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Examining the Relationship Between Socially-Shared Emotion Regulation and Building Team Coordination Mechanisms During a Hackathon

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Abstract

For effective teamwork, especially in demanding learning situations like a hackathon, coordination is crucial as it contributes to mutual trust and shared mental models of team members. However, teams experience challenges that mar team coordination. Research has shown that interpersonal skills such as socially-shared emotion regulation (SSER) can be key in dealing with such challenges. We examined the relationship between SSER and mutual trust, and SSER and shared mental models in the context of a hackathon. Adapted from a small SSER scale, we built a 27-item questionnaire to examine SSER and its relationship with mutual trust and shared mental modelsin programming teams. We also used heat maps to provide an overview of individual team members' perceptions of their teams' SSER strategy application, mutual trust, and strength of shared mental model bonds within the team. Regarding the relationship between SSER and shared mental models, our analyses revealed signification association (correlation) between: (a) SSER situation modification and shared mental model: task and communication skills and (b) SSER situation modification and shared mental model: team dynamics and interaction. For the relationship between SSER and mutual trust, our analyses revealed significant relationships between: (a) SSER situation modification and perceived trustworthiness, (b) SSER cognitive change and perceived trustworthiness, (c) SSER response modulation and cooperative behaviors, and (d) SSER response modulation and monitoring behaviors. These relationships highlight the power of SSER in building key team coordination mechanisms and strengthening team performance.

Keywords Collaborative Learning · Teamwork · Socially Shared Emotion Regulation · Hackathon · Computer Supported Collaborative Learning

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1 Introduction

Today's key problems require successful coordinated efforts of teams (Shuffler & Carter, 2018). Indeed, teamwork has come to assume an important role in function and performance in various settings and contexts (Dinh et al., 2021). As such, understanding teamwork processes has become a key research endeavor (Strode et al., 2022). At the heart of successful teamwork is effective team coordination, with key components such as (Salas et al., 2005): (1) shared mental models (Cannon-Bowers et al., 1993; Salas et al., 2005) and (2) mutual trust (Salas et al., 2005). Teams can reach their full potential if these coordination mechanisms are applied effectively (Salas et al., 2018).

However, effective teamwork involves challenges related to learning, communication, and prioritization (Strode et al., 2022) that may hinder team coordinating attempts (Nguyen-Duc et al., 2015). Dealing with such challenges also requires team members to apply effective interpersonal skills such as socially-shared emotion regulation (SSER), which encompasses shared and interactive regulatory processes where team members manage their shared emotionally challenging situations together (Gross, 2002; Järvenoja et al., 2013; Järvenoja & Järvelä, 2009; Thompson & Fine, 1999; Ujitani & Volet, 2008). The burgeoning literature on SSER has highlighted the need for fostering SSER to promote collaborative learning and manage team socio-emotional obstacles. The overarching aim of the current study is to examine the role of SSER on coordination mechanisms, namely shared mental models and mutual trust towards reaching effective team performance.

2 Literature Review

In this section we initially elaborate on two critical team concepts (i.e., shared mental models and mutual trust) that are the building blocks of team coordination. We then speak of challenges that impede team coordination (e.g., conflict, poor communication, time constraint) and introduce the concept of emotion regulation at its different layers. We further elaborate on recent yet scarce empirical research that has provided links between emotion regulation and the two key team coordination factors mentioned: emotion regulation and shared mental models; as well as emotion regulation and mutual trust.

2.1 Shared mental models and team coordination

Shared mental models (SMMs)—which refer to "knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and in turn coordinate their actions and adapt their behavior to demands of the task and other team members" (Cannon-Bowers et al., 1993, p. 228)—contribute to the understanding of the nature of coordinated team

performance, team problem solving and decision making (Hung, 2013). Recent research investigating the consequences of different types of conflict shows that unproductive conflict interferes with building shared mental models, decreases member satisfaction, and raises negative emotions within the team (Behfar et al., 2008; Nair, 2008). The team will only benefit if divergence in meaning is valued and can lead to deep-level processing of the different information and multiple viewpoints in the team towards convergence of meaning, and thus the development of shared mental models (Homan et al., 2007).

2.2 Mutual trust and team coordination

Rousseau et al. (1998) defined trust as 'a psychological state comprising of the intention to accept vulnerability based upon positive expectations of the intentions or behaviors of another' (p. 395). The reciprocal trust between team members is termed as *mutual trust* which refers to the "shared belief that team members will perform their tasks and protect the interest of other team members" (Salas et al., 2005, p. 561). Mutual trust is a principal factor in influencing the coordination of interpersonal interactions in teamwork (Bentzen, 2022; Lee et al., 2010; Mach et al., 2010; Martínez-Miranda & Pavón, 2011; Palanski et al., 2011).

2.3 Maintaining Coordination in Learning Teams

The benefits of coordinated teamwork are clear; yet successful coordination does not always occur. This has brought impetus to research that examines prerequisites for effective coordination. Research (Hobman et al., 2002) has shown that one main hindrance to the development of shared mental models and mutual trust are the emerging challenges that arise as teamwork unfolds; for example, difficulties in understanding others' thinking or negotiating multiple perspectives (Kirschner et al., 2008). Research has shown that challenges can have adverse effects on team performance (Cannon & Edmondson, 2001; Daim et al., 2012; Kazemitabar et al., 2022). These deficiencies have led researchers to recognize a need for supporting the challenging factors of teamwork and determine the prerequisites of effective coordination. To ensure successful collaboration, team members need to realize the type of challenge(s) they are facing, and accordingly regulate their internal constraints (e.g., change their strategy or their task perceptions), or proceed although having external limitations (e.g., downgrade to lower-level goals) (Panadero et al., 2015). To this end, extant research has highlighted the role of negative emotions when challenges arise and in adversely influencing coordinating strategies (e.g., Panadero & Järvelä, 2015). Thus, not only do team members need to understand their challenges, but they also require developing and applying effective regulatory strategies to manage the adverse effects that are raised by challenges and constraints.

2.4 Emotion Regulation and Team Coordination

Studying emotion regulation in the social context is especially important (Xie, 2022) since individual emotions can strongly be influenced from the social setting and contagiously spread into team emotions and intensify into stronger positive or more negative emotions (Barsade & Gibson, 1998). More positive emotions can motivate team members towards higher team coordination and therefore better team performance, and conversely more negative emotions can de-motivate members and downgrade them towards lower standards and poorer team performance (Anat et al., 2009). While studies of emotion regulation—which is a specific type of self-regulation that refers to "the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions" (Gross, 1998, p. 275)—within the individual learning context are well documented (e.g., Gross & Muñoz, 1995), research on shared emotion regulation has just started making appearances. A model comparing the three types of emotion regulation is illustrated in Fig. 1. The left side of the model represents an individual regulating their own emotions (i.e., *intrinsic* emotion regulation, Gross, 2008). In the middle, we find co-regulation of emotions, which refers to an individual helping another regulate their emotions (i.e., *extrinsic* emotion regulation; Gross, 2008). Finally, the right side of the model presents socially-shared emotion regulation, which refers to the social, shared, and interdependent emotion regulatory processes that collaborative members harmoniously apply to regulate the emotions of the team in order to reach the shared outcome (Isohätälä et al., 2017; Järvenoja & Järvelä, 2009; Kazemitabar et al., 2022; Panadero & Järvelä, 2015; Winne et al., 2013). An example of SSER is: "We accepted that different members have different goals, and we need to organize our working according to that" (Järvenoja et al., 2013, p. 57). In a team setting, along with self- and co-regulation of emotions, SSER should also be supported.

