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How to cite

AVRY, Sunny et al. Achievement appraisals, emotions and socio-cognitive processes: how they interplay in collaborative problem-solving? In: Computers in Human Behavior, 2020, vol. 107, n° 106267. doi: 10.1016/j.chb.2020.106267

This publication URL: https://archive-ouverte.unige.ch/unige:129097
Publication DOI: 10.1016/j.chb.2020.106267

Achievement appraisals, emotions and socio-cognitive processes: how they interplay in collaborative problem-solving?

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Abstract

The role of emotions in (computer-supported) collaborative learning has become an important research topic. However, research has mainly focused on the relationships between emotions and socio-emotional processes. Despite an extensive literature on the role of emotions in cognitive processes, socio-cognitive processes have been scarcely explored at this point. This article aims to investigate, using control-value theory (Pekrun, 2006) as a frame of reference, how task-achievement appraisals impact both self-experienced emotions and the perception of socio-cognitive processes. An experimental study involving 28 pairs of participants playing a collaborative problem-solving computer puzzle game was carried out. Depending on the experimental conditions, participants received different false feedback about group task mastery and ranking aiming at skewing in different ways how they appraised task achievement. At the end of the task, they reported self and partner's emotions as well as their perception of their socio-cognitive exchanges. The results indicate that 1) participants experienced a large variety of achievement emotions and some of them appear more closely related to specific task-achievement appraisals, 2) achievement emotions do not mediate the relationship between task-achievement appraisals and the perception of socio-cognitive processes, 3) the level of self-experienced activation as well as the perception of activation in the partner mediate the relationship between task-achievement appraisals and the perception of socio-cognitive processes and could be used as a heuristic of socio-cognitive collaborative involvement by problem solvers, 4) partner's emotions such as gratitude appear to increase the perception of socio-cognitive processes through the reinforcement of group mastery goal.

1. Introduction

Team collaboration is often an efficient way to deal with complex problems. In recent years, collaboration is increasing all around the world, as more and more students and employees work together to solve non-routine problems (Fiore et *al.*, 2017). Collaboration refers to the "synchronous activity that occurs as individuals engage in collective thought processes to synthesize and negotiate collective information in order to create shared meaning, make joint decisions, and create new knowledge" (Borge & White, 2016, p. 324). It is a multicomponent phenomenon resulting from the interplay of cognitive (e.g., self-explanation of content), emotional (e.g., self-regulation of affect), socio-cognitive (e.g., information sharing, constructive conflict; Decuyper, Dochy, & Van den Bossche, 2010; Dillenbourg, 1999) and socio-emotional processes (e.g., solidarity, tension release, antagonism; Bales, 1950). Therefore, collaboration involves the management of not only the problem to be solved (epistemic space) but also the relationship with others (relational space) (Andriessen, Baker, & van der Puil, 2011; Barron, 2003; Kreijns, Kirschner, & Jochems, 2003). In general, emotional aspects have been largely linked to socio-emotional processes in (computer-supported) collaborative learning ((CS)CL) literature (Barron, 2003; Järvenoja & Järvelä, 2013; Linnenbrink-Garcia, Rogat, & Koskey, 2011). Indeed, research in this domain is primarily focusing on the sharing/regulation of emotions in the promotion of favorable or unfavorable group attitudes (Isohätälä, Näykki, & Järvelä, 2019). However, a long tradition of research also studies the role of emotions in cognition such as reasoning, decision-making, or problem-solving strategies (Fredrickson, 2013; George & Dane, 2016; Labroo & Isen, 2003; Spering, Wagener, & Funke, 2005). Surprisingly, this research is scarcely referred to in (CS)CL literature and not extended to group cognition (Mullins, Deiglmayr, & Spada, 2013). In other words, if one assumes that emotions interplay with socio-cognitive processes, one still does not know clearly in which ways. Therefore, we need at this

point more evidence-based knowledge about how emotions and group cognition are bound together, especially in group problem-solving. As Calvo (2009) highlighted, this current state of affairs hampers the development of tools using emotions as a way to promote efficient collaboration because the role of emotions in collaborative mechanisms stays unexplored. At this point, deepening knowledge in this domain is, therefore, an essential step for building efficient tools and frameworks dedicated to fostering collaboration (Borge & White, 2016; Järvelä et *al.*, 2015). In this article, we aimed at increasing the understanding of the interplay between how problem-solvers evaluate task achievement, what kind of emotions it triggers, and what impact such an evaluation has on socio-collaborative processes. To this end, we examined the relationship between task-achievement appraisals, achievement emotions and emotional dimensions (valence, activation, dominance) and the perception of socio-cognitive processes in a dyadic computer-supported collaborative problem-solving task. What follows is a review of relevant considerations regarding our study, namely socio-cognitive processes (section 1.1), emotions in task-achievement settings (section 1.2), and the impact of emotions and especially achievement emotions in (CS)CL settings (section 1.3).

1.1 Socio-cognitive processes

Collaboration is undeniably grounded on communication. Throughout the collaboration, the different meanings conveyed by communicative exchanges constrain and forge the construction of a joint problem space (Roschelle & Teasley, 1995). In this perspective, collaboration relies critically on real-time communicative exchanges (Dechant, Marsick, & Kasl, 1993). In (CS)CL, studying the nature of those communicative exchanges and their consequences on group collaborative processes is therefore of great interest, as it helps to better apprehend the course of collaboration (Decuyper et *al.*, 2010; Meier et *al.*, 2007; Wilson, Goodman, & Cronin, 2007).

Referring to the speech act theory (Austin, 1975), communicative exchanges taking place during collaboration are dedicated to doing something (e.g., providing information, clarifying ideas, asking for help, encouraging others), and produce perlocutionary effects, i.e., consequences on feelings, thoughts, and actions of others (Sbisà, 2009). Several frameworks have been developed in (CS)CL to classify these communicative exchanges and grouped them into meaningful collaborative processes (e.g., Bales, 1950; Baker, Andriessen, Lund, van Amelsvoort & Quignard, 2007; Hughes, Ventura, & Dando, 2007; Meier, Spada, & Rummel, 2007; Noroozi, Teasley, Biemans, Weinberger, & Mulder, 2012). In such classifications, categories generally refer to both socio-cognitive (e.g., information pooling, argumentation, transactivity) and socio-emotional processes (e.g., group integration). In order to capture not only which processes problem-solvers engage but also how well they do it, Meier et *al.* (2007) have developed a rating scheme that allow computer-supported collaborative processes to be quantified according to nine qualitative (i.e., adding a plus value on collaboration outcomes) dimensions of collaboration, namely sustaining mutual understanding, dialogue management, information pooling, reaching consensus, task division, time management, technical coordination, reciprocal interaction, and individual task orientation. Some of them are of particular interest in the present contribution as problem-solvers have reported how they perceived communicative exchanges related to these following socio-cognitive processes (cf. section 2.5 and Table 4). These socio-cognitive processes are described below.

1.1.1 Sustaining mutual understanding

Sustaining mutual understanding includes communicative exchanges related to the creation of shared mental models, i.e., shared representations of group knowledge and understanding that both result from and shape learning processes in the group (Decuyper et *al.*, 2010). Different designations refer to the same or a closely related concept, especially grounding (Baker, Hansen, Joiner & Traum, 1999), cognitive convergence (Teasley et *al*., 2008), or mutual knowledge

or understanding. It includes, for example, exchanges dedicated to making one's contributions understandable or asking for clarification.

1.1.2 Information pooling

Information pooling refers to exchanges related to the sharing process that involves communication about non-previously shared knowledge, competencies, opinions, and creative thoughts from one person to others (Decuyper et *al*., 2010). It is a component of the construction of shared mental models. It includes, for example, exchanges dedicated to gathering relevant pieces of information or making links between different pieces of information.

1.1.3 Reaching consensus

Reaching consensus involves communicative exchanges dedicated to critically assessing information. The process of co-construction implies elaborating knowledge, competencies, opinions, and creative thoughts through others. It refers to repeated cycles where learners acknowledge, repeat, paraphrase, enunciate, question, concretize, and complete shared knowledge, competencies, opinions, or creative thoughts (Decuyper et *al*., 2010). On the other hand, constructive conflict involves that learners have diverse opinions that require negotiation, and the overcoming of disagreement. This divergence leads to integrate viewpoint differences in promoting exploration of the same problem from different perspectives. It includes, for example, exchanges dedicated to justifying the validity of a proposed solution.

1.1.4 Transactivity

The reaching consensus process does not address co-construction nor constructive conflict processes very explicitly (Baker, Andriessen, Lund, van Amelsvoort, & Quignard, 2007). Co-construction and constructive conflict can be refined in different social modes of co-construction, representing varying degrees of transactivity (Teasley, 1997; Weinberger & Fischer, 2006). Transactivity or transactive discussions (Berkowitz & Gibbs, 1983) refers to the degree to

which a person uses his or her conversational turn to operate on the reasoning of the partner or to clarify his or her ideas (Teasley, 1997, p. 362). It has emerged from research highlighting that students who engage in transactive discussions learn more from the collaboration than those who do not (Teasley, 1997, p. 364). Therefore, it reflects the quality of the conversational exchanges taking place in a group (Zoethout, Wesselink, Runhaar, & Mulder, 2017). Weinberger and Fischer (2006) have reviewed the process of transactivity and describe five sub-processes ranging from no transactive to highly transactive, namely externalization, elicitation, quick consensus building, integration-oriented consensus, and conflict-oriented consensus building. In the two latter forms of consensus, problem-solvers actively operate on the other's reasoning, are mutually responsive to persuasive arguments, change or give up their first view when it is appropriate. In conflict-oriented consensus building, a constructive conflict arises where problem-solvers receive critiques that challenge their perspective, leading them to operate deeper on their reasoning as well as that of their partner. Greater transactivity has been shown to stimulate productive collaborative learning (Noroozi, Teasley, Biemans, Weinberger, & Mulder, 2013; Teasley, 1997). It includes, for example, exchanges dedicated to enriching a proposition by challenging the validity of a partner's previous proposition.

1.1.4 Task and Time Management

Task management refers to team reflexivity, i.e., the consideration of what participants have already achieved (current situation), what they still plan to make (objectives), and how they are going to do it (strategies). It can be defined as "the extent to which group members overtly reflect upon the group's objectives, strategies, and processes and adapt them to current or anticipated endogenous or environmental circumstances" (West, as cited in Gurtner, Tschan, Semmer, & Nägele, 2007, p. 128). Finally, time management refers to exchanges that allow participants to manage time constraints adequately.

1.2 Emotions and emotional dimensions in task-achievement settings

Emotions are of critical importance in learning and problem-solving activities. During deep learning activities, that include effortful problem-solving, D'Mello and Graesser (2012) showed that emotions and cognitive states go hand in hand throughout task achievement. For example, a state of persistent failure can trigger hopelessness, which can lead to disengagement and boredom. On the contrary, resolving a problem and attaining one's goal can trigger delight. In the same vein, Pekrun and Linnenbrink-Garcia (2012) reported a variety of emotions occurring in learning activities (e.g., studying or taking exams), such as achievement emotions (related to achievement activities or outcomes), epistemic emotions (related to the cognitive processing of information) or social emotions (related to interpersonal relationships) (Pekrun & Linnenbrink-Garcia, 2012). Achievement emotions are the focus of this study.

1.2.1 Control-Value Theory (CVT) of achievement emotions

The CVT provides a framework explaining how achievement emotions emerge at the individual level through task-achievement appraisals. Achievement emotions relate to either the ongoing activity or its prospective or retrospective outcomes, depending on the learner's focus. Examples of activity-related achievement emotions are the enjoyment of learning new things or the frustration of not finding a solution to a problem. Disappointment following a failing grade, on the other hand, is an example of retrospective outcome-related achievement emotions. In addition to discrete labels, achievement emotions have also been described according to emotional dimensions, especially valence and activation (Pekrun & Linnenbrink-Garcia, 2012). The latter dimension refers to the arousal dimension of emotions (Fontaine, Scherer, Roesch, & Ellsworth, 2007). Hope, anger, pride, gratitude, frustration or joy are examples of activating emotions. Relief, sadness, boredom, contentment are examples of deactivating emotions. According to their valence and activation, achievement emotions are expected to have differential effects on

motivational, cognitive and socio-cognitive processes (Pekrun & Linnenbrink-Garcia, 2012) (see Table 2 for a comprehensive description of achievement emotions).

According to the CVT, control and value are subjective cognitive appraisals that lead to the emergence of achievement emotions. Subjective control refers to an overall evaluation of the control over the task, while subjective value relates to the perceived valence of the actions performed during the task as well as the outcomes accomplished. Subjective control and value emerge from different expectancies and attributions, which are task-achievement appraisals.

Control expectancies and attributions:

When learners focus on what they are doing or what will be accomplished (activity or prospective perspective), subjective control emerges from several expectancies regarding actions and outcomes (Pekrun, 2006). First, action-control expectancies are beliefs about the self-capability to initiate and perform an action (similar to self-efficacy; Bandura, 1977). Second, action-outcome expectancies are beliefs that self-actions will produce some positive outcomes or prevent negative ones. Third, situation-outcome expectancies are beliefs that the situation will produce positive or negative outcomes by itself whatever the actions performed. In addition, when the learner focuses on what has been accomplished (retrospective perspective), subjective control implies retrospective appraisals of the causes of success or failure (Pekrun, 2006), i.e., causal attributions of outcomes (self or external circumstances).

Value expectancies: When learners focus on what they are doing, subjective value emerges from either intrinsic (value of the activity per se) or extrinsic (instrumental usefulness of the activity) values (Zimmerman & Bradley, 2002). When the learner's focus is on prospective or retrospective outcomes, subjective value emerges from achievement expectancies in terms of success or failure.

In this study, different levels of action-outcome, situation-outcome and success expectancies have been manipulated (see Section 1.4 and Table 1).

1.3 Emotions in (computer-supported) collaborative learning settings

Although a clear vision of the interplay between emotions and socio-cognitive processes is still underway, research on individual and group converges around the idea that emotions and especially achievement emotions significantly impact cognitive and socio-cognitive strategies during individual and collaborative problem-solving.

