awareness and location*

The second analysis was to take into account the prior negative affect. If participants' prior negative affect were significantly related to their negative affect

during the experimental trials, the effects of awareness and location would be compromised. A 2x2x2 MANCOVA with the prior own negative affect as covariate, trial as within-participants factor and the awareness and location as between-participants factors, was run over the negative affect scores. The results indicated a significant covariation with the prior scores [(F(1,43)=4.73, MSE=28.09 p=.03, η_p^2= .09) and a marginal main effect of trial [F(1,43)= .33, MSE= 6.90, p=.05, η_p^2<.01).

The main effects of awareness were not significant [F(1,43)= .38, MSE=28.09, p=.53, η_p^2= .001), the same as the main effects of location [F(1,43)=2.04, MSE= 28.09, p=.16, η_p^2= .04] and the Awareness x Location effects [F(1,45)=2 .90, MSE=28.09, p=.09, η_p^2= .06]. These results indicate that the prior negative affect influenced the negative affect during the experimental trials. Moreover, this influence was stronger than the minimal decrease in negative affect as a function of affective awareness support during remote collaborations found in the first analysis.

In summary, the first prediction of H3 was that affective awareness support would decrease the negative affect overall. This prediction was not supported. There were no effects of awareness in none of the analyses.

The second prediction was that, overall, the negative affect would be higher during remote collaborations than during co-located collaborations. This prediction was not supported because the analysis showed no effects of location.

The third prediction was that affective awareness support would generate a larger decrease of negative affect during remote collaborations than during co-located collaborations. This prediction was not supported. Although the first analysis showed a trend for affective awareness support to reduce the negative affect during remote collaborations, this effect vanished after controlling for the effects of the prior negative affect.

5.4.5.5 Awareness and location effects on the perceived interaction quality

It was not possible to test the predictions made in H4 about the effects of affective awareness support in the perceived interaction quality because there were ceiling effects on the data. Table 5.8 presents the descriptive statistics of dyad appraisal and individual appraisal. Across trials and conditions, the scores of dyad appraisal and individual appraisal ranged from 5 to 7 and their *SD*s are rather small. This indicates that participants used only the highest half of the Likert scale presented in the Interaction Quality questionnaire, which ranged from zero to eight. These results indicate ceiling effects in the dyad appraisal and the individual appraisal measures. As a consequence, it was not possible to make a reliable testing of the predictions made in H4.

Table 5.8 *Mean and SD of dyad appraisal and individual appraisal in trials 2 and 3 as a function of awareness and location*

	Awareness				No Awareness			
	Remote		Co-Located		Remote		Co-Located	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
	Dyad appraisal							
Trial 2	6.67	1.11	6.03	0.97	6.27	1.18	5.89	1.27
Trial 3	7.03	1.05	6.40	0.95	6.02	1.54	6.66	0.82
	Individual appraisal							
Trial 2	5.91	1.40	5.68	1.28	5.54	0.95	5.166	1.1
Trial 3	6.36	1.13	6.02	0.99	6.04	1.23	5.81	1.22

5.4.5.6 Awareness and location effects on the performance score

Two analyses tested the predictions of H5 about the effects of affective awareness support on collaborators' performance. The first analyzed the effects of awareness and location on the performance score during Trial 2 and Trial 3, where there was full manipulation of awareness and location. To compare, the second analysis tested the effects of awareness and location in the performance score during Trial 1, where no differentiation was made between the awareness and no awareness conditions.

The first analysis consisted of a 2x2 MANOVA with awareness and location as between-participants factors over the performance score. Those in the awareness conditions had significantly higher performance scores than those in the no awareness conditions [$F(1,44)= 5.43$, $MSE=53.05$, $p=.02$, $\eta_p^2= .11$]. Those in the remote conditions had significantly higher scores than those in the co-located conditions [$F[1,44]=8.26$, $MSE=53.05$, $p= .006$, $\eta_p^2= .15$]. The Awareness x Location interaction was not significant [$F(1,44)= 1.24$, $MSE=53.05$, $p= .27$, $\eta_p^2= .02$].

Table 5.9 presents the Mean and SD of the performance scores. Post-hoc comparisons with the Tukey HSD test indicated that the performance score in the Awareness/Remote cell was significantly higher than the performance scores in the Awareness/Co-Located cell ($p<.05$) and the No awareness/Co-Located cell ($p<.05$), and marginally higher than the scores in the No awareness/Remote cell ($p<.09$).

Table 5.9 *Mean and SD of performance score as a function of awareness and location*

	Remote		Co-Located	
	M	*SD*	*M*	*SD*
Awareness	29.88	5.03	21.49	8.20
No awareness	22.63	8.70	18.93	6.6

Note: all cells N=12

These results show that per se, neither awareness nor location influenced participants' performance. However, the combined effect of affective awareness support and remote collaboration increased performance, as illustrated in Figure 5.6

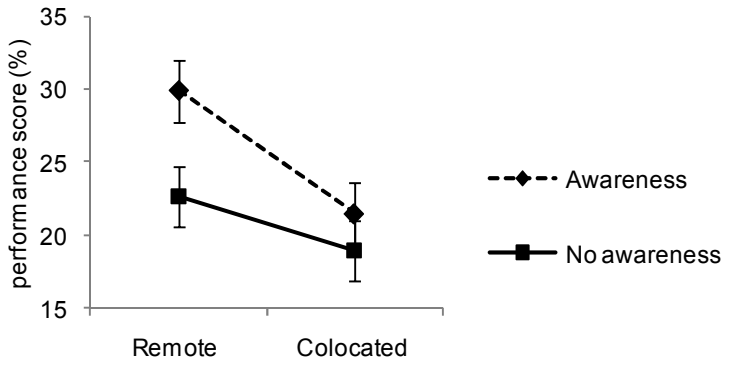


Figure 5.6 *Performance score as a function of awareness and location*

The second analysis was to investigate whether the significant effects of awareness and location reported above were fully attributable to the experimental manipulations. This consisted of a 2x2 MANOVA with awareness and location as between-participants factors over the performance score during Trial 1. Results indicated no main effects either for awareness [$F(1,44)=1.45$, $MSE= 35.74$, p=.23, $\eta_p^2= .03$], location [$F(1,44)=.75$, $MSE= 35.74$, $p=.39$, $\eta_p^2= .01$] or the Awareness x Location interaction [$F(1,44)=.39$, $MSE=35.74$, $p=.53$, $\eta_p^2< .01$]. Therefore, the performance improvement during remote collaborations with awareness support during Trial 2 and Trial 3 is fully attributable to the experimental manipulations of the study.

In summary, the first prediction of H5 was that affective awareness support would improve the collaborators' performance overall. This prediction was not supported. Although affective awareness support generated a tendency to improve performance, this tendency required of the conditions given by remote collaboration to reach significance.

The second prediction was that the performance would be, in general, better during co-located collaborations than during remote collaborations. This prediction was not supported. Although remote collaborations tended to have a better performance than co-located collaborations, this tendency required the effects of affective awareness support to reach significance.

The third prediction was that affective awareness support would generate a larger improvement in performance during remote collaborations than during co-located collaborations. This prediction was partially supported. There was a trend for affective awareness support to increase the performance score more during remote collaborations than during co-located collaborations.

5.4.5.7 Correlations between affective awareness index and performance score

One exploratory question asked whether affective awareness support could influence the relationship between emotion understanding and performance. To answer this, an analysis was made to test whether the correlation between collaborators' performance score and their own and their partner's affective awareness index changed across the four conditions of the study: Awareness/Remote, Awareness/Co-Located, No awareness/Remote, and No awareness/Co-Located.

Table 5.10 indicates that the correlations between participants' performance score with their own and their partner's affective awareness index had similar medium strength and positive direction in the Awareness/Remote cell. In the rest of the cells, the strength of these correlations is lower and non-significant.

The comparison across experimental conditions was made with the *Z* test developed by Fisher (1921) to compare correlations from different samples. There was a significant difference between the Awareness/Remote cell and the No

awareness/Co-Located cell; both for the correlation of the performance score with the own affective awareness index (Z=2. 14, p= .03) and the correlation of the performance score with the partner's affective awareness index (Z=2.37, p= .01).

Table 5.10
Correlations between collaborators' performance with their own and their partner's affective awareness index (AAI) as a function of awareness and location

	Awareness		No Awareness	
	Remote (N=12)	Co-Located (N=12)	Remote (N=12)	Co-Located (N=12)
Own AAI	$.58^{*}_{aa}$	$.41_{ab}$	$.32_{ab}$	$-.24_{bb}$
Partners' AAI	$.57^{*}_{aa}$	$.52_{ab}$	$.26_{ab}$	$-.32_{bb}$

Correlation coefficients in the same row which two subscript terms are different differ at $p<.05$

$^{*}p<.05$

These results indicate that the relationship between interpersonal emotion understanding and performance is reinforced by the interaction between affective awareness support and remote collaboration, and weakened under conditions of co-located collaboration without affective awareness support.

5.4.6 Discussion

The study presented in this chapter was designed to assess the potential benefits of affective awareness support during co-located and remote collaborations. Participants were organized into dyads to play LSW2. In this game, two players solve puzzles using characters whose skills complement each other. Importantly, collaboration is rewarded rather than forced. That is, collaborators can solve the puzzles even without cooperation; but they will play more efficiently if they collaborate.

To reduce the impact of cultural differences, participants were chosen who shared a similar cultural background and were native or fluent English speakers. The dyad

members did not know each other as familiarity might have influenced their ability to judge each other's emotions.

Two groups of dyads were formed. One group played LSW2 co-locatedly. The other group played LSW2 remotely, in 'real time', communicating through an audio channel. Affective awareness support consisted of presenting the collaborators with a graphical representation of the self-reported emotions of their partners. Within each group, dyads that collaborated without affective awareness support were compared with dyads that collaborated with affective awareness support.

The benefits of affective awareness support were assessed in four areas: emotion understanding, affective experience, perceived interaction quality and performance. In each of these areas, there were specific hypotheses in relation to the expected effects of affective awareness support in remote and co-located collaborations. All the hypotheses included three predictions:

1) Affective awareness support will have an overall positive effect
2) Collaborators playing LSW2 remotely would be inferior to collaborators playing LSW2 co-locatedly
3) Affective awareness support will have a more powerful positive effect among collaborators playing LSW2 remotely than among collaborators playing LSW2 co-locatedly

The findings are discussed to determine if affective awareness support could benefit the outcomes of co-located and remote-continuous collaborations. First, the results on each of the assessed areas are discussed separately. Second, conclusions are presented to provide an integrated interpretation of the results.

5.4.6.1 The benefits of affective awareness support on the understanding of a partner's emotions

The results in this area were key to confirm that affective awareness support actually benefited the understanding of a partner's emotions. This section discusses the adequacy of the affective awareness index as a measure of emotion understanding and the effects of affective awareness support.

The adequacy of the affective awareness index

The first step was to check that the affective awareness index actually indexed a more or less accurate understanding of a partner's emotions. First, the nominal dyad analysis indicated that collaborators' affective awareness indexes were larger than would be expected by chance, which indicated that the index was sensitive to the effects of the interaction with the partner.

Second, the non-significant correlations between the IRI scales and the affective awareness index suggested that this index was relatively independent of personal tendencies to be more or less 'empathic'. The subscales of the IRI correlate with other measures of individual differences in affective aspects such as susceptibility to emotional contagion (Doherty, 1997) and social skills (Riggio, Tucker, & Coffaro, 1989). Furthermore, the IRI is a widely used to take into account dispositional tendencies in empathy to investigate empathy in different areas such as neuroscience (e.g., Lamm, Meltzoff, & Decety, 2010) and interpersonal relationships (Péloquin & Lafontaine, 2010).

One could expect a significant correlation between the affective awareness index and the perspective-taking subscale of the IRI. Both affective awareness and perspective taking can be considered as forms of reasoning about mental states. However, it is likely that these measures did not correlate because the affective

awareness index is purely about emotions, whereas the perspective taking scale of the IRI seems to focus on 'cognitive' aspects[6]. A comprehensive literature review suggested that reasoning about emotions and reasoning about other more 'cognitive' mental states might be dissociable processes (Blair, 2005).

These findings indicate that the affective awareness index was adequate to measure emotion understanding. Higher indexes would indicate that individuals were attentive to the partner's emotional expressions, and/or that they accurately identified the circumstances underlying their partner's emotions.

The effects of affective awareness support

Affective awareness support consisted of presenting the collaborators with a graphical representation of the reported emotions of the partner. One could think the procedure generated a circularity that could explain any accuracy at reporting the emotions of the partner. In two occasions, individuals saw the emotions reported by the partner before playing for 10 minutes, and then they estimated the emotions of the partner again. However, partner's emotions could change substantially during the 10 minutes of game play - recall that in Study 2, partners' emotions could vary substantially in periods of 2-3 minutes. Therefore, accuracy might indicate awareness of how the game play affected the partner's emotions, more than a recall of the emotions previously reported by the partner.

[6] Only one item of the perspective scale of the IRI refers to affective states (*Before criticizing somebody, I try to imagine how I would feel if I were in their place*), and most of the items refer to the process of imagining other's points of view (e.g., *I try to look at everybody's side of a disagreement before I make a decision*), or imply cognitive states such as argumentation (*If I'm sure I'm right about something, I don't waste much time listening to other people's arguments*).

In general, receiving affective awareness support, or not, made no differences in the participants' affective awareness index. This did not support the first prediction of H1 that affective awareness support would improve the interpersonal emotion understanding overall.

It was also found that playing LSW2 remotely or co-locatedly made no difference in the affective awareness index. This did not support the second prediction of H1 that collaborators playing LSW2 co-locatedly would have a better understanding of the emotions of their partners than collaborators playing remotely.

Importantly, the affective awareness index of those who played LSW2 remotely and also received affective awareness support, was higher than the affective awareness index of those who also played LSW2 remotely, but did not receive affective awareness support. In contrast, receiving affective awareness support or not, made no difference in the affective awareness index of those who played LSW2 co-locatedly. These results support the third prediction made in H1 that affective awareness support would generate a larger improvement in the interpersonal emotion understanding during remote collaborations than during co-located collaborations.

These results suggest that the conditions of remoteness emphasized the effects of receiving affective awareness support. Collaborators playing LSW2 remotely interacted in real-time, without visual access to the partner and using an audio channel (i.e., headsets) to communicate. According to the results, these conditions favoured the effects of receiving information about the emotions of a partner, which resulted in a more accurate understanding of a partner's emotions. This is probably the result of a twofold mechanism.

First, those who played LSW2 remotely and also received affective awareness support, ascribed value to the 'artificial' information contained in the representation of

their partner's emotions. They used it to compensate for the loss of visual information about their partner's emotions, such facial expressions and gestures. The importance of facial expressions and gestures is indicated by the fact that the affective awareness index of those who collaborated remotely without affective awareness support was very similar to that expected by chance.

Second, affective awareness support also motivated collaborators playing LSW2 remotely to be more concerned about their partners' emotions. Therefore they paid more attention to the 'emotional content' of the partner's vocal intonation and discourse. In turn, the use of an audio communication channel focused the attention on the vocal intonation and discourse of the partner, facilitating the accurate perception of any changes in their emotions. This is consistent with recent research in Social Psychology, which indicates that when inferring feelings, people pay special attention to voice intonation and discourse content (Hall & Schmid, 2007).

In contrast, those who played LSW2 co-locatedly with affective awareness support ascribed no value to the artificial information contained in the graphical representation of the partner's reported emotions. It seems like they trusted more in the natural information about the emotions of the partner acquired while playing LSW2; such as the context of the game play, the intonation of the partner's voice and the content of her speech; as well as her facial emotion expressions and gestures. They possibly disregarded the artificial information because it was provided by an external 'agent' (i.e., a 'machine' and/or the experimenter), and not directly acquired during the actual interaction with the partner. In comparison, they relied on the natural information because it was directly acquired during the actual interaction with the partner.

In summary, collaborators who played LSW2 remotely, without visual access to the partner and communicating through an audio channel, ascribed an important value to the artificial information about the partner's emotions given as affective awareness

support. This motivated them to be more concerned about the emotions of the partner. In turn, during the playing of LSW2, they focused on the voice intonation and content speech of the partner transmitted through the audio channel. As a result, these collaborators were more aware of the changes in their partner's emotions, and of the game play situations leading to these changes. Therefore, their understanding of their partner's emotions increased from a rather low chance-expected level, to a fairly high level. In contrast, those who played LSW2 co-locatedly disregarded the artificial information about their partner's emotions in the presence of abundant natural information such as contextual information, voice intonation, discourse content, facial expressions and gestures. Therefore, affective awareness support did not change their understanding of their partner's emotions at all.

5.4.6.2 The benefits of affective awareness support on collaborators' emotions

The effects of affective awareness support on collaborators' emotions were measured in terms of positive affect and negative affect. The measure of positive affect covered the emotions happy, interested, hopeful, excited and challenged. The measure of negative affect covered the emotions frustrated and annoyed.

Smith & Ellsworth (1985) identified the contextual factors associated with these emotions. They found that people feel happy and interested in situations where they are attentive and pleased. The feelings of challenge and hope are associated with situations that demand effort, but where there is also certainty and understanding. The feelings of frustration and annoyance are associated with situations that imply uncertainty about the output and lack of control. A number of studies have reported that these situations are common during the use of computer games (Conati & Zhou, 2002; Ravaja et al., 2006). Therefore, if participants of this study reported more

positive affect and less negative affect, they presumably felt they had control and understanding of the situations presented by LSW2; and experienced the collaborative experience as pleasant and engaging.

Positive affect. Receiving affective awareness support or not, made no differences for the positive affect of collaborators. This did not support the first prediction of H2 that affective awareness support would increase the positive affect overall. It was also found that the positive affect of collaborators was not affected by whether they played LSW2 co-locatedly or remotely. This did not support the second prediction of H2, that the positive affect would be lower during remote collaborations than during co-located collaborations.

It was also found that those who played LSW2 remotely, and also received affective awareness support, reported more positive affect than those who also played LSW2 remotely, but did not receive affective awareness support. In contrast, affective awareness support made no differences in the positive affect of those who played LSW2 co-locatedly. These results support the third prediction of H2 that the increase of positive affect as a function of affective awareness support would be larger during remote collaborations than during co-located collaborations.

Negative affect. Receiving affective awareness support, or not, made no difference in the negative affect of collaborators playing LSW2. This did not support the first prediction oh H3 that affective awareness support would decrease the negative affect overall. Similarly, whether collaborators played LSW2 remotely or co-locatedly, made no differences for their negative affect. This did not support the second prediction of H3 that, overall, the negative affect would be higher during remote collaborations than during co-located collaborations overall.

It was also found that affective awareness support did not reduce the negative affect neither among those who played LSW2 remotely, nor among those who played LSW2 co-locatedly. This did not support the third prediction of H3, that the decrease of negative affect as a function of affective awareness support would be larger during remote collaborations than during co-located collaborations.

Thus, the emotions of collaborators playing LSW2 co-locatedly were, neither more positive nor less negative, than the emotions of collaborators playing remotely. This suggests that having visual access to the facial expressions and gestures of the partner was not relevant for the feelings of collaborators. Therefore, audio communication was sufficient for those who collaborated remotely to feel emotions of the same quality and intensity than those who played co-locatedly.

However, depending on whether collaborators played LSW2 remotely or co-locatedly, they reacted differently to the information about the partner's emotions provided as affective awareness support. Collaborators playing co-locatedly showed no emotional reaction, neither positive nor negative, to the information about the partner's emotions. This is probably because, as the results in emotion understanding suggest, they disregarded the representation of the partner's emotions since they had access to the gestures and facial expressions of the partner.

In contrast, collaborators playing remotely reacted to the information about the emotions of the partner more positively, but not less negatively. That is, after looking at the reported emotions of the partner, they felt more happiness challenge and interest; emotions associated with pleasantness, understanding and certainty about the outcomes of the situation. However, they did not feel less frustration and annoyance; emotions mainly associated with failure and lacking control.

These results are probably explained by a twofold mechanism. First, as suggested by the results in the area of emotion understanding, those who played LSW2 remotely valued the information about the partner's emotions given by affective awareness support. They used it to compensate the lack of access to the gestures and facial expressions of the partner. In turn, the information about the partners' emotions triggered more concern for the emotions of the partner. As a consequence, they paid more attention to partner's voice intonation and discourse content. This attention was focused by the audio channel, leading to a fairly accurate understanding of the partner's emotions.

Second, the achievement of an accurate understanding of the partner's emotions facilitated the social regulation of emotions between collaborators playing LSW2 remotely. Possibly they used the emotions of the partner as cues to distinguish whether the partner was motivated to collaborate or not. For example, if they were able to identify when the partner was not enjoying the game play, they could infer that the partner was not motivated to collaborate. As a response, they could provide encouragement or support for the partner to increase her enjoyment and motivation to collaborate. This would be consistent with studies that have reported how collaborators regulate each other's emotions during collaborative learning (Järvenoja & Järvelä, 2009) and that affective awareness is necessary to discern and react to the needs of the partner during collaboration (Artman & Wærn, 1998). Three hypothetical scenarios illustrate how this might have worked.

In the first scenario, one of the collaborators realized, after looking at the partner's reported emotions, that the partner was feeling less challenged and interested than her. Then she reacted giving hints, advice and encouragement to the partner. This in turn might have increased the partner's sense of control over the situation, leading to increased feelings of challenge and interest. A second scenario is that collaborators

realized that they were feeling similarly challenged and interested. For these collaborators, the realization of a shared affective experience might have reinforced their positive feelings. A third scenario is that collaborators realized that they were feeling equally low levels of challenge and interest. As a response, these collaborators gave each other more encouragement, mutual support, hints and advice during the game play. This increased their senses of pleasantness, control and understanding, which in turn increased their feelings of challenge and interest.

In summary, playing LSW2 remotely or co-locatedly made no differences in collaborators' emotions. This means that collaborating in real-time with an audio channel was enough for collaborators playing LSW2 remotely to feel emotions of the same quality as collaborators who played LSW2 co-locatedly. Nevertheless, collaborators reacted differently to the information about the partner's emotions presented as affective awareness support depending on whether they played co-locatedly or remotely. Those who played co-locatedly showed no reaction at all. In contrast, among those who played LSW2 co-locatedly, affective awareness support increased the feeling of positive emotions such as happiness, interest, hope, challenge and interest. This is possibly because the information about the emotions of a partner prompted mechanisms of social regulation leading to increased pleasantness, engagement, control, and understanding while solving the puzzles in LSW2.

5.4.6.3 The benefits of affective awareness support in the perceived interaction quality

In order to measure perceived interaction quality, participants were asked to answer a questionnaire with two scales. The questions in these scales covered aspects that, according to a review of various theoretical accounts (Bratman, 1992; Crook,

2000; Schwartz, 1998), determine the quality of the interpersonal interaction during a collaborative activity such as mutual support and responsiveness.

