An experimental study of facial expressions in collaborative teams that quit a game-based learning task: Within-team competition vs. no within-team competition

Muhterem Dindar[1[0000−0002−4094−5274]], Elizabeth Cloude[1[0000−0002−7599−6768]], and Kristian Kiili[1[0000−0002−4094−5274]]

[1] Tampere University, Tampere, FINLAND
{elizabeth.cloude,muhterem.dindar,kristian,kiili}@tuni.fi

Abstract. In collaborative learning, emotions serve crucial functions that regulate task progress and social relationships among the team members. Although the research on the role of emotions in collaborative learning has been emerging, there is limited knowledge on how emotions emerge at different levels (individuals, teams) and its impact on collaborative learning, particularly when teams fail to complete a collaborative task. Therefore, the aim of this study is to explore how facial expressions of emotions unfold at the individual and the collective team level in a digital game-based learning setting in which collaborative teams eventually quit the collaborative task. A total of 30 high-school students' emotions were captured using facial expressions software and high-resolution video cameras from beginning to the quitting of the digital game on Biology (Min=43 min; Max=60 min). Before the collaborative learning task, participants were randomly assigned to work in a triad involving one of two experimental conditions: 1) a within-team competition (n=5 teams) and a no within-team competition (n=5 teams). Utilizing FaceReader, participants' momentary facial expressions of basic (i.e., happy, sad, anger, surprise, fear, and disgust) and neutral emotions were classified, and recurrence quantification analysis was utilized to study the recurrence of facial expressions within and between the members across the team conditions. Our findings indicate significant differences in the recurrence of facial expressions between the experimental conditions when they eventually quit the task. The current findings provide novel insights on the interplay between emotions and competitive dynamics in collaborative learning settings.

Keywords: Emotions, Collaborative learning, Game-based learning.

1 Introduction

Collaborative learning is an interaction dominant activity in which a group of learners develop a shared understanding of a topic or solve problems together. To be successful in collaborative learning, learners must develop shared goals and coordinate different strategies and roles with others. This requires team members to respond the task challenges and manage social conflicts while maintaining team cohesion. A growing body of research has shown that emotions can serve as an important proxy for understanding the complex interactions between cognitive and social processes in collaborative contexts. However, the scarcity of experimental research on the topic makes it difficult develop a coherent understanding on how specific emotions ensue within and between the team members, and their impact on team performance [18].

A specific underexplored area in collaborative learning is the interplay between emotions that occur at varying levels (individual, team) and team failure. Majority of the experimental studies on collaborative learning include collaborative designs in which participants completed the task with a varying degree of success. The current study provides insight into collaborative learning by highlighting findings from a controlled experimental study of teammates who decided to quit the collaborative learning task voluntarily. Further, research on collaborative learning often ignores the competitive dynamics that may emerge naturally during collaboration. These competitive dynamics can be related to individual traits, social interactions, or differing motivational orientations among the team members. In real life, collaboration and competition may appear together on a continuum rather than be mutually exclusive phenomena. Therefore, the current study utilizes and experimental design to study intertwined nature of competitive and collaborative dynamics in team learning settings.

1.1 Literature review

Emotions. Emotions are multifaceted and involve a complex interplay between cognitive, affective, motivational, and physiological processes [20]. Emotions are subjective and short-lived feelings [10]. They arise in response to one's interpretations and appraisals of events surrounding the individual. Ekman et al. argues that some emotional states are universal among humans: contempt, surprise, joy, fear, sadness, anger and disgust [6]. These emotions are often coined as basic emotions. Emotions are often characterized by two features, valence and arousal. Valence refers to the extent which an emotion depicts a positive or negative experience. Arousal refers to the extent which an emotion reflects activating or deactivating sensation of energy [26]. For example, joy is regarded as a positive-activating emotion, whereas sadness is regarded as a negative deactivating emotion.

In educational settings, emotions have been often studied across two distinct research lines. The first line has embraced Control Value Theory of Emotions and focused on emotions that emerge in relation success or failure in academic tasks [25]. This line of research has identified several achievement emotions about emotional antecedents and outcomes of competence-related activities. Some of the achievement emotions studied in educational contexts are joy, hope, anger, anxiety, shame, and boredom [24]. The second line of research has focused the function of epistemic emotions on learning processes. Epistemic emotions deal with knowledge generation processes in learning tasks [1]. These knowledge generation processes can be, for example, about tacking information discrepancy or cognitive incongruity experienced in learning activities. Studies have shown that epistemic emotions such as surprise, curiosity and confusion are commonly experienced in learning contexts and related to facial expressions [2]. The coordination among facial expressions with achievement and epistemic emotions provide valuable insights in understanding students' motivation, learning achievement, academic success and well-being [5,20 30].