1.3.1 Emotions in individual learning

The CVT assumes that achievement emotions affect learning, especially the use of learning strategies in problem-solving settings. For example, positive and activating emotions (e.g., enjoyment, hope, pride) may foster flexible, holistic and creative strategies such as elaboration (e.g., relating the studying material to previous knowledge, paraphrasing, summarizing; Artino, 2009) or critical thinking whereas both negative (e.g., hopelessness, boredom) and positive (e.g., relaxation) deactivating emotions may discourage learners from investing in an effortful processing of information. Negative activating emotions (e.g., frustration, anger, anxiety and shame) could motivate learners to avoid failure but may promote more rigid learning strategies like the rehearsal of information (Barchfeld, & Perry, 2011; Pekrun, Goetz, Frenzel; Pekrun & Linnenbrink-Garcia, 2012). In addition, using a questionnaire developed by Greene, Miller, Crowson, Duke and Akey (2004) measuring meaningful cognitive strategies used by learners (e.g., "I make sure I understand the ideas that I study"), Marchand and Gutierrez (2012) showed that three achievement emotions (hope, frustration, anxiety) have an impact on such strategies. While hope and anxiety correlate positively and significantly with the use of efficient learning strategies, frustration appears to correlate with a decrease in the use of such strategies.

In studies focusing on emotions more broadly, it seems quite clear that negative emotions stimulate a more careful and bottom-up processing as well as a more systematic gathering of information, in contrast to positive emotions, that lessen systematic information processing and promote heuristic-based processing strategies (Spering et *al.*, 2005). Isen and Labroo (2012) also

showed that people experiencing positive emotions are more flexible, inclusive, creative, integrative, open to information, and efficient (see also Hascher, 2010). Up to now, evidence for a reverse effect concerning negative emotions appears less clear. However, according to Hacher (2010), negative emotions (e.g., anxiety) may direct the student's attention to themselves and their subjective feelings. Therefore, it can induce task-irrelevant thoughts that may interfere with task completion as it consumes additional cognitive resources (Pekrun & Linnenbrink-Garcia, 2012).

1.3.2 Emotions in group learning

Andriessen et *al.* (2011) have also explicitly linked the affective states of tension and relaxation to specific socio-cognitive behaviors such as questioning, compromising, or requesting justifications or clarifications. In their theoretical model of social and cognitive functions of emotions in collective argumentation, Polo, Lund, Plantin and Niccolai (2016) also postulate that, in the cognitive side, emotions are involved in a schematization process. In such a process, participants attach emotional tonalities to discourse objects (e.g., arguments), that act as a cognitive filter, orienting the choice of a given argumentative option. Other authors (Molinari, Chanel, Betrancourt, Pun, & Bozelle Giroud, 2013) showed that the emotional intensity of shared emotions correlates with the perception of some socio-cognitive processes as understanding and building upon the partner's ideas or challenging the partner's ideas (referring to co-construction and constructive conflict). Finally, sharing positive emotions also impacts positively the number of communicative exchanges dedicated to giving and eliciting information about how partners process task information (Avry & Molinari, 2018).

1.4 Research questions and hypotheses

The literature shows that (achievement) emotions are related to cognitive and socio-cognitive strategies during individual and collaborative problem-solving. However, there are still little

findings regarding the role of achievement emotions as well as their emotional dimensions (valence, activation, and dominance) in group cognition. As research demonstrates, affective aspects are crucial in cognitive processes but the extensive research regarding emotional aspects of individual learning and problem solving is little extended to socio-cognitive processes.

In a first approach, and in line with previous studies considering relationships between achievement emotions and cognitive or socio-cognitive processes (Marchand & Gutierrez, 2012; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011), we relied on participants' self-reporting. However, we are deeply aware that the socio-cognitive processes people think they mobilize (our approach) may differ from what they actually do. Both perspectives are crucial because implicit and explicit systems intertwine in learning (Hogarth, 2001). For example, a discrepancy can be found between how people link their subjective feeling (i.e., conscious frustration) to their collaborative judgments (e.g., inefficient) and how their emotions actually influence their cognitive (i.e., more systematic gathering of information) and socio-cognitive processes (e.g., stimulating information pooling). This point will be discussed further in section 4.3.

Besides, self-experienced emotions are not the only source of influence of cognitive and socio-cognitive processes. In the EASI - Emotion As Social Information - model, Van Kleef, De Dreu and Manstead (2010) point out that, in social interaction, the emotions perceived in others are also used in a controlled and strategic way to adjust one's own behavior. Therefore, we considered in this study both self-experienced emotions as well as emotions perceived in the partner and their relationships with the perception of both self and partner's socio-cognitive processes. In the following hypotheses, achievement emotions and emotional dimensions, as well as perceived socio-cognitive processes, refer to both self and partner reports. Furthermore, although our hypotheses are based mainly on results referring to achievement emotions in individual learning, we are strongly aware that learning together implies processes that are unique to the group (e.g., relatedness to others, Mullins et *al.*, 2013) and may influence socio-cognitive processes in different

ways, comparing to what was previously found in some research findings focalizing only on individuals. This point will be discussed further in section 4.4.

1.4.1 Research questions and hypotheses regarding the effects of achievement appraisals on emotional dimensions, achievement emotions and the perception of socio-cognitive processes

In this study, the focus is on achievement emotions (Pekrun & Linnenbrink-Garcia, 2012; Pekrun, 2006) and three emotional dimensions (valence, activation and dominance). Dominance was also considered in addition to valence and activation as it has a strong relationship with control, which has an essential role in the emergence of achievement emotions (cf. subjective control).

The research question here is to know whether different task-achievement appraisals modulate achievement emotions as well as their emotional dimensions in collaborative problem-solving. We relied on the CVT as it provides a clear theoretical framework for the emergence of achievement emotions, which can be used to make testable hypotheses.

On the other hand, we focused on socio-cognitive processes that are known to be central and beneficial to group learning (section 1.1), referring to the rating scheme developed by Meier et *al*. (2007). In this case, the research question is to know whether different task-achievement appraisals modulate the perception of socio-cognitive processes. The socio-cognitive processes described in section 1.1 includes several socio-cognitive communicative exchanges (Table 4).

Based on the CVT, we have considered different levels of action-outcome and situation-outcome expectancies, as well as different levels of success expectancies. They reflect four different situations that can be encountered in face-to-face and computer-supported collaboration. In the present research, an experimental design was set up to simulate these situations. According to their experimental condition, participants received different false feedback about task-achievement (task mastery and ranking) aiming at skewing action-outcome, situation-outcome

and success expectancies (cf. section 2.4 and Table 3 for a description of the experimental design). Table 1 summarizes the different hypotheses about their effects on emotional dimensions, achievement emotions, and perceived socio-cognitive processes. In these hypotheses, we assume no difference between self and partner reports. In each case, action-control expectancies are assumed to be high (i.e., the problem-solver is able to solve the task). The following situations correspond to the different experimental conditions.

Situation 1: the first experimental condition (Table 1, first row) refers to the high task mastery and high ranking (HMHR) condition (see section 2.4 and Table 3). It corresponds to a situation where problem-solvers think that their efforts can produce positive outcomes (high action-outcome expectancies, self-action is useful) and those efforts are a necessary condition to get positive outcomes (low situation-outcome expectancies, i.e., the situation, by itself, does not lead to positive outcomes). The situation also turns to be successful so they have high expectancies of success. This situation can be related to any problem-solving situation where problem-solvers receive feedback indicating positive outcomes and think that they are the cause of those positive outcomes.

In this case, we hypothesize that activation, dominance, and valence will be high, and positive activating emotions will predominate. We also assume that this experimental condition will lead to promoting socio-cognitive exchanges as the need to collaborate is a necessary condition to be ultimately successful in this situation.

Situation 2: the second experimental condition (Table 1, second row) refers to the low task mastery and high ranking (LMHR) condition (see section 2.4 and Table 3). It corresponds to a situation where problem-solvers think that the situation has been producing positive outcomes (high and positive situation-outcome expectancies, i.e., the situation, by itself, leads to positive outcomes) despite their self-action (low action-outcome expectancies, self-action is useless). In addition, the situation also turns to be successful so they have high expectancies of success.

This situation can be related to any problem-solving situation where problem-solvers receive feedback indicating positive outcomes but think they are not the cause of those positive outcomes.

In this case, we hypothesize emotional activation to be low. Indeed, as positive outcomes result from the situation and not themselves, problem-solvers should be less involved in the task. However, emotional dominance is posited to be high due to positive situation-outcome expectancies (i.e., they feel as they master the task even though it is not due to them, cf. Pekrun, 2006). We also hypothesize emotional valence to be high as success is expected. Therefore, we expect that deactivating positive emotions will predominate in this case. We assume that this experimental condition will lead to decreasing the perception of socio-cognitive exchanges. Indeed, the need to collaborate in a situation known to be successful by itself should appear of little use.

Situation 3: the third experimental condition (Table 1, third row) refers to the high task mastery and low ranking (HMLR) condition (see section 2.4 and Table 3). It corresponds to a situation where problem-solvers think that the situation has been producing negative outcomes (high and negative situation-outcome expectancies, i.e., the situation, by itself, leads to negative outcomes) despite their self-action (low action-outcome expectancies, self-action is useless). In addition, the situation also turns to be unsuccessful so they have low expectancies of success. This situation can be related to any problem-solving situation where problem-solvers receive feedback indicating negative outcomes but think they are not the cause of those negative outcomes.

In this case, we hypothesize emotional activation to be low. Indeed, as negative outcomes result from the situation whatever their self-action, problem-solvers should be less involved in the task. Emotional dominance is also posited to be low due to low action-outcome and high and

negative situation-outcome expectancies, as well as emotional valence due to low success expectancies. Therefore, we expect that deactivating negative emotions will predominate. We assume that this experimental condition will lead to decreasing socio-cognitive exchanges. Indeed, the need to collaborate in a situation already known to be unsuccessful should appear of little use.

Situation 4: the fourth experimental condition (Table 1, fourth row) refers to the low task mastery and low ranking (LMLR) condition (see section 2.4 and Table 3). It corresponds to a situation where problem-solvers think that their efforts cannot produce positive outcomes (low action-outcome expectancies, i.e., self-action is useless) but those efforts are necessary to get positive outcomes (low situation-outcome expectancies, i.e., the situation, by itself, does not lead to positive outcomes). In addition, the situation also turns to be unsuccessful so they have low expectancies of success.

This situation can be related to any problem-solving situation where problem-solvers receive feedback indicating negative outcomes and think they are the cause of those negative outcomes. In this case, we hypothesize that activation, dominance, and valence will be low, and deactivating negative emotions will predominate. We assume that this experimental condition will lead to decreasing socio-cognitive exchanges as the collaboration should appear unsuccessful in this condition.

1.4.2 Research question and hypothesis regarding the mediating effect of emotional dimensions and achievement emotions

Achievement emotions are assumed to mediate the relationships between several variables as achievement goals (Hall, Sampasivam, Muis, & Ranellucci, 2016) or individual variables (e.g., utility value, academic self-efficacy; Marchand & Gutierrez, 2012) and several mechanisms, that in turn affect task achievement. These mechanisms include cognitive resources, motivation

to learn, learning strategies, and regulation of learning (Pekrun 1992, 2006; Pekrun, Elliot, & Maier, 2009). The research question here is to know whether achievement emotions and their emotional dimensions also have a role in the relationship between task-achievement appraisals and the perception of socio-cognitive processes. As these affective states occur in-between task-achievement and socio-cognitive processes, the question is to know whether they change how participants see what they are doing in different task-achievement situations. Drawing on the previous results reported above, we postulate that emotional dimensions and achievement emotions mediate the relationship between how people appraise task achievement and how they perceive their socio-cognitive exchanges. In other words, people are assumed to perceive, at least partially, what they do through the prism of what they feel. For example, positive emotions like enjoyment could skew the perception of how participants perceive socio-cognitive processes even though they may not perform notably better (cf. cognitive bias and emotions, Blanco, 2017). As no study has investigated this possible effect yet, strong assumptions cannot be made, and mediation effects will be investigated in an exploratory way. Mediating effects are assumed for both emotional dimensions and achievement emotions, for both self-experienced emotions as well as emotions perceived in the partner.

Table 1

Taks-achievement appraisals in each of the four collaborative situations and hypotheses concerning achievement emotions, emotional dimensions and the perception of collaborative processes based on the control-value theory

	Task-achievement appraisals			Hypotheses				
	Success	Action-Outcome	Situation-outcome	Activation	Dominance	Valence	Achievement emotions	Perception of socio-cognitive processes use
Situation 1	High	High	Low	High	High	High	Joy/Pride/Gratitude[1]	High
Situation 2	High	Low	High (positive)	Low	High	High	Relaxation/Contentment/Relief[2]	Low
Situation 3	Low	Low	High (negative)	Low	Low	Low	Boredom/Hopelessness Sadness/Disappointment[3]	Low
Situation 4	Low	Low	Low	Low	Low	Low	Boredom/Hopelessness Sadness/Disappointment[3]	Low

Note. [1]activating positive emotions, [2]deactivating positive emotions, [3]deactivating negative emotion

Table 2

Achievement emotions[a]

	Positive		Negative	
Object focus	Activating	Deactivating	Activating	Deactivating
Activity	Enjoyment	Relaxation	Anger Frustration	Boredom
Outcome / Prospective	Hope Anticipatory joy	Anticipatory relief	Anxiety	Hopelessness
Outcome / Retrospective	Joy Pride Gratitude	Contentment Relief	Shame Anger	Disappointment Sadness

Note. [a]Pekrun & Linnenbrink-Garcia, (2012), Pekrun (2006)

Table 3

Experimental design

		Ranking			
		Low		High	
Task mastery	Low	LMLR condition	**Situation 4** Low action-out-come Low success Low situation-out-come	LMHR condition	**Situation 2** Low action-outcome High success High and positive situation-outcome
	High	HMLR condition	**Situation 3** Low action-out-come Low success High and negative situation-outcome	HMHR condition	**Situation 1** High action-outcome High success Low situation-out-come

2. Method

2.1 Participants

Fifty-six participants, mainly students in computer sciences at the University of Geneva (10 women and 46 men; $M = 22.02$ years, $SD = 3.49$ years), grouped into same-sex dyads, took part voluntarily to the experiment. The low proportion of women reflects the imbalance found in the computer sciences population. Each pair received 50 CHF as an inconvenience allowance. The members of each pair were acquainted. They had never played Portal 2®, according to the recruitment form.

2.2 Procedure

Participants took part in a collaborative problem-solving task in a 3D first-person puzzle-platform video game called Portal 2® (Figure 1) through networked computers.