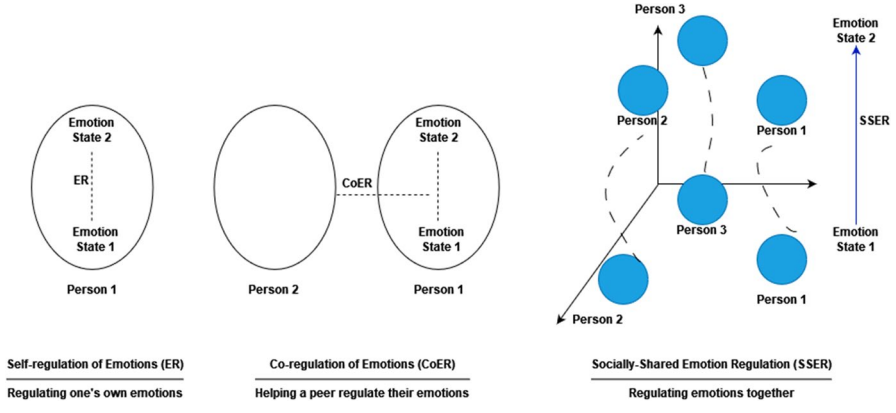

Fig. 1. A model of three emotion regulation mechanisms present in teams

2.5 SSER and shared mental models

Despite the theoretical link between SSER and team coordination, the lack of research on the link between SSER and the development of shared mental models in learning teams is noteworthy. However, some studies have focused on managing conflict (e.g., Davaei et al., 2022; Hamilton et al., 2014), as a key emotionally challenging hindrance to the development of shared mental. Therefore, it is important to examine the effect of SSER on managing emergent conflicts within teams to sustain the development of shared mental models (Fig. 2).

Several factors that contribute to conflict have been cited (e.g., Brett et al., 2014; Gelfand et al., 2014). These factors can be internal, relating to personal deficiencies and teamwork incompetence or external to the task or team dynamics. One principal factor contributing to conflict and challenging the development of shared mental models is barriers to "externalizing" individual mental models (Kirschner et al., 2014). Mental models are a mixture of what is learned explicitly and absorbed implicitly (Kim, 1998). The implicit integration of knowledge into an individual's cognitive knowledge structure makes mental model sharing difficult, and externalizing it requires effective communication patterns. Therefore, externalization challenges are to a high extent due to communication barriers. SSER can also facilitate perspective-taking to avoid conflicts. An open-minded discussion of diverse views is a critical social process by which a more complete appreciation of the complexity of the situation at hand is developed and allows incorporating diverse ideas (Chen et al., 2005). Goldman (2007) emphasized the need to embrace diverse perspectives to analyze a situation from different viewpoints and avoid biases that may lead to misinterpretations. Attending to and comprehending contradictory or diverse opinions requires sufficient emotional capacity and emotional management. Druskat and Wolff (2001) argue that perspective taking is more than a cognitive ability and includes an emotional component. When an emotionally competent team engages in reappraisal (an emotion regulation strategy) to understand different perspectives, team members feel that their views are being understood and considered, and make their viewpoints even though they may be contradictory, more available to each other. These dynamics facilitate the development of shared mental models and result in advanced team performance (Lovelace et al., 2001).

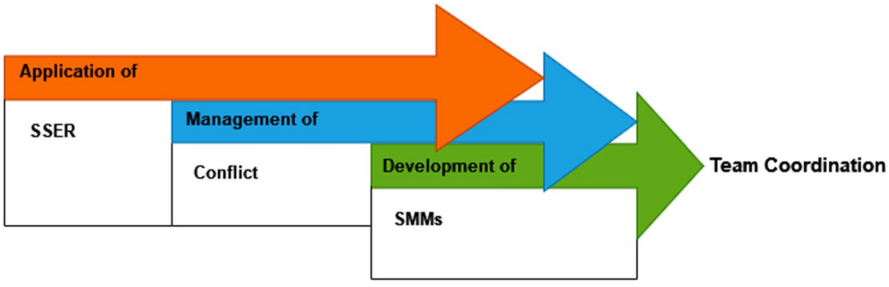

Fig. 2. The indirect relation between SSER and the development of shared mental models in the literature

2.6 SSER and mutual trust

Referring to the multidimensional model of trust, Jones and George (1998) emphasized the significant role of emotions in producing a dynamic state of trust or distrust in an individual collaborating with others. They proposed that emotions provide signals through which members recurrently evaluate the ongoing quality of their trust experience. Trust is built on expectations of other team members that if fulfilled, produces positive emotional responses within individuals and strengthened bonds of trust (Dunn & Schweitzer, 2005). But when the expectations are not met, individuals often experience negative emotions that indicate trust impairment and the need to protect the at-risk interaction. The literature has shown several strategies that a trustee (the trusted person) can use to repair distrust. Although efficient, these strategies present the trustor (individual who trusts) as a passive observer of efforts to trust repair. To accelerate the amelioration of trust in situations where trust is fundamental in reaching the team goals, Kim et al. (2006) argue that both the trustee and trustor should play an active role in the trust restoration process. Here it bears highlighting the role of SSER in trust restoration by helping the trustor regulate negative emotions induced due to expectation violations. There are several points (first two points are before emotions are elicited and the third is after emotion elicitation) in the trust dissolution path where SSER can intervene: around expectations (example of SSER self-reflective strategy: is our expectation of the trustee reasonable?); around violations of these expectations (example of SSER self-reflective strategy: is our perception of violation of expectations accurate?); and around emotional reactions (example of SSER self-reflective strategy: are we not overreacting?). These examples demonstrate how cognitive reappraisal of a team's expectations of a trustee's responsibilities, violation criteria of these expectations, and emotional reactions to violations can help restore trust in the team atmosphere. However, since emotions are signals of trust in uncertain situations, caution should be taken in their appropriate regulation to not put the team at high risk of the misbehavior of violating members. Lewicki and Brinsfield (2012) refer to trust as not always advantageous since it may lead to sacrificing high quality outcomes as wanting to not damage trust. Thus, at times when trust bonds in the team become weak, to a specific extent the trustor needs to have an active role in trust amelioration. We propose that this active role can be signified using specific SSER strategies.

3 Purpose of the Study and Research Question

The purpose of the current study is to examine the role of SSER on coordination mechanisms, namely shared mental models and mutual trust towards reaching effective team performance. The background covered the need to examine SSER and identify its role in managing conflicts and uncertainties that hinder the development of shared mental models, and strengthening mutual trust within learning teams. The context for the current study involves a programming competition, referred to as a hackathon, which "is a highly engaging, continuous event in which people in small groups produce working software prototypes in a limited amount of time" (Komssi et al., 2015, p. 60).