Emotions in collaborative learning

Emotions are not solely intra-personal or within-person experiences. They are inherent parts of our social lives and shape our relationships with others [31]. The social aspect of emotions has attracted a growing body of research in education, specifically in collaborative learning. Studies have found complex relationships between emotions and cognitive processes in collaborative settings, which have highlighted the role of effective emotion regulation within and between teammates who successfully collaborate [16]. However, many studies exploring emotions in collaborative learning are limited in how the temporality of emotions are measured. Common approaches capture emotional states in collaborative learning with self-reported instruments or utilize team interaction utterances [18]. However, self-reported measures fall short in capturing the transient and continuous nature of emotions, while team interaction utterances require extensive coding which is laborious and requires coders to infer an emotional state solely based on the verbal utterances from the team's interactions. A recent approach in capturing emotions in collaborative settings leverages machine learning models to automatically recognize facial expressions from video recordings of teammates. These methods continuously classify the type and intensity of facial expressions during the collaborative task.

Despite their widespread availability, only a limited number of studies have utilized automated facial recognition software to study the role and function of emotions in collaborative learning. Dindar et al. utilized a machine learning algorithm to classify facial expressions of high-school students in a video-recorded collaborative exam setting. In the study, the classified momentary facial expressions were utilized to detect leader-follower dynamics in collaborative teams [4]. Sharma et al. examined whether confusion, frustration, and boredom manifested differently between high- and low-performing collaborative teams that worked on creating games with Scratch. Teammates' individual expressions of confusion, frustration, and boredom were captured using facial recognition, and the results showed that high-performing teams showed more confusion and frustration than low-performing teams. Interestingly, high-performing teams' emotions were often followed by delight or neutral emotions, while low-performing teams' emotions were followed by boredom [29].

Similarly, Hayashi captured facial expressions while groups of students solved on a jigsaw-type collaborative task [13]. A qualitative analysis of team interactions indicated that when teammates work hard to develop a mutual understanding, facial expressions of anger often arise. Further, neutral facial expressions were common among the teammates when they worked individually on the collaborative task (instead of together). Ngo et al. conducted an automated facial recognition study to examine the interplay between facial expressions and regulatory processes in synchronous online collaboration [21]. The results showed that the most common facial expression was surprise among the collaborating students. Specifically, surprise was often experienced when teammates faced cognitive challenges, while sadness was most prominent in moments when teammates had increased their awareness about the task condition. In contrast, happy facial expressions emerged the most in situations where there were socio-emotional interactions between the teammates.

While these studies provide insights into the role of specific facial expressions on collaborative processes that emerge among teams, many questions remain regarding the role of facial expressions within and between teammates. First, the majority of literature on collaborative learning measure facial expressions at the individual learner level. However, emotions are contagious in social settings [9] and serve important social functions that may be conductive to collaboration within the team [31]. Thus, it is important to examine whether specific facial expressions are present among individuals and shared at the team level. Another challenge is the scarcity of experimental research on collaboration that employed different types of collaborations. For example, the causal relationships between specific facial expressions and collaborative processes could vary depending on different types of teams (e.g., competitive vs. non-competitive). Very few studies have examined the role of facial experiences among individuals who are competing in teams that shared a common goal. In real-life settings (e.g., business), individuals collaborate to achieve team goals with the aim of maximizing their personal benefits from the outcome [28]. Thus, we argue that competitive dynamics could induce different emotional experiences within and between teams and should be an area of study in collaborative learning research.

Finally, to our knowledge, no study has explored how facial expressions operate in teams before they quit. To address these limitations, the current study utilized a digital game-based learning environment with two experimental conditions: within-team competition (WTC) and no within-team-competition (NTC). Both conditions were instructed to collaborate within a triad and compete against other teams during a collaborative task. However, teams within the WTC condition were ranked by their teammates from the most to the least successful at the end of the task based on their individual success during their team collaboration. Thus, learners in a WTC condition were exposed to the dilemma of prioritizing between their individual success and the team success during game play. In contrast, in the NTC condition all the team members within teams failed or succeeded together, without any ranking among teammates.

The current study includes a subset of data collected for a larger project. During the larger project data collection, several teams decided to quit the collaborative game since they were not able to progress towards achieving game goals. The data from these failing teams were utilized to answer our research questions.

1.2 Current study

The objective of this study was to the examine the emergence of facial expressions across individual and team levels during failed collaborative tasks in conditions of WTC and NTC. Our specific research questions are:

RQ1. Is there a difference in the of recurrence of valence at the a) individual level and b) whole team level between the experimental conditions?

RQ2. Is there a difference in the recurrence of arousal at the a) individual level and b) whole team level between the experimental conditions?

RQ3. Is there a difference in the recurrence of emotions (joy, anger, sadness, surprise, fear, and neutral) at the a) individual level and b) whole team level between the experimental conditions?

2 Methods

2.1 Participants and Materials

A sample of 30 Finnish high-school students completed the study (n_{female}=18; n_{male}=11; n_{other}=1). Their mean age was 17 years (*SD*=1.1). Participation was voluntary and no compensation was offered for completing the study. However, it was announced that a surprise gift will be given to the most successful team in the game. An ethics review committee approved of this study prior to recruitment and data collection.