One scale was for the participants to evaluate their own and their partner's participation while playing LSW2. This included six questions covering the themes mutual support, expression of ideas and interest for the ideas of the other. The answers to these questions were averaged to form the variable 'individual appraisal'. The other scale was for the participants to evaluate their interaction quality 'as a dyad'. This included seven items covering the themes contribution equality, understanding of one another's ideas and overall performance. The answers to these items were averaged to form the variable 'dyad appraisal'.

The answers to the questions composing each of these scales were highly correlated with each other, indicating that they were measuring the same construct. This is a positive attribute for questionnaire-based measures. However, the strategy taken to measure perceived interaction quality was not adequate. The decision to use various questions and ask the participants to answer them three times was based on the intention to collect abundant data. However, this strategy turned out to be counterproductive because most participants, most of the times, answered the questions using the highest part of the Likert scale. That is, participants gave a biased evaluation of their interaction quality, generating a 'ceiling effect' in the measurement. Therefore, the data collected to assess the effects of affective awareness support in this area were not interpretable and, as a consequence, it was not possible to test the hypothesis made in H4.

5.4.6.4 The benefits of affective awareness support on performance

The collaborator's performance was measured with a score that matched the mechanics of LSW2. The steps necessary to solve the puzzles in LSW2 were

classified in three types: basic, rewardable and interdependent. To calculate the performance score, the basic steps were scored as 1, rewardable steps as 2 and interdependent steps as 3. In this way, the performance score accounted for individual performance but also for collaboration.

A higher performance score implied that collaborators not only solved more of the puzzles, but also that they did so in a collaborative manner. In practical terms, this means that they did as follows: First, they made the simple steps effectively. Second, they took advantage of the steps that reward collaboration. For example, they fairly distributed the work (e.g., stomping two buttons each when the step required to stomp four buttons) and they coordinated to make simultaneous actions (e.g., pulling two levers at the same time). Third, they effectively used the complementary skills of their characters during the interdependent steps, which means that both partners played their own role effectively.

It was found that receiving affective awareness support, or not, made no difference in collaborators' performance. This did not support the first prediction of H5 that affective awareness support would improve the collaborators' performance overall. Also, playing LSW2 remotely or co-locatedly made no difference for collaborators' performance. This did not support the second hypothesis of H5 that the performance would be, in general, better during co-located collaborations than during remote collaborations.

Importantly, it was also found that those who played LSW2 remotely and also received affective awareness support, performed better than those who also played remotely, but did not receive affective awareness support. In comparison, affective awareness support made no differences in the performance of those who played LSW2 co-locatedly. This supports the third prediction of H5 that the improvement in

performance as a function of affective awareness support would be larger during remote collaborations than during co-located collaborations.

These results indicate that the performance of collaborators playing LSW2 was as good as the performance of collaborators playing co-locatedly. This suggests that, in order to have an effective performance, it was sufficient for collaborators to interact in real-time while communicating through an audio channel, whereas visual access to the gestures and expressions of the partner was irrelevant. Possibly the interactions that occurred 'outside' the game (e.g., gesturing to co-ordinate with the partner), were redundant because in order to play LSW2 effectively, all the relevant interaction between players occurs 'inside' the game. LSW2 has well defined rules, and the skills of the characters complement each other while interacting in the same screen. This is consistent with a study on collaborative educational games that explains the importance of a clear rule definitions and complementary roles to directly benefit performance (Infante et al., 2009), and with the literature suggesting continuous-remote collaborations are as effective as co-located collaborations providing the audio communication is of good quality (for a review, see Ertl et al., 2006), and also when the collaboration occurs in a shared interface (Pauchet et al., 2007).

The results also suggest that those who played LSW2 remotely and also received affective awareness support increased their performance because they had a more accurate understanding of their partner's emotions. In the discussion about the effects of affective awareness support on collaborators' emotion understanding, it was argued that those who collaborated remotely valued the information about the emotions of the partner given as affective awareness support. In turn, this information generated more concern for the partner's emotions. Therefore, these collaborators paid more attention to the voice intonation and discourse content of their partners, leading to a fairly accurate understanding of their partner's emotions.

It was discussed that the accurate understanding of a partner's emotions helped collaborators playing LSW2 to regulate each other's emotions, leading them to feel more positive emotions like challenge and interest. Possibly, collaborators' enhanced awareness about the partner's emotions not only helped them to regulate each other's emotions. As the results suggest, affective awareness support also helped collaborators playing remotely to collaborate more and, therefore, to perform better. Possibly they made more effort to understand the ideas and actions of the partner while, at the same time, they also made more effort to express their own ideas clearly. This means that, for example, these collaborators used the understanding of the partners' emotions to make accurate predictions and/or interpretations of the actions of the partner while playing LSW2. This might have worked as in the following hypothetical scenario:

Say two collaborators are facing a step that rewards collaboration. It is possible for one collaborator to solve this step by her self, but the step is more efficiently solved if the two collaborators cooperate. For example, in order to open a door, players need to pull two levers. One of the collaborators can pull the two levers if she rapidly moves from one to another. This will open the door, but at the cost of individual effort and time, and that would be reflected in a lower performance score. In contrast, if players decide to collaborate, they can easily distribute the work and pull one lever each; this would be more efficient and reflect in a higher performance score.

Suppose then, that collaborators are facing the door with the two levers and one of them stands still for no apparent reason. There could be (at least) two possible explanations. One is that the collaborator who stands still has a decreased motivation to collaborate, possibly because she is not enjoying the game, so she is waiting for the partner to pull the two levers. Another explanation is that the collaborator who stands

still is actually motivated to collaborate. She may be enjoying the game and is waiting for the partner to make a move or say something to in order to initiate coordination.

Let us assume that the one who is observing is enjoying the game and is motivated to collaborate. With an accurate understanding of her partner's emotions, she could more easily discern between these options in order to interpret the standing still of the partner. Then, if the observer attributes a decreased motivation to collaborate to the standing still partner, she has at least two options. She can pull the two levers by herself, which would open the door, but at the cost of time and effort. Alternatively, she can invite the partner to do one lever each, with an unknown response from the partner. Conversely, if the observer attributes motivation to collaborate to the standing still partner, then she has the option of standing in front of one lever and propose the strategy of distributing the levers; confidently assuming the partner will promptly go to pull the other lever.

In summary, playing LSW2 remotely or co-locatedly made no differences in collaborators' performance. This indicates that, in order to effectively play LSW2, it is sufficient to interact in real-time using audio while having visual access to the partner is irrelevant. This is because in LSW2, collaborators interact using characters with abilities that complement each other in a shared interface. It seems like those who played LSW2 remotely took advantage of the benefits that they gained with affective awareness support; namely an accurate understanding of the partner's emotions and more positive emotions. Apparently, these collaborators recruited their understanding of the partner's emotions to regulate each other's emotions with mutual support. Moreover, the accurate understanding of a partner's emotions also helped collaborators playing LSW2 to collaborate more and, because LSW2 rewards collaboration, they performed better

5.4.6.5 The relationship between emotion understanding and performance

The exploratory question (EQ) asked: To what extent are the collaborators' emotion understanding and performance related, and how is this relationship influenced by affective awareness support? Only among those who played LSW2 remotely and also received affective awareness support; was there a significant correlation between the participants' performance score with both their own affective awareness index and the affective awareness index of the partner. This indicates that, as a consequence of receiving affective awareness support, these collaborators performed better when they accurately understood the emotions of one another.

5.4.6.6 General expectations of the study

The findings differ with some general expectations of the study derived from the literature, which probably reflects that the knowledge about affect in computer-supported collaboration is still very little.

General benefits of affective awareness support. The literature suggests that the understanding of a partner's emotions might play a key role in the motivation to collaborate (Crook, 2000; Tomasello et al., 2005) and the social regulation of emotions (Artman & Wærn, 1998; Järvenoja & Järvelä, 2009). These processes are central for collaboration and therefore, if individuals acquired a better understanding of the partner's emotions, benefits could be expected in all the assessed areas regardless of the location. However, the findings indicated that affective awareness support per se, was insufficient to generate benefits in any of the assessed areas. Instead, it required of the conditions of remoteness to generate the expected benefits.

Inferiority of remote collaborations. The current literature suggests that during remote collaborations, the use of CMC generates difficulties for performance (Stone & Posey, 2008) and diminishes the perceived social presence between collaborators (Pauchet et al., 2007). Therefore, remote collaborations were expected to be inferior in comparison to co-located collaborations. However, the findings indicated that interacting with an audio channel was sufficient for remote collaborators to feel and perform in the same way as co-located collaborators, which is probably not surprising because a reliable audio quality is enough for remote collaborations to be as effective as co-located ones (Ertl et al., 2006). Moreover, the affective awareness index of remote collaborators was slightly lower than amongst co-located collaborators, but this was not significant.

Differential effects of affective awareness support. During co-located collaborations, affective awareness support was expected to bring benefits; whereas in remote collaborations, it was not only expected to bring benefits, but also compensatory effects. The findings partially supported this expectation. As we have seen, affective awareness support had no effect in co-located collaborations. The effect was stronger in remote collaborations, but it was not compensatory since, as we have also seen, remote collaborations were not inferior to co-located ones.

In previous sections, it has been argued that unlike co-located collaborators, remote collaborators valued the affective awareness support, which prompted a concern for the partner's emotions. Therefore, collaborators playing remotely focused their attention on the voice intonation and content speech of the partner. Because vocal cues and discourse content are specially relevant when inferring feelings (Hall & Schmid, 2007) this increased their understanding of the partner's emotions, which in line with the literature, probably generated more motivation to collaborate (Crook,

2000; Schwartz, 1998) and/or enhanced their social regulation (Järvenoja & Järvelä, 2009), leading to more positive affect and better performance.

5.4.7 Conclusions

Thus, an accurate understanding of a partner's emotions helped collaborators playing LSW2 remotely to feel more happy, interested, hopeful, challenged and excited; but not less frustrated and annoyed. It was argued that this resulted from a more effective regulation of emotions between partners, sustained in the accurate understanding of each other' emotions. In other words, collaborators interacting remotely were more concerned about the emotions of their partners after receiving affective awareness support. In turn, they used the emotions of the partner as cues to distinguish whether the partner was motivated to collaborate or not. If one of the partners showed little interest or enjoyment, the other one could be aware of it and act accordingly by, for example, giving encouragement or support. This interpretation is in line with studies that report how collaborators regulate each other's emotions during collaborative learning (e.g., Järvenoja & Järvelä, 2009) and that awareness of the partner is necessary to discern and react to the partner's needs during collaboration (Artman & Wærn, 1998).

Affective awareness support also helped collaborators playing LSW2 remotely to perform better. Possibly, collaborative partners employed their understanding of one another's emotions to aid their interaction. This is suggested because their performance score was correlated with their affective awareness index and also with the affective awareness index of the partner. Possibly, the accurate understanding the partner's emotion helped them to understand the motivation and intentions of the partner in order to provide mutual support and coordinate with each other. Therefore, they performed better and took advantage of the "collaborative mechanics" of LSW2.

In summary, the results indicate that affective awareness support is helpful when collaborators ascribe value to the information about the emotions of a partner. It helps collaborative partners to achieve an accurate understanding of one another's emotions, which in turn facilitates a more pleasant and productive collaboration. This is in line with the theorized value of 'sensing' a shared enjoyment during collaboration (Crook, 2000; Tomasello, 2009).

Chapter 6

Discussion

6.1 Summary of the Thesis motivation and aims

This thesis aimed to explain how the task environment and interaction with a partner influence people's emotions and their understanding of other's emotions during computer-supported collaboration, focusing on co-located and remote-continuous interactions. The results contribute to a better understanding of emotions in the field of CSCL, where knowledge about affect is scarce and scattered. On the one hand, some studies focus on affective aspects of the interaction between learners, such as affinity (Vass, 2007) or the social regulation of emotions (Järvenoja & Järvelä, 2009). These studies are valuable contributions but they overlook the mediating role of technology. On the other hand, some studies propose 'affective components' to be implemented in CSCL technologies, such as tools to regulate group tension (Karlegren & Sins, 2009) or communicate emotions during group work (Mentis et al., 2010). These studies are also valuable contributions, but they treat the interaction between partners as a secondary factor.

Three studies were conducted to answer the main research question of the thesis, posed this: *How does the task environment and interaction with a partner influence people's emotions during computer-supported collaboration?*

- Study 1 compared people's emotions and emotion understanding during the use of collaborative technologies with clearly different designs (i.e., a concept-mapping tool and a collaborative-educational computer game).

- Study 2 investigated the changes in people's emotions and emotion understanding around a collaborative computer game, focusing on the factors associated with the dynamics of the affective state challenge.

- Study 3 assessed the potential benefits of helping collaborators to understand the emotions of one another during co-located and remote-continuous interactions around a collaborative computer game.

6.2 Structure of the discussion

The results of each study were discussed in depth in their corresponding chapters. This section offers a general discussion that integrates the findings of the three studies under five headings:

1. *How does the task environment and interaction with a partner influence people's emotions during computer-supported collaboration?* This section integrates the findings within the framework of the main research question.

2. *Implications.* This section discusses the implications that can be drawn from the results of this thesis, covering four areas: The appraisal theory of emotions, the relationship between emotions and learning, the role of emotions in collaborative learning, and the integration of affect in the design and evaluation of collaborative technologies.

3. *Methodological contributions*. This section discusses the implications of combining a dyadic statistical approach with qualitative video data.

4. *Limitations.* This section discusses three limitations of the study: reduced control over the technological environment, employment of questionnaires to investigate emotions and generalization constrains.

5. *Future research.* This section outlines research topics that emerge from the findings of this thesis.

6.3 How does the task environment and interaction with a partner influence people's emotions during computer-supported collaboration?

This section integrates the findings to answer the main research question. Five themes are discussed:

1. *Collaborative computer games as research context.* This theme covers two topics. First, the advantages of having used the collaborative computer games Astroversity and LSW2 as research tools. Second, the contributions of the thesis to the understanding of collaborative computer games as learning technologies.

2. *The emotions people feel during computer supported collaboration*. This theme explains the nature of the emotions people felt during the computer-supported collaborative activities studied in this thesis, as well as the emotions people did not feel.

3. *Complementarity and mutual influence.* This theme explains how the collaborative tasks of Astroversity and LSW2 generated a situation of mutual influence between collaborators, which in turn shaped their emotions.

4. *Mutual influence and emotional similarity*. This theme discusses how the mutual influence between collaborators could lead them to feel similar emotions.

5. *Thinking about a partner's emotions.* This theme discusses two aspects of what collaborators thought about the emotions of a partner. One refers to the relationship between affective projection and perspective taking. The other one refers to the mechanisms and ethical implications associated with the support of awareness about a partner's emotions.

6.3.1 Collaborative computer games as research environments

This section outlines two ways in which the usage of collaborative games such as Astroversity and LSW2 helped to answer the main research question. One way refers to the usefulness of collaborative computer games as research tools to investigate emotions in computer-supported collaboration. The other way refers to the potential of collaborative computer games as collaborative learning environments.

6.3.1.1 Collaborative computer games as research tools

Astroversity and LSW2 were adequate research environments because their usage generated abundant emotional reactions within a well-defined structure. To achieve a joint goal (e.g., to rescue an injured student in Astroversity and to solve the puzzles in LSW2), players played complementary roles whilst solving collaborative tasks embedded in a graphic user interface full of affective components such as expressivity and aesthetics. Although other sorts of collaborative learning technology, or collaborative learning tasks without technology, might not generate emotional reactions with the same abundance and intensity of computer games, the results of this thesis may be transferable to other kinds of collaborative learning technology, such as digital tabletops.

Moreover, the study of emotions would have been more difficult around other forms of collaborative technology, for which design is limited to provoke emotional reactions in the user, as indicated by the comparison between Astroversity and the concept-mapping tool 2Connect in Study 1. The specific usage of Astroversity and LSW2 was also an advantage over other sorts of computer games. Whilst playing Astroversity and LSW2, players performed collaborative tasks such as data gathering and puzzle solving. In doing so, they displayed 'social' skills such as coordination and discussion with a partner, all of them important aspects for collaborative learning. Observation of these aspects would have been difficult around competitive computer games (the most popular format of social computer gaming), or around collaborative computer games that require only coordination between players during visual-spatial tasks (e.g., collaborative *Tetris*).

6.3.1.2 Collaborative computer games as learning environments

The usage of Astroversity and LSW2 allowed observing a sort of collaboration that implied aspects thought to be related to learning, such as problem solving and certain social skills. For example, problem solving was implied in tasks such as the data gathering of Astroversity and the puzzle solving of LSW2. Whilst solving these tasks, collaborators could employ social skills such as coordination and mutual advice, as observed in the detailed analysis of individuals' game play in Study 2.

This is important because the potential of collaborative computer games as educational tools is underexplored. Kirriemuir & McFarlane (2004) reviewed the literature and pointed that most educational computer games have been designed for individual use, even when it is recognized that computer games are powerful catalysers of social interaction that may facilitate motivation, engagement and learning. Although the literature is still small in scale, the interest about collaborative

educational games seems to be expanding, and the investigation of affective issues is emerging as a topic to be attended.

Kaptelinin & Cole (1997) organized students to collaborate around educational computer games, and identified a number of factors that should be taken into account when setting up collaborative learning environments, such as constructive conflicts, time, and resonant with this thesis, the sharing of emotions. More recently, there have been efforts to advance the design of collaborative educational computer games beyond the desktop computing paradigm. For example, Facer et al. (2004) presented the *Savannah Project,* which explored the potential of a mobile collaborative game to facilitate learning about animal behaviour outside the classroom. They explained that the generation of self-motivation was one of the major challenges of the project. For their part, Infante et al. (2009) reported that *Role Game,* a co-located CSCL game in which three players share an interface prompted useful social interaction in the classroom. The authors listed recommendations for the design and usage of educational computer games including, among many others, opportunities for learners to avoid frustration and the promotion of positive social interaction (e.g., preventing collaborators from ignoring or patronizing one another).

To summarize, the usage of collaborative computer games such as Astroversity and LSW2 informed us about the way educational collaborative computer games may facilitate learning. In upcoming sections, discussions will be presented about two mechanisms that might be implemented in collaborative learning technologies to take advantage of people's emotions and thereby foster learning, namely the promotion of complementarity between partners (Section 6.3.3) and the support for their understanding of one another's emotions (Sections 6.3.5).

6.3.2 The emotions people feel during computer supported collaboration

The appraisal theory of emotions was taken as a reference to conceptualize people's emotions in the context of computer-supported collaboration. The appraisal theory of emotions was outlined in the review of the literature presented in Chapter 2 (section 2.2), and the implications that can be drawn from the findings of this thesis in relation to the validation of this theory are discussed in section 6.4.1.This section focuses on the way in which the appraisal theory of emotions helped to understand the nature of the emotions felt by people during the computer-supported collaborative activities studied in this thesis. This implies a discussion about people's emotions at the individual level. The interpersonal aspects of people's emotions are discussed in upcoming sections, including the emotional similarity between partners and its implications for the processes and outcomes of collaboration (Section 6.3.4 and the mechanisms and implications of collaborators' emotion understanding (Section 6.3.5).

The findings suggest that participants were likely to enjoy the different formats of collaboration presented in the studies. In Study 2, collaborators reported emotions that denoted enjoyment and pleasantness such as happiness and interest, irrespective the design features of the collaborative environment. In Study 2, it was observed that during relatively extended collaborations, individuals could report a stable or oscillating happiness, but low levels of this emotion were rare. Moreover, in Study 3, partners reported at least mild levels of happiness, regardless of collaborating remotely or co-locatedly.

The technology and interaction with a partner were mostly associated with the feeling of 'goal-oriented' emotions such as challenge and frustration. Study 1 showed that people felt these emotions more intensely while playing Astroversity, and attributed to the activity as the main source of these emotions, presumably because of

the fixed goal and collaborative tasks embedded in the affectively loaded GUI of this game. Study 2 showed that the reports of challenge and frustration made by participants whilst playing LSW2 during an extended period of time (4 sessions) could oscillate meaningfully from moment to moment (periods of 2-3 minutes), suggesting these emotions were more associated with the game play events than other emotion like happiness. Moreover, the detailed analysis of challenge change suggested this emotion was likely to change depending on the effectiveness of the partners' collective response to the momentary demands of LSW2.

There is a trade-off in the generation of challenge and frustration, mainly because these emotions are not intrinsically 'positive' or 'negative'. On the one hand, these emotions denote 'cognitive' engagement, something desirable for the use of collaborative technologies with educational intentions. On the other hand, people feel these emotions when they appraise the context negatively (i.e., when they feel uncertainty, lack of control of the situation, and lack of ability). The technology can play a key role in balancing the positive and negative aspects of challenge and frustration. Study 2 identified features of LSW2 likely to prompt changes in challenge, such as the complexity of the puzzles, the coordination requirements or the occurrence of key game events. When individuals struggled with these features, they typically reported an increased challenge, but did not disengage from the activity. Probably the abundant expressive (e.g., sounds, colourful GUI, expressive characters) and complementary elements (e.g., distracters) of LSW2 helped collaborators to reduce the negative appraisals that often accompany challenge, such as the perception of extreme effort.

One unexpected finding was that 'social emotions' such as guilt, shame, pride or anger, were not reported in the studies. These emotions are closely related to the norms of the social environment. For example, being caught stealing provokes shame, being praised by others provokes pride, and being the victim of aggression generates

anger (Hareli & Parkinson, 2008). However, participants in the studies did not report social emotions, even if technologies such as Astroversity and LSW2 established norms of complementarity between partners, and not even if they were collaborating for an extended period of time, as the two dyads that played LSW2 collaboratively in four sessions in Study 2. Probably the social norms in the studies of this thesis (cooperating with the partner and 'doing' the activity) were too relaxed to trigger social emotions. Something different might occur in contexts such as schools, where CSCL activities are embedded in a complex social environment with stronger social norms.

Lastly, another unexpected finding was that anthropomorphism (i.e., treating computers as if they were humans) was not related to people's emotions. Study 2 showed that collaborators rarely thought the computer was controlling the situation while playing LSW2, probably because this game lacks an advanced AI. Nevertheless, anthropomorphism might be a major source of affective reactions during the use of sophisticated collaborative environments, such as the ones that implement intelligent companions as collaborative partners (e.g., Maldonado et al., 2005; Morishima et al., 2004).

To summarize, the findings suggest that computer-supported collaborative activities are, in general, enjoyable. However, goal-oriented emotions such as challenge and frustration are more susceptible to the influence of the technology design and interaction with a partner. These emotions denote engagement, which is desirable but also implies the cost of feeling uncertainty and lack of control. Lastly, people did not report social emotions, probably because the social norms of the computerized collaborative activities of this thesis were too relaxed. Also, anthropomorphism was not a source of emotions because games such as LSW2 lack advanced AI engines. However, anthropomorphism should affect people's emotions during the usage of more 'intelligent' CSCL environments.