The overarching question thus addressed is: Is there a relationship between SSER and shared mental models, and between SSER and mutual trust withing socially challenging learning teams?

4 Methods

4.1 Participants

The study was approved by the institutional review board of the principal investigator's university (Kazemitabar, 2019). We collected data during a Physics programming hackathon competition at a North American University. Before the hackathon began, the organizers of the hackathon emailed the participants with details about the study. Further, the principal investigator also presented the details and logistics of participating in the study during the introductory session of the hackathon. Of the 59 total participants in the hackathon, 53 students volunteered to participate in the study. From this sample, five participants had to be excluded: two were minors, two participants only attended the first day of the event, and one was from a team where other team members did not provide consent to participate. For this study, we refer to hackathon participants as hackathonists to differentiate from the study participants. The final sample of the study included 48 participants (71% male; mean age=22 years, *SD*=3.28). Participants (31% Asian, 21% Middle Eastern, and 48% Caucasian) included undergraduate and graduate students, with backgrounds in Physics (42%), software engineering and computer science (19%), and electrical, mechanical, and civil engineering fields (31%). Participants average GPA was 3.87/4.3 (*SD*=1.18). All participants signed the consent form. Participants were eligible to win one of the ten $40 gift cards along with the hackathon awards.

4.2 Team formation

The participants formed their own teams using an online platform in advance of the event. There were 16 teams of 2 to 5 participants (see Table 1 for basic team information), with different expertise backgrounds (programmer, physicist, designer) and levels (novice, intermediate, expert).

4.3 Task, Context, and Data Gathering

The task involved building a novel computer program to demonstrate a physics phenomenon of their choice artistically. Students could interact with mentors (computer science graduate students) in the venue and through a private Slack chatroom. Teams were ranked by a team of four expert judges at the conclusion of the competition: a physics professor, a Microsoft technologist, a Nexalogy technologist, and a Lenovo salesman. The three top teams were awarded prizes. The judging criteria focused on the team project not the performance of the members.

Table 1 Hackathon Teams' General Information

Number[a]	Team name	Gender composition	Programming level	Prior familiarity	Team size	*M* age
1	Nanomon Go	Mixed	Low to moderate	Yes	2	24.5
2	NMR fun	Mixed	Moderate	Partial[c]	3	22.3
3	Team Guestlist	Male only[b]	Moderate to high	Partial	5	18.8
5	BIO-Hazard	Mixed	Moderate to high	Yes	2	24
7	Team Hype	Mixed	Moderate	Partial	4	19.3
8	Pendulums	Male only	Moderate to high	Partial	3	22
9	Fire Workers	Mixed	Low to moderate	No	3	19.7
10	Team Nix	Mixed	Moderate	Yes	2	21
11	Apollo	Mixed	Moderate	Partial	3	23.3
14	Space Rangers	Male only	Moderate	No	5	24.4
15	Physics Hot	Mixed	Low to moderate	Partial	3	22
16	Team Rocket	Mixed	Low to moderate	Yes	4	22.7
17	Hack Formula	Mixed	Moderate	Yes	3	26
18	Light	Mixed	Moderate	Partial	3	20
19	ECSE200	Male only	Moderate	Yes	2	19.5
20	Fluid Guys	Male only	Moderate	No	2	23[d]

[a]Numbers indicate team-labelled numbers at the event

[b]There were no teams composed of only females, and the mixed-gender teams generally included only one female

[c]Only some of the participants knew each other prior to the hackathon

[d]Participants age range fell within early adulthood

Therefore, winners picked by the judges were not necessarily high performing teams, and teams with high performance did not necessarily win.

The event included two spaces: (1) a hall with twenty "team pods" and (2) a dome with 360 degrees projection where presenters could project their work to the audience. The competition officially started at 12:00 pm on Day 1 and continued until 12:00 P.M. on Day 2 for a consecutive 24-hour period. At the conclusion of day two, teams presented their project to the judges. The judges rated teams based on the judging criteria and selected three teams as winners during the awards ceremony.

During the event, cameras (captured who was talking with whom and students' postural behavior) were placed beside team pods and audio recorders (captured team dialogue) were placed on tables. The following data were gathered: questionnaires, in-session audio/video records of team interactions, and post-competition interviews. The timeline of data collection is illustrated in Fig. 3.

4.4 Data Used in the Present Study: The SSER Questionnaire

For the purpose of this study, the following data sources were analyzed: AIRE questionnaire, shared mental model scale, and trust scale.

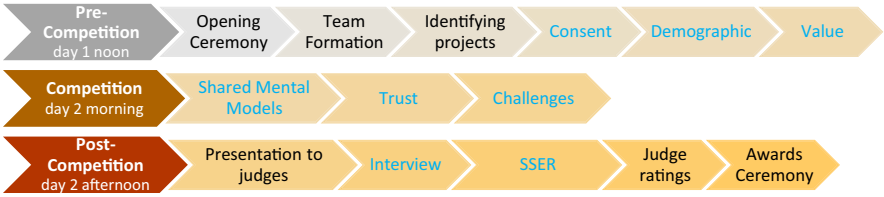

Fig. 3 Data collection schedule pre-, during, and post-competition (blue wordings represent data collection steps, whereas black wordings represent hackathon events)

The SSER questionnaire was adapted from section three of the AIRE instrument (Järvenoja et al., 2013) for measuring shared emotion regulation strategies teams applied to regulate their team emotions at times of experiencing challenges. Strategies used for individual emotion regulation were reworded to reflect SSER attempts. The final questionnaire (Appendix A Table 9) included 21 items. All items were measured on a five-point Likert scale from 1 (*Strongly disagree*) to 5 (*Strongly agree*). Cronbach's alpha was calculated for each factor and revealed a value above the 0.7 threshold. Since the focus of the current study was on the role of SSER, we did not analyze individuals' self or co-regulated attempts to manage socio-emotional challenges in the team.

The validated shared mental models questionnaire (Johnson et al., 2007) was used for measuring individual members' perceptions of shared cognition among their team members (Appendix A Table 10). The full measure consisted of 42 items that fall within five factors. Of these factors, items of the third and fifth factors were similar to items of the trust questionnaire. To avoid redundancy, these two factors were removed from the questionnaire. Cronbach's alpha for the remaining three factors (total 25 items) from Johnson et al.'s (2007) article was reported as $\alpha = .76$ (task and team knowledge), $\alpha = .89$ (task and communication skills) and $\alpha = .81$ (team dynamics and interactions) showing adequate internal consistency. All items were measured using a five-point Likert scale from 1 (*Completely disagree*) to 5 (*Completely agree*).

The trust questionnaire is a validated self-report inventory (Costa & Anderson, 2011) for measuring trust between team members including 21 items (Appendix A Table11). Cronbach's alpha was not reported for this measure in the original article. All items were measured using a seven-point Likert scale from 1 (*Completely disagree*) to 7 (*Completely agree*). The measures provide insight into one-way trust (trust perception of a trustor in a trustee), thus for identifying mutual trust between members, aggregate responses from all team members were considered.