The collaborative mode of Portal 2® was chosen as a generic computer-supported collaborative problem-solving task. Indeed, it meets the defined criteria of a collaborative problem-solving task, namely symmetry of actions, symmetrical knowledge, pursuit of a shared goal, spontaneous division of flexible and interchangeable roles (Dillenbourg, 1999; Roschelle & Teasley, 1995). It also requires cognitive and motivational skills usually involved in learning such as problem-solving, spatial cognition, and persistence (see Shute, Ventura, & Ke, 2015, for a complete description).

Participants did not see each other during the collaboration but communicated orally through audio headsets. The task consisted of finding together a way to get out of a succession of chambers using objects available in their environment. These objects had to be combined in a sophisticated way to trigger game behaviors, opening passages, and continuing through the next chambers. When a possible solution was found, players had to coordinate their actions, being highly dependent on one another. Participants started with individual training (15 minutes) to

become familiar with the game environment and game basics. Then, they performed the collaborative task *per se*. This stage lasted 30 minutes. Immediately after the collaboration, participants individually completed two questionnaires (cf. section 2.5). Finally, at the end of the task, the goal of the study was revealed, and the compensation given.

2.3 False feedback

During the collaborative task, participants received false feedback about task achievement, displayed through a window on the right side of their respective screen (Figure 1). In the instructions (oral and written), it was explained to the participants that an algorithm would track their group's actions during the game. From these actions, the algorithm was supposed to compute an estimation of group task mastery. A percentage of 100% indicated a complete task mastery (participants did precisely what was expected) while a percentage of 0% indicated no task mastery (participants did not do at all what was expected). Based on this task-mastery evaluation, the algorithm was also supposed to compute a rank and display a dyad's ranking among 14 previous dyads of participants. The ranking was also associated with an estimation of the final gain. Feedback information was the same for both participants in the dyad and was displayed six times during the task, that is, every five minutes.

In reality, the algorithm just displayed dummy information. Indeed, participants received predefined feedback in each experimental condition (cf. section 2.4). The level of task mastery displayed varied randomly from 10 to 20% for the low task mastery conditions, and from 80 to 90% for the high task mastery conditions. The ranking varied randomly from 12th to 15th (10 to 12 CHF) in the low ranking conditions and from 1st to 3rd (46 to 50 CHF) in the high ranking conditions (Figure 1). Slight randomized variations of percentage and ranking were introduced to enhance the perceived feedback credibility. At the very end of the task, participants were asked if they had noticed that the given feedback was false. Regardless of the experimental condition, all dyads actually received the same final remuneration (50 CHF).

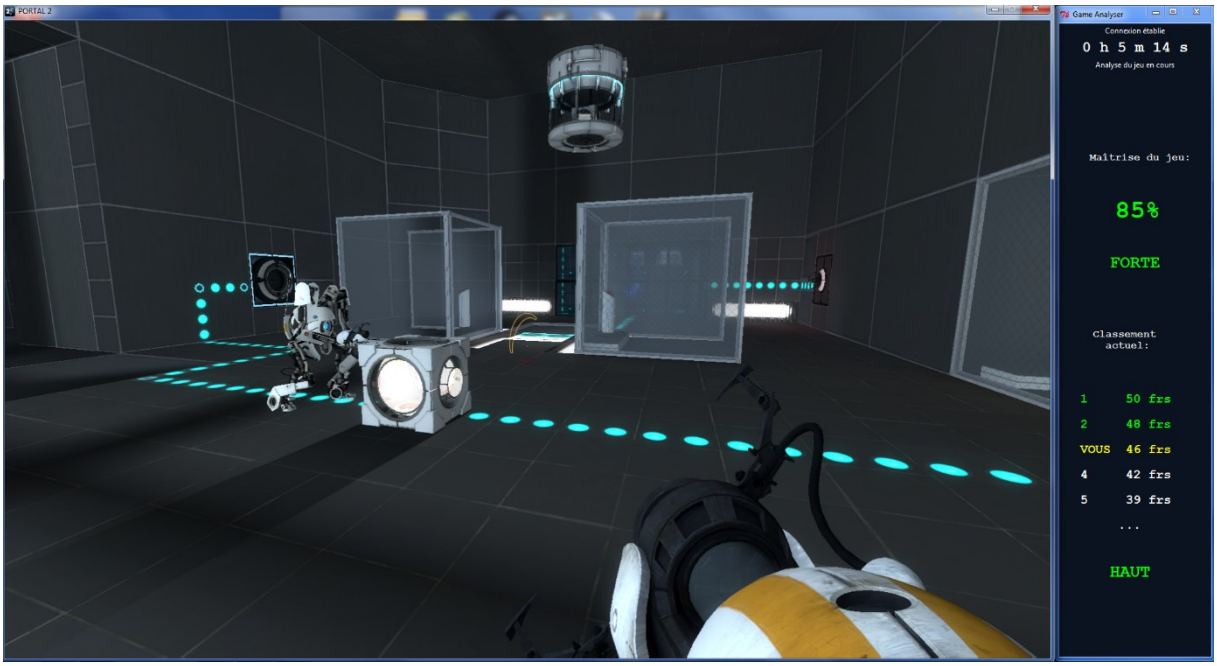

Figure 1. The collaborative video game Portal 2® (left) and the feedback window (right)

2.4 Design

2.4.1. Experimental conditions

Participants received feedback according to four combinations of high or low task mastery and ranking: high task mastery and high ranking (HMHR) corresponding to situation 1 (see section 1.4.1), low task mastery and high ranking (LMHR) corresponding to situation 2, high task mastery and low ranking (HMLR) corresponding to situation 3, and low task mastery and low ranking (LMLR) corresponding to situation 4. These different situations represented the different modalities (HMHR, HMLR, LMHR, and LMLR) of the independent variable (Task-achievement situations) of the study.

The overall combination of different task-mastery and ranking levels was intended to generate different combinations of success, action-outcome, and situation-outcome expectancies (Table 3). In addition, the repetition of feedback information (six times) throughout the task aimed at reinforcing high situation-outcome expectancies in incongruent conditions (LMHR and

HMLR). In these conditions, there was a discrepancy between task mastery and ranking. Indeed, participants saw that their task mastery (high or low) did not produce the expected result (positive or negative). Therefore, they were led to think that the outcome depended more on the situation than on their self-action. For example, in the HMLR condition, high task mastery led to low ranking, leading participants to believe that other previous dyads were in any event better than them. Feedback information was regularly repeated throughout the task to reinforce this belief and therefore maintain situation-outcome expectancies high. In congruent conditions (LMLR and HMHR) though, there was no discrepancy between task mastery and ranking (e.g., a low task mastery led logically to a low ranking). In these conditions, situation-outcome expectancies were intended to be low as participants could directly associate the outcome to their self-action. In this case, the repetition of feedback information was therefore not supposed to change situation-outcomes expectancies.

2.4.2 Variables

Dependent variables were the rating scores to the questionnaires concerning achievement emotions and emotional dimensions (Questionnaire 1), and the perception of socio-cognitive processes (Questionnaire 2) (cf. section 2.5). The participants' gaming experience was controlled in the following ways: participants had never played at the game; they all had previous experience of 3D first-person shooter games; they completed individual 15-minute training before the collaborative task where game basics and objects manipulation were addressed; participants with too much difficulty to master the game basics were excluded *a priori* (after training) or *a posteriori* (after the task). The perception of progress into the game map was also controlled as follows: participants did not previously know the game map; they were told in the instructions to go as far as possible without receiving any indication of their actual progress; the game map

could not be fully completed within the time allowed. Besides, fluid intelligence (i.e., the capacity to adapt one's own reasoning to new ideas and situations) was evaluated through a questionnaire derived from Raven's progressive matrices test (Raven, 1998). No significant difference was found between the experimental groups: $F(3, 51) = 1.12$, $p = 0.35$. A performance score was also computed to test a difference in performance between experimental conditions. No significant difference was found: $F(3, 24) = 0.97$, $p = 0.42$.

2.5 Questionnaires

Participants completed two questionnaires just after the task, an emotion questionnaire (Questionnaire 1) and a socio-cognitive exchanges questionnaire (Questionnaire 2). Questionnaire 1 was divided into two sections. The first section focused on the three emotional dimensions, namely valence, dominance, and activation. Participants were asked to answer three questions with 5-point Likert scales: "How did you rate the overall situation you have just been in?" (from *very negative* to *very positive*; Valence question); "To what extent have you been able to maintain or improve the situation you have just been in?" (from *very slightly* to *very strongly*; Dominance question); "How much did you feel aroused by the situation you have just been in?" (from *very slightly* to *very strongly*; Activation question). The second section was derived from the Achievement Emotions Questionnaire (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011) and aimed at measuring the achievement emotions experienced during the game. Participants were asked to assess the intensity of their emotions using a list of 16 emotions with 7-point Likert scales (from *not at all to very strongly*): 4 negative and activating emotions (anxiety, anger, frustration, shame), 4 negative and deactivating emotions (disappointment, hopelessness, boredom, sadness), 5 positive and activating emotions (hope, pride, joy, enjoyment, gratitude), and 3 positive and deactivating emotions (relaxation, relief, contentment). The questionnaire 2 was based on the rating scheme developed by Meier et *al.* (2007). This questionnaire aimed at measuring the perceived use of computer-supported socio-cognitive exchanges. It addressed six

socio-cognitive processes: sustaining mutual understanding, information pooling, transactivity, reaching consensus, task management, and time management (cf. section 1.1). Each of these processes includes 2 to 5 socio-cognitive exchanges with 7-point Likert scales (Table 4). Participants had to indicate with which frequency (from *never to every time*) they and their partner have used the collaborative exchanges in question. Frequency measure was preferred to an overall judgment of quality to enhance participants' focus on their actual communicative exchanges. The sustaining mutual understanding dimension concerned the participants' readiness to make contributions understandable to the partner (e.g., making sure to be well understood). Information pooling referred to the sharing of relevant information (e.g., gathering as many important pieces of information as possible). Transactivity was defined as the process through which participants reason and build on their partner's contributions (e.g., building on partner's ideas by adopting or integrating them). Reaching consensus was the process by which common decisions were taken based on a critical discussion about the pros and cons (e.g., looking for facts that confirm or invalidate a solution). Task management focused on the ability to manage efficiently what needs to be done to achieve the task (e.g., defining clear subtasks with fair burden-sharing). Finally, time management referred to the ability to take into account the time available and manage the collaborative work accordingly (e.g., allocating enough time and resources for each step).

Table 4

Socio-cognitive processes (in bold) and their related communicative exchanges

Sustaining Mutual understanding

- Make my contributions understandable for the other
- Make sure being understood by the other
- Give verbal feedback on my understanding or ask for clarification

Information pooling

- Gather as many relevant pieces of information as possible
- Relate new information to facts that have already been established
- Point out the relevance of new information
- Give an explanation to the other about what I'm currently doing

Reaching consensus

- Find the best arguments for and against a solution
- Look for facts that confirm or invalidate a solution to prevent errors
- Try to convince the other by justifying my proposed solution
- Question a decision only if valid reasons

Transactivity

- Build on other's propositions by adopting or integrating them to mine
- Build on other's propositions by rejecting or modifying them

Task management

- Define clearly subtasks with fair burden-sharing
- Co-ordinate the work
- Be careful about other's actions and needs

Time management

- Allocate enough time and resources for each step
- Monitor remaining time for preventing time waste

3. Results

Three dyads were excluded from the analyses. One dyad had difficulty to manage the game basics and remained blocked at the early beginning of the game. Another one was excluded due to technical problems during the game. Finally, one dyad identified that feedback information was false.

3.1 Unit of analysis

In order to assess the (non-)independence of peers' measures and confirm the possibility to use the individual as unit of analysis (see Kenny, Kashy, & Cook, 2006 for further discussion), intraclass correlation was performed between subject A and subject B's data (A and B being of the same pair). We computed the ICC for all the dependent variables of interest. No evidence of a dyad effect was supported by these analyses (cf. Appendix A). Therefore, individual-level measures were used as unit of analysis with standard inferential statistical methods.

3.2 Descriptive statistics

Descriptive statistics are reported in Table 8. A series of one-sample *t*-tests was conducted to test, for each condition, which emotions were self-experienced and perceived in the partner at least more than a "weak" level. These emotions are reported in Table 9 for each condition.

Achievement emotions that were not reported more than a weak level in each condition are reported in Appendix B.

3.3 Effect of Task-achievement situations on emotional dimensions

A series of ANOVAS was conducted to test the effects of Task-achievement situations on the rating scores of the emotional dimensions evaluated by participants. Inferential statistics are reported in Table 5. Significant effects are depicted in Figure 2 and described in detail below.

3.3.1 Activation dimension

Overall, participants self-experienced a rather "strong" level of activation (M = 3.80, SD = 0.92). An effect of the Task-achievement situations on the activation self-experienced by participants was found ([$F(3, 52) = 3.60$, $p = .02$, $\eta_p^2 = .17$]). As depicted in Figure 2 A, participants in HMHR (high task mastery high ranking) condition self-experienced a higher level of activation ($M = 4.18$, $SD = 0.65$) than participants in LMLR (low task mastery low ranking) condition ($M = 3.16$, $SD = 1.19$) (Post hoc t-test: $p = .01$). The same pattern was found for participants in the LMHR (low task mastery high ranking) condition ($M = 4.00$, $SD = 0.81$) (Post hoc t-test: $p = .01$). No difference was found between HMLR (high task mastery low ranking) ($M = 3.66$, $SD = 0.77$) and LMLR conditions (Post hoc t-test: $p = .16$). Overall, participants also perceived a rather "strong" level of activation in their partner (M = 3.71, SD = 0.94). An effect of the conditions on the activation perceived in their partner was found ([$F(3, 52) = 4.00$, $p < .01$, $\eta_p^2 = .24$]). As depicted in Figure 2 D, participants in HMHR ($M = 4.00$, $SD = 0.81$), LMHR ($M = 3.87$, SD = 0.50) and HMLR (M = 4.00, SD = 0.81) conditions perceived in their partner a higher level of activation than participants in LMLR condition ($M = 2.83$, $SD = 1.11$) (Post hoc t-test: $p < .01$ for HMLR and LMHR, $p < .001$ for HMHR).

3.3.2 Dominance dimension

Overall, participants self-experienced a "moderate" level of dominance (M = 2.94, SD = 1.09). An effect of the Task-achievement situations on the dominance self-experienced by participants was found ([$F(3, 51) = 3.16$, $p = .04$, $\eta_p^2 = .14$]). As depicted in Figure 2 B, participants in LMHR condition self-experienced a higher level of dominance (M = 3.18, SD = 0.83) than participants in LMLR condition (M = 2.25, SD = 1.21) (Post hoc t-test: $p = .02$). The same pattern was found for participants in the HMLR condition (M = 3.41, SD = 0.51) (Post hoc t-test: $p < .01$). No difference was found between HMHR (M = 2.86, SD = 1.35) and LMLR conditions (Post hoc t-test: $p = .13$).