6.3.3 Complementarity and mutual influence

Often, the task environment demanded partners to play complementary roles, creating a situation of mutual influence. This was 'visible' with the microgenetic approach to the analysis of challenge change in Study 2. LSW2 allocated partners to play complementary roles and often demanded cooperation, creating situations in which the partners' actions were interrelated and, therefore, influenced the feelings of challenge of each other. It was argued these situations of mutual influence could explain why, in the analysed cases, partners typically increased or decreased their reports of challenge similarly. For example, in some cases individuals could make insight about a complex puzzle through the actions of the partner, leading to a decreased challenge in both. In other cases, the collective performance of a dyad could be disrupted if one partner had problems controlling her character in a situation that required coordinated action, which could increase the sense of challenge in the two partners.

These results are relevant for the usage of interdependence as a strategy to foster knowledge at the 'group level' (i.e., knowledge that cannot be constructed by individuals on their own). This idea was applied in the early notion of *Jigsaw Learning* developed by Aronson, Blaney, Sikes, & Snapp (1978). More recently, Buchs, Butera, & Mugny (2004) showed that during collaborative learning, working with interdependent information produces more positive interactions (e.g., more questions and explanations to the partner, responsiveness and positive affective reactions towards partners' propositions) than working with identical information.

However, Meier & Spada (2007, 2009) showed that the benefits of resource interdependence are not easy to achieve. They demonstrated that during collaborative problem solving, inferences constructed from interdependent resources are more powerful to create knowledge at the group level than inferences constructed from

individual resources. However, inferences constructed from interdependent resources are the most difficult to generate. The benefits of interdependence could be facilitated with role complementarity. Do-Lenh, Kaplan, & Dillenbourg (2009) compared the effects of collaborative concept-mapping in a desktop PC and a digital tabletop. One undesirable effect of the tabletop was that partners often worked in parallel, and therefore they learned less from their partners than when using the desktop PC. One explanation is that collaborators interacted more with each other around the PC because they shared the same input device (i.e., the mouse), whereas in the tabletop, each individual could work without necessarily interacting with the partner. Probably the implementation of role complementarity in the tabletop task could increase the interaction between partners, which would help to capitalize on the advantages of tabletops over desktop PC's, namely tangibility and simultaneous actions.

There is space for more research about the relationship between aspects such as the emotional similarity between partners and the sort of cognitive processes that have been investigated in the context of resource interdependence (e.g., inference making and perspective taking). For example, in order to design collaborative tasks and technologies that effectively facilitate learning, it would be useful to understand the extent to which affective factors might influence the making of inferences from interdependent information.

To summarize, collaborators played complementary roles while solving the collaborative tasks of LSW2. This situation generated a situation where partners' emotions were susceptible to the influence of one another's actions, reflecting on emotional similarity. This illustrated one way in which a collaborative environment can influence people's emotions by means of 'shaping' the interaction with a partner. This is relevant for the study of CSCL and collaborative learning because there is an interest in understanding the benefits of complementarity between partners to foster learning from collaboration.

6.3.4 Mutual influence and emotional similarity

We have discussed that playing complementary roles in collaborative tasks could make partners' emotions (e.g., challenge) susceptible to the actions of one another. Although not conclusively, some results of Study 1 and Study 2 suggested that situations of mutual influence could generate emotional similarity.

In some illustrative cases of Study 1, it was observed that good quality interactions were accompanied by emotional similarity. Some collaborators who felt equally challenged and frustrated around Astroversity also coordinated fluently and responded to the ideas of one another to solve tasks such as the scanning of alien presence (e.g., they distributed the labour in a way that one partner scanned the alien presence in the computer while the other one plotted the alien presence on a paper grid). In Study 2, the microgenetic analysis of challenge change showed that whilst playing LSW2; the partners' actions were interrelated, and therefore individual performance affected the performance as a dyad. It was argued that this situation of mutual influence could explain that partners typically reported challenge similarly.

6.3.5 Thinking about a partner's emotions

Two issues are discussed in relation to what collaborators think about the emotions of one another. One refers to role that the projection of the own emotions might play in the perspective taking between partners. The other one refers to the mechanisms involved in the provision of support for collaborators to be aware about the emotions of the partner, as well as its ethical implications.

6.3.5.1 Affective projection and perspective taking

It has been discussed that the mutual influence between partners could prompt emotional similarity. It turns out that regardless of feeling similar emotions or not,

individuals tended to assume emotional similarity with the partner (i.e., they rated the emotions of their partners in a very similar way as they rated their own). This tendency was consistent across technologies (Study 1), and for the specific case of challenge, it seemed to be independent of whether the emotion intensity increased or decreased over a relatively extended periods of interaction (Study 2).

This is resonant with the interpersonal perception bias known as the *false consensus effect*, which is known as the tendency to think about the opinions of others on the basis of the one's own opinions (Ross et al., 1977). The literature suggests that the tendency to project the own emotions onto the partner might play a role in the process of perspective taking during collaboration.

It is known that the tendency to project the own mental states to infer the mental states of others is stronger when the observed is more similar to the observer. This could explain why collaboration partners projected their own emotional states onto one another. Although they played different complementary roles during the collaborative tasks (e.g., the puzzles of LSW2), they were in similar conditions. Moreover, recent research shows that the projection of one's own mental states onto a partner is a feature of interpersonal perception that distinguishes collaboration from other forms of social interaction such as competition (Toma et al., 2010).

But the projection of one's own emotions might be more than a bias in interpersonal perception because it might be instrumental for perspective taking. There is evidence that the capacity to reflect about one's own mental states is related with the ability to think about the mental states of others (see the review of Dimaggio, Lysaker, Carcione, Nicolò, & Semerari, 2008). Epley, Keysar, Van Boven, & Gilovich (2004) reported that people begin to take the perspective of other's opinions by first 'anchoring' on their own opinions. Then they gradually adjust their opinions to take into account the differences with the opinions of others. This is in line with

Gendolla & Wicklund (2009), who reported that self-awareness (attention centred on the self) enhances perspective taking and reduces egocentrism when cues about the perspective of others are provided.

To summarize, Study 1 and Study 2 showed that collaborators rated the emotions of their partners in a very similar way as they rated their own emotions, suggesting they had a strong tendency to project their own emotions onto their partners. It turns out that aspects related to projection, such as egocentrism and self-awareness are useful mechanisms during perspective taking. This indicates the need for understanding the role of affective projection in the process of perspective taking in collaborative learning and CSCL.

6.3.5.2 Supporting awareness about the emotions of a partner

Study 3 assessed the potential benefits of informing collaborators about the emotions of their partners in co-located and remote-continuous collaborations. Remote collaborators valued this information and employed it to make more accurate judgements about one another's emotions, which helped them to feel more positive emotions and perform better. These results were discussed in depth in Chapter 5. In this section, these results are discussed further, covering two aspects. First, the possibility the benefits of receiving information about the emotions of a partner involved not only partner-awareness but also self-awareness. Second, the ethical implications of supporting affective awareness.

Self-Awareness and Other-Awareness

This section discusses the possibility that the benefits of affective awareness support found in Study 3 could be explained by an overlap of self-awareness and other-awareness. On the one hand, the straightforward explanation (discussed in depth in Chapter 5) is that improved awareness about the emotions of a partner (other-

awareness) helped collaborators to regulate the emotions of one another, as well as to coordinate better by means of using the emotions of the partner as cues to interpret their behaviour. On the other hand, it is also plausible that enhanced awareness about the emotions of a partner 'overlapped' with a self-awareness effect.

Collaborators who received affective awareness support not only received information about the emotions of their partners. They also 'disclosed' their own emotions to the partner, which might have facilitated the understanding of their partner's emotions. Recall that the capacity to understand one's own mental states is linked to the capacity to understand the mental states of others (Dimaggio et al., 2008). Thus, the information about the partner's emotions in combination with an enhanced reflection about one's own emotions may explain the increase in positive affect and performance. One probable scenario is that the enhanced self-awareness motivated collaborators to 'align' their own emotions with the emotions of a partner – as an anecdote, one participant reported during the debriefing that she 'modulated' her stress after having seen the emotions of her partner-.

In future research, it would be useful to investigate the relationship between the mechanisms of self-awareness and other-awareness. This would be timely since there is a current interest about the relationship between understanding the own mental states (i.e., metacognition) and the understanding of other's mental states (i.e., mindreading) (see a review in Carruthers, 2009). The theoretical aspects underlying this issue are explained in more detail in section 6.7.2.

Ethical implications

It is important to discuss the ethical implications of supporting awareness about the emotions of a partner during CSCL. This would complement the current interest to develop technology aimed to support interpersonal awareness (for a recent review, see Engelmann, Dehler, Bodemer, & Buder, 2009). However, one needs to be more

careful when thinking about supporting affective awareness than when thinking about, for example, knowledge awareness. The difference given by the sensitivity of emotions. It is known that people has a natural tendency to 'disclose' their emotions to others (for a review, see Bieke et al., 2005). However, it is unknown how people would react if their emotions are not disclosed intentionally, but by an external 'agency' (i.e., the computer).

6.3.6 Summary

The main research question of this thesis asked how the task environment and interaction with a partner influence people's emotions during computer-supported collaboration. Five themes were outlined to answer this question:

1. Collaborative computer games were useful to answer the main research question because they prompted abundant emotional reactions in a well-structured environment, which helped to observe the role of technology in the generation and shaping of people's emotions; and the relationship between emotions and aspects thought to be related to learning, such as problem solving and certain social skills (e.g., coordination and discussion with a partner).
2. The computer-supported collaborative activities of the studies were generally enjoyable; but they mainly provoked goal-oriented emotions such as challenge and frustration.
3. Playing complementary roles and the need for coordination seemed to generate a situation of mutual influence between partners during the collaborative tasks of LSW2. This is useful to understand how collaborative learning tasks and technologies can increase their potential to foster learning by allocating complementary roles for partners to play.

4. The mutual influence between partners could reflect on emotional similarity.
5. There were two aspects to highlight on what collaborators' emotion understanding. First, the fact that collaboration partners project their own emotions onto one another might actually be part of the perspective taking mechanisms that help them to create a shared understanding of the context. Second, the benefits of supporting awareness about the emotions of a partner might involve the enhancement of both self-awareness and other-awareness. At the same time, supporting awareness about the emotions of a partner involves ethical implications that remain to be defined.

6.4 Implications

This section discusses the implications that can be drawn from the results of the studies of this thesis, focusing on four areas:

1. The appraisal theory of emotions.
2. The relationship between emotions and learning.
3. The role of emotions in collaborative learning.
4. The integration of affect in the design and evaluation of collaborative learning technologies

6.4.1 Implications for the appraisal theory of emotions

The appraisal theory of emotions was an adequate framework to interpret the results of the studies in this thesis. In the literature review of Chapter 2 (Section 2.2), it was argued that this theory is robust because its assumptions have been tested across

a number of scenarios with various methodologies. This thesis contributes to further validation of the appraisal theory of emotions by using its assumptions in the context of computer-supported collaboration. This is relevant for the general understanding of emotions because both interaction with technology and the interaction with a partner during collaboration are aspects rarely touched in current assessments of the appraisal theory of emotions.

The microgenetic analysis of Study 2 included information about the way in which individuals appraised the context during moments of increased and decreased challenge. The set of appraisals included effort, ability, understanding, uncertainty and problems controlling their characters. Although the results of this study cannot be generalised, they are interesting because they take the assumptions of the appraisal theory to a context with strong ecological validity, such as playing LSW2. The findings were not all in line with the expected from previous research.

Typically, individuals reported high effort both in moments of increased and decreased challenge. Also, individuals typically thought they had the ability to play the game, regardless of having increased or decreased their reports of challenge, suggesting that in the particular case of playing LSW2, participants could have perceived the game as challenging but not necessarily difficult to play. These results seem to contradict other studies in which challenge was described as a consequence of more effort and less ability (C. A. Smith & Ellsworth, 1985). However, in this same study there were results that confirmed the expected, such as more uncertainty reported by individuals during moments of increased challenge.

These results are relevant for the general understanding of emotions because they suggest that the relationships between emotions and cognitive appraisals are sensitive to the context. Further research should be directed to investigate the issue of whether the meditational role of technology or the interaction with a partner can actually affect

the relationship between emotions and cognitive appraisals in computer-supported collaboration.

The results of the study are also in line with the current interest to apply the cognitive appraisal theory in the development and evaluation of learning technologies in particular, and in HCI in general. For example, Conati & Zhou (2002) employed a cognitive appraisal model (the Orthony, Clore and Collins' model) to infer the affective states of users playing an educational computer game. More recently, Mahlke & Lindgaard (2007) found that the perception of instrumental qualities (i.e, usability) of personal audio players affects not only users' emotions, but also their cognitive appraisals. Moreover, they also found that the users' emotions and appraisals were more affected by the functionality than by non-instrumental qualities such as aesthetics.

6.4.2 The relationship between emotions and learning

In Chapter 2 (Section 2.3), research was reviewed that postulates a close relationship between emotions and a number of cognitive processes recruited for learning, including 'basic' processes such as memory and attention, as well as relatively more complex processes such as problem solving, transfer and metacognition.

This thesis was not specifically aimed to test the relationship between emotions and problem solving capacity. However, the tasks performed by participants in the studies required the employment of problem solving reasoning (e.g., data gathering and interpretation in Astroversity, and puzzle solving in LSW2). There is a current debate about the role of emotions in problem solving. Some research suggests that emotions are not directly related to problem solving (Spering et al., 2005). However, there is evidence that positive affect helps to create more flexible and creative reasoning during problem solving (Estrada et al., 1997; Frederickson & Branigan,

2005). Moreover, negative affect might also have a positive influence on problem solving (Barth & Funke, 2009; Gasper, 2003).

There is no straightforward comparison between the sort of 'problems' solved by participants while playing LSW2 and Astroversity and the sort of problems that are more widely used in formal learning settings (e.g., mathematics problems or argumentation problems). However, the results of this thesis are still useful as evidence that emotions influence problem-solving capacity. Importantly, the results of this thesis also contribute to the understanding of how technology can be used to take advantage of the relationship between emotions and learning. It was found that features of the collaborative computer games Astroversity and LSW2 such as their affectively loaded GUIs, and their allocation of complementary roles, helped collaborators to sustain their 'cognitive' engagement with the activity (e.g., frustration and challenge) without sacrificing their enjoyment and pleasantness (e.g., happiness and interest). These are desirable aspects that may be implemented in other sorts of collaborative learning technologies (e.g., digital tabletops).

6.4.3 The role of emotions during collaborative learning

This thesis followed two theoretical assumptions about the role of emotions during collaborative learning. One assumption was that the positive affect associated with the creation of a shared understanding drives collaborators' motivation (Crook, 1998a; Schwartz, 1998; Tomasello, 2009). The other assumption was that the understanding of a partner's emotions plays a key role in social interaction mechanisms such as emotional similarity, social regulation and mutual support. The results of the studies supported these assumptions, and also presented the unexplored theoretical issue of whether the understanding of one's own emotions could be related to the understanding of a partner's emotions during collaboration.

Study 1 and Study 2 consistently found that collaborators' projected their own emotions onto their partners. It was discussed that the projection of collaborators' own emotions could be a mechanism of affective self-awareness (i.e., thinking about the own emotions), which may play a key role in their perspective taking ability. Probably collaborators emotional self-awareness overlapped with their awareness about the emotions of a partner, which may explain the positive effects of affective awareness support in Study 3.

Thus, one intuition would be that self-awareness and other-awareness operated complementarily. On the one hand, collaborators employed their understanding about the emotions of their partners (other-awareness) to interpret their partner's behaviours and motivations. On the other hand, they reflected on their own emotions (self-awareness) to direct the interaction with a partner. One scenario may be helpful to illustrate this idea. Let us think about two partners struggling to solve a problem. This situation may imply, at least, two different versions.

In the first version, collaborative partners are committed to the activity. Therefore they feel similarly frustrated (i.e., their emotions are directed towards the achievement of the shared goal, namely solving the problem). If they accurately 'sense' a shared commitment with the activity, they could also think that they are feeling equally frustrated. Then they could react by either trying to regulate their own frustration and the frustration of the partner by, for example, using time-out which is a useful strategy to manage frustration during collaborative problem solving (Azmitia, 2000). In this case, self-awareness would help collaborators to 'modulate' their own emotions and the emotions of the partner.

In the second version, one of the partners is committed to the activity but the other one is not. As a consequence, the one who is committed feels frustrated, while the one who is not committed feels no frustration. If collaborators accurately sense their

unshared commitment with the activity, they could take the decision to keep trying to solve the problem or not. The one who is committed could either disengage from the activity –*why should I bother if you are not?*- or feel more frustrated because the situation is unfair. In contrast, the one who is not committed could either engage with the activity –*I should bother as well*- or just keep disengaged, not bothering about the frustration of the partner.

This example is obviously simplistic and includes no contextual factors (e.g., whether collaborators have a shared history, or have established power relationships). However, it is useful to illustrate how emotion self-awareness and other-awareness might be overlapping mechanisms, functional to the interaction with a partner.

The overlapping of emotion self-awareness and other-awareness could be a mechanism of emotional alignment that accompanies the recursive perspective taking required for effective collaboration. Further investigation, theoretical or empirical, should be helpful to test the plausibility of this idea. Moreover, this issue could be extended to a more general problem, namely the relationship between understanding own mental states (i.e., metacogntion) and understanding other's mental states. Such investigation could extend the current understanding of collaborative learning.

6.4.4 The integration of affect in the design and evaluation of collaborative learning technologies

This thesis has shown that the technology design is a main influence for people's emotions during computer-supported collaboration. First, it was found that playing complementary roles in collaborative tasks facilitated collaborators' emotional engagement whist playing Astroversity and LSW2. This suggests that complementarity between learners should be an element in the design of collaborative learning tasks. Recent research in CSCL for co-located interaction (Infante et al.,

2009) also points to the importance of role complementarity between partners. Thus, more research is needed to define, for example, the optimal level of complementarity between partners that promotes enjoyable and useful collaboration.

Second, the collaborative tasks of Astroversity and 2Connect were embedded in an affectively loaded GUI, which helped collaborators to avoid negative aspects such as the perception of extreme effort. This implies that features such as aesthetics and expressivity were helpful to sustain the enjoyment during collaborative activities. This contradicts some aspects of prior research in learning technology, which suggests that 'seductive details' (e.g., features added to learning technologies to generate user's appeal) are harmful for learning (Harp & Mayer, 1998), and is more in line with resent research suggesting that the inclusion of 'expressive' features (e.g., attractive pictures) in multimedia learning environments facilitates learner's positive emotions (Park & Lim, 2007). Nevertheless, different sorts of learning technology might require different degrees of expressivity and aesthetics, and the definition of an adequate degree for collaborative learning technology is a matter of future research.

Third, it was also found that supporting collaborators to be more aware about the emotions of their partners was potentially helpful to generate more pleasant and productive collaborations. This suggests that it is worth developing technologies to support affective awareness, which opens a number of issues. For example, how to get data about the user's emotions? This is indeed a major problem in HCI, where there is interest about the 'automatic' identification of emotions. Another problem would be to define how to represent emotions. Study 3 represented a partner's emotions as raw scores in a Likert-like scale that could resemble a histogram. This representation was useful to test the benefits of receiving information about the emotions of a partner, but it is obviously not a design solution. The use of expressive avatars (e.g., emoticons or smileys) is a very common way to represent emotions, but there are also other ways. For example, Alsmeyer, Luckin, Good, & Harris (2009) implemented the 'Subtle

Stone'. This is a ball-like artefact capable of changing its colour. Learners are meant to use it in classrooms to communicate their emotions to the teacher by assigning a colour to represent and communicate their emotional states.

Fourth, the support of affective awareness in CSCL technologies opens ethical issues. It was discussed that people might not be comfortable if their emotions are disclosed to others by an external agency (i.e., a computer), which is a sort of anthropomorphism that remains to be investigated.

6.5 Methodological contributions

To investigate people's emotions in computer-supported collaboration, the studies in this thesis analysed people's emotions in contexts of actual social interaction (i.e., computer-supported collaborative activities). Arguably, this methodology has more ecological validity than other methodologies that could have been used, such as vignette paradigms. The employment of vignette paradigms is a widely used approach to study collaboration (Toma et al., 2010) and emotions in social contexts (e.g., de Hooge, Zeelenberg, & Breugelmans, 2007; Jakobs et al., 1997; Seger et al., 2009). Although this approach has proven useful, it lacks the ecological validity of actual social interaction. In comparison, the study of social processes during actual social interaction has the advantage of ecological validity. However, it also implies the challenge of analysing the effects of interacting with a partner.

The data collected in the studies of this thesis was analysed with a combination of statistical analyses that accounted for interpersonal processes during actual social interaction (i.e., dyadic analyses) and detailed qualitative descriptions of video data. This section discusses the implications of this approach.

6.5.1 Dyadic analysis

Statistical procedures that take into account the effects of social interaction in dyads were employed throughout this thesis. This is a methodological contribution because it helps to demonstrate the validity and usefulness of dyadic data analysis to study collaboration and emotions. Dyadic analyses have been employed in a number of studies related to collaboration and emotions, including for example studies on coordination during cooperation (e.g., Becchio, Sartori, Bulgheroni, & Castiello, 2007), studies that investigate whether partners in close relationships influence the emotions of one another (e.g., Langner & Keltner, 2008; Laurenceau & Bolger, 2005), and interpersonal understanding of emotions (e.g., Elfenbein, Der Foo, Boldry, & Tan, 2006).

Dyadic analyses permitted a number of findings about the collaborators' understanding of their partners' emotions. In Study 1, the tendency of collaborators to project their own emotions onto their partners was discovered with a dyad-wise regression. This included the partner's judgements about the emotions of the partners as dependent variable, and both their own emotions and the emotions of their partners as independent variables. A dyadic approach was also applied to measure collaborators' emotion understanding in the form of 'dyadic indexes' such as affective similarity, affective projection and affective awareness. These indexes were then tested with a nominal dyad analysis, which gave a by-chance baseline for interpretation. It could have been difficult to approach the study the interpersonal understanding of emotions without these indexes. For example, the effects of supporting awareness about the emotions of a partner (Study 3) were testable because the nominal dyad analysis validated the affective awareness index as a measure of collaborators' accuracy at judging the emotions of their partners.

This thesis has shown that dyadic analyses are useful to study emotions in the context of 'actual' social interactions such as computer-supported collaboration. This is a contribution for the study of emotions in collaboration, both in the general sense and within CSCL in particular.

Lastly, most studies in CSCL research employ dyads in actual social interaction as unit of analysis, which enhances their ecological validity. However, it is common to find that CSCL studies do not take into account (at least for statistical analysis) the effects of social interaction, and only few studies have taken advantage of dyadic data analysis (e.g., Fischer & Mandl, 2005). This thesis has demonstrated that doing so may give valid information about effects otherwise difficult to assess systematically, such as mutual influence between partners and interpersonal perception.

6.5.2 The combination of statistics and qualitative data analysis

Detailed qualitative descriptions of video data were employed to provide with illustrative examples of the statistical analysis of Study 1 and to conduct a microgenetic analysis of challenge change in Study 2. All in all, the main advantage of having combined dyadic statistical analyses with qualitative analysis of video data is that it permitted an integrated view of how the technological environment and the interaction with a partner influenced collaborators' emotions. Moreover, this approach was adequate to analyse people's emotions during computer-supported collaborative activities, which implied complex scenarios with many interacting factors (e.g., simultaneous interaction with the partner and with the computer).