5 Analysis

5.1 Preliminary analyses

Preliminary analyses were run to determine whether differences in team composition were statistically significant or not. Nonsignificant team composition would enable

valid between-team comparisons on the research variables which examine whether there is a relationship between *SSER* and *shared mental models*, and *SSER* and *mutual trust.* Any significant differences in team composition would count as study covariates and would need to be controlled for in the main analyses. Based on previous literature, potential significance in differences of team compositions might be due to:

- Mixed gender vs. male only teams (e.g., Schrock & Knop, 2014, studying emotions and gender differences).
- Team size ranging from two to five members (e.g., Amason & Sapienza, 1997 identifying the impact of team size in teamwork).
- Average prior programming expertise with three levels of low, moderate or high (e.g., Rentsch & Klimoski, 2001 identifying positive relations between team experience levels and team effectiveness).
- Members' prior familiarity with each other (e.g., Huckman et al., 2009 describing the positive effects of prior familiarity on team performance).

Some studies have shown that age differences might impact teamwork, however they have situated age within different developmental stages of the lifespan (e.g., Wegge et al., 2012). In the current study, all the current study participants were within one developmental stage (early adulthood), and descriptive statistics indicated that there was little difference in mean age in teams with low standard deviation and skewness ($M = 21.92$, $SD = 2.14$, skewness =.16). Therefore, age was not considered as a potential covariate. The five SSER categories, four mutual trust categories, and three shared mental model categories resulted in 12 dependent variables (DVs). To test significance in team differences based on gender, an independent samples *t*-test was conducted between mixed-gender teams vs. male-only teams (see Table 2). Based on the *t*-test *p*-values, no significant differences in SSER, mutual trust or shared mental models were attributed to differences in gender composition (mixed vs. male-only teams). Therefore, gender was removed from the list of potential covariates.

To assess significance in team differences based on *programming expertise levels, prior familiarity, and team size*, one-way ANOVAs were run. One-way ANOVAs were chosen for each analysis as there was one dependent variable (DV) and one independent variable (IV) with multiple levels. Based on participants' self-reports, programming expertise had three levels (low, medium, high expertise levels) and prior familiarity also had three levels (no, partial, full familiarity). Also, team size (via counting the number of participants in each team) had four levels (two, three, four, or five members). Based on the number of DVs, a total of 12 separate one-way ANOVAs were run. Tables 3 through 5 provide a summary of the analyses with significant relationships ($p < .05$) marked with an asterisk (*). Individual ANOVAs were run for each factor and are provided in rows below.

Based on the *p*-values provided in Table 4, no significant differences in SSER, trust or shared mental models were attributed to differences in programming levels (low, moderate, high expertise). Therefore, programming expertise was removed from the list of potential covariates.

Table 2 Preliminary Analysis: Examining Significance between Study Variables and Potential Study Covariate: Team Gender (Mixed vs. Male only)

Measures	*n*		*M*		*SD*		*t*
	Male- only	Mixed	Male- only	Mixed	Male- only	Mixed	
SSER1: Situation selection	9	20	3.22	3.20	1.39	1.51	0.38
SSER2: Situation modification	9	22	3.29	2.69	0.70	0.86	1.87
SSER3: Attention deployment	9	20	1.67	2.60	1.50	1.64	-1.46
SSER4: Cognitive change	9	22	2.97	2.87	0.84	0.74	0.51
SSER5: Response modulation	9	20	1.67	2.15	1.00	1.27	-1.01
Trust 1: Propensity to trust	13	24	6.09	5.58	0.76	0.99	1.63
Trust 2: Perceived trustworthiness	13	24	5.97	5.37	0.87	0.89	1.98
Trust 3: Cooperative behaviors	13	23	6.04	5.64	0.73	0.89	1.39
Trust 4: Monitoring behaviors	13	23	4.74	4.57	1.27	1.46	0.37
S1: Task & Team knowledge	13	26	4.14	3.87	0.68	0.57	1.35
S2: Task & Communication Skills	13	26	4.00	3.83	0.80	0.57	0.74
S3: Team Dynamics & Interaction	13	25	4.20	3.97	0.69	0.56	1.13

Table 3 Preliminary Analysis: ANOVA Results for Team Programming Expertise (Low, Moderate, High)

Items	*df*		*F*	*p*
	Between	Within		
SSER1: situation selection	2	26	0.51	.606
SSER2: situation modification	2	28	2.60	.089
SSER3: attention deployment	2	26	2.14	.137
SSER4: cognitive change	2	28	0.61	.545
SSER5: response modulation	2	26	0.06	.941
Trust 1: propensity to trust	2	34	0.06	.938
Trust 2: perceived trustworthiness	2	34	0.51	.612
Trust 3: cooperative behaviors	2	33	0.47	.623
Trust 4: monitoring behaviors	2	33	0.26	.779
S1: task & team knowledge	2	36	1.00	.381
S2: task & communication skills	2	36	1.29	.290
S3: team dynamics & interaction	2	35	0.12	.892

Table 4 Preliminary Analysis: ANOVA Results for Prior Familiarity (No, Partial, & Full)

Measures	*df*		*F*	*p*
	Between	Within		
SSER1: Situation Selection	2	26	0.14	.871
SSER2: Situation Modification	2	28	5.61*	.012
SSER3: Attention Deployment	2	26	2.26	.128
SSER4: Cognitive Change	2	28	1.52	.239
SSER5: Response Modulation	2	26	0.47	.653
Trust 1: Propensity to Trust	2	34	1.54	.228
Trust 2: Perceived Trustworthiness	2	34	0.02	.981
Trust 3: Cooperative Behaviors	2	33	1.75	.185
Trust 4: Monitoring Behaviors	2	33	1.99	.147
S1: Task & Team Knowledge	2	36	2.11	.143
S2: Task & Communication Skills	2	36	3.01	.061
S3: Team Dynamics & Interaction	2	35	1.02	.374

*$p < .05$

Table 5 Preliminary Analysis: ANOVA Results for Team Size (2, 3, 4, & 5 Members)

Measures	*df*		*F*	*p*
	Between	Within		
SSER1: Situation Selection	3	25	0.41	.751
SSER2: Situation Modification	3	27	0.56	.654
SSER3: Attention Deployment	3	25	4.53*	.012
SSER4: Cognitive Change	3	27	0.36	.779
SSER5: Response Modulation	3	25	2.82	.064
Trust 1: Propensity to Trust	3	33	1.33	.278
Trust 2: Perceived Trustworthiness	3	33	4.47*	.013
Trust 3: Cooperative Behaviors	3	32	0.83	.491
Trust 4: Monitoring Behaviors	3	32	2.23	.103
S1: Task & Team Knowledge	3	35	0.79	.512
S2: Task & Communication Skills	3	35	0.68	.569
S3: Team Dynamics & Interaction	3	34	0.77	.522

*$p < .05$

As indicated in Table 4, differences in prior familiarity (comparing teams of none, partial, or full familiarity) were significantly meaningful only for SSER2 ($F(2,28) = 5.608$, $p = .009$). Cohen's $\underline{d}$ was calculated to be lower than .5 ($\eta = .26$), revealing a small effect size (Cohen, 1988). Therefore, familiarity was not included as a covariate either.