Overall, participants also perceived a "moderate" level of dominance in their partner (M = 3.24, SD = 1.01). An effect of the Task-achievement situations on the dominance perceived in their partner was found ([$F(3, 49) = 3.28$, $p = .03$, $\eta_p^2 = .17$]). As depicted in Figure 2 E, participants perceived a higher level of dominance in their partner in the LMHR condition (M = 3.60, SD = 0.73) than in the LMLR condition (M = 2.58, SD = 0.99) (Post hoc t-test: $p < .01$). The same pattern was found for participants in the HMLR condition (M = 3.63, SD = 0.67) (Post hoc t-test: $p = .01$). No difference was found between HMHR (M = 3.13, SD = 1.24) and LMLR conditions (Post hoc t-test: $p = .14$).

3.3.3 Valence dimension

Overall, participants self-experienced a "moderate" level of valence (M = 3.32, SD = 1.20). An effect of the Task-achievement situations on the valence self-experienced by participants was found ([$F(3, 51) = 5.56$, $p < .01$, $\eta_p^2 = .24$]). As depicted in Figure 2 C, participants in HMHR (M = 3.62, SD = 1.31), LMHR (M = 3.43, SD = 0.96) and HMLR (M = 3.90, SD = 0.83) conditions self-experienced the situation as more positive than participants in LMLR condition (M = 2.25, SD = 1.05) (Post hoc t-test: $p < .01$ for HMHR and LMHR, $p < .001$ for HMLR).

Overall, participants perceived a "moderate" level of valence (M = 3.25, SD = 1.14) in their partner. An effect of the Task-achievement situations on the valence perceived in their partner was found ([$F(3, 51) = 5.35$, $p < .01$, $\eta_p^2 = .22$]). As depicted in Figure 2 F, participants in HMHR (M = 3.50, SD = 1.21), LMHR (M = 3.43, SD = 1.03) and HMLR (M = 3.72, SD = 1.21) conditions perceived in their partner a more positive situation than participants in LMLR condition (M = 2.25, SD = 0.96) (Post hoc t-test: $p < .01$ for HMHR, LMHR and HMLR).

Table 5

ANOVA results for the reported intensities of activation, dominance and valence for self and partner

Dependent variables	Self					Partner				
	df	*SS*	*F*	*p*	*Partial* η^2	*df*	*SS*	*F*	*p*	*Partial* η^2
Activation	52	8.07	3.60	**0.02**	0.17	52	12.01	5.56	**0.00**	0.24
Dominance	52	9.50	2.92	**0.04**	0.15	49	9.02	3.28	**0.03**	0.17
Valence	51	19.26	5.56	**0.00**	0.25	51	16.07	5.35	**0.00**	0.23

Note. Significant effects (p<=.05) are in bold

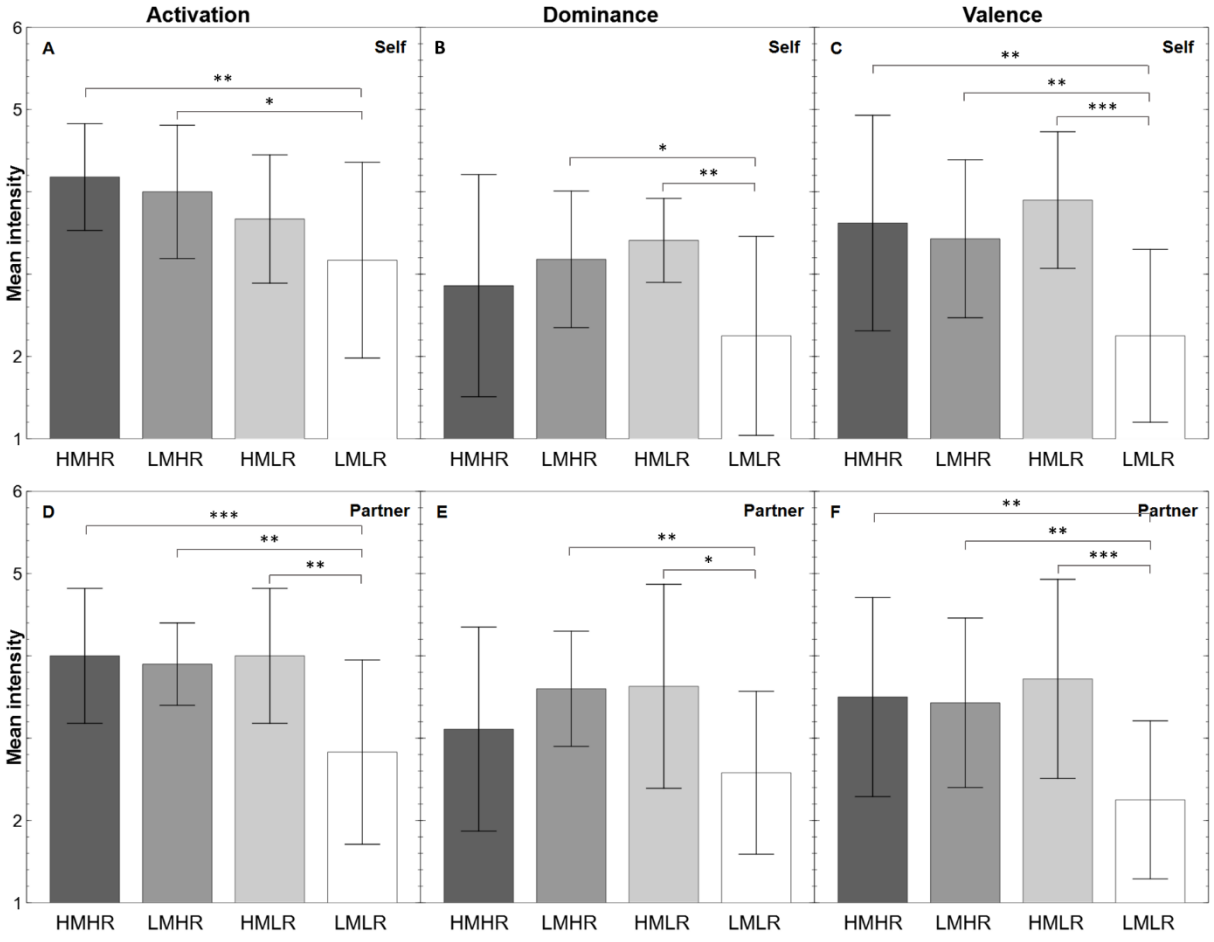

Figure 2. Mean intensities on 5-point Likert scales of activation, dominance and valence according to the different conditions of Task-achievement situations (HMHR : high task mastery, low ranking; LMHR: low task mastery, high ranking; HMLR: high task mastery, low ranking; LMLR: low task mastery, low ranking) ; *: $p <= .05$, **: $p <= .01$, ***: $p <= .001$

3.4 Effect of Task-achievement situations on achievement emotions

A series of ANOVAS was conducted to test the effects of the Task-achievement situations on the rating scores of the achievement emotions. Inferential statistics are reported in Table 6. Significant effects are depicted in Figure 3 and described in detail below. No effect of the Task-achievement situations was found for the following achievement emotions: anxiety, anger, frustration, disappointment, boredom, hope, pride, enjoyment and relaxation.

3.4.1 Shame

Overall, participants self-experienced a "very low" level of shame ($M = 2.16$, $SD = 1.49$). An effect of the Task-achievement situations on the shame self-experienced by participants was found ([$F(3, 52) = 7.30$, $p < .001$, $\eta_p^2 = .29$]). As depicted in Figure 3 A, participants in HMHR ($M = 1.50$, $SD = 0.89$), LMHR ($M = 2.25$, $SD = 1.29$) and HMLR ($M = 1.50$, $SD = 0.79$) conditions self-experienced significantly less shame than participants in LMLR condition ($M = 3.58$, $SD = 1.97$) (Post hoc *t*-test: $p < .001$ for HMHR, HMLR, $p < .01$ for LMHR).

Overall, participants also perceived a "very low" level of shame ($M = 1.91$, $SD = 1.40$) in their partner. An effect of the Task-achievement situations on the perceived shame in their partner was found ([$F(3, 52) = 3.85$, $p = .01$, $\eta_p^2 = .18$]). As depicted in Figure 3 B, a similar pattern to self-experienced shame was found for the shame perceived in the partner. Participants in HMHR ($M = 1.43$, $SD = 0.81$), LMHR ($M = 1.56$, $SD = 0.96$) and HMLR ($M = 1.91$, $SD = 0.81$) conditions perceived in their partner significantly less shame than participants in LMLR condition ($M = 3.00$, $SD = 1.90$) (Post hoc *t*-test: $p < .01$ for HMHR, LMHR, $p = .04$ for HMLR).

3.4.2 Joy

Overall, participants self-experienced a "moderate" level of joy (M = 4.39, SD = 1.66). An effect of the Task-achievement situations on the shame self-experienced by participants was found ([$F(3, 52) = 2.98$, $p = .03$, $\eta_p^2 = .14$]).

As depicted in Figure 3 D, participants in HMHR (M = 4.50, SD = 1.36) and HMLR (M = 5.25, SD = 1.28) conditions self-experienced significantly more joy than participants in LMLR condition (M = 3.33, SD = 1.55) (Post hoc t-test: $p = .05$ for HMHR, $p < .01$ for HMLR). However, no difference was found between LMHR (M = 4.43, SD = 1.96) and LMLR conditions (Post hoc t-test: $p = .07$).

Overall, participants also perceived in their partner a "moderate" level of joy (M = 4.29, SD = 1.61). An effect of the Task-achievement situations on the joy perceived in the partner was found ([$F(3, 51) = 3.31$, $p = .02$, $\eta_p^2 = .16$]). As depicted in Figure 3 E, participants in HMHR (M = 4.56, SD = 1.50), LMHR (M = 4.31, SD = 1.57) and HMLR (M = 5.00, SD = 1.50) conditions perceived in their partner significantly more joy than participants in LMLR condition (M = 3.09, SD = 1.13) (Post hoc t-test: $p < .05$ for HMHR, LMHR, $p < .01$ for HMLR).

3.4.3 Hopelessness

Overall, participants self-experienced a "low" level of hopelessness (M = 2.53, SD = 1.66). No effect of the Task-achievement situations on the hopelessness self-experienced by participants was found ([$F(3, 52) = 2.61$, $p = .06$]). Overall, participants also perceived in their partner a "very low" level of hopelessness (M = 2.25, SD = 1.51). An effect of the Task-achievement situations on the hopelessness perceived in the partner was found ([$F(3, 51) = 4.13$, $p = .01$, $\eta_p^2 = .19$]). As depicted in Figure 3 C, participants in HMHR (M = 2.31, SD = 1.40), LMHR (M =

1.93, *SD* = 1.28) and HMLR (*M* = 1.50, *SD* = 1.40) conditions perceived in their partner significantly less hopelessness than participants in LMLR condition (*M* = 3.45, *SD* = 1.96) (Post hoc *t*-test: $p < .01$ for HMLR, LMHR, $p < .05$ for HMHR).

3.4.4 Sadness

Overall, participants self-experienced a "very low" level of sadness (*M* = 1.55, *SD* = 1.21). No effect of the Task-achievement situations on the sadness self-experienced by participants was found ([$F(3, 52) = 1.89$, $p = .14$]).

Overall, participants also perceived a "very low" level of sadness in their partner (*M* = 1.64, *SD* = 1.27). An effect of the Task-achievement situations on the sadness perceived in the partner was found ([$F(3, 52) = 2.92$, $p = .04$, $\eta_p^2 = .14$]). As depicted in Figure 3 E, participants in HMHR (*M* = 1.43, *SD* = 1.09) and LMHR (*M* = 1.18, *SD* = 0.54) conditions perceived in their partner significantly less sadness than participants in LMLR condition (*M* = 2.50, *SD* = 1.50) (Post hoc *t*-test: $p < .01$ for LMHR, $p < .05$ for HMHR). However, no difference was found between HMLR (*M* = 1.66, *SD* = 1.09) and LMLR conditions (Post hoc *t*-test: $p = .09$).

3.4.5 Gratitude

Overall, participants self-experienced a "low" level of gratitude (*M* = 3.30, *SD* = 1.66). No effect of the Task-achievement situations on the gratitude self-experienced by participants was found ([$F(3, 51) = 1.53$, $p = .21$]).

Overall, participants also perceived a "low" level of gratitude in their partner (*M* = 2.86, *SD* = 1.55). An effect of the Task-achievement situations on the gratitude perceived in the partner was found ([$F(3, 49) = 4.26$, $p < .01$, $\eta_p^2 = .20$]). As depicted in Figure 3 G, participants in HMHR (*M* = 2.86, *SD* = 1.84), LMHR (*M* = 2.66, *SD* = 1.39) and LMLR (*M* = 2.00, *SD* = 1.12)

conditions perceived in their partner significantly less gratitude than participants in HMLR condition (M = 4.09, SD = 1.84) (Post hoc t-test: $p < .001$ for LMLR, $p < .05$ for HMHR and LMHR).

3.4.6 Relief

Overall, participants self-experienced a "low" level of relief (M = 3.12, SD = 1.79). No effect of the Task-achievement situations on the relief self-experienced by participants was found ([$F(3, 50) = 2.19$, $p = .09$]).

Overall, participants also perceived a "low" level of relief in their partner (M = 3.33, SD = 1.88). An effect of the Task-achievement situations on the relief perceived in the partner was found ([$F(3, 49) = 3.05$, $p = .03$, $\eta_p^2 = .15$]). As depicted in Figure 3 H, participants in HMHR (M = 3.85, SD = 2.34), LMHR (M = 3.81, SD = 1.42) and HMLR (M = 3.45, SD = 2.34) conditions perceived in their partner significantly more relief than participants in LMLR condition (M = 2.00, SD = 1.65) (Post hoc t-test: $p < .05$ for HMHR, LMHR and HMLR).

3.4.7 Contentment

Overall, participants self-experienced a "moderate" level of contentment (M = 4.07, SD = 1.82). No effect of the Task-achievement situations on the contentment self-experienced by participants was found ([$F(3, 52) = 2.27$, $p = .09$]).