6.6 Limitations

This section discusses three limitations inherent to the methodologies employed in this thesis: control over the technological environment, the use of questionnaires to investigate emotions and generalization constraints.

6.6.1 Control over the technological environment

The utilization of already developed technology (e.g., collaborative computer games) was a limitation in the studies. On the one hand, employing already developed technology gave a 'naturalistic' view about the influence of technology in the emotions felt by people during computer-supported collaboration. However, it did not permit the manipulation of specific components within the technology. This in turn implied a lack of control for variables that could have affected the emotions of collaborators and their understanding of the emotions of their partners. For example, the amount of complementary interaction required to play LSW2 was accounted with a performance score. However, it could also have been useful to manipulate the 'degree' of complementarity required to play LSW2, and then test the effect of such manipulation on collaborators' emotions.

6.6.2 The use of questionnaires to investigate emotions

Questionnaires are widely used to collect data about people's emotions. Nevertheless, it is necessary to recognize that this methodology presents a number of limitations. Robinson & Clore (2002) explained that self-reports cannot directly capture information about people's emotions because people have direct experiential information about their emotions only whilst feeling their emotions. Therefore, when people are asked to make an account of their emotions in retrospection, they make a 'reconstruction' gathering information from three sources: their episodic memory (i.e., recalling the most emotionally arousing parts of a given event), their general beliefs about emotions (i.e., the sort of events associated with specific emotions) and their individual beliefs (e.g., personality traits such as emotional reactivity). Robinson & Clore concluded that self-reports of emotions made directly after the event are much less susceptible to biases of memory, general beliefs about emotions (i.e., stereotypical responses such as 'I should have felt *x…*'*)* and personality traits.

In the studies of this thesis, it was not possible to determine the extent to what the reconstruction made by participants in order to report their emotions 'matched' their actual emotional experience. This is an unavoidable issue that limits the direct interpretability of the data. However, the methodology of the studies helped to reduce biases in the participants' self-report of emotions, such as *memory biases*, *stereotypical responses*, and *individual differences*.

Memory biases. The emotion self-reports in Study 1 were the most sensitive to memory biases because participants reported their emotions in only one occasion, right after using 2Connect and Astroversity. This might have forced them to make a gross summary of the emotions they felt whilst using these learning environments, which consequently implies a loss of information about their emotions. Although the data was limited in what it could tell about which specific events generated participants' emotions, it was adequate to compare across learning environments. This limitation was overcome in Study 2 and Study 3. In Study 2, participants made various retrospective accounts of their emotions, right after using LSW2 and employing a recording of their game play as a prompt. This hopefully helped participants to make a more accurate reconstruction of their emotions, linked to specific events. Moreover, in Study 3, participants reported their emotions at three key moments during their playing of LSW2. This methodology was the closest to an online measurement of people's emotions without being excessively intrusive.

Stereotypical responses. Another danger of using questionnaires to investigate emotions is that people could respond stereotypically. For example in Study 1, the fact that participants reported more intense emotions in Astroversity than in 2Connect might look like a stereotypical response because games are meant to be exciting. However, participants focused on certain emotions (challenge, hope and frustration) to differentiate the emotions they felt whilst using these learning environments. They could just report more positive emotions (including happiness and interest) and less

negative ones (including boredom) if they were responding stereotypically. Moreover, Astroversity was engaging but it was not stereotypically 'exciting' as commercial games (e.g., it had no stimulant sounds, realistic graphics or a complex story line), so partners could report the game as not challenging, which did not occur.

Moreover, in Study 2, giving various opportunities for participants to report their emotions, using a video recording of their game play as a prompt, hopefully facilitated the partners' recall of the emotions they actually felt, and reduced the need to respond stereotypically. This seemed to be the case since the participants' reports varied substantially for challenge and frustration and much less for happiness. This sort of differentiation between emotions and the variation of the emotion self-reports suggest that partners made an effort to report their emotions faithfully, rather than stereotypically. One stereotypical response could have been, for example, constantly high challenge, but in fact the reports of this emotion varied substantially.

Moreover, the variability (i.e., SD's not excessively larger or smaller than the mean) on the collected data indicated that participants' had different views about their emotions. Had the data showed no variability, this would indicate that participants reported their emotions with an extreme stereotypical bias, as in fact occurred when they reported their perceived interaction quality in Study 3.

Individual differences. Biases for individual differences were controlled in Study 3 by means of assessing individual differences in game play habits and interpersonal reactivity. It was found that individual differences in these variables were not strong enough to bias the results of the study, which assessment was based on emotion self-reports. It is likely that the emotion self-reports of participants in Study 1 and Study 2 were also not biased by individual traits, given that participants, tasks, and questionnaires, were similar to those in Study 3.

Lastly, one alternative to the use of questionnaires could have been the employment of physiological or behavioural measures. However, the employment of these kinds of measures in the studies of the thesis might have required an excessively complicated setting. For example, measuring participants' physiological responses (e.g., brain activity as measured with an EEG) whilst playing a collaborative computer game might have been excessively complicated and intrusive. What is more, a recent review of emotion measures (Mauss & Robinson, 2009) concluded that it is unclear whether physiological and behavioural measures are reliable to measure emotions in discrete terms (e.g., happiness, interest, hope), whereas self-report data is reliable to distinguish between emotions. In the studies of this thesis, the employment of self-report questionnaires with discrete emotions helped to establish links between participants' emotions and specific features of the context during computer-supported collaborative activities. What is more, the validity of discrete terms (i.e., emotion words) to describe emotions is indicated by the research about appraisal-emotion relationships, which results are robust in ecological terms and across methodologies, as reviewed in Chapter 2 (Section 2.2).

6.6.3 Generalization constrains

Another limitation is that, although the studies were conducted with participants during actual social interaction, they were conducted in a laboratory. Although the results are valid, different results could have been obtained if the studies were conducted in naturalistic scenarios, e.g., schools or groupwork. For example, participants did not report social emotions (e.g., shame, guilt, pride) across studies. It was argued this was due to the relaxed nature of the social situation involved in the study sessions. Perhaps social emotions could arise in computer-supported collaboration that occurs in scenarios such as schools, were the social norms are stronger.

Lastly, the generalization of results is also constrained because gender effects were not investigated. Although in Study 1 the selection of participants was balanced in terms of gender, in Study 2 and Study 3, participants were all females. This responded to the need to reduce gender biases, given the current debate on whether gender differences exists in terms of emotion understanding (e.g., Baron-Cohen & Wheelwright, 2004).

6.7 Future research

This section outlines issues for future research that emerge from the findings of this thesis, which need attention in order to advance the current understanding of emotions in collaborative learning and CSCL. Three issues are outlined: the relationship between affective and epistemic states, the relationship between self-awareness and other-awareness, and the design of experimental paradigms to investigate emotion understanding during collaboration.

6.7.1 Understanding the affective and epistemic states of a partner

This thesis has shown that what collaborators think about the emotions of a partner is that they have a shared emotional experience. It was also found that supporting awareness about the emotions of a partner is potentially useful to improve the outcomes of collaboration. It is difficult to find a relationship between these findings and cognitive aspects of collaborative learning such as knowledge co-construction or knowledge awareness, mainly because little is known about the relationship between understanding affective states (e.g., emotions, moods) and epistemic states (e.g., domain knowledge, beliefs) during collaboration.

This is indeed a problem in the general understanding of emotions in social contexts. On the one hand, it is known that the mechanisms recruited to understand other's emotions overlap with the mechanisms recruited to understand other's

cognitive states such as intentions (see the review of Olsson & Ochsner, 2008). On the other hand, clinical psychology research suggests that understanding other's emotions should be different to the general understanding of other's mental states (Blair, 2005). There are examples of the interaction between affective and cognitive/epistemic states in social contexts. For example, Parkinson & Simons (2009) studied the effects of a person's own emotions and the emotions of a closely related person in people's decision making during every-day situations. They found that people's decisions were affected by their own feelings of anxiety and excitement, as well as by the anxiety and excitement perceived in others.

Collaborative learning and CSCL are optimal social contexts to investigate the relationship between the understanding of affective and epistemic states. The implications of thinking about the emotions and knowledge of a partner could be observed in the process of knowledge co-construction (e.g., in terms of verbal exchange), and the implications could be observed in outcome variables such as performance or learning gains. Thus, investigating the relationship between the understanding of affective states and epistemic states in collaborative learning will help to the more general integration of emotions in the comprehension of how people get to understand the minds of others.

6.7.2 The relationship between self-awareness and other-awareness

This thesis focused on what collaborators think about the emotions of a partner. In Study 1 and Study 2, collaborators filled in scales to report their own emotions and the emotions of a partner. Collaborators consistently based their judgements about their partners' emotions on the basis of their own emotions. It was discussed that probably, the projection of the own emotions could be a self-awareness mechanism employed to understand the emotions of a partner. This could explain the benefits of helping collaborators to be more aware about the emotions of a partner reported in Study 3.

Receiving information about the emotions of the partner whilst also disclosing one's own emotions to the partner might have facilitated two complementary mechanisms: the accurate understanding of a partner's emotions (other-awareness), and emotional self-awareness.

Thus, future research should look into the relationship between emotional self-awareness and awareness about other's emotions. Collaborative learning is an optimal scenario to do so because collaborative partners have a joint goal and play complementary roles. In this situation, collaborators are expected to make an effort to understand one another. In turn, little is known about the relationship between the inference of the mental states of the partner and the attention to the person's own mental states (i.e., metacognition). This research issue could be investigated by looking into the processes (e.g., collaboration qualities) and outcome (e.g., performance) of collaboration.

The investigation of the relationship between emotional self-awareness and awareness about a partner's emotions would be in line with current research about interpersonal perception. There is for example, evidence that people tends to overestimate the extent to what their internal states are 'visible' to others during social situations. Something called the *illusion of transparency* (Dimaggio et al., 2008), which in turn is associated with difficulties to take the perspective of others (Gilovich et al., 1998). What is more, there is a currently growing interest to understand the relationship and difference between the way people understand their own minds and the minds of others (see the review of Carruthers, 2009).

6.7.3 Design of experimental paradigms to investigate emotion understanding in collaborative learning

One endeavour for future research would be the design of experimental paradigms to investigate aspects such as emotion understanding during collaboration. This would allow, for example, direct testing of the effects of variables like the degree of complementarity between partners during collaboration. In this thesis, people's emotions and their understanding of other's emotions were investigated whilst using professionally developed collaborative technologies. One of the outputs has been the finding that technologies such as collaborative computer games influence partner's emotions by means of 'shaping' the interaction with the partner, leading to a situation of mutual influence.

Further research should aim to develop tasks or technologies in which factors such as complementarity of roles can be manipulated with more control. Inspiration can be taken from two sources. On the one hand, there are economic games (e.g., dictator game) in which variables such as the availability of public goods or different aspects of individuals' social perception have been manipulated to study emotions in cooperation (Vorauer & Ross, 1999). On the other hand, in collaborative learning and CSCL, a number of tasks have been developed to test knowledge interdependence (e.g., Haselhuhn & Mellers, 2005; van't Wout et al., 2006)

Thus, paradigms for the experimental investigation of emotion understanding could help to investigate topics for future work that emerge from this thesis, such as the relationship between understanding affective states and epistemic states, and the relationship between self-awareness and other-awareness.

6.8 Summary

This thesis aimed to explain how the task environment and interaction with a partner influence people's emotions and their understanding of their partners' emotions during computer-supported collaboration, focusing on co-located and remote-continuous interactions. The thesis relied on the systematic study of collaborations around professionally developed collaborative learning technologies such as concept-mapping tool and collaborative computer games. There were limitations inherent to the lack of control given by the employment of already developed technology, the use of emotion self-reports, and the generalization of results. However, every effort was made to reduce such limitations and therefore, the results contribute to a better understanding of emotions, both in the general sense, and in the particular cases of collaborative learning and CSCL.

The results indicate that collaborative computer games are optimal research contexts to observe how the interaction with a partner and the mediational role of technology might influence people's emotions and their understanding of a partner's emotions.

In relation to people's emotions at the individual level, it was found that features such as collaborative tasks for partners to play complementary roles and an affectively loaded GUI helped collaborators to sustain their cognitive engagement without sacrificing their enjoyment of the activity.

In relation to the understanding of a partner's emotions, it was found that the complementary nature of the roles played by partners during collaborative tasks made their emotions susceptible to the influence of one another. Sometimes, this situation led collaborators to feel similar emotions, which is related to the fact that collaboration partners assumed they were feeling the same. In turn, receiving support

to be more aware about the emotions of one another, helped collaboration partners to have a more pleasant and productive collaboration.

These results have implications for four areas. (1) The results help to further validate the appraisal theory of emotions (2) The studies showed that collaborators' emotions were relevant for their performance during problem solving activities (e.g., data gathering and interpretation and puzzle solving), which is a contribution to the understanding of the relationship between emotions and learning. (3) Theoretical issues in the understanding of emotions in collaborative learning are also opened, namely the need to investigate the relationship between understanding the one's own mental states and the mental states of a partner. (4) The results also prove that the design of collaborative tasks with role complementarity and the provision of affective awareness support are two ways in which affect can be incorporated in the design and evaluation of collaborative learning technologies.

Lastly, three issues for future research about emotions in collaborative learning emerge from the thesis. (1) Whether understanding a partner's affective states works in the same way as the understanding of a partner's epistemic states. (2) The relationship between emotion self-awareness and other-awareness. (3) The need for experimental paradigms to assess emotion understanding during collaborative learning.

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List of appendices

Appendix A Questionnaires in Study 1

Prior Emotions questionnaire

Male Female Age _____ Initials_____ D 01-S

This questionnaire is for you to tell about the emotions you have felt during the last 20 minutes. Please answer it according to the following instructions:

1. Below you will find three boxes: A, B and C. Box A contains a list of words that describe different emotions. Please read these words carefully and indicate if you felt each of the listed emotions during the last 20 minutes. Mark 'No' for those emotions you have not felt at all and 'Yes' for those emotions you have felt.
2. For each emotion you marked as yes, please indicate **how often** you felt the emotion using the scale in the box B and how **intense** the emotion was using the scale in the box C

A			B				C			
Did you feel…			**If yes, how often?**				**How intensely?**			
	No	Yes	Rarely	Some of the time	Frequently	All the time	Slightly	Moderately	A lot	Extremely
Happy	( )	( )	1	2	3	4	1	2	3	4
Sad	( )	( )	1	2	3	4	1	2	3	4
Fearful	( )	( )	1	2	3	4	1	2	3	4
Angry	( )	( )	1	2	3	4	1	2	3	4
Bored	( )	( )	1	2	3	4	1	2	3	4
Challenged	( )	( )	1	2	3	4	1	2	3	4
Interested	( )	( )	1	2	3	4	1	2	3	4
Hopeful	( )	( )	1	2	3	4	1	2	3	4
Frustrated	( )	( )	1	2	3	4	1	2	3	4
Contempt	( )	( )	1	2	3	4	1	2	3	4
Disgusted	( )	( )	1	2	3	4	1	2	3	4
Surprised	( )	( )	1	2	3	4	1	2	3	4
Proud	( )	( )	1	2	3	4	1	2	3	4
Ashamed	( )	( )	1	2	3	4	1	2	3	4
Guilty	( )	( )	1	2	3	4	1	2	3	4

Own Emotions questionnaire page 1

D | SES

Male Female Age Initials

Part 1

This questionnaire is for you to tell about your emotions while you were playing astroversity. Please answer it according to the following instructions:

1. Below you will find four boxes: A, B, C and D. Box A contains a list of words that describe different emotions. Please read these words carefully and indicate if you felt each of the listed emotions while you were playing astroversity. Mark 'No' for those emotions you have not felt at all and 'Yes' for those emotions you have felt.
2. For each emotion you marked as yes, please indicate **how often** you felt the emotion using the scale in the box B and how **intense** the emotion was using the scale in the box C.
3. In the box D, please indicate the extent to what the emotions you felt **had to do** with *playing astroversity, your self* and *your partner*.
4. Once you have finished with the boxes in this page, turn the sheet to complete the questionnaire.

A			B				C				D											
Did you feel..			If so, how often?				How intensely?				To what extent did your feeling had to do with…											
											Playing astroversity				your self				your partner			
	No	Yes	Rarely	Some of the time	Frequently	All the time	Slightly	Moderately	A lot	Extremely	Not at all	A little	Somewhat	A great deal	Not at all	A little	Somewhat	A great deal	Not at all	A little	Somewhat	A great deal
Happy	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Sad	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Fearful	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Angry	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Bored	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Challenged	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Interested	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

Please turn page to continue →

Own Emotions questionnaire page 2 and Interaction Quality questionnaire

Please, answer the following according to the instructions provided.

A			B				C				D											
Did you feel..			If so, how often?				How intensely?				To what extent did your feeling had to do with…											
											Playing astroversity				your self				your partner			
	No	Yes	Rarely	Some of the time	Frequently	All the time	Slightly	Moderately	A lot	Extremely	Not at all	A little	Somewhat	A great deal	Not at all	A little	Somewhat	A great deal	Not at all	A little	Somewhat	A great deal
Hopeful	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Frustrated	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Contempt	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Disgusted	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Surprised	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Proud	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Ashamed	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Guilty	( )	( )	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

Part 2

Please indicate the extent to what you agree or disagree with the following statements by marking the appropriate option

While my partner and I were playing astroversity, we…	Not at all	A little	Somewhat	To a great extent
…understood each other's ideas and opinions	0	1	2	3
…were thinking alike	0	1	2	3
… were cooperating equally	0	1	2	3

Partner Emotions questionnaire

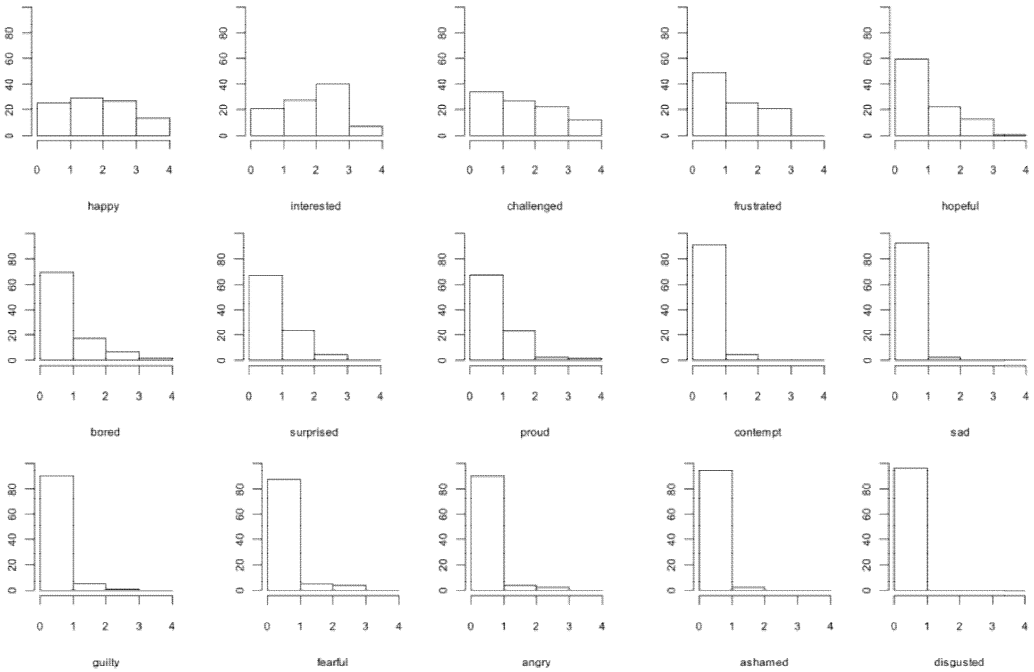
Male Female Age _____ Initials _____ _____ | D | G-P |

This questionnaire is for you to tell about the emotions of your peer while you were playing astroversity. Please answer it according to the following instructions:

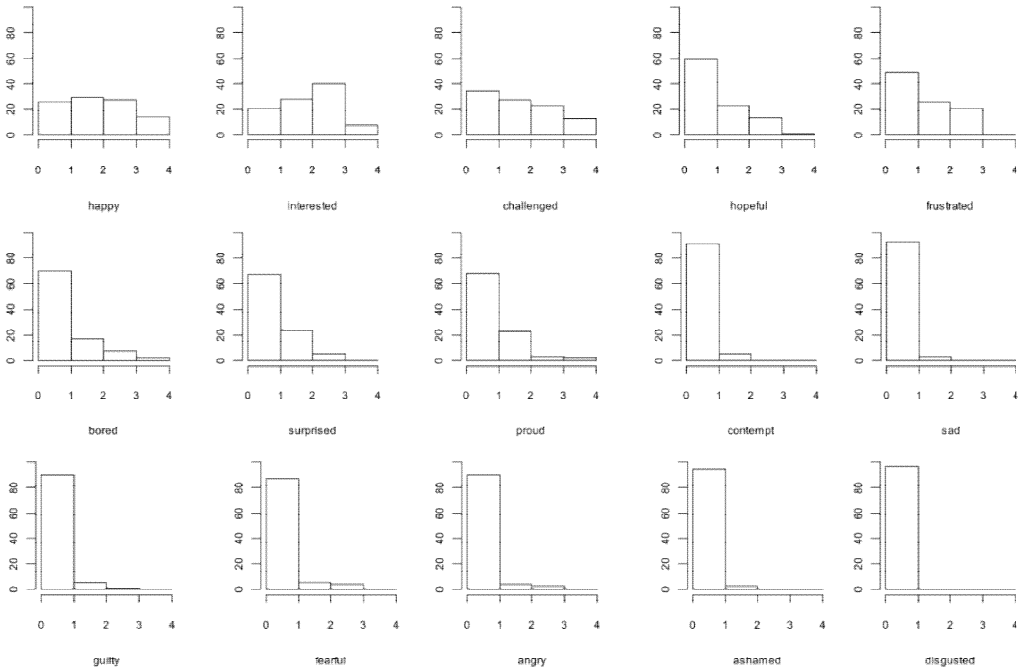
3. Below you will find three boxes: A, B and C. Box A contains a list of words that describe different emotions. Please read these words carefully and indicate if you think your partner felt each of the listed emotions while playing astroversity. Mark 'No' for those emotions you think your partner did not feel and 'Yes' for those emotions you think your partner felt.
4. For each emotion you marked as yes, please indicate **how often** you think your partner felt the emotion using the scale in the box B and how **intense** the emotion was using the scale in the box C