Based on results of Table 5, variance in team size (comparing teams of 2, 3, 4 or 5 members) was significant for two out of the 12 items: SSER3 ($F(3,25)$

= 4.534, p = .011) and Trust 2 (F(3,33) = 4.471, p = .010). Cohen's d was calculated for each of the significant factors (η = .35 and η = .29 respectively) which again revealed a small effect size (Cohen, 1988). Thus, team size was not included as a covariate.

In sum, although pre-existing literature has shown relationships between teamwork and gender, team size, prior familiarity and expertise levels, such relationships were not found to be strong in the current study. For our additional confidence, each of the four afore-mentioned factors were individually included as co-variates in the correlations, however, the directionality of the relationships remained unchanged. Therefore, gender, team size, prior familiarity, and expertise levels were finally not included as covariates.

5.2 Main Analysis

Correlation analyses were conducted to identify possible relationships between shared emotion regulation strategies and the two coordination mechanisms (shared mental models and mutual trust). A summary of the analyses is provided in Table 6 (mutual trust: T and shared mental models: S). As can be seen, there is a significant correlation between (a) SSER2 and Trust 2, (b) SSER2 and S2, (c) SSER2 and S3, (d) SSER4 and Trust 2, (e) SSER5 and Trust 3, and (f) SSER5 and Trust 4. All other correlations are insignificant. The insignificance of other relations may be due to the small sample size.

Multicollinearity was observed between situation modification and cognitive change as indicated by a strong correlation (F (31) = .77, p <.01). Although in some subscales multicollinearity was observed, the items are conceptually different and in the questionnaires the phrasing of the questions was in a manner that multi-collinear constructs were disparate with no overlaps. Since cognitive change and situation modification are both adaptive strategies, it might be that students who frequently used one adaptive strategy also used another adaptive strategy frequently. For other cases of multicollinearity, the items were reviewed and considered conceptually different. Heat map representations are provided along with their legends in Figs. 7, 8, 9, presenting an overview of the results of questionnaires that students filled in for the study variables (i.e., SSER, mutual trust, and shared mental models). Questionnaire items measured students' perceptions about their team in terms of their application of different SSER strategies, perceived mutual trust within the team, and strength of shared mental model bonds among members. Darker red cells indicate less occurrence of SSER, lower frequency of mutual trust and lower shared mental model bonds among members. As an example, Team 7 (a low performing team) exerted low levels of SSER strategies, had instances of mistrust and low shared mental models within the team.

Table 6 Correlations Among Continuous Study Variables

Measure	1	2	3	4	5	6	7	8	9	10	11
1. SSER1: Situation Selection	-										
2. SSER2: Situation Modification	.22	-									
3. SSER3: Attention Deployment	.20	.08	-								
4. SSER4: Cognitive Change	.28	.77**	.19	-							
5. SSER5: Response Modulation	.06	.34	.18	.43*	-						
6. Trust 1: Propensity to Trust	-.02	.37	-.07	.27	-.08	-					
7. Trust 2: Perceived Trustworthiness	-.04	.45*	-.15	.45*	-.15	.62**	-				
8. Trust 3: Cooperative Behaviors	-.01	.13	.10	.26	-.48*	.58**	.65**	-			
9. Trust 4: Monitoring Behaviors	.12	-1.3	-.10	.13	-.43*	.08	.05	.27	-		
10. S1: Task & Team Knowledge	-.06	.31	-.05	.09	-.13	.55**	.60**	.42*	-.33*	-	
11. S2: Task & Communication Skills	-.06	.39*	.07	.11	.05	.45**	.42*	.27	-.46**	.86**	-
12. S3: Team Dynamics & Interaction	.08	.47*	-.03	.16	.05	.64**	.56**	.33	-.28	.73**	.77**

SSER Socially-shared Emotion Regulation, *Trust* Mutual Trust, *S* Shared Mental Models

* $p < .05$. ** $p < .01$

6 Discussion

The overarching research question focused on the relationship between SSER and shared mental models, and between SSER and mutual trust. The relations are described individually below.

6.1 SSER and Shared Mental Models

Previous literature has focused on the indirect relation between SSER and shared mental models through the management of challenges and conflicts teams face. To our knowledge, the direct link between emotion regulation (specifically SSER) and shared mental models has not yet been explored. The general trend so far has been to investigate two independent relationships: (a) the negative relationship between emotion regulation and challenges (that may result in conflicts), and the number of challenges and shared mental models. A few studies have considered both relationships and focused on managing conflict as a key emotionally challenging hindrance to the development of shared mental models (e.g., Hamilton et al., 2014). We examined whether there is a direct relation between SSER and shared mental models (upper image in Figure 4 shows the indirect relation between SSER and shared mental models through the management of conflicts, while the lower image refers to the direct relationship between SSER and shared mental models).

Our analyses found that there was a significant direct relationship between: (a) "SSER situation modification" and "shared mental model: task and communication skills," and (b) "SSER situation modification" and "shared mental model: team dynamics and interaction." We describe these significant relationships.

6.1.1 SSER2 (situation modification) and S2 (task and communication skills)

Looking at items describing task and communication skills, we can see that there is high correspondence between such skills and situation modification. Specific skills such as effective communication, supporting continuous improvements of members and the team, using a common vocabulary in task discussions, and consistently demonstrating effective listening skills are positively associated with the situation modification strategy. SSER situation modification items that are associated with the shared mental model category

Fig. 4 The direct relationship between SSER and shared mental models

include contribution encouragement, increasing communication, being open minded and unbiased. The strong positive correlations between the two aforementioned factors suggests that the more members of a team apply SSER situation modification, the more they can advance their task and communication skills. Our analyses comparing the low and high performing teams demonstrated that a lack of such skills can weaken teamwork and lead to poor team performance.

6.1.2 SSER2 (situation modification) and S3 (team dynamics and interaction)

Items that describe team dynamics and interactions include understanding roles and responsibilities, updating each other about different work issues, collaborative decision making, flexibly adapting to roles within the team to carry out various tasks, knowing where to get information, and solving problems that occur during teamwork. Several such items have been addressed in SSER situation modification. Again, some of the SSER situation modification items are collaborative problem solving, adapting to increased workload, increasing communication, and help seeking and help giving behavior. Thus, items of SSER situation modification and items of shared mental models, team dynamics, and interactions are in correspondence to each other. Positive correlations between there is a strong correlation between the two aforementioned factors. As a next step, regression analyzes can inform the direction or bidirectionality of this relationship, i.e., determine whether the more members of a team apply SSER situation modification, the more they can enhance their team dynamics and interaction skills. Our analyses comparing the low and high performing teams showed how lack of such skills can weaken teamwork and lead to the failure. The correspondence between SSER situation modification and shared mental model items in the two aforementioned factors is provided in Table 7. Higher frequencies in the situation modification category are associated with higher frequencies in two specific categories of shared mental models.

Based on the afore-mentioned significant relationships, we conclude that SSER has direct and positive relations on enhancing shared mental models within team members.