Overall, participants also perceived a "moderate" level of contentment in their partner (M = 4.00, SD = 1.66). An effect of the Task-achievement situations on the contentment perceived in the partner was found ([$F(3, 52) = 3.92$, $p = .01$, $\eta_p^2 = .18$]). As depicted in Figure 3 I, participants in HMHR (M = 4.75, SD = 1.98), LMHR (M = 4.12, SD = 1.36) and HMLR (M = 4.08, SD = 1.98) conditions perceived in their partner significantly more contentment than participants in LMLR condition (M = 2.75, SD = 1.60) (Post hoc t-test: $p < .05$ for LMHR and HMLR, $p < .01$ for HMHR).

Table 6

ANOVA results for the reported intensities of the achievement emotions for self and partner

Dependent variables	Self					Partner				
	df	*SS*	*F*	*p*	*Partial* η^2	*df*	*SS*	*F*	*p*	*Partial* η^2
Anxiety	51	2.2	0.34	0.80	0.02	50	4.33	0.95	0.42	0.05
Anger	52	1.66	0.18	0.91	0.01	52	5.97	0.71	0.55	0.04
Frustration	52	15.82	1.48	0.23	0.08	52	8.94	0.96	0.42	0.05
Shame	52	36.64	7.30	**0.00**	0.30	52	19.76	3.86	**0.01**	0.18
Disappointment	51	17.66	1.76	0.17	0.09	52	12.29	1.29	0.30	0.07
Hopelessness	52	19.91	2.61	0.06	0.13	51	24.33	4.13	**0.01**	0.20
Boredom	52	7.55	2.50	0.07	0.13	51	3.76	1.23	0.31	0.07
Sadness	52	8.05	1.89	0.14	0.10	52	12.82	2.92	**0.04**	0.14
Hope	50	8.43	1.12	0.35	0.06	50	6.02	0.91	0.44	0.05
Pride	52	13.81	1.21	0.31	0.07	51	14.59	1.35	0.27	0.07
Joy	52	22.50	2.98	**0.04**	0.15	51	23.06	3.31	**0.03**	0.16
Enjoyment	52	5.15	1.07	0.37	0.06	52	14.86	2.23	0.1	0.11
Gratitude	51	12.41	1.54	0.22	0.08	49	26.10	4.26	**0.01**	0.20
Relaxation	52	6.61	0.76	0.52	0.04	49	13.55	1.38	0.26	0.08
Relief	50	19.83	2.20	0.10	0.12	49	29.01	3.06	**0.04**	0.16
Contentment	52	21.30	2.27	0.09	0.12	52	28.08	3.93	**0.01**	0.18

Note. Significant effects (p<=.05) are in bold

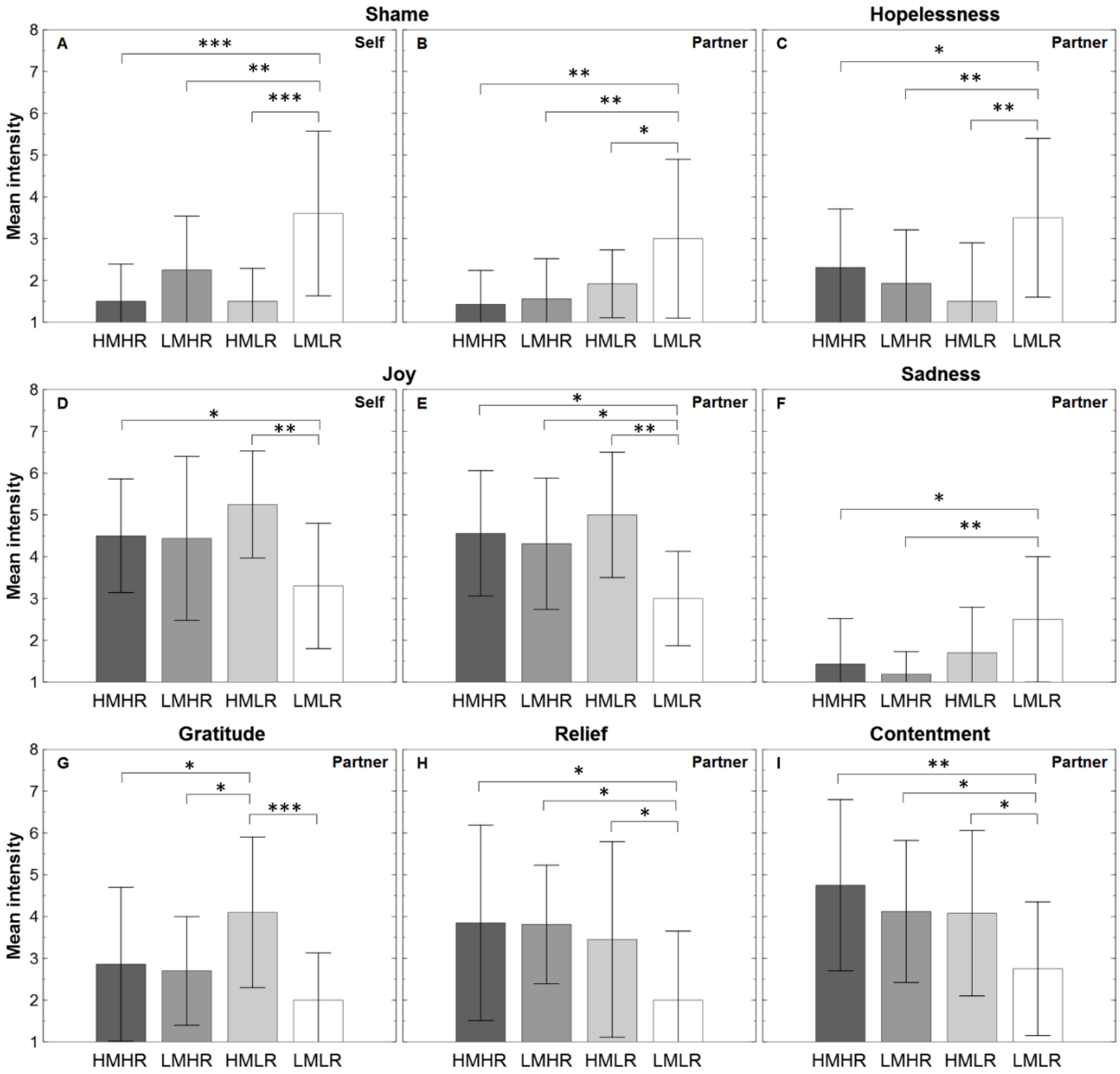

Figure 3. Mean intensities on 7-point Likert scales of emotions according to the different conditions of Task-achievement situations (HMHR : high task mastery, low ranking; LMHR: low task mastery, high ranking; HMLR: high task mastery, low ranking; LMLR: low task mastery, low ranking) ; *: $p <= .05$, **: $p <= .01$, ***: $p <= .001$

3.5 Effect of the Task-achievement situations on the perception of socio-cognitive processes

A series of ANOVAS was conducted to test the effects of the Task-achievement situations on the average scores corresponding to the different socio-cognitive processes. For a given socio-cognitive process, the average score corresponds to the average rating scores of its constitutive communicative socio-cognitive exchanges (cf. Table 4). Inferential statistics are reported in

Table 7. Significant effects are depicted in Figure 4 and described in detail below. No effect of the Task-achievement situations was found for the following socio-cognitive processes: sustaining mutual understanding, information pooling, reaching consensus, and time management.

3.5.1 Transactivity

Overall, participants reported a "moderately often" self-use of transactive exchanges ($M = 4.18$, $SD = 1.46$). An effect of the Task-achievement situations was found ([$F(3, 52) = 4.46$, $p = .02$, $\eta_p^2 = .16$]). As depicted in Figure 4 A, participants in HMHR ($M = 4.43$, $SD = 1.35$) and LMHR ($M = 4.75$, $SD = 1.39$) conditions reported significantly more self-use of transactive exchanges than participants in LMLR condition ($M = 3.12$, $SD = 1.28$) (Post hoc *t*-test: $p < .01$ for LMHR, $p < .05$ for HMHR). However, no difference was found between HMLR ($M = 4.16$, $SD = 1.46$) and LMLR conditions (Post hoc *t*-test: $p = .06$).

Overall, participants also reported a "moderately often" partner-use of transactive exchanges ($M = 4.19$, $SD = 1.53$). An effect of the Task-achievement situations was found ([$F(3, 52) = 3.28$, $p = .02$, $\eta_p^2 = .15$]). As depicted in Figure 4 B, participants in HMHR ($M = 4.28$, $SD = 1.58$), LMHR ($M = 4.75$, $SD = 1.35$) and HMLR ($M = 4.45$, $SD = 1.58$) conditions perceived significantly more partner-use of transactive exchanges than participants in LMLR condition ($M = 3.08$, $SD = 1.27$) (Post hoc *t*-test: $p < .05$ for HMHR, HMLR, $p < .01$ for LMHR).

3.5.2 Task management

Overall, participants reported a "quite often" self-use of task management exchanges ($M = 4.86$, $SD = 1.25$). An effect of the Task-achievement situations was found ([$F(3, 52) = 3.32$, $p = .02$, $\eta_p^2 = .16$]). As depicted in Figure 4 C, participants in HMHR ($M = 5.16$, $SD = 1.25$) and LMHR ($M = 5.59$, $SD = 1.09$) conditions reported significantly more self-use of task management exchanges than participants in LMLR condition ($M = 4.16$, $SD = 1.09$) (Post hoc *t*-test: $p < .01$ for LMHR, $p < .05$ for HMHR). Participants also reported more self-use of task management

in LMHR condition than in HMLR condition (Post hoc *t*-test: $p < .05$). However, no difference was found between HMLR ($M = 4.44$, $SD = 1.38$) and LMLR conditions (Post hoc *t*-test: $p = .06$).

Table 7

ANOVA results for the perception of self and partner-use of the different socio-cognitive processes

Dependent variables	Self					Partner				
	df	*SS*	*F*	*p*	*Partial* η^2	*df*	*SS*	*F*	*p*	*Partial* η^2
Sustaining mutual understanding	52	7.14	1.69	0.18	0.09	52	6.79	1.39	0.25	0.07
Information pooling	52	10.77	2.28	0.09	0.12	52	8.41	1.69	0.18	0.09
Transactivity	52	19.62	3.46	**0.02**	0.17	52	20.71	3.29	**0.03**	0.16
Reaching consensus	52	8.80	1.80	0.16	0.09	52	10.34	1.94	0.14	0.10
Task management	52	13.94	3.32	**0.03**	0.16	52	11.37	2.58	0.06	0.13
Time management	51	6.75	1.13	0.35	0.06	52	2.04	0.33	0.80	0.02

Note. Significant effects ($p<=.05$) are in bold

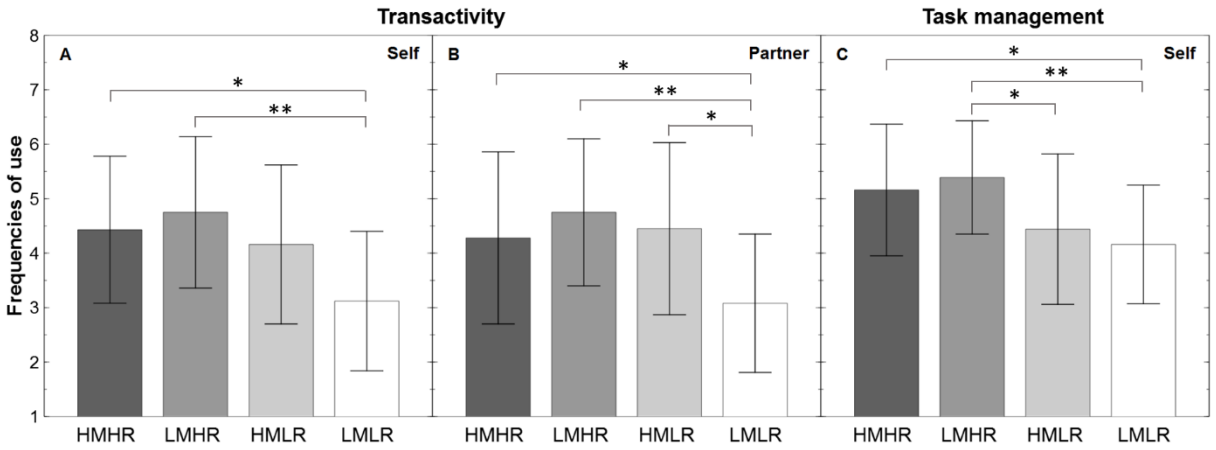

Figure 4. Mean frequencies on 7-point Likert scales of the perception of socio-cognitive processes use according to the different conditions of Task-achievement situations (HMHR : high task mastery, low ranking; LMHR: low task mastery, high ranking; HMLR: high task mastery, low ranking; LMLR: low task mastery, low ranking) ; *: $p <= .05$, **: $p <= .01$.

3.6 Mediation effects

Mediation analyses were carried out to test the hypothesis that emotions have a key role in collaboration, acting as go-betweens between task-achievement appraisals and the perception of socio-cognitive processes. Following Baron and Kenny's (1986) requirements, a mediation model was tested when a significant effect of the Task-achievement situations on the collaborative process (Figure 5, C Path) and a significant effect of the Task-achievement situations on the emotion (Figure 5, A Path) were found. Applying these requirements, 45 models were tested

in total. A mediation effect was validated when the effect of the emotion (or emotional dimension) on the collaborative process (controlling the effect of the Task-achievement situations) was significant (Figure 5 B path), the effect of the Task-achievement situations on the collaborative process (controlling the effect of the emotion) (Figure 5 C' path) was not significant anymore or reduced and the indirect effect (AB path) was significant (as showed through a Sobel test). As the independent variable (Task-achievement situations) implied more than two modalities, the following contrasts of the independent variable were chosen: LMLR versus LMHR (Figure 5 X1), LMLR versus HMLR (Figure 5 X2), LMLR versus HMHR (Figure 5 X3). Only models involving the emotional dimension of activation gave rise to significant mediation effects. They are described in detail below and reported in Appendix C. For the sake of brevity, non-significant models are not reported here (overall results are available upon request to authors).

3.6.1 Mediation effect of self-experienced activation

The level of self-experienced activation by participants appeared to mediate the relationship between the Task-achievement situations and the self-use perception of the transactivity process in the HMHR (Figure 5 A X1) and LMHR (Figure 5 A X3) conditions. However, the Sobel tests were not significant in these two cases ($z^{X1} = 1.85$, $p = .09$; $z^{X3} = 3.09$, $p = .06$). Therefore, one cannot conclude to a mediation effect.