A			B				C			
Did your partner feel...			**If yes, how often?**				**How intensely?**			
	No	Yes	Rarely	Some of the time	Frequently	All the time	Slightly	Moderately	A lot	Extremely
Happy	( )	( )	1	2	3	4	1	2	3	4
Sad	( )	( )	1	2	3	4	1	2	3	4
Fearful	( )	( )	1	2	3	4	1	2	3	4
Angry	( )	( )	1	2	3	4	1	2	3	4
Bored	( )	( )	1	2	3	4	1	2	3	4
Challenged	( )	( )	1	2	3	4	1	2	3	4
Interested	( )	( )	1	2	3	4	1	2	3	4
Hopeful	( )	( )	1	2	3	4	1	2	3	4
Frustrated	( )	( )	1	2	3	4	1	2	3	4
Contempt	( )	( )	1	2	3	4	1	2	3	4
Disgusted	( )	( )	1	2	3	4	1	2	3	4
Surprised	( )	( )	1	2	3	4	1	2	3	4
Proud	( )	( )	1	2	3	4	1	2	3	4
Ashamed	( )	( )	1	2	3	4	1	2	3	4
Guilty	( )	( )	1	2	3	4	1	2	3	4

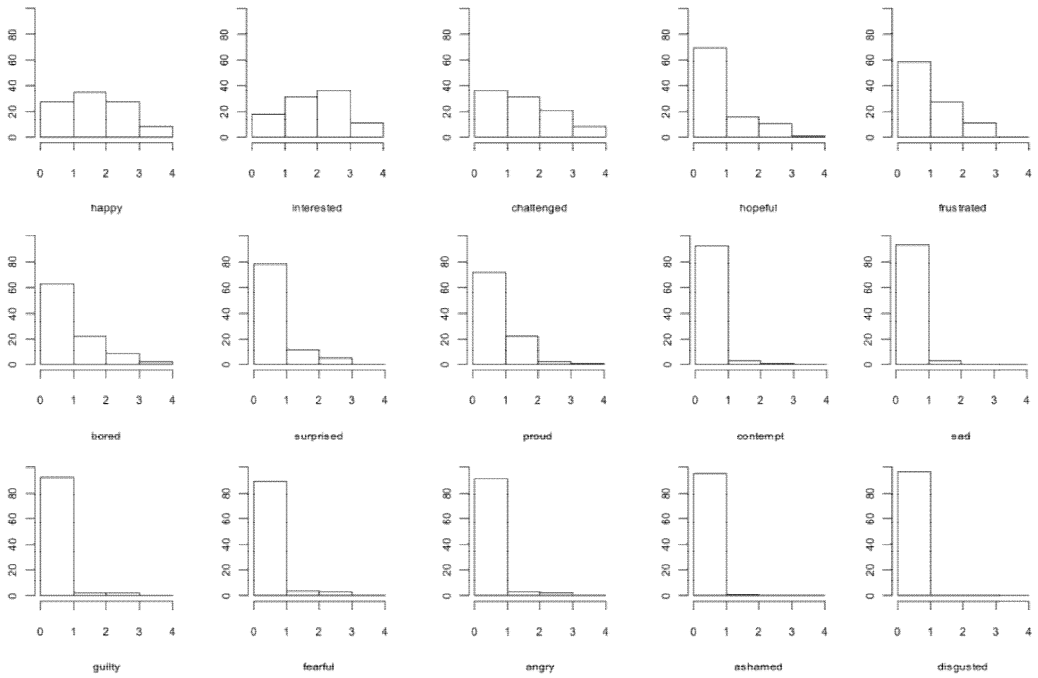
Appendix B Histograms of questionnaire data in Study 1



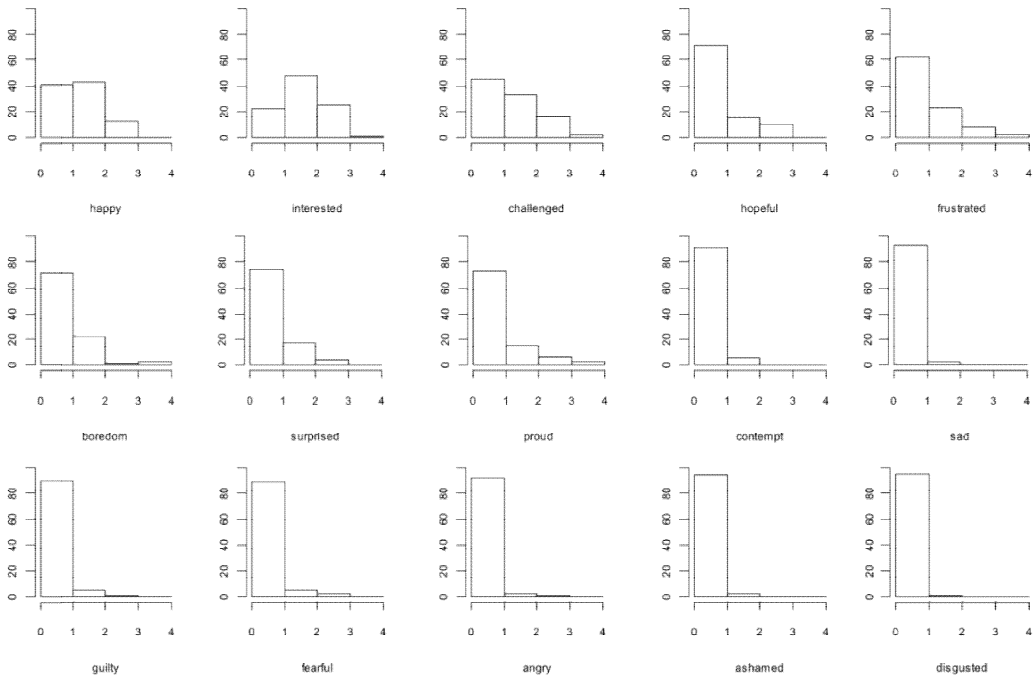
Histograms of the frequency scale in the Own Emotions questionnaire



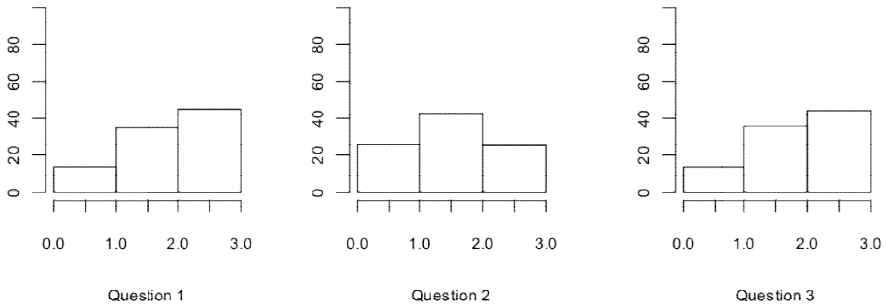
Histograms of the intensity scale in the Own Emotions questionnaire



Histograms of the frequency scale in the Partner Emotions questionnaire



Histograms of the intensity scale of the Partner Emotions questionnaire



While my partner and I were playing Astroversity/Using 2Connect, we...

1. ... *understood each other's ideas and opinions*

2. ... *were thinking alike*

3. ... *were cooperating equally*

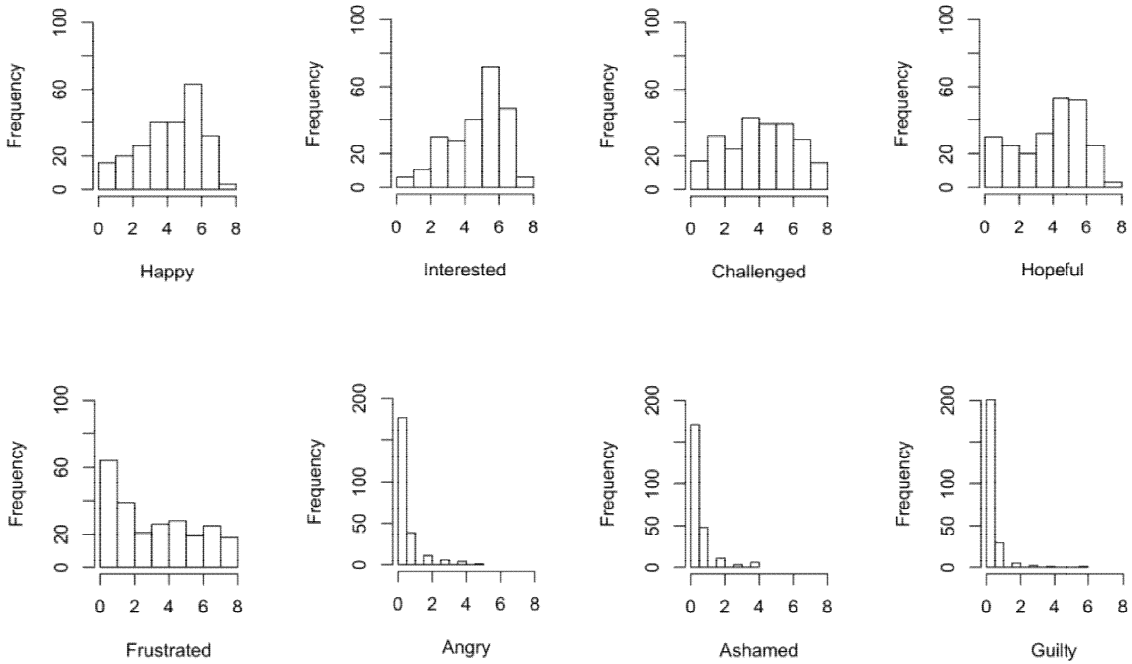
Histograms of the questions in the Interaction Quality questionnaire

Appendix C Regression analyses testing accuracy at reporting the partners' emotions

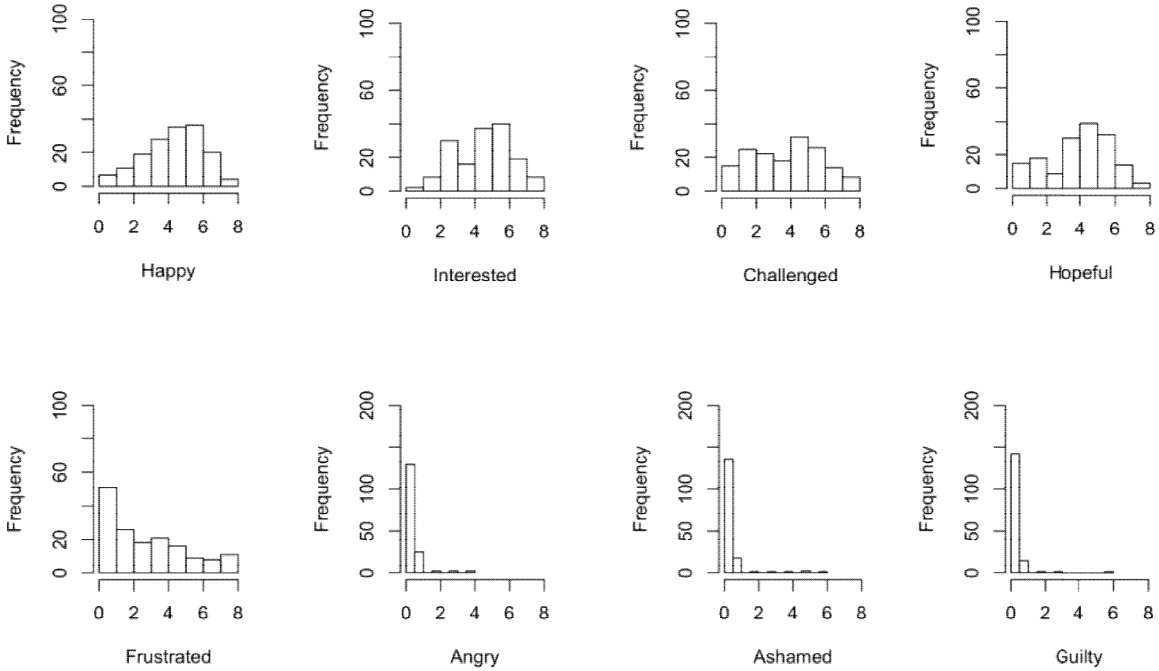
		Own				Partner			
		B	*SE*	*β*	*t*	*B*	*SE*	*β*	*t*
2Connect	Happy	0.52**	0.09	0.61	5.5	0.17	0.09	0.2	1.8
	Interested	0.40**	0.1	0.51	4.03	0.04	0.1	0.06	0.45
	Challenged	0.52**	0.11	0.55	4.54	0.003	0.115	0.004	0.03
	Hopeful	0.56**	0.14	0.5	4.04	-0.13	0.14	-0.11	0.92
	Frustration	0.33[1]	0.15	0.3	2.17	-0.07	0.15	-0.063	-0.45
	Bored	0.58**	0.12	0.55	4.7	0.20	0.12	0.2	1.68
Astroversity	Happy	0.36*	0.13	0.37	2.82	0.25	0.13	0.36	1.96
	Interested	0.30[1]	0.12	0.34	2.63	0.32*	0.11	0.36	2.8
	Challenged	0.24[1]	0.12	0.28	2.03	0.16	0.12	0.18	1.33
	Hopeful	0.58**	0.13	0.55	4.6	0.18	0.13	0.17	1.44
	Frustration	0.52**	0.125	0.52	4.15	-0.02	0.12	-0.02	-0.17
	Bored	0.30[1]	0.13	0.32	2.3	0.12	0.13	0.13	0.9

[1]$p<.05$, *$p<.01$, **$p<.005$

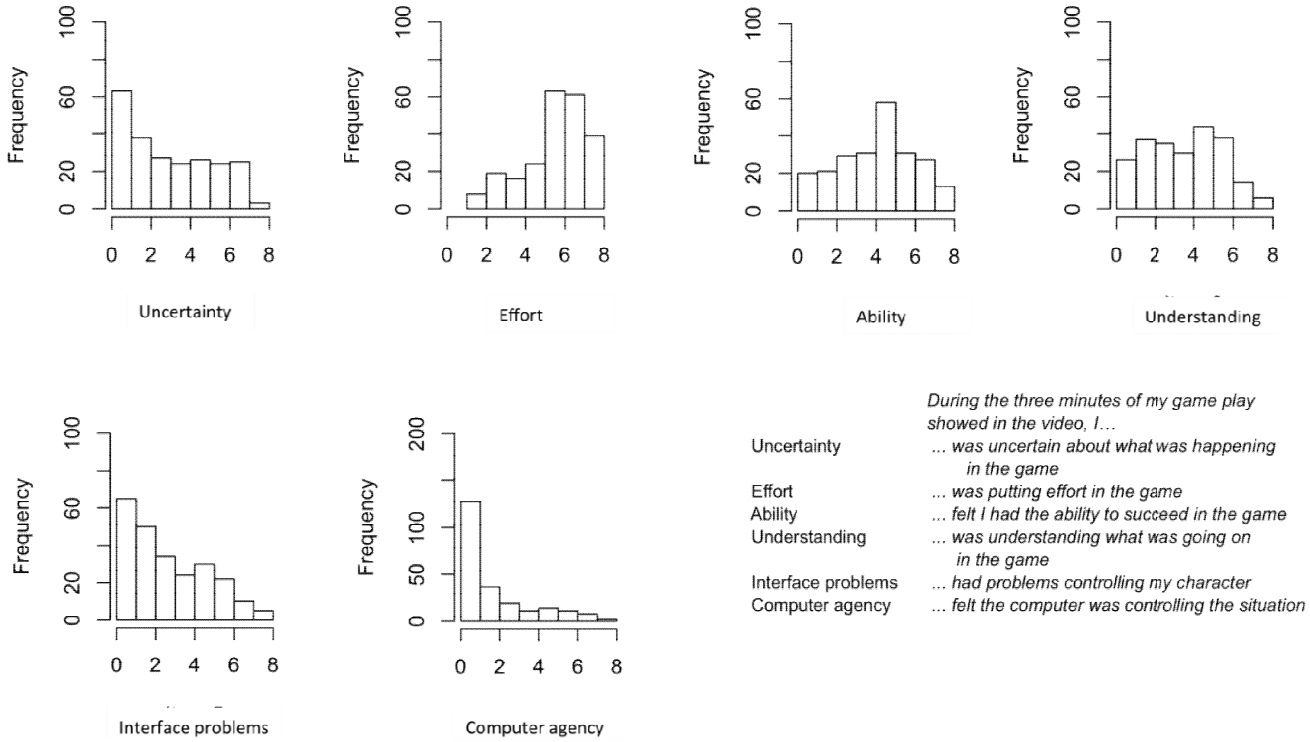
Appendix D Histograms of questionnaire data in Study 2



Histograms of the answers to the Own Emotions questionnaire



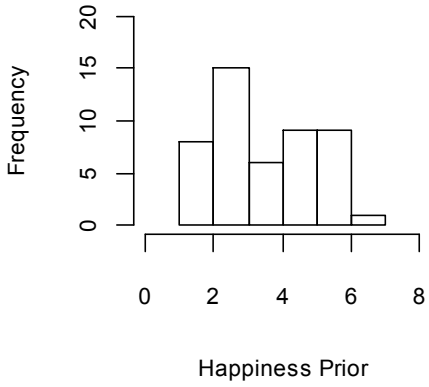
Histograms of the answers to the Partner Emotions questionnaire

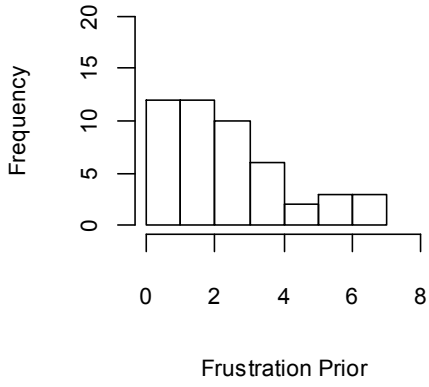


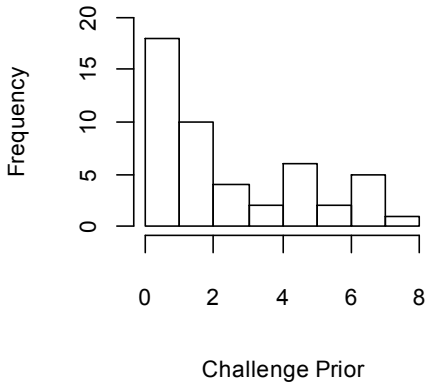
	During the three minutes of my game play showed in the video, I…
Uncertainty	*… was uncertain about what was happening in the game*
Effort	*… was putting effort in the game*
Ability	*… felt I had the ability to succeed in the game*
Understanding	*… was understanding what was going on in the game*
Interface problems	*… had problems controlling my character*
Computer agency	*… felt the computer was controlling the situation*

Histograms of the answers to the Contextual Appraisal questionnaire

Appendix E Histograms of the prior happiness, frustration and challenge in Study 2







Appendix F Correlations between emotion scores in Study 2

	Challenge	Interest	Hope	Frustration
Happiness	-0.14	**0.61**	**0.57**	-0.34
Challenge	--	0.01	-0.17	**0.70**
Interest	--	--	**0.54**	-0.21
Hope	--	--	--	-0.32

Values represent the averaged correlation coefficients across participants (N=12)

Bold coefficients are significant with at least p<.05

Appendix G Profiles of trials of increased and decreased challenge in Study 2

GA. Trials with challenge increase

	Increased trial A-4,4
Experience	Collaborative session 4 (I-I-C-C), trial 4
Intensity and change	The challenge increase as a dyad was small (2). The challenge of Member A did not change, and increased only for Member B. For Member A, challenge remained equally high from the previous trial (6) to the current trial (6). For Member B, challenge increased but remained medium from the previous trial (3) to the current trial (5).
Similarity	Partners became a little more similarly challenged. The difference between their challenge intensity decreased from medium (3) to low (1)
Accuracy	Both members were accurate at estimating the challenge of one another. Their accuracy was closely related to their similarity The inaccuracy of Member A decreased from medium (3) to little (1). The inaccuracy of Member B was little in the previous (1) and current trials (2).
Game situation	Previous trial: They solved one puzzle which objective was to cross a swamp. This implied several simple steps that did not require skill (e.g., shooting enemies, operating panels to dry the swamp) and one step that required interdependence (i.e., partners had to walk together to find a panel). Collaboration was mandatory. Current trial: They solved one puzzle and started, but did not complete, a second one. Puzzle 1: They have to cross a gap. This implies simple steps (jumping and shooting enemies) and one step interdependent step (one player has to assemble blocks to build a bridge, employing her special ability to manipulate objects at distance). Insight is necessary to realize the blocks are to build the bridge. Collaboration is mandatory. Puzzle 2: they have to make a bridge and cross a swamp. This implies simple steps (e.g., push a box, assembling blocks), no insight is necessary and collaboration is redundant. Key game events: None
Performance	Puzzle 1. Both partners effectively execute simple steps like shooting enemies and jumping, and quickly resolve some coordination problems: One partner falls in the gap whilst trying to jump onto a column because the other keeps walking, moving the shared screen. They realize this and correct their coordination. Then, they figure out that Member B needs to use her special ability to assemble the blocks to build a bridge and cross the gap, which she does effectively. Puzzle 2. They executed some of the simple steps (e.g., shooting enemies) but did not complete it because the trial finished. Because they solved various simple steps and some interdependent steps, the performance score was good both for Member A (pspm=2.33) and member B (pspm=3).
Context perception	Member A made a lot of effort (7), felt little uncertainty (1), had high understanding of the game, and rated her ability as medium (5). She also had medium problems for controlling her character (5) and thought the computer had little control of the game (4). Member B made a lot of effort (8), did not feel uncertainty (0), had high understanding of the game (6) and rated her ability as medium (5). She had little problems for controlling her character (1) and thought the computer had little control of the situation (1).

Social situation	Member A talked less (17.33 wpm) than Member B (27 wpm).
	Member A talked less because she used more backchannel. However, both she and Member B effectively communicated to coordinate:
	`A: (falling in the gap as the screen pushes her)`
	`B: (jumping onto a column) you need to jump up`
	`A: you need to come back (because B is pushing the shared screen)`
	`B: yea (walking back)`

	Their talk also included suggestions and ideas that helped them to gain insight to solve the puzzles: A: can you jump in the other side? (standing still) B: probably not without you, but let's have a look (as she jumps onto the stone) A: I think those are the things to build the bridge (in reference to the glowing blocks) B: yeah... ahh... yes… (moving the glowing blocks, making the bridge) A: ok…

	Increased trial A-3,5
	Collaborative session 3 (IICC), trial 5
Intensity and change	Challenge increase as a dyad was medium (3). But challenge actually decreased Member A and increased for member B. For Member A, challenge had a little decrease, but remained high from the previous trial (8) to the current trial (7). For member B, challenge increased mildly from low (2) to high (6).
Similarity	Partners became much more similarly challenged. The difference between their challenge intensity decreased from high (6) to little (1)
Accuracy	Member A was more accurate than Member B. But the accuracy of Member A was closely related to the similarity, whereas the accuracy of Member B was dissociated from the similarity. The inaccuracy of Member A decreased from medium (5) to little (1). The inaccuracy of Member B increased from little (0) to high (6). Her accuracy was not associated with the similarity.
Game situation	Previous trial: They faced one puzzle and did not complete it. The objective was to reach the top of a building. This implied several simple steps that required skill (e.g., jumping from one platform to another) and interdependent steps (e.g., one player needs her special ability to open a platform for the other to jump onto it). Collaboration was mandatory. Current trial: They solved one puzzle and did not complete a second one. Puzzle 1. They made the necessary interdependent steps and solved the building puzzle (i.e., jumping onto the platforms to reach the top). Puzzle 2. Their objective is to open a door. This implies simple steps (i.e., breaking ladders) and one interdependent step (i.e., Member A needs to employ her special ability to open some valves, which opens the door. Member B cannot do that). Collaboration is mandatory Key game events: Last trial of the session
Performance	Puzzle 1. Member B is effectively solving the last steps of the building puzzle (i.e., jumping from platform to platform) and reaches the top of the building, whereas member A has problems to jump onto a column. Member B keeps solving steps and finishes the puzzle, then member A is automatically taken to the top of the building. Puzzle 2. Partners effectively solve the initial simple steps (i.e., breaking ladders) but do not complete it because the session finishes. Because of her problems to jump onto the column, Member A did not make any step in puzzle 1, and did only a few simple steps in puzzle 2. Therefore her performance score was low (pspm=0.66). Member B did more steps in the two puzzles, therefore her performance score was better (pspm= 3)
Context perception	Member A made a lot of effort (7), felt high uncertainty (6), little understanding of the situation (2), and rated her ability as medium (5). She had a lot of problems for controlling her character (8) and thought the computer was having a lot of control of the situation (7). Member B made a lot of effort (7), felt little uncertainty (0), had good understanding of the game (6) and rated her ability highly (7). She did not have problems controlling her character (1) nor thought the computer was controlling the situation (0).