6.2 SSER and Mutual Trust

The second hypothesis was that SSER has a positive relationship to mutual trust between members of a team. Our analyses revealed significant relationships between: (a) SSER situation modification and perceived trustworthiness, (b) SSER cognitive change and perceived trustworthiness, (c) SSER response modulation and cooperative behaviors, and (d) SSER response modulation and monitoring behaviors. We describe these significant relations.

SSER2 (situation modification) and Trust2 (perceived trustworthiness) Items that describe perceived trustworthiness refer to the level of reliability of members (Costa et al., 2001). These include members having complete confidence in each other's' ability to perform tasks, keeping their word and staying committed, and looking for

Table 7 Correspondence Between Situation Modification and Two Shared Mental Model Factors

SSER2 (situation modification)	S2 (task & communication skills)	S3 (team dynamics & interactions)
Collaborative problem-solving		Collaborative decision-making Solving problems that occur while doing various tasks
Contribution encouragement	Supporting personal and team improvements	
Adapting to increased workload		Flexibly adapting to roles in the team Taking interdependent tasks
Help seeking/ help giving behavior	Knowing the team has skills for doing various tasks	Knowing where to get information from
Increasing effective communication	Communicating tasks with teammates Using a common vocabulary defining communication channels at the start	Knowing how to exchange information Knowing about roles and responsibilities
Being open-minded and unbiased	Demonstrating effective listening skills	

each other's interests honestly. These items are coherent with the second category of SSER (situation modification strategies): the more members show collaborative problem-solving behaviors, convey help giving behaviors, adapt to increased workload, provide constructive criticisms, be open-minded and unbiased, and have efficient communication and time management skills; the more they become reliable and signal their responsibility taking and commitment to the overall project goals. This is also in line with previous literature describing reliability and trustworthiness of members collaborating in a team (e.g., Cogliser et al., 2012), identifying high commitment levels as strong predictors of being reliable.

SSER4 (cognitive change) and Trust2 (perceived trustworthiness) An interesting finding from this research was the strong correlation between cognitive change as an SSER strategy and perceived trustworthiness. This previously unexplored relation indicates the power of changing original thoughts about other members towards more positive thoughts on how much others can be perceived trustworthy. Cognitive change items include optimism, putting into perspective, problem shrinkage, decreasing standards, and decreasing expectations. As mentioned earlier, cognitive strategies can significantly influence trust repair since expectations and violation of expectations have a thick cognitive dimension (Jones & George, 1998). Therefore, changing thoughts through decreasing high expectations or seeing violations of expectations as minor can help the trustor forgive more easily and maintain mutual trust. There are several points in the trust dissolution path where SSER can intervene. One main point is around expectations, another is around violations of these expectations, and a third is around emotional reactions. The first two points are before emotions are elicited, but the third is after emotion elicitation (see Fig. 5). Through cognitive reappraisal of a team's expectations of a trustee's responsibilities, violation criteria of these expectations, and emotional reactions to violations can help maintain or restore trust in the team atmosphere. Examples include: (a) is our expectation reasonable; (b) is our perception of violation accurate; and (c) are we overreacting? These questions and considerations help change thoughts when trust is at risk of dissolution.

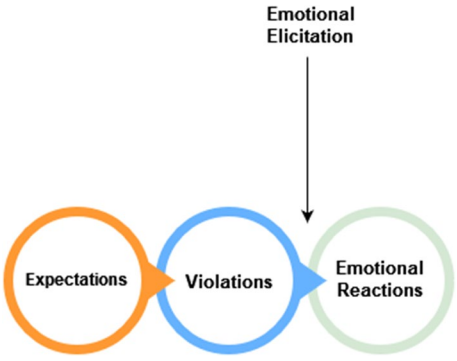

Fig. 5 Trust dissolution path: Three points where SSER can intervene through cognitive change

SSER5 (response modulation) and Trust3 (cooperative behaviors) The third trust category refers to working in a climate of cooperation and openness. The significant negative relationship between response modulation and this trust category can be explained through the categories of this SSER strategy; like suppressing maladaptive emotions and resisting maladaptive emotional contagion. Previous literature has proven the maladaptive nature of suppression of emotions for the wellbeing of the self (Gross & John, 2003). It may be the case that suppression or resisting the contagion of negative emotions of the self within a team has similar negative effects, and other members may possibly perceive that the suppressing member does not discuss and deal with issues openly and prefers to hold back relevant information (reverse items of the trust questionnaire on cooperative behaviors). Research in this regard (English & John, 2013) has shown that the link between suppression of emotions and poor collaborative performance is mediated by inauthenticity (Lehman et al., 2019), or the incongruence between the inner-self and outer-behavior. Likewise, in this research we can infer that suppressing negative emotions and resisting contagion of maladaptive emotions may have negative effects on trust between members. Members should either target the four former SSER strategies prior to emotion elicitation (Gross, 1998), or openly express their negative emotions to maintain high levels of mutual trust with each other.

SSER5 (response modulation) and Trust4 (monitoring behaviors) The fourth significant relationship between SSER and mutual trust refers to the negative significant correlation between SSER response modulation and monitoring behaviors. This relationship indicates that the more members suppress their negative emotions and resist contagion of maladaptive emotions, the less they show monitoring behaviors. This may be because efforts to hide negative emotions, and attentional resources required to suppress negative emotions may decrease opportunities to attend to others or put them under surveillance. As we saw in the data provided in this dissertation, it may be very common that teams face anxiety and moments of stress. When members experience such emotions, their attention to hide such emotions in favor of the overall team goals, may remove much of their attention to others (Sänger et al., 2014). Therefore, response modulation may have advantages as well as disadvantages. One of the disadvantages is not connecting well with others, and one of the advantages may be that those members have less chances to check others work and keep other's work under surveillance.

Based on the afore-mentioned significant relationships, we conclude that SSER has direct and positive relations on enhancing mutual trust within team members.

A summary of such relations is shown in the following table (Table 8). As can be seen six of the correlations revealed significant results.

In the following section and based on the study findings, we define a new model of trust evolution (both in enhancing trust and violating trust) during teamwork.