The level of self-experienced activation appeared to mediate the relationship between the Task-achievement situations and the partner-use perception of the transactivity process in the HMHR (Figure 5 B X1) and LMHR (Figure 5 B X3). This is confirmed for HMHR ($z^{X3} = 1.90$, $p = .05$) but not for LMHR ($z^{X1} = 1.74$, $p = .08$). Therefore, one can conclude to a mediation effect only in HMHR condition.

Finally, no mediation effect was found for the self-use perception of the task management process as B path was not significant (Figure 5 C).

3.6.2 Mediation effect of activation perceived in the partner

The level of activation perceived in the partner appeared to mediate the relationship between the Task-achievement situations and the self-use perception of the transactivity process in HMHR (Figure 5 D X1), HMLR (Figure 5 D X2) and LMHR (Figure 5 D X3) conditions. This is confirmed in these three cases by the Sobel tests ($z^{X1} = 1.99$, $p = .04$; $z^{X2} = 2.02$, $p = .04$; $z^{X3} = 2.07$, $p = .03$). Therefore, one can conclude to a mediation effect in this case.

The level of activation perceived in the partner appeared to mediate the relationship between the Task-achievement situations and the partner-use perception of the transactivity process in HMHR (Figure 5 E X1), HMLR (Figure 5 E X2) and LMHR (Figure 5 E X3) conditions. This is confirmed in these three cases by the Sobel tests ($z^{X1} = 2.00$, $p = .04$; $z^{X2} = 2.04$, $p = .04$; $z^{X3} = 2.09$, $p = .03$). Therefore, one can conclude to a mediation effect in this case.

The level of activation perceived in the partner appeared to mediate the relationship between the Task-achievement situations and the self-use perception of the task management process in HMHR (Figure 5 F X1) and LMHR (Figure 5 F X3) conditions. This is confirmed in these two cases by the Sobel tests ($z^{X1} = 2.92$, $p = .03$; $z^{X3} = 2.72$, $p = .02$).

Table 8

Descriptive statistics

	Overall		HMHR		LMHR		HMLR		LMLR	
	Self	*Partner*	*Self*	*Partner*	*Self*	*Partner*	*Self*	*Partner*	*Self*	*Partner*
Dependent variables	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Emotional dimensions										
Activation	3.80 (0.92)	3.71 (0.94)	4.18 (0.65)	4.00 (0.81)	4.00 (0.81)	3.87 (0.50)	3.66 (0,77)	4.00 (0.81)	3.16 (1.19)	2.83 (1.11)
Dominance	2.94 (1.09)	3.24 (1.01)	2.86 (1.35)	3.13 (1.24)	3.18 (0.83)	3.60 (0.73)	3.41 (0.51)	3.63 (0.67)	2.25 (1.21)	2.58 (0.99)
Valence	3.32 (1.20)	3.25 (1.14)	3.62 (1.31)	3.50 (1.21)	3.43 (0.96)	3.43 (1.03)	3.90 (0.83)	3.72 (1.21)	2.25 (1.05)	2.25 (0.96)
Achievement emotions										
Anxiety	2.49 (1.45)	1.96 (1.22)	2.75 (1.23)	1.81 (1.10)	2.31 (1.49)	1.66 (1.11)	2.27 (1.73)	2.09 (1.10)	2.58 (1.50)	2.41 (1.37)
Anger	2.71 (1,69)	2.41 (1.65)	2.68 (1.13)	2.75 (1.43)	2.87 (1.96)	2.25 (2.01)	2.41 (1.97)	1.91 (1.43)	2.83 (1.80)	2.66 (1.82)
Frustration	4.14 (1.91)	3.67 (1.75)	3.56 (1.99)	3.62 (1.66)	4.43 (2.15)	3.43 (1.75)	3.75 (1.42)	3.33 (1.66)	4.91 (1.72)	4.41 (1.88)
Shame	2.16 (1.49)	1.91 (1.40)	1.50 (0.89)	1.43 (0.81)	2.25 (1.29)	1.56 (0.96)	1.50 (0.79)	1.91 (0.81)	3.58 (1.97)	3.00 (1.90)
Disappointment	3.49 (1.86)	3.00 (1.79)	2.68 (1.88)	2.81 (1.83)	3.46 (1.80)	2.43 (1.75)	4.00 (1.70)	3.33 (1.83)	4.08 (1.88)	3.66 (2.10)
Hopelessness	2.53 (1.66)	2.25 (1.51)	2.31 (1.35)	2.31 (1.40)	2.50 (1.63)	1.93 (1.28)	1.83 (1.26)	1.50 (1.40)	3.58 (2.06)	3.45 (1.96)
Boredom	1.44 (1.04)	1.47 (1.01)	1.31 (0.60)	1.31 (1.01)	1.06 (0.25)	1.56 (0.89)	1.50 (1.24)	1.16 (1.01)	2.08 (1.62)	1.90 (1.44)
Sadness	1.55 (1.21)	1.64 (1.27)	1.43 (0.89)	1.43 (1.09)	1.43 (1.09)	1.18 (0.54)	1.16 (0.38)	1.66 (1.09)	2.25 (1.95)	2.50 (1.50)
Hope	4 (1.59)	3.90 (1.48)	4.00 (1.60)	4.26 (1.48)	4.53 (1.50)	4.00 (1.50)	3.91 (1.67)	3.90 (1.48)	3.41 (1.56)	3.33 (1.37)
Pride	3.35 (1,95)	3.12 (1,91)	3.56 (2.50)	3.26 (2.43)	3.56 (1.86)	3.50 (1.89)	3.75 (1.13)	3.41 (2.43)	2.41 (1.83)	2.16 (1.33)
Joy	4.39 (1.66)	4.29 (1.61)	4.50 (1.36)	4.56 (1.50)	4.43 (1.96)	4.31 (1.57)	5.25 (1.28)	5.00 (1.50)	3.33 (1.55)	3.09 (1.13)
Enjoyment	5.35 (1.27)	4.67 (1.53)	5.56 (1.37)	5.18 (1.47)	5.31 (1.25)	4.75 (1.91)	5.66 (1.37)	4.8.3 (1.47)	4.83 (1,52)	3.75 (0.96)
Relaxation	3.35 (1.68)	3.32 (1.82)	3.12 (1.70)	2.66 (1.67)	3.00 (1.59)	3.62 (2.06)	3.75 (2.17)	4.00 (1.67)	3.75 (1.21)	3.09 (1.64)
Relief	3.12 (1.79)	3.33 (1.88)	3.43 (1.89)	3.85 (2.34)	3.40 (1.72)	3.81 (1.42)	3.54 (1.75)	3.45 (2.34)	2.00 (1.47)	2.00 (1.65)
Contentment	4.07 (1.82)	4.00 (1.66)	4.75 (2.04)	4.75 (1.98)	4.12 (1.70)	4.12 (1.36)	4.16 (1.33)	4.08 (1.98)	3.00 (1.80)	2.75 (1.60)
Gratitude	3.30 (1.66)	2.86 (1.55)	3.53 (1.95)	2.86 (1.84)	3.06 (1.52)	2.66 (1.39)	4 (1.41)	4.09 (1.84)	2.66 (1.55)	2.00 (1.12)
Socio-cognitive processes										
Sustaining mutual under-standing	4.90 (1.21)	4.86 (1.28)	4.88 (1.10)	4.92 (0.95)	5.25 (1.18)	5.16 (1.43)	5.11 (1.18)	5.02 (0.95)	4.27 (1.30)	4.22 (1.38)
Information pooling	4.20 (1.29)	4.58 (1.25)	4.68 (1.22)	4.58 (1.25)	4.46 (1.21)	4.45 (1.21)	3.77 (1.28)	3.87 (1.25)	3.64 (1.31)	3.64 (1.35)
Transactivity	4.18 (1.46)	4.19 (1.53)	4.43 (1.35)	4.28 (1.58)	4.75 (1.39)	4.75 (1.35)	4.16 (1.46)	4.45 (1.58)	3.12 (1.28)	3.08 (1.27)
Reaching consensus	3.13 (1.30)	3.19 (1.36)	3.62 (1.10)	3.69 (1.10)	2.97 (1.26)	3.03 (1.38)	3.30 (1.44)	3.41 (1.10)	2.54 (1.31)	2.52 (1.38)
Task management	4.86 (1.25)	4.87 (1.26)	5.16 (1.21)	5.08 (1.27)	5.39 (1.04)	5.39 (1.13)	4.44 (1.38)	4.55 (1.27)	4.16 (1.09)	4.22 (1.24)
Time management	3.28 (1.41)	3.46 (1.40)	3.40 (1.41)	3.53 (1.39)	3.46 (1.25)	3.65 (1.41)	3.54 (1.78)	3.45 (1.39)	2.62 (1.20)	3.12 (1.36)

Note. **Activation and Dominance** (1 = *very weakly,* 2 = *weakly*, 3 = *moderately*, 4 = *strongly*, 5 = *very strongly*). **Valence** (1 = *very negatively,* 2 = *negatively*, 3 = *neither negatively nor positively*, 4 = *positively*, 5 = *very positively*). **Achievement emotions** (1 = *not at all,* 2 = *very weakly*, 3 = *weakly*, 4 = *moderately*, 5 = *quite strongly*, 6 = *strongly*, 7 = *very strongly*). **Socio-cognitive processes** (1 = *never,* 2 = *very rarely*, 3 = *rarely*, 4 = *moderately often*, 5 = *quite often*, 6 = *often*, 7 = *very often*)

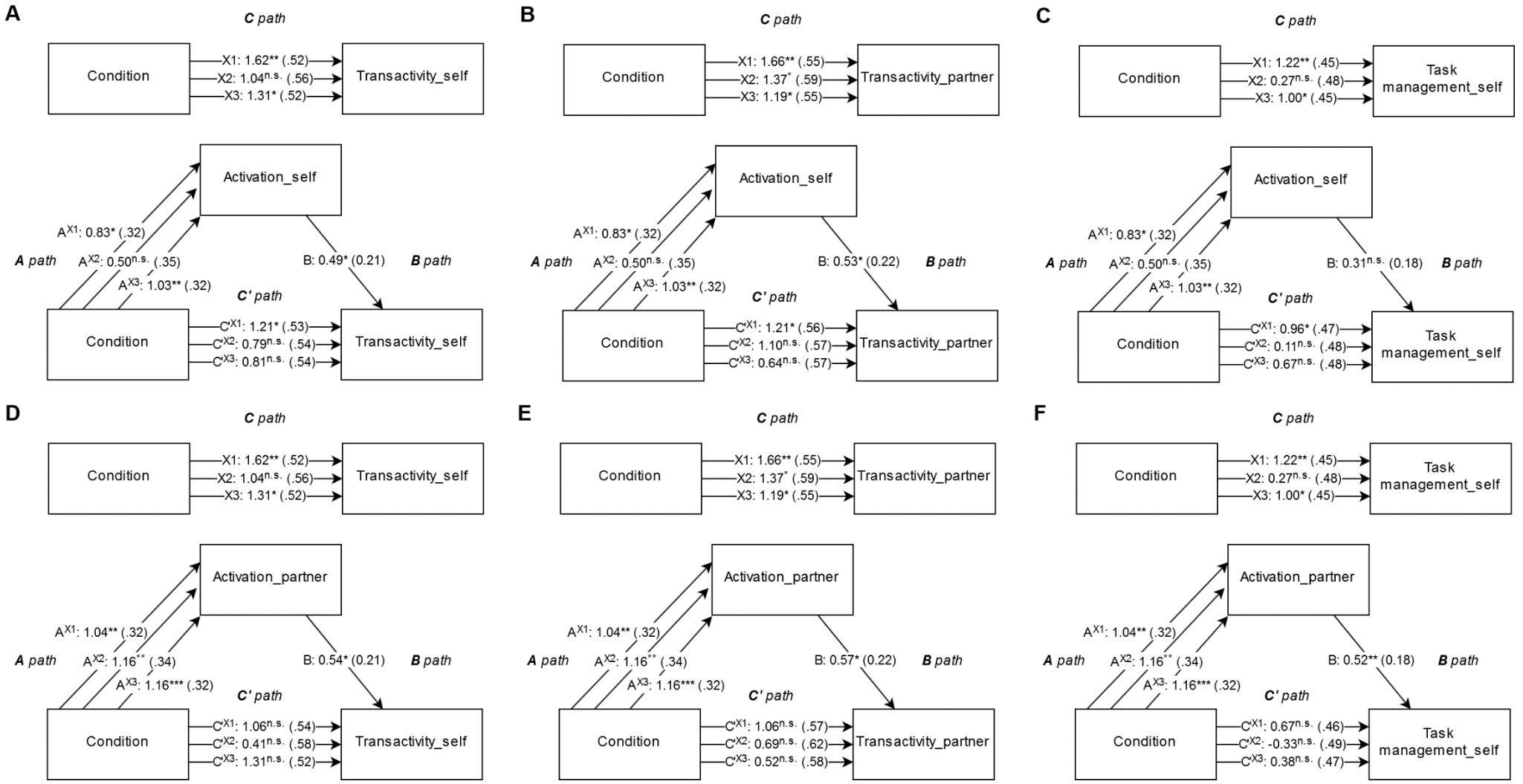

Figure 5. Mediation effects of Activation

Table 9

Results concerning emotional dimensions, achievement emotions, and perception of socio-cognitive processes use

	Emotional dimensions						Emotions		Socio-cognitive processes use		
	Activation		Dominance		Valence		Achievement emotions		Transactivity		Task management
Conditions	Self	Partner	Self	Partner	Self	Partner	Self	Partner	Self	Partner	Self
HMHR	High†	High†	**nd**	**nd**	High†	High†	Joy† *Anxiety Anger Frustration Enjoyment Relaxation Hope Sadness Pride Relief Contentment Gratitude*	Joy† Relief† Contentment† *Anger Frustration Enjoyment Hope Disappointment Pride Gratitude*	High†	High†	High†
LMHR	High†	High†	High†	High†	High†	High†	**Joy**† *Anger Frustration Boredom Enjoyment Relaxation Hope Pride Disappointment Relief Contentment Gratitude*	**Joy**† Relief† Contentment† *Frustration Enjoyment Relaxation Hope Pride Gratitude*	**High**†	**High**†	**High**†
HMLR	nd	**High**†	**High**†	**High**†	**High**†	**High**†	**Joy**† *Frustration Enjoyment Relaxation Disappointment Pride Relief Contentment Gratitude Hope*	**Joy**† **Relief**† **Contentment**† **Gratitude**† *Frustration Enjoyment Relaxation Hope Disappointment Pride*	nd	**High**†	nd
LMLR	Low	Low	Low	Low	Low	Low	*Frustration Enjoyment Relaxation Joy Hope Hopelessness Shame Disappointment*	Hopelessness‡ Sadness‡ *Frustration Enjoyment Relaxation Hope Shame Joy Disappointment*	Low	Low	Low

Note. LMLR is used as control condition (Low). †: significant difference with LMLR condition. ‡: significant difference with the other conditions. nd: no significant difference with LMLR condition. **bold:** non-expected significant results (contrary to hypotheses). *italic*: emotions self-experienced and perceived in partner at least more than a "weak" level.