Social situation	Talk frequency was similar for member A (6 wpm) and member B (7 wpm). Overall, they played silently, communicating only briefly to coordinate:
	`A: start shooting (telling to B, as she can't shoot)`
	`B: ... (shoots)`
	`A: ... (breaking things around)`

	Increased trial B-3,3
Experience	Collabortive session 3 (I-I-C-C), trial 3
Intensity and change	Dyad challenge increase was medium (4). Both partners increased B1's challenge increased from little (2) to medium (5) B2;s challenge increased but remained medium from the prior trial (3) to the current trial (4).
Similarity	Partners remained similarly challenged. Their challenge similarity remained little from the previous trial (1) to the current trial (1).
Accuracy	Both partners made accurate estimations about the challenge intensity of one another. B1's inaccuracy remained little from the previous trial (2) to the current trial (1) B2's inaccuracy remained little from the previous trial (0) to the current trial (2)
Game situation	Previous trial: Partners solved two puzzles and started, but did not complete, a third one. The first puzzles required simple steps (e.g., pushing boxes), collaboration was redundant. Second puzzle had rewardable steps (e.g., stomping two lines of buttons, pulling two levers), collaboration was not compulsory but it was rewarded. The third puzzle had simple steps (e.g., pushing a turnstile, operating panels). Collaboration was redundant. Current trial: Partners continued, and did not complete, the ladt puzzle of the previous trial Puzzle 1. Their objective is to liberate a droid who is in a cage. Partners need to push a turnstile, which controls a vacuum. When collocated upon the cage, a panel is unlocked. Then they need a droid to operate the panel, which liberates the droid. They need to realize the relationship between the turnstile, the vacuum and the panel. Once the droid is free, they need to use it to open a door. This puzzle implies only simple steps (e.g., operating panels, shooting enemies, pushing the turnstile). Collaboration is redundant.
Performance	In the previous trial, partners made initial manipulations of the puzzle elements (i.e., moving the droid, pushing the turnstile). In the current trial they keep manipulating the turnstile and the droid without realizing the relationship between the turnstile, the magnet and the panel. Also, they frequently engage with irrelevant elements (e.g., useless boxes) or just walk around. The sometimes refer to the hints but that do not helps them. After much manipulation of the turnstile they realize it controls the magnet and the panel. After this they play co-ordinately to solve the next steps (e.g., operating panels), but they do not complete the puzzle before the end of the trial. They spend most of the trial without realizing the key aspect of the puzzle (i.e., the relationship between steps). When they figure this out, they start making the adequate steps, simple per se. Thus, the performance score was equally low for B1 (pspm= 0.67) and B2 (pspm=0.67)
Context perception	B1 made a lot of effort (6), felt medium uncertainty (5), medium understanding (3) and rated her ability to play the game as little (2).She had little problems controlling her character (2) and thought the computer had little control over the situation (1). B2 made a lot of effort (7), felt medium uncertainty (4), little understanding (2), and rated her ability to play the game as medium (5). She had no problems controlling her character (0) and thought the computer had no control over the situation (0).

Social situation	Talk frequency was similar for B1 (28 wps) and B2 (22 wps.
	Partners talked less when they were either engaging with distracters or walking around. They interacted mostly with backchannel whilst manipulating the elements of the puzzle as well as other irrelevant ones.
	`B2: [walking towards the droid] ehm.. that's not making any difference`
	`B1: [pushes] no.. (inaudible)`
	`B1: [stops pushing, shoots around]...`
	`B2: [pushes turnstile]`
	`B2: [uses the force on the droid]... mhhh`

	B1: [pushes turnstile]... They talked more when they figured out how to solve the puzzle, giving suggestions that accompanied their practical interactions: B1: uh? [as B2 pushes the turnstile, the magnet turns a green light when above a cage] oh yeah.. that moved B2: ok, right [goes to push, but misses the turnstile] B1: this way [goes to push]... maybe [colocates the magnet upon the droid's cage] yeah.. B2: eh.. now what? … B1: [goes to push] maybe i should push more [pushes, and then the panel gets blocked again] B2: [notices the panel blocks] uh, right, push again.. it needs, is, this.. B1: which way? B2: [stands in fron the panel] back that way, a litle bit B1: [pushes]... B2: [panel is liberated] that's right, stop... oh it's r2d2, right B2:[switches to droid] all right.. r2d2 [operates the panel and c3po is liberated]

	Increased trial B-4,2
Experience	Collaborative session 4 (I-I-C-C), trial 2.
Intensity and change	Dyad challenge had a large increase (8). Both dyad members increased. B1's challenge increased from little (0) to medium (4) B2's challenge increased from little (2) to high (6)
Similarity	Partners remained similarly challenged. Their challenge difference remained little from the previous trial (2) to the current trial (2)
Accuracy	B1 was inaccurate at estimating the challenge intensity of B2. Her estimations about B were unrelated to the similarity. In contrast, B2 was accurate at estimating the challenge intensity of B1. Her estimations about A were related to their similarity. B1's inaccuracy increased from little (2) to medium (4). B2's inaccuracy remained little from the previous (1) to the current trial (1)
Game situation	Previous trial: Partners solved 3 puzzles and started, but did not complete, a fourth one. The first 3 puzzles had simple and rewardable steps). Collaboration was either redundant rewardable. The third puzzle had simple steps (i.e., various steps are linked). They figured out the key step before the trial finished but they did not complete the puzzle. Current trial: Partner solved two puzzles and started, but did not complete, a third one. Puzzle 1. Their objective is to liberate a droid who is in a cage. Partners need to push a turnstile, which controls a vacuum. When collocated upon the cage, the vacuum takes the droid off. They need to realize the relationship between the turnstile and the vacuum. Once the droid is free, they need to use it to open a door. This puzzle implies only simple steps (e.g., operating panels, shooting enemies, pushing the turnstile). Collaboration is redundant. Puzzle 2. Their objective is to open a door. This implies simple steps (i.e., breaking ties). Collaboration is redundant. Puzzle 3. The objective is to cross a swamp. This implies simple steps and interdependence. Simple steps are to operate two panels, shoot enemies and cross a bridge. Interdependent step is that partners need to walk together to find a panel. Collaboration is mandatory
Performance	Puzzle 1. The key step of the puzzle (i.e., liberating the droid) has been resolved in the previous trial. When the current trial starts, they have to use the droid to operate a panel and open a door, which completes the puzzle. They realize what to do quickly, but some enemies are impeding them to operate the panel freely. They organized for one of them to operate the panel whilst the other one keeps the enemies away. Puzzle 2. They quickly resolved the puzzle, effectively breaking the ties on the door. Puzzle 3. They spend most of the trial solving this puzzle. Quickly realize they need to use the panels to cross the swamp. They reach access to one panel, but do not figure out they need a second one. They cooperate most of the time, but they do so for solving solve irrelevant steps (e.g., one partner uses her special to build a grapple point for her partner to grapple) or walk together in wrong places The performance score was similar for B1 (pspm= 2.67) and B2 (pspm=1.67).
Context perception	B1 made a lot of effort (8), felt highly uncertain (6), had little understanding of the game (3) and rated her ability to play as medium (5). She had little problems controlling her character (2) and thought the computer had no control of the situation at all (0). B2 made a lot of effort (6), felt little uncertainty (2), had medium understanding (5) and rated her ability to play as medium (4). She had little problems controlling her character (2) and thought the computer had little control of the situation (2).

Social situation	B1 talked relatively more (31.66 wpm) than B2 (20 wpm).
	Partners' talk was totally task oriented. They interacted silently whilst making simple things like assembling blocks and shooting enemies. Whilst figuring out puzzle 3 they usually cooperated (e.g., acted complementarily or walked together) albeit to make useless steps. Whilst doing so they could be interacting with short exchanges that denoted wondering, altogether with backchannel
	`B1: [walking around] there must be somewhere, somewhere else..`
	`B2: [follows R] yeah... that is fine [a glowing column] can you move it?`
	`B1: [tries to move the column] maybe… mh…`
	When their talk was more abundant, it was composed by explanations that denoted understanding of the mechanics of the game
	`B1: so this (a panel) can definitively be only activated by him (the droid)`
	`B2: [goes and gets the droid]`
	`B1: [standstill] yeah... but he can't jump (there is a step that impedes the droid to reach the panel)`
	`B2: [standing in the step] try and move him a bit`
	`B1: [goes to move the droid] ok…`
	`B2: [as the droid does nothing] no… is not the right way`

	Increased trial C-1,2
Experience	Collaborative session 1 (C-C-I-I), trial 2
Intensity and change	Dyad challenge had a little increase (2). Only C1 increased. C1's challenge increased from medium (5) to high (7). C2's challenge remained medium from the previous trial (5) to the current trial (5)
Similarity	Partners remained similarly challenged. Their challenge difference remained little from the previous trial (0) to the current trial (2)
Accuracy	Both partners made accurate estimations about the challenge intensity of one another. Their accuracy was related to their similarity. C1's inaccuracy remained little from the previous trial (0) to the current trial (2) C2's inaccuracy remained little from the previous trial (0) to the current trial (2)
Game situation	Previous trial: Partners resolved one puzzle and started but did not complete a second one. In the first puzzle they fluently did simple steps (e.g., shooting enemies) but did not cooperate in rewardable steps (e.g., did not divide the task to pulling two pairs of levers). Collaboration was rewardable. The second puzzle was made of simple steps (e.g., shooting enemies). They did most steps except the last one. They just needed to cross a door but did not do it. Instead, they engaged with distracters (e.g., pulling useless levers) or walked around, without realizing they need the door. Current trial: They continued with the same puzzle they were solving before and did not solve it Puzzle 1: The objective is to walk across a corridor and cross a door. This implies simple steps (e.g., shooting enemies, crossing the door) and there are some potential distracters (e.g., useless levers and windows). Collaboration is redundant.
Performance	Puzzle 1: They spend the trial without realizing they had to cross the door. Instead, they engage with distracters (e.g., useless levers, doors they cannot open and) and went back to previous parts of the game they have already solved. Sometimes they consulted the hints provided but interpreted them wrongly (i.e., they read hints for a different puzzle), which also contributed to their lack of success in the puzzle. Because they spent all the trial trying to solve this puzzle, they did not make any meaningful step, leading to performance scores of zero for both partners.
Context perception	Data about context perception was lost for this session.

Social situation	C1 talked less (18 wpm) than C2 (35.66 wps).
	
	Talk was composed by frequent short exchanges. Most of the time, C2 made commentaries or suggestions that accompanied the manipulations of irrelevant components. C1 also made suggestions and commentaries, but with less frequency. This sort of interaction was observed for example, when they went back to puzzles they had already solved.
	`C2: [walking back to the the previous puzzle, which is a corridor or with levers]`
	`do we need to stand and see?`
	`C1: ... mmhh [approaching a lever and pulling it]`
	`C2: ... [standstill, then pulls down the other 2 lever)`
	…
	`C2: have we pulled down all the levers?`
	`C1: mhh`
	`C2: is not working... [trying to pull down a lever that is already down]`
	`C1: [walking around]...`

	Occasionally, they explicitly expressed misunderstanding of the situation, which in turn was provoked by a misinterpretation of the hints (they were reading hints that applied for a different puzzle)
	`C1: [reading hints that apply for a different puzzle] boxes with yellow stripes`
	`C1: [walking around] I do not understand...`
	`C2: [walks forward, towards the door]`
	`C2: [in a distracter window] can we get back there or something? [to the previous puzles]`
	`C1: [walking back]...`
	`C2: I thought it meant to be boxes.`
	`C1: is… (inaudible) pull down levers?`

	Increased trial D-1,3
Experience	Collaborative Session 1 (C-C-I-I), trial 3
Intensity and change	The challenge increase as a dyad was small (5). Both partners increased moderately. D1's challenge increased from little (2) to moderate (5). D2's challenge increased from little (1) to moderate (6).
Similarity	Partners became more similarly challenged. Their challenge difference decreased from medium (4) to low (2)
Accuracy	Both members were accurate at estimating the challenge of one another. Their accuracy was closely related to their similarity. The inaccuracy of D1 remained little from the previous trial (1) to the current trial (2) The inaccuracy of D2 remained little from the previous trial (2) to the current trial (1)
Game situation	Previous trial: Solved three puzzles that required simple steps (e.g., crossing doors, shooting enemies and pulling levers) and started, but did not complete, a fourth puzzle that also required one simple step. Collaboration was redundant. Current trial: They solved one puzzle. Puzzle 1. They are solving a puzzle they started in the previous trial. They find the droids for the first time. Now they need to control them to operate panels and open doors. These are simple steps. Also, as part of this puzzle implies that one of the characters they have been controlling leaves the scene without apparent reason. Collaboration is redundant, and no insight is necessary. But there are two key game events. First, they find the 'droids' for the first time. Second, one character leaves the scene for no apparent reason.
Performance	Puzzle 1. Players had problems for controlling the droids. So it took them most of the trial to figure out how to use them to operate the panels and open the doors. Also, when the character left the scene, they tried to look for it (i.e., they went back) and were confused about which character were hey controlling (e.g., their original character or a droid). They opened the doors and solved the puzzle towards the end of the trial. The puzzle required only two simple steps (i.e., opening the doors) and each member did one, so their performance score was equally low (pspm= .33)
Context appraisal	D1 reported low uncertainty (1) and mild understanding (4). She rated her ability mildly (5), as well as her problems to control her character. She did not think the computer was controlling the situation (0) D2 made a lot of effort (7). She felt highly uncertain (7) her understanding of the game was little (1) and rated her ability lowly (3). She had little problems for controlling her character (4), and thought the computer had little control of the situation (2)

Social situation	D1 talked more (42.33 wpm) than D2 (17.33 wpm)
	Although D1 seemed to contribute more, D2 also made suggestions and answered questions. Their talk was mainly composed by practical suggestions, especially whilst figuring out how to control the droids:
	`D2: all right, you just press 1, so now I am in control of him (as a droid)`
	`D1: no, I am him in this...`
	They also made commentaries to explicitly Express their lack of understandign about the situation, or to explain it. However, these expressions and explanation were not elaborated further:
	`D2: maybe is like .. on the way  you got him (walking around, smashing electric wall)`
	…
	`D1: I don't know what would ... (walking back the corridor)`
	`D2: ... (walking towards the door)`
	…
	`D1: now, you can open the door`
	`D2: no, I think it's him because it got his face (inreference to r2d2, so she goes and get it)`

	Increased trial D-1,4
Experience	Collaborative session 1 (C-C-I-I), trial 4
Intensity and change	The challenge increase as a dyad was medium (4). Both partners had a little increase. D1's challenge increased from medium (5) to high (7) D2's challenge increased but remained high from the previous trial (6) to the current trial (8)
Similarity	Partners remained similarly challenged. Their challenge difference remained little from the previous trial (1) to the current trial (1)
Accuracy	Partners were equally accurate at estimating the challenge intensity of one another. Their accuracy was closely related to their similarity D1's inaccuracy remained little from the previous trial (2) to the current trial (1) D2's inaccuracy remained little from the previous trial (1) to the current trial (1)
Game situation	Previous trial. They solved one puzzle that required simple steps. They found the droids, and needed to use them to operate panels and open doors. Although this puzzle required simple steps, it also implied two key game events. First one character left for no apparent reason. Second, they found the droids for the first time, which caused confusion on players. Collaboration was redundant. Current trial: They started and did not solve one puzzle. Puzzle 1. They have to use a crane to pass one droid across a gap. To do so, they need to make some simple steps (e.g., open doors) and various interdependent steps (e.g., D1 has to control the droid. D2 uses the crane to pass A side of the gap. Then D1 can use the droid to open the door). There are various steps that need to be combined. Collaboration is mandatory.
Performance	Puzzle 1. Partners use the game hints to figure out they need to pass the droid to the other side. But the hints do not say how. They did coordinated to try several strategies (e.g., use the crane to manipulate irrelevant objects, using an elevator that seems useful but is not, precipitating the droid in the gap and trying to catch it with the crane), but they could not figure out how to use the crane properly (e.g., to eliminate enemies and pass the droid to the other side). They did not make any of the necessary steps to solve puzzle 1. So the performance score of both partners was zero.
Context appraisal	D1 made little effort (2), felt high uncertainty (7) and little understanding (1) and rated her ability to play the game as little (1). She had no problems for controlling her character (0) and did not think the computer was controlling the situation. D2 made a lot of effort (7), felt high uncertain (7) and little understanding (1) and rated her ability to play as little (1). She had medium problems for controlling her character (3) and thought the computer has having much control of the situation (7).
Social situation	D1 talked a little more (17 wpm) than D2 (10.33 wpm). Mostly, their talk accompanied their attempts to solve the crane puzzle with strategies other than the right one (e.g., using distracters or trying the worng usage of elements like the crante). In these moments, their talk was composed by an exchange of practical suggestions and some commentaries about their understanding (or lack of): D2: ... (jumps into the crane) D1: I though I can be... what's this thing? (waling onto the elevator) D2: I can go left and right (moving the crane) D1: but you can't go forwards and backwards (standing in the elevator) D2: that's ... I need to know

	Increased trial E-1,2
Experience	Collaborative session 1 (C-C-C-C), trial 2
Intensity and change	Dyad challenge increased highly (7). Both partners increased E1's challenge increased from little (1) to high (6) E2's challenge in creased from medium (4) to high (6)
Similarity	Partners became more similarly challenged. Their challenge difference decreased from medium (3) to little (0)
Accuracy	Partners were equally accurate at estimating the challenge intensity of one another. Their accuracy was closely related to their similarity E1's inaccuracy remained little from the previous trial (1) to the current trial (0) E2's inaccuracy decreased from medium (4) to little (1).
Game situation	Previous trial: They solved two puzzles composed by simple (e.g., shooting enemies, grappling) and rewardable (e.g., pulling two levers, building a pair of bridge engines). They required frequent usage of the hints provided, but solved the simple steps and collaborated in the rewardable steps. Collaboration was rewarded, but not mandatory. Current trial: They solved one puzzle and started, but did not finish, a second one. Puzzle 1. They have to open a door, which implies simple steps (e.g., pushing two boxes). Collaboration is redundant. Puzzle 2. They find the droids for the first time, and need to use them to open doors and cross a corridor. This implies simple steps. collaboration is redundant. However, the puzzle implies two key game events. They find the droids and need to use them for the first time. Also, one of the characters leaves the scene for no apparent reason.
Performance	Puzzle 1. They first tried to divide the simple steps required to open the door (i.e., pushing one box each). However, E2 had problems to figure out where to put the box. After some time, E1 pushed the two boxes. Puzzle 2. Partners started the puzzle by fluently making simple steps such as shooting enemies. However, they showed difficulties for controlling the droids. Often, they denoted confusion about how to switch between becoming a droid and returning to their original characters. They invested an important portion of the trial getting to understand how to use the droid in order to open the doors, which is in it self a simple step. Moreover, part of the game situation was that on of the characters with which they started the game left for no apparent reason. This key game event also caused disorganization. Partners did some simple steps. But their difficulties controlling the droids in puzzle 2 lowered the performance score both for E1 (pspm=1.67) and E2 (1).
Context appraisal	E1 made a lot of effort (6), felt highly uncertain (6), had medium understanding of the situation (4) and rated her ability to play the game as medium (4). She had medium problems controlling her character (4) and thought the computer had no control of the situation at all (0). E2 made medium effort (4), felt medium uncertainty (4), had little understanding of the game (2) and rated her ability to play the game as medium (3). She had little problems controlling her character (3) and thought the computer had medium control of the situation (3).

Social situation	Talk frequency was similarly abundant for E1 (wpm=27.33) and E2 (wpm=20.66).
	During puzzle 1, their talk was mainly composed of practical suggestions, a little more from E1, although E2 also did suggestions:
	`E1: [pushing one box) push them [the boxes]`
	`E2: oh, [goes for the other box]`
	`E1: [has put the box in the adequate place]`
	`E2: [showing problems pushing the box] should you push too?`
	`E1: [walks towards B, but notices A is now pushing the box herself] I'll just leave you…`

	During puzzle 2, their talk was directed to resolve their confusion about how to use the droids, which mostly included exchange of practical advice: E2: [noticing they have found the droids]oh we got them! E1: [walking against the electric door] but I am not allowed to do anything E2: [approaching one droid but still not gaining control of it] press that one E1: [walks towards the panel that opens the door].. I can't get it and turn to the droid... how you?... oh, you need to make them open the door E2: [walks against the electric wall] They did not make commentaries about the mechanisms of the game, and made some questions, denoting missunderstanding of the game events: E1: wait, where has my character gone? E2: now I am this one [she has gained control of r2d2) E1: wait, whare's my character gone? E2: ha..