Table 8 Relationships between SSER and Trust

Measure	1	2	3	4	5	6	7	8	9	10	11
1. SSER1: Situation selection	-										
2. SSER2: Situation modification	.22	-									
3. SSER3: Attention deployment	.20	.08	-								
4. SSER4: Cognitive change	.28	.77**	.19	-							
5. SSER5: Response modulation	.06	.34	.18	.43*	-						
6. Trust 1: Propensity to trust	-.02	.37	-.07	.27	-.08	-					
7. Trust 2: Perceived trustworthiness	-.04	.45*	-.15	.45*	-.15	.62**	-				
8. Trust 3: Cooperative behaviors	-.01	.13	.10	.26	-.48*	.58**	.65**	-			
9. Trust 4: Monitoring behaviors	.12	-1.3	-.10	.13	-.43	.08	.05	.27			
10. S1: Task & Team knowledge	-.06	.31	-.05	.09	-.13	.55**	.60**	.42*	-.33*	-	
11. S2: Task & Communication Skills	-.06	.39*	.07	.11	.05	.45**	.42*	.27	-.46**	-86**	-
12. S3: Team Dynamics & Interaction	.08	.47*	-.03	.16	.05	.64**	.56**	.33	-.28	.73**	.77**

SSER Socially-shared Emotion Regulation, *Trust* Mutual Trust, *S* Shared Mental Models

*$p < .05$. ** $p < .01$

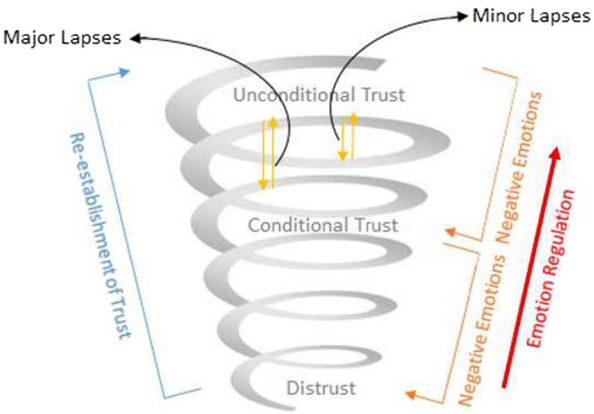

Fig. 6. Emotion regulation facilitating the maintenance of mutual trust during violation lapses.

6.3 The Trust Model

We first start with a conceptual model of trust (refer back to Fig. 1). This model presented the dynamic evolution of trust from distrust to unconditional trust through ongoing expectation fulfillments signaled by positive emotions. Minor expectation violations (lapses) would result in minor levels of negative emotional arousal and would not affect mutual trust between members as much, however major violations would lead to major lapses, strong negative emotional arousal, and trust would spiral downward to lower levels.

The findings of this study support such a conceptualization and show that negative emotions signal lapses in trust, pushing it towards distrust, and positive emotions signal strengthened trust bonds. Specifically in challenging moments, SSER helped manage emotions and therefore maintain mutual trust. For example, close to the competition deadline (extreme situation; Driskell et al., 2018), members of Team 3 (third ranked winners) realized that one of the members had made a mistake in a part of the program and because of this, the project would not run (a major lapse). Using SSER cognitive change (problem shrinkage), response modulation (telling each other to chill down) and SSER situation modification (encouraging each other to continue) they managed to work around the obstacle in time, express signs of joy and happiness. Based on their trust questionnaire, they also reported having strong trust in each other. These findings provide empirical support to the conceptual model of trust evolution (see Fig. 6).

This graphic model can be used to visually understand how mutual trust evolves during challenging teamwork, how it inclines towards higher levels of trust, and how it declines towards lower levels and distrust. Moreover, it highlights the power of emotion regulation (SSER) in re-establishing trust.

6.4 Implications

This research provides a better understanding of team effectiveness. This research contributes to the theoretical literature by extending our understanding of socially shared emotion regulation. Overall, the findings have implications for enhancing team

performance in teams with coordination breakdowns by focusing on SSER strategies in challenging settings. From our research, we see prospects for intervention programs to help facilitate SSER in collaborative learning contexts, especially in technology enhanced settings. As an example, mobile apps can be developed to help each member of the team apply adaptive individual emotion regulation strategies using self-report or physiological data. In addition, educators can develop workshops where teams can be guided to practice applying SSER strategies to adaptively manage the challenges.

In this research, teamwork was examined in the context of an international hackathon that provided an excellent opportunity to observe the natural but complex behavior of participants in the process of knowledge co-construction. We see opportunities to test our findings in other challenging teamwork settings and contexts.

6.5 Limitations and Future Directions

The present study has limitations that provide avenues for future research. The study is subject to potential sample selection issue. The sample studied in the present study is relatively small. Future research may attempt to recruit more participants. We should also be mindful that the research was conducted with students in the context of a hackathon, which raises the possibility of reduced applicability of the findings to the broader population. The hackathon had a short observation period. It is not clear if the findings of the present study will hold for learning situations that have a longer observation period. This research only focused on the SSER strategies students applied. However, as self- regulation of emotions and perhaps co-regulation of emotions can co-occur during collaborations, future studies might consider the three different modes of regulation simultaneously. Moreover, further studies need to understand the effect of SSER on moving from conditional trust to unconditional trust. In addition to shared mental models and mutual trust, other salient variables apropos effective team coordination also likely to play an important role. Therefore, future research may explore this research direction.

7 Summary

The aim of this research was to create a better understanding of socially-shared emotion regulation (SSER) and identify its role in managing conflicts and uncertainties that hinder the development of shared mental models and mutual trust within learning teams. In the present study, we quantitatively analyzed the relationship between SSER and mutual trust, and SSER and shared mental models. Analyses revealed six significant correlations between study variables (SSER2 and Trust 2, SSER2 and SMM2, SSER3 and S3, SSER4 and Trust 2, SSER5 and Trust 3, and SSER5 and Trust 4). In addition, heat maps were created to provide an overview of individual team members' perceptions of their teams' SSER strategy application, mutual trust within the team, and strength of shared mental model bonds among team members.

Appendix A

Table 9 Socially-Shared Emotion Regulation (Developed based on the AIRE instrument; Järvenoja et al., 2013)

1. We understood that we have to reconcile our goals closer to one another.
2. We decided that we had to work out the situation together in order to carry on working.
3. We considered each other's feelings when criticizing each other's work.
4. To resolve conflict we needed to keep open-minded and learn from one another.
5. We reminded each other that our discussions should be friendly and polite.
6. We incorporated everyone's ideas.
7. By not making a mountain out of a molehill we continued on our work.
8. We reminded ourselves that frustration wouldn't help solve our problem.
9. When conflict arose, we talked it out and/or shared our feelings.
10. We told each other to take arguments positively and not personally.
11. When challenges arose we discussed off-task topics.
12. When someone didn't do their share of the work, more competent team members put more effort.
13. We focused more on accomplished tasks rather than uncompleted tasks.
14. We reassured ourselves that we will do the best we can do.
15. We optimistically justified that external constraints were the cause of a member's shortcomings not his/her irresponsibility.
16. We told ourselves that winning isn't as important as learning.
17. After finding causes of our team shortcomings, we set rules to reach our top goals.
18. We sought help from mentors to possibly overcome our weaknesses.
19. We focused on our competing teams' shortcomings to relieve ourselves.
20. We took a break and went away to eat.
21. We didn't manage our team challenges well.