4. Discussion

4.1 Hypotheses and findings

At a descriptive level, a wide range of emotions (positive and negative) were self-experienced and perceived in the partner more than "weakly" in every condition, contrasting, with the few polarized emotions highlighted in the CVT (Pekrun, 2006). Indeed, our study shows that even "fully positive" situations (HMHR) are prone to elicit negative emotions and "fully negative" situations (LMLR) are prone to elicit positive emotions (Table 9). In our view, several reasons may explain this result: (1) all participants, regardless of task achievement, enjoyed, on average, "quite strongly" the task (Table 8), (2) some emotions are not exclusively related to task achievement (e.g., frustration may also reflect cognitive processing of information) and therefore occurs no matter how well the task is achieved, (3) most of the time (and in our task as well), success and failure are probabilistic. Indeed, even when failure is almost inevitable, there is always some hope that the situation may improve or some relief after an almost certain success. Therefore, it makes sense that some positive and negative, activating and deactivating emotions are reported in each experimental condition more than "weakly". This result supports the idea that an emotional profile is better suited than a single emotion to plainly explain how people's emotions relate to task achievement (Jarrell et *al.*, 2016). However, it is worth noting that some emotions are highly unlikely to emerge in certain situations (e.g., shame and hopelessness when task mastery and ranking are high or pride or relief when task-mastery and ranking feedback are low). As proposed in the CVT, some emotions, therefore, appear prototypical to specific task-achievement situations. Therefore, these prototypical emotions were posited to significantly differ according to the different levels of action-outcome, situation-outcome and success expectancies. For the sake of clarity, assumptions regarding emotional dimensions, achievement emotions and the perception of socio-cognitive processes (Table 1) are compared

with actual findings (Table 9) and discussed in the following sections, also considering how the collaborative situations may explain some observed discrepancies.

4.1.1 Low task mastery low ranking condition

In this condition, participants were intended to think that their work was producing negative outcomes due to their poor self-action. As expected, participants self-experienced and perceived in their partner the lowest level of activation. This result is consistent with a situation where participants disengage the task (i.e., give up when faced with dull or difficult tasks; Liem, Lau, & Nie, 2008). Participants also self-experienced and perceived in their partner the lowest level of dominance, which is also consistent with the combination of low action-outcome and low situation-outcome expectancies. Consistently, participants also self-experienced and perceived in their partner this situation as the most negative, in line with low success expectancies. Regarding achievement emotions, negative and deactivating emotions were expected to be self-experienced more intensively in this condition comparing to the other conditions. It is the case for the hopelessness and sadness perceived in the partner. However, shame (activating emotion) was self-experienced and perceived in the partner at a relatively high level in this condition, indicating, as expected, that participants attribute negative outcomes to themselves and not to external circumstances. Finally, and in line with the assumption proposed, the use of the socio-cognitive processes transactivity and task-management was perceived as relatively low compared to the other conditions, consistently with false feedback. Therefore, this condition seems to decrease how participants reason and build on their partner's contributions and manage group work.

4.1.2 High task mastery high ranking condition

In this condition, participants were intended to think that their work was producing positive outcomes and that their self-action was necessary for these positive outcomes. As expected,

participants self-experienced and perceived in their partner a relatively high level of activation, compared to LMLR condition. This result denotes a higher level of engagement in this condition. Participants also self-experienced the situation as more positive and perceived the same thing in their partner, consistently with high success expectancies. However, and as opposed to the assumption made, they did not feel and perceive a higher level of dominance compared to LMLR condition. This result could be explained in terms of loss aversion (i.e., the tendency for losses to have a more significant hedonic impact than comparable gains; Rick, 2011), as success was just expected and not guaranteed. As loss aversion has a tight connection with fear (Schulreich, Gerhardt, & Heekeren, 2016), a low coping potential emotion (Broekens, 2012), the dread of seeing a highly positive situation deteriorate could have lessened the overall dominance perception. Regarding achievement emotions, positive and activating emotions were expected to be self-experienced more intensively in this condition comparing to the other conditions. If participants indeed self-experienced and perceived in their partner a higher level of joy (activating) compared to LMLR condition, they also perceived relief and contentment (retrospective and deactivating) in their partner. This result seems to go hand in hand with a weaker level of dominance. However, and interestingly, these emotions are more intensively perceived in their partner rather than self-experienced (self-reported results are marginally significative, Table 6). This result could indicate that, in this collaborative context, participants could primarily focus on their partner's emotions rather than theirs. Finally, and in line with the assumption made, the use of the socio-cognitive processes transactivity and task-management was perceived as relatively high in this condition. Therefore, this condition seems to increase how participants reason and build on their partner's contributions and manage the group work.

4.1.3. Low task mastery high ranking condition

In this condition, participants were intended to think that the situation was producing positive outcomes in any case despite their poor self-action. As expected, participants self-experienced

and perceived in their partner a relatively high level of dominance compared to LMLR condition. This result is consistent with the combination of low action-outcome and high and positive situation-outcome expectancies (Pekrun, 2006). Participants also self-experienced the situation as more positive than in the LMLR condition and perceived the same thing in their partner, consistently with high success expectancies. However, and contrary to what was expected, participants self-experienced and perceived in their partner a higher level of activation (compared to LMLR condition). This result contradicts our assumption because, in a kind of situation where one's own work is poor and no self-action is needed to succeed, participants should tend to disengage and reduce group work, leading to low activation. One possible explanation for this result could be the expected high reward. Indeed, the unexpected possibility to be successful against the run of play could have kept the participants aroused. Regarding the achievement emotions, positive and deactivating emotions were expected to be self-experienced and perceived in the partner more intensively in this condition than in LMLR condition. This hypothesis appears correct for the perception of contentment and relief in their partner. However, participants also self-experienced and perceived a relatively high level of joy (retrospective and activating) in their partner. Finally, and in disagreement with the assumption made, the use of the socio-cognitive processes transactivity and task-management was perceived as relatively high in this condition. A positive outcome could, therefore, contribute to increasing how participants reason and build on their partner's contributions and manage the group work, despite low task mastery. This point will be discussed in section 4.2.

4.1.3 High task mastery low ranking condition

In this condition, low action-outcome expectancies were the result of high and negative situation-outcome despite high task mastery. In other words, even if participants had a good task

mastery, it was useless as the ranking was staying low, leading them to believe that other previous dyads (i.e., external circumstances, the situation) were better than them (high and negative situation-outcome expectancies).

As expected, participants did not self-experience a higher level of activation compared to LMLR condition. However, they perceived a higher level of activation in their partner. In addition, and contrary to our assumption, participants self-experienced and perceived in their partner a relatively high level of dominance despite low action-outcome expectancies. Counterintuitively also, participants self-experienced the situation as more positive than LMLR condition and as positive as the other conditions, despite low success expectancies. They also perceived the same thing in their partner. More surprising still, participants self-experienced (joy) and perceived in their partner positive emotions (relief, contentment, gratitude) at a relatively higher level than LMLR condition and at the same level than conditions with high success expectancies. It was also the only condition where gratitude was perceived in the partner at a higher level than all the other conditions. Finally, although participants did not perceive an increase in their own use of socio-cognitive processes, they perceive a higher partner-use of processes dedicated to reason and build on the partner's contributions (transactivity process). Taken as a whole, these results seem to show that 1) participants seem to overlook task outcomes and focus on task mastery and 2) see task mastery mainly through their partner. These points will be discussed in section 4.3.

4.2 Does achievement emotions skew the perception of socio-cognitive processes?

Activation (especially activation perceived in the partner) is the only emotional dimension mediating the relation between task-achievement appraisals and the perception of the use of the socio-cognitive processes transactivity and task-management. No other emotional dimensions

nor achievement emotions appeared to mediate this relationship. In our view, this result reinforces the idea that people hardly associate their own or partner's conscious discrete emotions with the use of specific socio-cognitive processes. Indeed, although people deliberate actions based on what is available to conscious awareness (e.g., subjective feeling), an implicit system also process complex information that can influence actions below the level of consciousness (Sentman, 2007). Therefore, the cognitive and socio-cognitive effects of specific emotions, although significant, could operate mostly under the level of consciousness and be challenging to report explicitly. Instead, at a conscious level, participants seem to rely on vaguer affective states to evaluate how they use some socio-cognitive processes during collaborative problem-solving. In our case, high levels of activation mediating the relationship between task-achievement appraisals and the perception of socio-cognitive processes could, therefore, interfere with that perception. Indeed, participants in LMHR condition perceive that they reason and build more on their partner's contributions and manage more the group work in a situation where they regularly received low task mastery feedback. We propose that, as participants self-experienced and perceived in their partner a high level of activation due to positive expected outcomes in this condition, they also tend to perceive themselves as collaborating more efficiently. One question then arises: to what extent is this perception in line with the actual use of socio-cognitive exchanges? Affective arousal (identical to activation) is known to influence judgments, learning, and memory (Tyng, Amin, Saad, & Malik, 2017). For Storbeck and Clore (2008), arousal can serve as information and influence judgments by indicating the importance of an event. However, these authors also outline that the cause of increased arousal can sometimes be misattributed and transferred to another contiguous but unrelated events (Dutton & Aron, 1974). In LMHR condition, we assume that a similar process could have occurred. Indeed, activation elicited by high success expectancies could have led the participants to evaluate a greater use of some collaborative processes. However, this evaluation could be more or less

disconnected from what they really did. This possible explanation must, of course, be deepened (cf. section 6)

4.3 Do partner's emotions influence group achievement goal?

Another unexpected result is how participants perceive task achievement in HMLR condition. In this condition, participants, according to feedback, fail to reach a positive outcome despite high task mastery. The combination of low action-outcome and high and negative situation-outcome expectancies should have led them to decrease group work and, hence, the perception of the use of the socio-cognitive processes. This is found at an individual level since participants did not evaluate themselves as reasoning and building on the partner's contributions or manage the group work more than in LMLR condition. However, in this collaborative condition (HMLR), although participants did not feel particularly aroused by the task, they perceived in their partner a relatively high level of dominance and valence. Why do participants perceive high dominance and valence in their partner when failure is expected? We propose that some emotions perceived in the partner intervene in these circumstances. First, activation perceived in their partner may lead participants to evaluate their partner as reasoning and building more on their contributions (mediating effect, Figure 5 E). Second, participants perceive a higher level of gratitude from their partner only in this condition (Figure 3 G). Taken as a whole, these results are consistent with some findings concerning group influence in collaborative learning and problem-solving. According to Mullins et *al.* (2013), collaboration with a partner may increase the feeling of relatedness when group activity appears positively valued by the other, promoting task enjoyment, collective efficacy, and group cohesiveness. In doing so, it could strengthen motivation and engagement, reinforce group persistence and effortful learning, leading to appraise a difficult situation more as a challenge than a predictable failure (Kaplan & Maehr, 2002; Mullins et *al.*, 2013). In our view, these different aspects intervened in the HMLR condition and drove the group focus towards a mastery (i.e., the desire to understand the task

and develop abilities) rather than a performance goal (i.e., the desire to obtain positive outcomes) (Darnon, Butera, & Harackiewicz, 2007; Pintrich, Conley, & Kempler, 2003). What we found is in line with the fact that a mastery goal drives people to associate their performance with individual standards. In other words, they could compare their performance, not to inter-groups (the previous dyads in our study) but intra-group standards (Hall et *al.*, 2016). In this way, participants could not have considered the ranking as relevant to reflect their performance. Instead, they may have self-experienced and perceived in their partner high dominance and positive valence related to their group standards (e.g., high task mastery). We propose that activation and gratitude perceived in the partner could facilitate a switch toward a mastery goal in difficult collaboration when collective efficacy is preserved (i.e., the conviction that the group is able to perform a given task; Mullins et *al.*, 2013).

5. Conclusion

Drawing on the CVT that highlights the role of achievement emotions in learning, we elaborated an experiment aiming at studying the relationships between task-achievement appraisals, emotions, and the perception of the socio-cognitive processes use in group problem-solving. Four different collaborative situations were built by the manipulation of action-outcome, situation-outcome, and success expectancies through false feedback concerning group task mastery and group expected ranking. Emotional dimensions, achievement emotions and socio-cognitive processes, both self-experienced and perceived in the partner, were compared in these different conditions. Besides, the mediating effects of emotions on the relationship between task-achievement appraisals and the perception of the socio-cognitive processes have been tested. In general, four main results can be highlighted. First, we confirm that group task achievement is related to emotions. Both emotional dimensions and achievement emotions are influenced by task-achievement appraisals. In addition, this effect is not limited to self-experienced emotions

but also found for the emotions perceived in the partner. Self-experienced activation, dominance, valence, shame, and joy, as well as activation, dominance, valence, hopelessness, sadness, gratitude, relief, and contentment perceived in the partner, were significantly influenced by task-achievement appraisals.

Second, no mediating effects of achievement emotions have been found. This seems to demonstrate that subjective feelings of achievement emotions do not intervene to evaluate how participants mobilize socio-cognitive processes during real-time collaborative problem-solving. In our view, this can be explained through at least two reasons: 1) discrete emotions are too specific to be related to particular socio-cognitive processes in synchronous collaboration and 2) the effects of achievement emotions on socio-cognitive processes could be mostly unconscious, or at least implicit.

Third, what we found, however, is that the level of activation (especially perceived in the partner) could serve as a heuristic giving an overview of the socio-cognitive involvement. This could be depicted as follows: "If my partner and I are aroused by what we are doing, then our group has a valuable collaborative involvement". In this way, activation could skew how people appraise collaboration and may lead to inaccurate judgments under certain circumstances. For example, in our experiment, a high level of activation probably induced by high success expectancies could have skewed the participants' perception regarding their use of some socio-cognitive processes (transactivity and task management) Fourth, the partner's emotions could change the group achievement goal (towards mastery) in a difficult collaborative situation when collective efficacy is preserved. Indeed, activation and gratitude perceived in the partner could enhance group relatedness and stimulate mastery rather than performance goals. In this way, the group could exhibit more persistence than what we could expect in individual settings.