	Increased trial F-1,2
Experience	Collaborative session 1 (C-C-C-C) trial 2.
Intensity and change	Dyad challenge had a medium decrease (3). The challenge of both partners increased F1's challenge increased from medium (5) to high (6) F2's challenge increased, but remained medium from the previous trial (3) to the current trial (5)
Similarity	Partners remained similarly challenged. Their challenge difference remained little from the previous trial (2) to the current trial (1)
Accuracy	Both partners were accurate at estimating the challenge of one another. Their accuracy was related to their similarity F1's inaccuracy decreased from medium (3) to little (2). F2's inaccuracy decreased from medium (3) to little
Game situation	Previous trial: They solved two puzzles composed by simple (e.g., shooting enemies, grappling) and rewardable (e.g., pulling two levers, building a pair of bridge engines). They expressed some confusion about whether they were doing the necessary steps, but solved the simple steps fluently and collaborated in the rewardable steps. Collaboration was rewarded, but not mandatory, and no insight was necessary. Current trial: They resolve three puzzles Puzzle 1. The objective is to reach the door in the end of a corridor and cross it. This implies simple steps (e.g., shooting enemies, crossing the door). No skill or insight is necessary. Collaboration is redundant Puzzle 2. They have to open a door, which implies simple steps (e.g., pushing two boxes). No insight is necessary and collaboration is redundant. Puzzle 3. They find the droids for the first time, and need to use them to open two doors and cross a corridor. This implies simple steps. No insight is necessary and collaboration is redundant. However, the puzzle implies two key game events. They find the droids and need to use them for the first time. Also, one of the characters leaves the scene for no apparent reason.
Performance	Puzzle 1. They fluently solved the simple steps (shooting enemies and crossing the door). Puzzle 2. First they get to understand how to push the boxes. Although it is redundant, they try to push one box each. But in the end F1 pushes the two boxes since F2 is having problems to push her box. Puzzle 3. They finally resolved the puzzle. But whilst doing so, they are confused about the usage of the robots (e.g., problems for switching from the current character to a robot and back, and also did not realize immediately that robots are capable to open the doors by operating panels). It is also confusing when one of the characters leaves for no apparent reason. They briefly go back looking for it, but in the end they just keep playing. The puzzles they solved were made of simple steps. Therefore, although they played effectively, the performance score was relatively low for F1 (2) and F2 (1)
Context appraisal	F1 made a lot of effort (6), felt high uncertainty (7), little understanding (1) and rated her ability to play as medium (4). She had medium problems controlling her character (3), and thought the computer had little control of the situation (1). F2 made medium effort (4), felt medium uncertainty (5), little understanding (1) and rated her ability to play the game as medium (4). She had medium problems controlling her character (4) and thought the computer had medium control of the situation (3).
Social situation	Talk was abundant both for F1 (32.66 wpm) and F2 (30.35 wpm) Their talk included explanations aimed to resolve confusions about how to solve the puzzles (e.g., how to use the boxes in puzzle 2, and the droids in puzzle 3), altogether with a mutual ask and provision of practical suggestions: [In puzzle 1, after one character leaves for no apparent reason] F1:[walks around] oh wait... where?

	F2: I think you are now me and now I'm the robot F1: where is me? [laughs] F2: [laughs] you are runaway and he [the droid] is going to follow us [walking back towards the boxes room] is ok. Just stay like this F1: ok, [lauhgs] I lke you know. strange world There were also explicit expressions of confusion, especially in puzzle 2, when the character leaves for no apparent reason: F1: where has the other person gone? [her original carácter] I'm really confused F2: is there another way to play around... or maybe should go throughout the door
	Increased trial E-4,2
Experience	Collaborative session 4 (C-C-C-C), trial 2
Intensity and change	Challenge increase as a dyad was medium (5). Partners had a little or medium increase. E1's challenge increased from medium (5) to high (7) E2's challenge increased from medium (4) to high (7)
Similarity	Partners remained similarly challenged. Their challenge difference remained little from the previous trial (1) to the current trial (0).
Accuracy	Partners were equally accurate at estimating the challenge intensity of one another. Their accuracy was closely related to their similarity. E1's inaccuracy remained little from the previous trial (2) to the current trial (1). E2's inaccuracy remained little from the previous trial (1) to the current trial (1).
Game situation	Previous trial: They completed one puzzle that required simple steps (e.g., pushing a box, opening a door), no skill or insight was necessary, and collaboration was redundant. By the end of the trial, they are solving one puzzle that requires rewardable steps. Current trial: They continued and completed the puzzle with rewardable steps they were solving in the previous trial. Then they started, but did not complete, a second one. Puzzle 1. The objective is to open a door, for which they need to stomp two button lines and then pulls two levers. Collaboration is not mandatory, but the task is more efficiently solved if partners cooperate (e.g., pull the levers one each). Therefore collaboration is rewardable. Puzzle 2. The objective is to liberate a droid who is in a cage. Partners need to push a turnstile, which controls a vacuum. When collocated upon the cage, the vacuum takes the droid off. They need to realize the relationship between the turnstile and the vacuum. This puzzle implies simple steps (e.g., operating panels, shooting enemies, pushing the turnstile). Collaboration is redundant.
Performance	Puzzle 1. Partners spend most of the trial solving this puzzle. They intend to collaborate by splitting the task (i.e., one button line each, and one lever each). In the previous trial they have made half of the steps (i.e., they stomped one line of buttons each). However, in the current trial, 2E2 had problems for pulling her lever. After a while, E1 pulls the two levers. Puzzle 2. They start the puzzle with manipulation of the main elements (e.g., pushing the turnstile, approaching the droid in the cage). However, the trial finished before they can get on track to solve the puzzle, mainly because they do not yet realize the relationship between the turnstile and the vacuum and the droid. Because they spent most of the trial solving half of puzzle 1 and they did not make any useful step to solve puzzle 2. Therefore the performance score was low for E1 (pspm=.67) and E2 (0).

Context appraisal	E1 made a lot of effort (8), felt moderate uncertainty (5), had little understanding of the situation (3) and rated her ability to play as moderate (5). She had medium problems for controlling her character (5) and thought the computer was not controlling the situation at all (0). E2 made little effort (3), felt moderate uncertainty (5), had medium understanding of the situation (5) and rated her ability to play the game as low (4). She reported little problems for controlling her character (2) and thought the computer had medium control of the situation (5).

Social situation	Talk frequency was similar for partner A (wpm=13.66) and partner B (wpm=15).
	Most of their talk was directed to exchange practical suggestions to resolve the problems of E2 to pull the lever in puzzle 1.
	`E2: [her character not responding] c'mon`
	`E1: maybe we have to do it at the same time. 1, 2, 3 [pulls the lever down]`
	`E1: now go.`
	`E2: [pressing buttons] no... 2?`
	`E1: 2`
	`E2: [moaning] oh...`
	During their initial manipulations in puzzle 2, they interacted silently sometimes, but also expressed some practical propositions and advice
	`E2: pushing the turnstile`
	`E1: [pushing the turnstile to the other way] maybe we are going the wrong way`
	`E2: [walks around] mumbles`
	`E1: [approaches the droid, and it starts glowing] it glows`

	Increased trial F-1,5
Experience	Collaborative Session 1, (C-C-C-C), trial 5
Intensity and change	Dyad challenge had a medium increase (4). Challenge increased for both dyad members F1's challenge increased from moderate (4) to high (6) F1's challenge increased from moderate (4) to high (7)
Similarity	Partners remained similarly challenged. Their challenge similarity remained little from the previous trial (0) to the current trial (1)
Accuracy	F1 inaccurately estimated the challenge intensity of F2. Her inaccuracy was not related to the similarity. In contrast, F2 accurately estimated the challenge intensity of F1. Her accuracy was related to the similarity. F1's inaccuracy increased from little (2) to medium (4) F2's inaccuracy remained little from the previous trial (1) to the current trial (1)
Game situation	Previous trial. They started, and did not complete, one puzzle that required a number of interdependent steps and insight. No skill was necessary but collaboration was mandatory. Current trial. They keep solving, but do not complete, the same puzzle as in the previous trial Puzzle 1. The objective is to pass a droid across a gap. This implies a number of interdependent steps (e.g., one partner controls a crane whilst he other one controls the droid) and insight (i.e., they have to realize how to use the crane to get rid of some enemies and to pick the droid across the gap). No skill is necessary, but collaboration is mandatory.
Performance	Puzzle 1. They realized that they needed the crane, and also realized that one of them had to use the droid whilst the other one controls the crane. However, they could not figure out other steps necessary to solve the puzzle, such as using the crane to eliminate some enemies and operate a lever. Instead, they played in a coordinated manner to make an incorrect usage of the droids and the crane (e.g., they used the wrong droid, and employed distracters like a useless elevator). Because they did not complete any of the necessary steps, leading to performances of zero for both partners
Context appraisal	F1 made a lot of effort (6), felt little uncertainty (3), little understanding (4), but rated her ability to play highly (6). She had little problems for controlling her character (1) and thought the computer had little control of the situation (1) F2 made medium effort (4), felt high uncertainty (6), did not understanding the situation (1) and rated her ability to play the game as little (1). She had little problems for controlling her character (1) and thought the computer had medium control of the situation (3).

Social situation	Talk was abundant, and F1 talked a little more (35 wpm) than F2 (23wpm).
	One main portion of the talk was made of practical commenteries to coordinate whilst trying strategies to solve he puzzle. For example:
	`F1:[switches to droid and flies] oh, oh, oh... he can like, fly!`
	`F2: [laughs]`
	`F1: [flies on the gap and falls] I think you can pick me up like that! if I fly into the middle`
	`F2: that's right, let me get back [jumps into the crane]`
	There were also various expressions of misunderstanding. For example:
	`F1: [stands next to the crane]`
	`F2: [walks around] no idea what to do...`
	`F1: I just can't do anything!`
	`F2: I do not know... not very easy`

GB. Trials with challenge increase

	Decrease trial A-3,2
Experience	Collaborative session 3 (IICC), trial 2
Intensity and change	Challenge decrease as a dyad was medium (-4). Both partners decreased a little. A1 decreased but remained high from the previous trial (8) to the current trial (7). A2 decreased from medium (5) to little (2).
Similarity	Partners remained differently challenged. The difference between their challenge intensity remained medium from the previous trial (3) to the current trial (5).
Accuracy	A2 was more accurate than A1. The accuracy of A1 was closely related to the similarity, whereas the accuracy of A2 was very dissociated of the similarity. The inaccuracy of A1 increased from little (2) to medium (4). The inaccuracy of A2 remained low from the previous trial (1) to the current trial (1).
Game situation	Previous trial: They faced one puzzle and did not complete it. They had to cross a gap, which implied simple steps (e.g., jump onto a box, jump across a gap). Collaboration was redundant. Current trial: They solved one puzzle and started, but did not complete, a second one. Puzzle 1. They continue with the same puzzle as in the previous trial, and finally cross the gap. Puzzle 2. Their objective is to reach the top of a vehicle. This implies simple steps (e.g., jumping from one platform to another) and interdependent steps (e.g., one player has to employ her special ability to open a platform, so the other one can jump onto it). Collaboration was mandatory. Key game events: None
Performance	Puzzle 1. Partners spend a good portion of the trial solving this puzzle. They show coordination problems whilst trying the cross the gap. A2 crosses, leaving A1 without space to run and jump onto a box (a consequence of the shared screen), which is necessary to cross the gap. They realize the problem, and A2 returns to give space to A. Puzzle 2. Partners start the first part of the vehicle puzzle, and effectively solve steps that demand little skill but require interdependence (e.g., opening a platform for the partner to jump). The coordination problems in puzzle 1affects the performance scores of both partners. They do better in the vehicle puzzle, but the performance scores are still low both for A1 (sspm= .66) and A2 (sspm=1).
Context perception	A1 made medium effort (5), and also felt medium uncertainty (5) and understanding (5), and rated her ability to play the game as medium (5). She had a lot of problems to control her character (6) and thought the computer had moderate control of the game (5). A2 made little effort (3), felt little uncertainty (1) and high understanding (6), but rated her ability to play as low (2). She did not have problems to control her character (0) or thought the computer was controlling the game (0)

Social situation	Talk frequency was similar for A1 (wpm=9) and A2 (wpm=12.33).
	During puzzle 1, partners' interaction was often silent, especially when A was trying to jump onto the box. But then, they started exchanging explanations and practical suggestions, which helped them realize and resolve their coordination problems:
	`A1: something is pulling me... (pushed by the screen)`
	`A2: Is because of the screen,`
	`A1: (laughs, tries to jump onto the box but falls)`
	`A2: maybe if I come back a bit (walking back)`
	`A1: we can try (now she can jump onto the box)`

	When solving the vehicle puzzle, their interaction was mostly silent, they only occasionally made open general questions to one another:
	`A2: …how are going to get into there now?`
	`…`
	`A1: ... how do I do that? (stands in the grapple poiont and moves the glowing platform at distace)`

	Decrease trial A-4,2
Experience	Collaborative session 4 (I-I-C-C), trial 2
Intensity and change	Challenge decrease as a dyad was small (-2). Both partners decreased a little. A1 decreased from high (6) to medium (5) A2 decreased from medium (3) to little (2)
Similarity	Partners remained equally challenged. The difference between their challenge intensities remained small from the previous trial (2) to the current trial (2).
Accuracy	A1 was more accurate than A2. The inaccuracy of A1 remained small from the previous trial (2) to the current trial (2). The inaccuracy of A2 increased from small (2) to medium (5).
Game situation	Previous trial. They solved one puzzle that required simple steps (e.g., pushing boxes, operating panels) and started, but did not complete, a puzzle which objective was to open a door. They had to make two steps: stomp two button lines and then pull two levers. They could divide the task (i.e., one button line and one lever each). Collaboration was rewardable Current trial: They solved three puzzles. Puzzle 1. They made the last rewardable step of the door puzzle (i.e., they pulled one lever each). Puzzle 2. Their objective is to liberate a droid who is in a cage. Partners need to push a turnstile, which controls a vacuum. When collocated upon the cage, the vacuum takes the droid off. They need to realize the relationship between the turnstile and the vacuum. This puzzle implies steps (e.g., operating panels, shooting enemies, pushing the turnstile), but insight is necessary. Collaboration is redundant. Puzzle 3. Their objective is to open a door. This implies simple steps (i.e., breaking ties). No insight is necessary and collaboration is redundant.
Performance	Puzzle 1. Partners solve the door puzzle with collaboration (i.e., they coordinate to pull one lever each). Puzzle 2. They need to liberate the droid. A1 pushes the turnstile, without realizing the relationship between this and the vacuum. Then both partners walk around and engage with distracters and irrelevant steps (e.g., shooting enemies). Finally A2 pushes the turnstile and collocates it upon the droid cage. Then she fluently makes the rest of the simple steps of the puzzle (e.g., operating panels) whilst A1 follows her Puzzle 3. Partners started breaking the ties but did not finish them all (they break 3 out 4). Then they walk around and engage with distracters. They coordinate to make irrelevant steps (e.g., one builds a staircase and the other walks one it to operate a useless panel). Then they finally break all the ties and open the door. Although sometimes partners worked collaboratively (e.g., puzzle 1) A2 did most of the simple steps in the puzzles. Therefore A1 had lower performance score (pspm=1.33) A2 (pspm=3.67).
Context perception	A1 made a lot of effort (7), felt little uncertainty (2), had a high understanding of the game (7) and rated her ability highly (7). She had a lot of problems for controlling her character (6), but thought the computer had little control of the game (2). A2 made a lot of effort (8), felt no uncertainty at all (0), had high understanding of the game (7) and rated her ability highly (8). She did not have problems for controlling her character (0) and thought the computer was not controlling the game at all (0).

Social situation	Partners often interacted silently or briefly. Talk frequency was little both for A1 (7.33 wpm) and A2 (5.66 wpm).
	When they talked, it was to coordinate:
	`A2: could you put away your gun and then press 2? (standing in front of the lever)`
	`A1:… hey (pulls the lever down)`
	`A2: ... (pulls the other lever, the door opens)`

	And for requesting and giving practical advice: A2: ... what do I press? (in reference to the button she needs for controlling the droids) A1: press 1 (standing) A2: ... (controlling one droid, goes to operate the panel, which liberates the other droid) A1: (cheers)

	Decrease trial B-3,4
Experience	Collaborative session 3,trial 4 (I-I-C-C)
Intensity and change	Dyad change was small. Only the challenge of B1 decreased, B2 remained similarly challenged. B1's challenge decreased but remained medium from the previous trial (5) to the current trial (3) B2;s challenge remained medium from the current trial (4) to the current trial (4).
Similarity	Partners remained similarly challenged. Their challenge difference remained little from the previous trial (1) to the current trial (1)
Accuracy	Both partners made accurate estimations about the challenge intensity of one another. Their accuracy was closely related to their similarity
Game situation	Previous trial. Partners spent all the previous trial solving a puzzle in which various simple steps are sequentially linked (e.g. need to use a turnstile to control a magnet, when the magnet is collocated in the adequate place, this unblocks a panel.). They figured out the key step of the puzzle before the trial finished the trial, but missed the last simple steps. Collaboration was redundant. Current trial: Solved a puzzle and started, but did not finish, a second one. Puzzle 1. Their objective is to open a door. This implies simple steps (i.e., breaking ties). Collaboration is redundant. Puzzle 2. The objective is to cross a swamp. This implies simple steps and interdependence. Simple steps are to operate two panels, shoot enemies and cross a bridge. Insight is necessary to find the panel, and collaboration is mandatory. Interdependent step is that partners need to walk together to find a panel. Collaboration is mandatory.
Performance	Puzzle 1: They start making the necessary simple steps (i.e., breaking the ties of the door) effectively, but get distracted with irrelevant elements, which they effectively use showing coordination (e.g., B2 builds a staircase using her special ability, B1 uses the staircase and operates a panel, all this is useless). Then, finally finish the last tie and open the door. Puzzle 3: They spent most of the time fluently solving simple steps (e.g., shooting enemies, assembling blocks) using irrelevant elements (e.g., went together into a cave, assembled a grapple point that takes them to the top of a rock where there is nothing). In the very end of the trial they realize they need the droid to operate the panel, but did not resolve how to pass the droid across the swamp (they need a hidden second panel). Partners played effectively and cooperated. They resolved a number of simple steps in puzzle 1 and puzzle 2. But hey but often engaged in irrelevant steps, and could not figure out the main aspect of puzzle 2. Therefore the performance score was relatively low both for B1 (pspm=1.33) and B2 (psmp=1.33).
Context perception	B1 made a lot of effort (8), felt medium uncertainty (3), little understanding (2), and rated her ability to play as little (3). She had medium problems controlling her character (4) and thought he computer had no control of the situation at all (0). B2 made medium effort (5), felt medium uncertainty (3), medium understanding (5), and rated her ability to play as medium (5). She had little problems controlling her character (4) and though the computer had medium control over the situation (2).

Social situation	Talk frequency was similar for B1 (19.66 wpm) and B2 23.66 wpm).
	They communicated frequently. But their talk was often composed by backchannel and brief remarks, about whatever they were doing or general aspects of the game.
	`B2: [walks and shoots] mh... [falls in the swamps] ups`
	`B1: [walks and shoots] ...`
	`B2: [falls in the quicksand] oh is quicksand or something... I am not going there (laughs)`
	`B1: [assembling grapple point] yeah...`

	B2: [hitting enemies] yeah... B1: [shooting enemies]... They also showed this sort of interaction whilst coordinating their actions, as they did in the usage of irrelevant steps: B1: [standing on the grapple point, which is irrelevant] ehm.. oh, this is other thing [an anchor that only B2 can manipulate with her ability] B2: [does the anchor]... B1: [uses the anchor to grapple upon a rock] now I can go up B2: you can go there…[to the top of the rock]

	Decrease trial B-4,4
Experience	Collaborative session 4 (I-I-C-C), trial 4
Intensity and change	Dyad challenge decreased was medium (-5). Both partners decreased. B1's challenge decreased from medium (4) to little B2's challenge decreased from medium (4) to little (1)
Similarity	Partners remained similarly challenged. Their challenge difference remained similarly little from the previous trial (0) to the current trial (1)
Accuracy	Both partners made accurate estimations about the challenge of one another. Their accuracy was related to their similarity B1's inaccuracy remained little from the previous trial (0) to the current trial (1) B2's inaccuracy remained little from the previous trial (1) to the current trial (1)
Game situation	Previous trial. They solved one puzzle with one interdependent step (i.e. partner shave to find a panel walking together, which is hidden and they cannot find it if walk separately), and some other simple steps (i.e., operating panels, building a ramp). Took them most of the trial to find the panel, after which they solved the simple steps fluently. Collaboration was mandatory. Current trial: They completed two puzzles. Puzzle 1: They have to cross a gap. This implies simple steps (jumping and shooting enemies) and one step interdependent step (one player has to assemble blocks to build a bridge, employing her special ability to manipulate objects at distance). Collaboration is mandatory. Puzzle 2: they have to make a bridge and cross a swamp. This implies simple steps (e.g., push a box, operating panels) and interdependent steps (i.e., only one member can build the bridge using her special ability) Collaboration is mandatory
Performance	Puzzle 1: They played mostly cooperatively. In the beginning they cooperate to use irrelevant elements (e.g., B built a staircase using her special ability, and then A used it However, the staircase takes to the top of a rock where there is only coins). Then B1 finds a column which top can only be reach by B2. This is the interdependent step. Then B2 uses the column, which takes her near the blocks to build the bridge. She quickly realizes the usage of the blocks and builds the bridge. Then they both cross the gap, completing the puzzle. Puzzle 2. Rapidly did simple steps (shooting enemies). Then they cooperated to do other simple and interdendent steps. B2 pushed a box, which turns into blocks for B1 to assemble a bridge using her special ability. B1 does so and then B2 uses the bridge to cross the swamp. Then they do the rest of the simple steps (e.g., operating a panel, walking forward) quickly.
Context perception	B1 made a lot of effort (8), felt little uncertainty (1), medium understanding (4) and rated her ability to play the game as high (7). She had little problems controlling her character and thought the computer had no control over the situation (0). B2 made a lot of effort (7), felt little uncertainty (1), high understanding (7) and rated her ability to play the game as high (7). She had little problems controlling her character (2) and thought the computer was not controlling the situation at all (0).

Social situation	Talk frequency was similar for B1 (13.33 wps) and B2 (17 wps)
	Their interaction was often silent. However, they occasionally made short commentaries a bout their actions in the game, this seemed to call the partner's attention to the own actions but also to sustain some sort of chatting:
	`B: ups, I built us a bridge (as she uses her character's skill to build a bridge)`
	`A: great (walking towards the bridge)`
	`B: that's handy`
	Backchannel was also frequent. For example, during the execution of interdependent steps (e.g., when a partner had to use her special ability to build a bridge), in which A makes a practical suggestion to B, which is followed by backchannel:

	A: mhh.. I think is is for you [trying to jump onto the column and failed because this for B to do] B: ok [walks towards the column] B: ups… oh… [as she tries to jump onto the column and fails] A: [standing still] B: ... (jumps onto the column)

	Decrease trial C-2,4
Experience	Collaborative session 2 (C-C-I-I), trial 4
Intensity and change	Dyad challenge had a medium decrease (-3). Only C1 decreased. C1's challenge decreased from high (7) to medium (5) C2's challenge decreased remained similarly medium from the previous trial (5) to the current trial (5)
Similarity	Partners remained similarly challenged. Their challenge difference decreased, but remained little from the previous trial (2) to the current trial (0)
Accuracy	Both partners made accurate estimations about the challenge of one another. Their accuracy was closely related to their similarity. C1's inaccuracy remained little from the previous trial (0) to the current trial (1) C2's inaccuracy remained little from the previous trial (2) to the current trial (0)
Game situation	Previous trial: Solved the last steps of a puzzle in which they had to use a crane to pass a droid across a gap. This implies interdependent steps (e.g., one partner used the crane whilst the other one controls the droid). They spent most of the trial without realizing they had to use the crane to pass the droid, but finally managed to do so. Collaboration was mandatory. Then they start, but did not complete, a puzzle that required simple steps (e.g, shooting enemies, walking across corridors). Current trial: solved one puzzle and started, but did not complete, a second one Puzzle 1. Objective was to walk through a corridor. This implies simple steps (e.g., shooting enemies, assembling and crossing bridges). There are potential distracters. Collaboration is redundant. Puzzle 2. The objective is to open a series of doors, which requires simple steps (e.g., when a door is open, they have to go inside a corridor and pull a lever, which liberates one panel, so they can use it to open the next door). Collaboration is redundant. This puzzle implies a key event, which is that it is the last puzzle of the mission.
Performance	Puzzle 1. Fluently make the simple steps they find whilst walking through the corridor (e.g., shooting enemies, assembling bridges). They had little coordination problems (i.e., one partner got trapped because of the shared screen), which they resolve quickly. They pay attention to the distracters, but forget about them rapidly. Puzzle 2. Rapidly realize they need to use the panels to open the doors. They had little problems switching to droids, and sometimes confused which droid to use. They opened two out of three doors before the trial finishes. Both partners made a similar number of steps. They did various steps but they were simple, therefore the performance score was not especially high or low for C1 (pspm=1.67) and C2 (pspm=1.67).
Context perception	C1 made high effort (6), felt medium uncertainty (5), had high understanding (6) and rated her ability to play the game as medium (8). She had medium problems controlling her character (3) and thought the computer had little control over the situation (6). C2 made high effort (6), felt little uncertainty (2), had medium understanding (4) and rated her ability to play the game as medium (4). She had little problems controlling her character (2) and thought the computer had no control over the situation at all (0).