Table 10 Shared Mental Models (Adapted from Johnson et al., 2007)

1. My team have general ideas of how to proceed
2. My teammates do what they are assigned to do
3. My team knows how they are going to consolidate members' contributions
4. My team looks for different interpretations of a problem when seeking a solution to various task issues
5. My team evaluates their limitations while performing their project
6. My team has a shared goal for various project tasks
7. My team discusses its goal and attains the agreement of teammates
8. My team knows specific strategies for completing their various tasks
9. My team knows the general process involved in conducting a given task
10. My team understands that they have the skills necessary for doing various tasks
11. My team communicates effectively with other teammates while performing tasks
12. My team supports personal and team-level skill improvement
13. My team defines its communication style at the beginning of their work
14. My team uses a common vocabulary in task discussions
15. My team members effectively listen to each other's suggestions
16. My team understands their roles and responsibilities for doing various team tasks
17. My team understands where/from whom they can get information for doing their tasks
18. My team understands their interaction patterns
19. My team informs each other about different work issues
20. My team is likely to make a decision together
21. My team can flexibly adapt to any role within the team for carrying out various team tasks
22. My team undertakes interdependent tasks
23. My team understands how they can exchange information for doing various team tasks
24. My team solves problems that occur while doing various team tasks
25. My team acknowledges and rewards behaviors that contribute to an open team climate
26. My team encourages each other's work in order to improve outcomes
27. My team is committed to the team goal

Table 11 Trust Questionnaire (Adapted from Costa & Andersen, 2011)

1. My team members do not hesitate to help each other if they can
2. We speak out for what we believe is a good strategy
3. We stand behind our opinions
4. We are sincerely concerned about challenges any of us faces
5. We act as much as helpful to each other when needed
6. We usually tell each other the truth, even if we know were better off by lying
7. We can rely on one another
8. We have complete confidence in each other`s ability to perform tasks
9. We do as we have promised
10. Some of us have often tried to get out of previous commitments
11. We try to address each other`s interests as much as possible
12. We work in a climate of cooperation
13. We discuss with issues and problems openly
14. While taking a decision, we take each other`s opinions into consideration
15. Some of us have tried to hold back relevant information
16. We have minimized what we tell each other about our personal life
17. We are mostly open to advice and help from others
18. In our team people watch each other very closely
19. Our team keeps checking whether we have kept our promises
20. Most of us have tended to keep each other`s work under surveillance

Appendix B

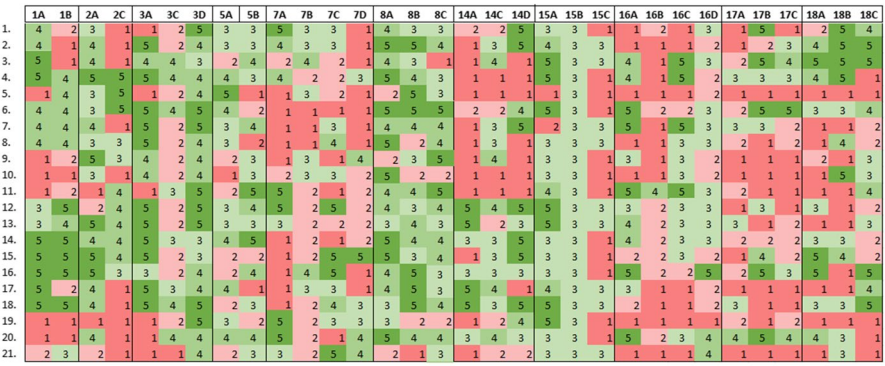

Fig. 7 Heat map representation of SSER among team members for all teams.

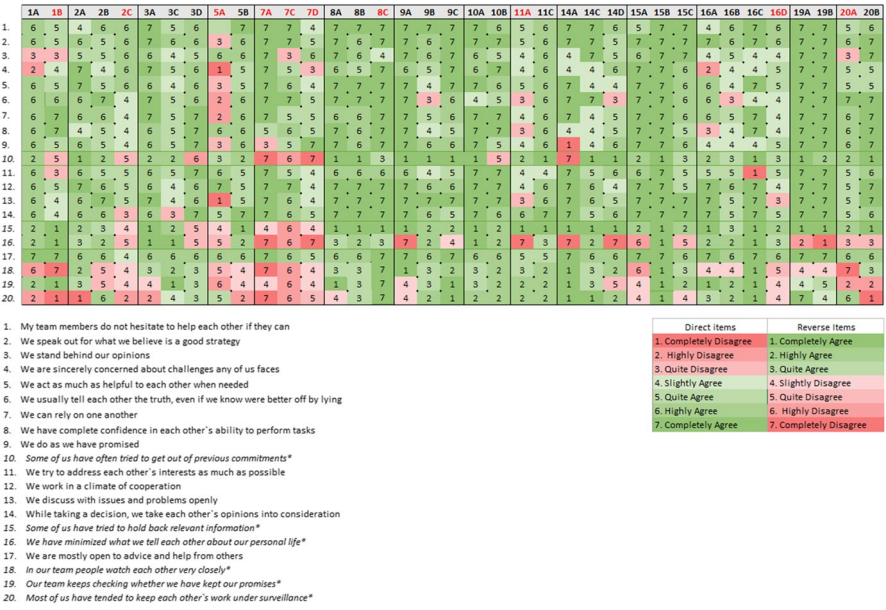

Fig. 8 Heat map representation of mutual trust within teams for all teams. Reverse items are italicized and marked with an asterisk, however heat maps represent trust directly (not reversely).

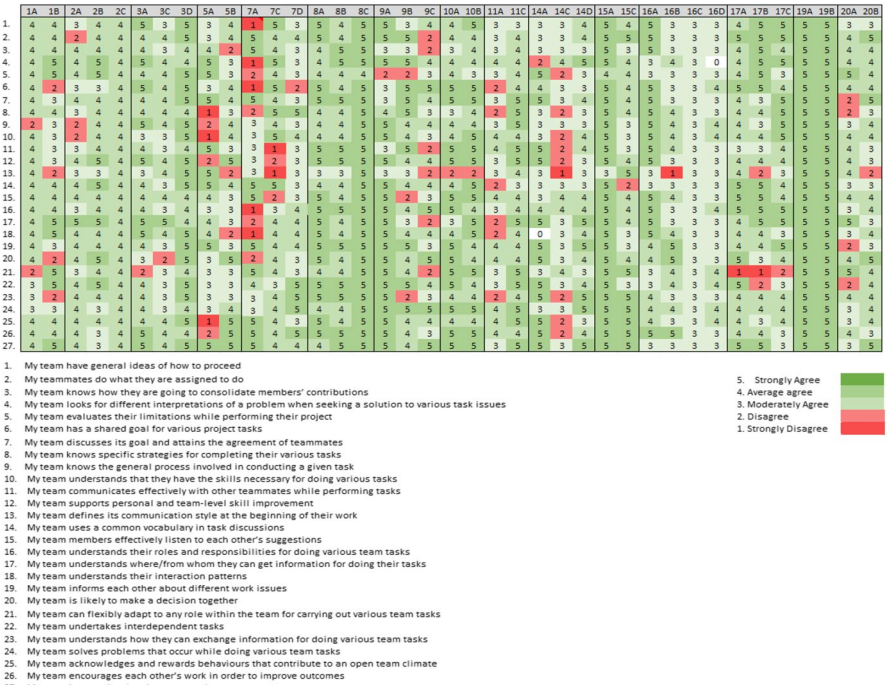

Fig. 9 Heat map representation of shared mental models in teams for all teams.

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Data availability The data that support the findings of this study are available on request from the corresponding author.

Declarations

This article is based on a doctoral dissertation (Kazemitabar, 2019) conducted by the first author at McGill University. The authors have no relevant financial or non-financial interests to disclose.

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