6. Further considerations

As with any research involving human subjects, the present study is not without limitations. This is especially true in this experiment as we tried to preserve both experimental (in order to identify causal relationships) and ecological (in order to assess genuine collaboration) sides in the assessment of the perception of socio-cognitive processes. Three limitations to the present study should be noted. First, although several methodological precautions have been taken to maximize the belief that feedback was true, we cannot be sure that participants have entirely related their achievement to it. In addition, some confounding variables such as the experience with similar problem-solving collaborative games or the perception of the actual progress in the game map could have weakened the feedback effect (perceived progress is also related to task-achievement appraisals and achievement emotions; see Hall et *al.*, 2016). Second, our study included a vast majority of men (46) and only a few women (10). In addition to limiting the scope of the results obtained, the low number of women prevented us from evaluating a potential gender effect. Finally, another limitation is the sample size that allowed us to uncover findings with only large effect sizes. Therefore, some interesting but more moderate effects could not be considered in this study, which limits the global comprehension of the investigated phenomenon.

Besides, as our experiment focused on the perception of socio-cognitive processes, we did not investigate the actual socio-cognitive exchanges nor their relationship with group performance. However, as outlined above, we assume that, in at least one condition (LMHR), the activation could have skewed judgment regarding the use of socio-cognitive processes. It is also difficult to clearly explain why the perception of only two socio-cognitive processes (viz., transactivity and task management) were mediated by emotional activation. Drawing on our findings, it is, in fact, possible that all socio-cognitive processes are influenced by emotions but only some are related to the subjective feeling of emotional activation. Transactivity (as it may involve constructive conflict) and task management (as it may involve negotiation and compromise) could

be more related to arousal than other socio-cognitive processes, such as sharing mutual understating or information pooling for example. In this regard, we plan to compare the participants' self-evaluation and the actual use of socio-cognitive processes through an objective assessment (e.g., by transcribing and categorizing all the communicative exchanges). This could help to deeply enrich the relationships between emotions (self-experienced and perceived in the partner) and their impact (implicit or explicit) on socio-cognitive processes.

Metacognitive aspects have not been considered as part of this study. Metacognitive processes refer to the knowledge of one's own cognitive processes (Davidson, Deuser, & Sternberg, 1994), and precisely, higher-order thinking directed to the appraisal, monitoring, and control of the cognitive processes involved in problem-solving (Livingston, 2003). Similarly, socio-metacognition refers to the learner's abilities to regulate group processes to optimize collaboration (Hogan, 1999), especially regarding socio-cognitive processes. In our study, we only focused on "default" socio-cognitive behaviors under some task-achievement appraisals constraints. In other terms, we have not systematically analyzed how participants explicitly change their socio-cognitive processes to adapt to the different situations encountered. However, socio-metacognitive abilities are of growing interest in (CS)CL and people's ability to monitor and regulate socio-cognitive collaborative processes is a major component of efficient collaboration (Borge & White, 2016, Järvelä & Hadwin, 2013). In this regard, the results uncovered in this study outline that meta-emotional monitoring and regulation could play an important role in socio-metacognition. Especially, stimulating the sharing (regulation aspect) of emotion such as gratitude or taking into account the possible skewing effect of some affective states such as group arousal (monitoring aspect) could lead to better regulation of socio-cognitive processes in (CS)CL.

Finally, although we do not think that this specific experimental design can be used as it stands for practical purposes, we believe that more research in this area could lead to a better understanding of collaborative problem-solving and enrich the development of collaborative tools integrating these research findings in their design. For example, in difficult collaborative tasks, developing tools promoting the sharing of social emotions such as gratitude to foster a feeling of relatedness and persistence between group members, which could, as our results suggest, preserve the use of qualitative socio-cognitive processes. Also, the possible skewing effect of activation on the perception of some socio-cognitive processes leads us to believe that the perception of some socio-cognitive processes could not be always in line with what is really done by collaborators. In our opinion, tools should be developed to counterbalance this effect. For example, some computational linguistic techniques such as semantic analysis of discourse could provide cues about real-time use of socio-cognitive processes and help problem-solvers to increase awareness and usage of qualitative socio-cognitive processes.

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Appendix A

Dependant variables	ICC	p-value
Activation_self	0,417289220917823	0,996909113824028
Dominance_self	0,650286819147686	0,999998308302363
Valence_self	0,737035500644138	0,999999985713471
Anxiety_self	0,306593503825315	0,975353778024148
Anger_self	0,253863134657837	0,946836870331608
Deception_self	0,535534326405373	0,99986420552872
Hopelessness_self	0,401133738918553	0,995625537586906
Boredom_self	0,407874420998456	0,996208023405852
Hope_self	0,24875246798104	0,943099326006245
Pride_self	0,563855215980878	0,999946576797504
Frustration_self	0,474014259943304	0,999207197107365
Gratitude_self	0,175680748821071	0,866043067941281
Shame_self	0,267725840336134	0,956034577750471
Joy_self	0,301263958767947	0,973206381602526
Enjoyment_self	0,257211538461538	0,949182274273816
Relaxation_self	0,152212939845283	0,830989323574365
Contentment_self	0,668216440795331	0,999999282441861
Relief_self	0,289897992760777	0,968125336080946
Sadness_self	0,288321167883212	0,967363749162101
Activation_other	0,526526001252056	0,999820379856196
Dominance_other	0,183674727819329	0,876797441955735
Valence_other	0,582233344404024	0,999972176823447
Anxiety_other	-0,0164948789344277	0,459513859430736
Anger_other	0,548622945067088	0,999910842404882
Deception_other	0,489689102899613	0,999478362295305
Hopelessness_other	0,213703198378005	0,911932588003048
Boredom_other	0,181795720377371	0,874323483112849
Hope_other	-0,184522336666673	0,123012380106421
Pride_other	0,298590807966487	0,972074148005347
Frustration_other	0,357303370786517	0,989636494904887
Gratitude_other	0,321783556305163	0,980722957120587
Shame_other	0,49540596287268	0,999554458558424
Joy_other	0,278800522911944	0,962454335481835
Enjoyment_other	0,143078712679333	0,815943951501539
Relaxation_other	0,116529137464281	0,767884019123022
Contentment_other	0,538277385647779	0,999875488770369
Relief_other	0,335784725238282	0,984786625206083
Sadness_other	0,0852696185883385	0,703675361334315
Reaching_consensus_self	0,183667093699473	0,876787457438374
Mutual_understanting_self	0,288833034128322	0,967612538482882
Transactivity_self	0,121259029927761	0,77690462669245
Task_management_self	0,221257247267444	0,919507588832159
Information_pooling_self	0,051842612661327	0,627553641166723
Time_management_self	0,406435189168062	0,996089605717987
Reaching_consensus_other	0,15453250681249	0,834685561478128
Mutual_understanting_other	0,267678127462687	0,956005189292426
Transactivity_other	0,293687282613041	0,969897899770278
Task_management_other	0,258477983285197	0,950048428985867
Information_pooling_other	0,0840014077923792	0,700914519889903
Time management_other	0,42644533485976	0,997480424830841

Appendix B

In HMHR condition, shame $t(15) = -2.23$, $p = 0.97$, disappointment $t(15) = 1.45$, $p = 0.08$, hopelessness $t(15) = 0.92$, $p = 0.18$, boredom $t(15) = -4{,}56$, $p = 0.99$ and sadness $t(15) = -2.53$, $p = 0.33$ were not self-experienced by participants at more than a "weak" level. Boredom $t(15) = 1.23$, $p = 0.11$, sadness $t(15) = 1.60$, $p = 0.06$, anxiety $t(15) = -0.67$, $p = 0.74$, shame $t(15) = -2.76$, $p = 0.99$, hopelessness $t(15) = 0.89$, $p = 0.19$ and relaxation $t(14) = 1.54$, $p = 0.07$ were not perceived at more than a "weak" level in the partner.

In LMHR condition, boredom $t(15) = 1$, $p = 0.16$, sadness $t(15) = 1{,}60$, $p = 0.06$, anxiety $t(15) = 0.83$, $p = 0.20$, shame $t(15) = 0.77$, $p = 0.22$ and hopelessness $t(15) = 1.22$, $p = 0.11$ were not self-experienced by participants at more than a "weak" level. Sadness $t(15) = 1.37$, $p = 0.09$, anxiety $t(14) = -1.16$, $p = 0.86$, anger $t(15) = 0.49$, $p = 0.31$, shame $t(15) = -1.81$, $p = 0.95$, disappointment $t(15) = 1$, $p = 0.16$, hopelessness $t(15) = -0.19$, $p = 0.57$ and boredom $t(15) = -1.96$, $p = 0.96$ were not perceived at more than a "weak" level in the partner.

In HMLR condition, boredom $t(11) = 1.39$, $p = 0.09$, sadness $t(11) = 1.48$, $p = 0.08$, anxiety $t(10) = 0.52$, $p = 0.30$, anger $t(11) = 0.73$, $p = 0.24$, shame $t(11) = -2.17$, $p = 0.97$ and hopelessness $t(11) = -0.45$, $p = 0.67$ were not self-experienced by participants at more than a "weak" level. Boredom $t(11) = 1$, $p = 0.16$, sadness $t(11) = 1.43$, $p = 0.09$, anxiety $t(10) = 1.04$, $p = 0.15$, anger $t(11) = -0.23$, $p = 0.58$, shame $t(11) = -0.19$, $p = 0.57$ and hopelessness $t(11) = -2.17$, $p = 0.97$ were not perceived at more than a "weak" level in the partner.

In LMLR condition, anxiety $t(11) = 1.34$, $p = 0.10$, anger $t(11) = 1.60$, $p = 0.06$, boredom $t(11) = 0.17$, $p = 0.43$, sadness $t(11) = 0.44$, $p = 0.33$, pride $t(11) = 0.78$, $p = 0.22$, relief $t(11) = 0$, $p = 0.50$, contentment $t(11) = 1.62$, $p = 0.06$ and gratitude $t(11) = 1.48$, $p = 0.08$ were not self-experienced by participants at more than a "weak" level. Anxiety $t(11) = 0.15$, $p = 0.15$, anger $t(11) = 1.26$, $p = 0.11$, boredom $t(10) = -0.20$, $p = 0.58$, sadness $t(11) = 1.14$, $p = 0.13$, pride $t(11) = 0.43$, $p = 0.33$, relief $t(11) = 0$, $p = 0.50$, contentment $t(11) = 1.62$, $p = 0.06$ and gratitude $t(11) = 0$, $p = 0.5$ were not perceived at more than a "weak" level in the partner.

Appendix C

Mediation Effects for the emotional dimensions Activation and Dominance (self-experienced and perceived in partner), N = 56

		Transactivity (self)				Transactivity (partner)				Task management (self)			
				95% CI				*95% CI*				*95% CI*	
	Effect	*Estimate*	*SE*	*Lower*	*Upper*	*Estimate*	*SE*	*Lower*	*Upper*	*Estimate*	*SE*	*Lower*	*Upper*
Activation (self)	*Indirect*												
	X1	**0.41**	**0.28**	**0.01**	**1.07**	**0.45**	**0.29**	**0.01**	**1.15**	0.26	0.18	-0.06	0.68
	X2	0.24	0.22	-0.17	0.71	0.27	0.24	-0.19	0.79	0.15	0.13	-0.15	0.42
	X3	**0.50**	**0.25**	**0.10**	**1.08**	**0.54**	**0.27**	**0.11**	**1.19**	0.32	0.19	-0.4	0.74
	Direct												
	X1	**1.21**	**0.53**	**0.14**	**2.28**	**1.21**	**0.56**	**0.09**	**2.34**	**0.96**	**0.47**	**0.21**	**1.90**
	X2	0.79	0.54	-0.30	1.89	1.10	0.57	-0.05	2.26	0.11	0.48	-0.85	1.08
	X3	0.81	0.54	-0.29	1.91	0.64	0.57	-0.50	1.80	0.67	0.48	-0.29	1.64
	Total												
	X1	**1.62**	**.52**	**0.57**	**2.67**	**1.66**	**0.55**	**0.55**	**2.77**	**1.22**	**0.45**	**0.32**	**2.13**
	X2	1.04	.56	-0.08	2.16	**1.37**	**0.59**	**0.18**	**2.56**	0.27	0.48	-0.69	1.24
	X3	**1.31**	**.52**	**0.25**	**2.36**	**1.19**	**0.55**	**0.08**	**2.30**	**1.00**	**0.45**	**0.09**	**1.90**
Activation (partner)	*Indirect*												
	X1	**0.56**	**0.26**	**0.11**	**1.15**	**0.60**	**0.28**	**0.14**	**1.23**	**0.55**	**0.23**	**0.14**	**1.04**
	X2	**0.63**	**0.35**	**0.82**	**1.46**	**0.67**	**0.7**	**0.10**	**1.53**	**0.61**	**0.29**	**0.11**	**1.25**
	X3	**0.63**	**0.31**	**0.12**	**1.34**	**0.67**	**0.32**	**0.14**	**1.40**	**0.61**	**0.27**	**0.15**	**1.20**
	Direct												
	X1	1.06	0.54	-0.03	2.15	1.06	0.57	-0.09	2.21	0.67	0.46	-0.24	1.60
	X2	0.41	0.58	-0.77	1.59	0.69	0.62	-0.54	1.94	-0.33	0.49	-1.33	0.65
	X3	0.68	0.55	-0.43	1.80	0.52	0.58	-0.65	1.70	0.38	0.47	-0.56	1.32
	Total												
	X1	**1.62**	**0.52**	**0.57**	**2.67**	**1.66**	**0.55**	**0.55**	**2.77**	**1.22**	**0.45**	**0.32**	**2.13**
	X2	1.04	0.56	-0.08	2.16	**1.37**	**0.59**	**0.18**	**2.56**	0.27	0.48	-0.69	1.24
	X3	**1.31**	**0.52**	**0.25**	**2.36**	**1.19**	**0.55**	**0.08**	**2.30**	**1.00**	**0.45**	**0.09**	**1.90**

Note. Estimate = unstandardized coefficient. When confidence interval does not cross 0, a significant effect (in bold) is found. Bootstrap method for confidence intervals (simulations = 5000). X1 (LMLR vs. LMHR), X2 (LMLR vs. HMLR), X3 (LMLR vs. HMHR)