Social situation	Talk frequency was similar for C1 (23.6 wpm) and C2 (27 wpm)
	Talk was scarce whilst partners do things like shooting enemies and assembling bridges, occasionally communicating to give practical suggestions:
	`C2: [walking forward, shooting]...`
	`C1: [walking forward, shooting]...`
	`C2: [in front of the gap] do we have to run and jump there?`
	`C1: ok`

	Talk was more abundant whilst figuring out how to operate the panels to open the doors. They mostly made commentaries about their own actions, which helped them to coordinate their actions and eventually to resolve the puzzle. C2: [tries to operate the panel, she can't' cause she needs the other droid] I am not making anything C1: oh wait here with that one [switches to the other droid, the one that opens the panel] C2: him? C1: yeah [operates panel] … C2: [has unblocked the panel] so what do we do? you are him... (the robot that operates the panel) C1: [operates the panel] mhm... o wait I'll do it

	Decrease trial C-2,5
Experience	Collaborative session 2 (C-C-I-I), trial 5
Intensity and change	Dyad challenge had a medium decrease (-3). Only C1 decreased
Similarity	Partners' challenge became different. Their challenge dissimilarity increased from little (0) to medium (3).
Accuracy	Both partners made inaccurate estimations about the challenge of one another. Their inaccuracy was related to the increase on their dissimilarity. C1's inaccuracy increased from little (0) to medium (3) C2's inaccuracy increased from little (0) to medium (3)
Game situation	Previous trial: in the last part of the trial, partners were effectively solving a puzzle with simple steps (i.e., opening doors). Collaboration was redundant. Current trial: They completed the puzzle they were solving as in the previous trial. Puzzle 1. The objective is to open a series of doors, which requires simple steps(e.g., when a door is open, they have to go inside a corridor and pull a lever, which liberates one panel, so they can use it to open the next door). Collaboration is redundant. This puzzle implies a key event, which is that it is the last puzzle of the mission. Key game events: they reach the end of the mission
Performance	Puzzle 1. In the previous trial, they have already opened two out of three doors. Now they have to open the third one, but first they need to unblock it. Spend about half the puzzle walking around together, operating the levers inside the rooms. Then they unblock the panel and quickly resolved the rest of the steps (i.e., switched to droid to operate the panels. After the last step, there was a short sequence of images before the game tells them the mission is over. They did a number of simple steps whilst opening the doors (e.g., operating panels). Because there were not many steps left to do, their performance scores were not especially high or low for C1 (pspm=1.67) and C2 (pspm=1)
Context perception	C1 made high effort (6), felt medium uncertainty (4), had little understanding (2) and rated her ability to play the game as high (8). She had little problems controlling her character and felt the computer had a lot of control over the situation (6). C2 made little effort (1), felt little uncertainty (1), had high understanding (2) and rated her ability to play the game as high (7). She had little problems controlling her character

Social situation	Talk was equal for C1 (9.33 wps) and C2 (12.66 wps)
	Partners' interaction was made of short exchanges. Often, partners made commentaries about the game events that had no apparent function:
	`C2: [shooting] oh, they are bad guys (the enemies in the room)`
	`C1: yeah...`
	This sort of commentaries were sometimes combined with request and provision of practical suggestions
	`C2: [in the room with pool] oh, this water?`
	`C1: [laughs, jumps off the water and operates the lever]oh, cool`
	`C2: how did you get up there?`
	`C1: ah, press 3`

	Decrease trial D-2,3
Experience	Collaborative session 2 (C-C-I-I), trial 3
Intensity and change	Dyad challenge decrease was small (2). Both partners had a small decrease. D1's challenge decreased from high (6) to medium (5) D2's challenge decreased from high (6) to medium (5)
Similarity	Partners remained equally challenged. The difference between their challenge was little in the previous 0) and the current trial (0).
Accuracy	Both partners were equally accurate at estimating the challenge intensity of one another. D1's inaccuracy remained little from the previous trial (2) to the current trial (3) D2's inaccuracy remained little from the previous trial (2) to the current trial (0)
Game situation	Previous trial: They solved one puzzle. They had to use a crane to pass one droid across a gap. To do so, they needed to make simple steps (e.g., open doors) and various interdependent steps (e.g., D1 has to control the droid. D2 uses the crane to pass A side of the gap. Then A can use the droid to open the door). Collaboration was mandatory. Current trial: They solved one puzzle. Puzzle 1. They have to go through a corridor, shooting enemies and building a bridge to cross a gap. These are simple steps and collaboration is redundant.
Performance	Puzzle 1. They started fluently solving simple steps such as shooting enemies and building bridges. But they engaged with distracters (e.g., a pointless door), which slowed them down, but they finished the puzzle before the end of the trial. They only solved one puzzle with simple steps and invested time with distracters. Therefore the performance score was low both for D1 (pspm=1) and D2 (pspm=1.5)
Context perception	D1 made medium effort (5), felt medium uncertainty (4) and had medium understanding of the game. She had a lot of problems for controlling her character (6) and did not think the computer was controlling the situation (1) D2 made medium effort (5), felt medium uncertainty (4) and had medium understanding of the game (4). She had no problems for controlling her character at all (0), and thought the computer had little control of the game (1)
Social situation	D1 talked a little less (wpm=7) than D2 (wpm=17). They often played silently, especially whilst doing simple steps such as shooting enemies and assembling blocks. The most extended sequence of interaction was still relatively short of length, and it was observed when they tried to use a useless door (i.e., a distracter). D2 proposed some explanations about the door, to which D1 responded with backchannel or with actions only: D1: ... (trying to operate the panel in the distracter door) D2: maybe we need to be ... D1: I don't' think it is... is that a picture? ... and it says only stormtroopers (in the distracter door) D2: ok what do we do (as she walks away from the distracter door) D1:… D2: is that what we ... (as she crosses to the other corridor) D1: ... (follows B)

	Decrease trial D-2,,4
Experience	Collaborative session 2 (C-C-I-I), trial 4.
Intensity and change	Dyad challenge decrease was medium (5). Both partners decreased D1's challenge decreased from medium (5), to little (2) D2's challenge decreased but remained medium from the prior trial (5) to the current trial (3)
Similarity	Partners remained similarly challenged. The difference between their challenge intensities remained little from the previous (0) to the current trial (1).
Accuracy	D1 was more accurate at estimating the challenge intensity of D2 than the opposite way. D1's accuracy was related to the challenge similarity, whereas the accuracy of D2 was unrelated to the similarity. D1's inaccuracy remained low from the previous (2) to the current trial (0) D2's inaccuracy increased from little (0) to medium (3)
Game situation	Previous trial: They resolved one puzzle that required simple steps such as going through a corridor, shooting enemies and building bridges to cross a gap. They briefly engaged with some distracters (e.g., a pointless door), but resolved it. Collaboration was redundant. Current trial: They solved one puzzle and started, but did not complete, a second one. Puzzle 1. They have to go through a corridor, shooting enemies and building a bridge to cross a gap. These are simple steps that require no skill or insight, and collaboration is redundant. Puzzle 2. They need to open a series of doors, which requires simple steps (e.g., when a door is open, they have to go inside a corridor and pull a lever, which liberates one panel, so they can use it to open the next door).. Collaboration is redundant.
Performance	Puzzle 1. Players fluently solved simple steps such as shooting enemies and assembling bridges to cross the gaps across the corridors. Puzzle 2. They had some problems to figure out how to start opening the doors (e.g., they do not know which one to open first). Once they start, they fluently made the simple steps (e.g., operating panels, shooting enemies) to open some doors. Then the current trial finishes. They played fluently, but the puzzles were made of simple steps. Therefore the performance score was low both for D1 (pspm=1.5) and D2 (pspm=0.5).
Context perception	D1 made a lot of effort (6), felt a little uncertain (1), had medium understanding (5) and rated her ability as medium (5). She had little problems for controlling her character (2) and thought the computer had little control of the situation (1). D2 made a lot of effort (6), felt highly uncertain (6), had medium understanding (5) and rated her ability as medium (5). She had little problems for controlling her character (1) and thought the computer had little control of the situation.

Social situation	D1 talked less (11.6 wpm) than D2 (20.8 wpm).
	The main feature of their talk was the usage of backchannel and incomplete sentences. There was another difference between partners. D2 asked for practical suggestions to A, but not the opposite way. Still, D1 usually responded to D2's question.
	They showed very little verbal interaction whilst fluently manipulating the elements in the puzzles, usually to request practical advice. As in the puzzle 2:
	`D2: how do you get through the door? (the blocked panel in door 3)`
	`D1: press 2?`
	`D2: ... no (tries to operate the panel and she can't)`
	
	`D1: ...`
	`D2: ... (switches to droid and operates panel)`
	`D1: ... (goes into room 1)`
	`D2: ... go (gets into room 1)`

	D2: ... (trying to pull the lever as r2d2) D1: do we have to ... (in reference to the lever) D2: yeah ... (gives way to K) D1: ... (operates the lever)

	Decrease trial E-2,5
Experience	Collaborative session 2 (C-C-C-C), trial 5
Intensity and change	Dyad challenge decreased medially (-5). The challenge of both partners decreased a little. E1's challenge decreased from medium (4) to little (2) E2's challenge decreased from medium (4) to little (1)
Similarity	Partners remained similarly challenged. Their challenge difference remained little from the previous trial (0) to the current trial (1)
Accuracy	Both partners made accurate estimations about the challenge intensity of one another. Their accuracy was closely related to their similarity E1's inaccuracy remained little from the previous trial (0) to the current trial (1) E2's inaccuracy remained little from the previous trial (1) to the current trial (1)
Game situation	Previous trial: They completed one puzzle that required simple steps (e.g., assembling blocks to make bridges, shooting enemies), and started but did not complete, one puzzle that required simple steps (i.e., shooting enemies, operating panels to open doors). Collaboration was redundant. Current trial: They continued and completed the puzzle they started on the previous trial. Puzzle 1. The objective is to open a series of doors, which requires simple steps (e.g., when a door is open, they have to go inside a corridor and pull a lever, which liberates one panel, so they can use it to open the next door). Collaboration is redundant. This puzzle implies a key event, which is that it is the last puzzle of the mission.
Performance	Puzzle 1. At the beginning of the trial, partners are already solving the puzzle. They have figured out the sort of sequence that the simple steps have to follow in order to open the doors. They have small coordination problems (e.g., moving to different directions of the shared screen), but they fluently open the remaining doors (2 out of 3), which solves the puzzle. A short sequence of story line appears followed by an indication that the mission is completed.
Context appraisal	Partner A made a lot of effort (8), felt little uncertainty (0), had a high understanding of the game (8) and rated her ability to play highly (8). She did not have problems for controlling her computer at all (0) and thought the computer was not controlling the situation at all (0). Partner B made little effort (1), felt little uncertainty (0), had a high understanding of the game (7) and rated her ability to play highly (7). She had little problems controlling her character (1) and thought the computer had little control of the situation (1).

Social situation	E1 talked more (20 wpm) than E2 (14 wpm).
	Their talk was composed by commentaries about what they were doing, as updates about the own status.
	`E1: now, he [the droid] can open this door.`
	`E2: [accidentally beating A} oh..`
	`E1: ah ahah`
	`E2: [switches to C3PO]... where his arm gone? he's lost his arms`
	`E1: and leg..`
	`E2: oh..`
	They also gave some practical suggestions, mostly E1. This helped them to resolve small coordination problems, and to make the necessary sequence of steps to solve the puzzle. For example:
	`E1: [noticing they need a droid to open this door] oh where is the other guy? [trying get out from from the room. But she can't do it cause C is not moving and the screen is shared] why can't I get out again?`
	`E2: maybe is cause I am in...`
	`E1: we need to get the other guy to open it [both go out of the room]`
	`E2: we need come back… [inaudible]`

	E1: [pulls the lever in room 2. Then the panel that opens door 3 is accesible] E2: wow.. . E1: now, he [one of the droids] can open this door E2: [accidentally beating A} oh.. E1: [laughs]

	Decrease trial E-4,3
Experience	Collaborative session 4 (C-C-C-C), trial 3.
Intensity and change	The dyad challenge decreased highly (-8). The challenge of both partners decreased. E1's challenge decreased from high (7) to medium (4) E2's challenge decreased from high (7) to little (2)
Similarity	Partners remained similarly challenge. Their challenge difference remained little from the previous trial (0) to the current trial (2).
Accuracy	E1 accurately estimated the challenge intensity of E2, whereas the estimation of E2 about E1 was inaccurate. E1's inaccuracy increased from little (0) to medium (4) E2's inaccuracy remained little from the previous trial (0) to the current trial (1)
Game situation	In the previous trial, they completed one puzzle that required rewardable steps (e.g., stomping two button lines, pulling two levers). Then, they started, but did not complete, a puzzle that implied simple steps (e.g., operating panels, pushing a turnstile). Collaboration was redundant. Current trial: They continued and completed the puzzle with simple steps that requires insight. Then they completed a second puzzle and started, but did not complete, a third one. Puzzle 1. The objective is to liberate a droid who is in a cage. Partners need to push a turnstile, which controls a vacuum. When collocated upon the cage, the vacuum takes the droid off. They need to realize the relationship between the turnstile and the vacuum. This puzzle implies simple steps (e.g., operating panels, shooting enemies, pushing the turnstile) Collaboration is redundant. Puzzle 2. Their objective is to open a door. This implies simple steps (i.e., breaking ties). Collaboration is redundant. Puzzle 3. The objective is to cross a swamp. This implies simple steps and interdependence. Interdependent step is that partners need to walk together to find a panel. They cannot find it unless they walk close together. Simple steps are to operate other panels, shoot enemies and cross a bridge. Collaboration is mandatory
Performance	Puzzle 1. Partners spend most of the trial trying to figure out how to liberate the droid. They realized the turnstile is the main component of the puzzle, but it takes time for them to realize its relationship between this and other elements (e.g., a magnet, the droid and a panel). Whilst figuring out, they also engage with distracters. Puzzle 2. They effectively make the simple steps such as breaking the ties to open the door. They divided the task, although this is redundant. Puzzle 3. They read the hints to know what they need to do: crossing the swamps. Then they start making simple steps (e.g., shooting enemies) and manipulating a number of distracters (e.g., there is a grappling platform that takes them to nowhere). By the end of the trial they are not finding the panel they need to operate to dry the swamps. They did a number of simple steps in puzzle 1 and puzzle 2. Therefore, even though they did not resolve puzzle 3, the performance score was relatively high both for E1 (pspm=3) and E2 (pspm=1.67).
Context appraisal	E1 made a lot of effort (8), felt very little uncertainty (2), had high understanding of the situation (6) and appraised her ability to play as high (6). She reported little problems for controlling her character (2) and thought the computer was not controlling the game at all (0). E2 made little effort (4), felt little uncertainty (3), had a moderate understanding of the situation (5) and rated her ability to play as medium (5). She had little problems controlling her character (1) and thought the computer had little control of the situation (2).

Social situation	Talk frequency was similar for E1 (17.33 wpm) and E2 (13.66 wpm)
	In puzzle 1, whilst trying different manipulations of the game elements, trying to figure out how to use the turnstile to liberate the droid, and whilst trying to figure out puzzle 3, they communicated with backchanneling and short commentaries. For example:
	`E1: … over his this [pushes the turnstile to put move a magnet, making a panel accesible]`
	`E2: [standing in front the panel]`
	`E1: [collocates the magnet upon the cage, making the panel accesible] above it, is moving over his like, cage`
	`E2: yeah, yeah... oh I see [operates the pannel and the droid is liberated] yeeh...`
	In puzzle 2, which they resolved quickly, their interaction was completely silent.

	Decrease trial F-1,4
Experience	Collaborative session 1 (C-C-C-C), trial 4
Intensity and change	Dyad challenge decrease was medium (-5). The challenge of both dyad members decreased. F1's challenge decreased from high (6) to medium (4). F2's challenge decreased from high (7) to medium (4)
Similarity	Partners remained equally challenged. Their challenge difference remained little from the previous trial (1) to the current trial (0)
Accuracy	Both partners made accurate estimations about the challenge of one another. Their accuracy was related to their similarity. F1's inaccuracy decreased from medium (3) to little (2) F2's inaccuracy remained little from the previous trial (2) to the current trial (1)
Game situation	Previous trial. They started, and did not complete, one puzzle that required a number of interdependent steps and insight. No skill was necessary but collaboration was mandatory. Current trial. They keep solving, but do not complete, the same puzzle as in the previous trial Puzzle 1. The objective is to pass a droid across a gap. This implies a number of interdependent steps (e.g., one partner controls a crane whilst he other one controls the droid) and insight (i.e., they have to realize how to use the crane to get rid of some enemies and to pick the droid across the gap). No skill is necessary, but collaboration is mandatory.
Performance	Puzzle 1. Partners made several parallel actions and did not coordinate. These actions were unrelated to the solution of the puzzle (e.g., walking around, shooting objects). They did not complete any of the necessary steps, leading to performances of zero for both dyad members.
Context appraisal	F1 made a lot of effort (6), felt high uncertainty (6), medium understanding of the situation (3) and rated her ability to play the game as medium (5). She had little problems controlling her character (1) and thought the computer had little control of the situation (1). F2 made medium effort (3), felt high uncertainty (6), little understanding of the game (1) and rated her ability to play the game as little (0). She had little problems controlling her character (3) and thought the computer had medium control of the situation (3).

Social situation	Talk was abundant, and talk frequency was similar for F1 (30.33 wpm) and F2 (32.66).
	Whilst doing parallel actions (e.g., walking around, shooting objects), partners often communicated with one another to tell what they were doing, altogether with expressions of confusion. For example:
	`F1: what happens if I try [inaudible]`
	`F2: I tried to push it towards the edge and didn't do anything`
	`F1: oh yea...[walks around] I'm really confused`
	`F2: me too, I don't actually understand`
	…
	`F2: [jumps off the crane] ups... I do not know what to do, seems like should be easy but I still can't`
	`F1: [gains control of the droid, one legged] I'm just walking around [laughs]`
	`F2: [laughs]`

	Decrease trial F-2,3
Experience	Collaborative session 2 (C-C-C-C), trial 3.
Intensity and change	Dyad challenged had a little decrease (-2). Only F1 decreased F1's challenge decreased from high (6) to medium (4) F2's challenge remained little from the previous trial (2) to the current trial
Similarity	Partners became more similarly challenged. Their challenge difference decreased from medium (4) to little (2)
Accuracy	Both partners made accurate estimations about the challenge intensity of one another. Their accuracy was related to their similarity F1's inaccuracy remained little from the previous trial (0) to the current trial (1) F2's inaccuracy decreased from medium (4) to little (2)
Game situation	Previous trial: They did not complete one puzzle. They had to use a crane to pass one droid across a gap. To do so, they needed to make simple steps (e.g., open doors) and various interdependent steps (e.g., F1 has to control the droid. F2 uses the crane to pass A side of the gap. Then A can use the droid to open the door). Various steps needed to be combined. The puzzle required insight and collaboration was mandatory. They solved the key steps of this puzzle, but did not complete before the end of the trial. Current trial: They solved two puzzles and started, but did not complete, a third one. Puzzle 1. They have to use a crane to pass one droid across a gap. To do so, they need to make some simple steps (e.g., open doors) and various interdependent steps (e.g., F1 has to control the droid. F2 uses the crane to pass A side of the gap. Then A can use the droid to open the door). There are various steps that need to be combined. The puzzle requires insight and collaboration is mandatory. Puzzles 2 and 3. They have to go through corridors shooting enemies and building bridges to cross a gap. These are simple steps that require no skill or insight, although there are potential distracters (e.g., a useless door). Collaboration is redundant.
Performance	Puzzle 1. The made the key steps of the puzzle during the previous trial (i.e., they have figured out how to pass the droid to the other side of the gap). The remaining steps are interdependent, but require no insight and its mechanics are straightforward (e.g., one partner has to jump across a gap, whilst the other one has to make the droid to open a door, then the two partners can go out of the room). Puzzles 2 and 3. They fluently solved the simple steps in these puzzles (e.g., shooting enemies and building and using bridges). During this trial, partners resolved a number of interdependent steps in puzzle 1, and did fluently the steps in puzzles 2 and 3. Therefore their performance score was relatively high for F1 (pspm=5) and F2 (pspm=4.5).
Context appraisal	F1 was making a lot of effort (6), felt medium uncertainty (4), had medium understanding of the game (4) and rated her ability as medium (4). She had medium problems controlling her character (4) and thought the computer had little control of the situation (2). F2 was making medium effort (3), felt little uncertainty (1), had medium understanding of the game (3) and rated her ability to play as medium (3). She had little problems controlling her character (1) and thought the computer had little control of the situation.

Social situation	F1 talked more (37.5 wps) than F2 (16 wps).
	Whilst finishing puzzle 1, they talked more, mostly making comments reassuring they were doing the right thing:
	`F1: [jumps into the crane and takes the droid across the gap] does someone needs to be him (the droid)?, are you him?`
	`F2: yeah I'm him, so it's ok [operates the pannel and door opens]`
	Then, in puzzles 2 and 3, A made more commentaries about the overall status of the game and her own status, not always responded by B, or responded with short backchannel, which accompanied their fluent execution of simple steps

	F1: [close to the blocks to build the bridge] oh we have to... fix it (laughs)? [builds the bridge] F2: [keeps walking] laughs F1: [crossing the bridge] like, we just need t cross up? F2: [crossing the bridge] yeah..