Prior to the collaborative task, participants were administered several pre- and post-test measures, including multiple validated instruments to capture their metacognition and prior biology knowledge. The information regarding the content of pre-test measures is omitted in this paper since they are not related to the current research questions.

2.2 Collaborative game

Bird Breeder, a multiplayer open-source game developed in Netlogo agent-based modelling environment, was utilized in the current study [36]. The game was originally developed to teach selective breeding to high-school students. In this game, three players work together to develop a breed of colorful looking birds with a specific crest, wing, breast and tail color. At the beginning of the game, each player is assigned three birds that have only some features of the desired features. Players keep mating their birds with other teammates' birds until all of them have at least three birds that carry the desired features. The team score was calculated by the total number of bird mating until all desired birds are produced. Lower number of bird mating referred to higher team ranking. Thus, teammates had to be strategic while mating the birds rather than mating them in a random manner.

2.3 Experimental Design

In the WTC condition, participants were instructed that the overall objective in the game was to complete the game with a minimum number of bird mating. It was also announced that team members will be ranked as first, second and third within their team based on how fast each member produced the three desired birds compared to their teammates. In the NTC condition, participants were instructed that the objective was to collaborate with teammates to complete the game with minimum number of bird mating. No ranking was introduced between the teammates in this condition.

2.4 Procedure

Participants arrived at the laboratory on the agreed time in groups of six. Upon arrival, they were presented consent forms and pre-test measures. After completing the consent form and the pre-tests, a raffle was drawn to determine teammate assignment. Participants were then guided to separate soundproof cabins and asked to watch a prerecorded instruction video on how to play the game. The instruction video included the same content for both conditions except for one aspect. In the WTC group, the video explained the ranking process among the team members, while this information was not provided to the NTC group. After watching the instructional video, participants were asked to play the game with their teammates via voice communication through their headphones and microphones. No time limit was set for completing the game. Participants played the game with their teammates until the whole team decided to quit since they were not able to create the desired bird breed. It took a minimum of 43 minutes and a maximum of 60 minutes for the teams to quit the game. From beginning to the end of game play, participants' facial expressions were recorded with high resolution video cameras that were placed behind their computer screens.

2.5 Post Processing and Data analysis

Facial Expressions Data. FaceReader [Version 9.0], an automated and validated facial recognition software, was used to classify facial expressions of emotions from video recordings at a sampling rate of 30Hz. FaceReader was built from the Facial Action Coding System (FACS) to detect facial expressions based on specific configurations of facial muscular movements. With an average accuracy rate of 99% [38], FaceReader provides a range of metrics, including a continuous measure of arousal, valence, and the intensity of six emotions: joy, sadness, anger, surprise, fear and disgust. In the current study, Facereader classified facial emotions with a continuous calibration to account for individual baselines in expression of facial emotions.

Data were post-processed at a sampling rate of 5 frames per second. Next, a binary times series was created for each of the basic emotions. Since an intensity score was provided for all emotions at each frame, we determined that the most dominant emotion was represented by the highest intensity score compared to the other emotions. Thus, the most dominant facial expression of emotion was coded as 1 and the remaining were coded as 0.

Recurrence Quantification. To answer our research questions, recurrence quantification analysis (RQA) was calculated at the individual and whole team level. RQA is a nonlinear method that detects recurrent patterns in dynamical systems with nonlinear temporal properties [35]. In RQA, recurrence indicates the percentage of repetitions that occurs in a phase space trajectory compared to all measurement points in a time series data [34]. Using either continuous or categorical time series, RQA can extract recurring patterns. Data were analyzed from beginning to the end of gameplay in five-minute intervals.

To study the recurrence of facial expressions at the individual level, Auto Recurrence Quantification Analysis (ARQA) was utilized. ARQA calculates the extent of recurrence within a *single* time series by plotting it against itself [35]. To study recurrence of emotions at whole team level, Multidimensional Recurrence Quantification Analysis (MdRQA) was utilized. MdRQA allows for studying the extent of coupling between *more than two* series [33]. In the current study, ARQA was used to examine the rate of recurring facial expressions at the individual level, while MdRQA was used to examine the rate of recurring facial expressions at the team level. Continuous ARQA and MdRQA were calculated on valence and arousal scores, while categorical ARQA and MdRQA were calculated on the emotions binary time series.

Given that that five of the quitting teams were from WTC condition and five were from NTC, the small sample sizes made it impossible to conduct statistical tests to compare differences in recurrence rate scores between conditions. Instead, we utilized RQA plots to provide qualitative information regarding the recurrence of facial expressions at the individual and team level. This allowed us to conduct a qualitative how specific emotions unfolded from beginning of the gameplay towards quitting of the game.

3 Results

RQ1. Is there a difference in the recurrence of valence at the a) individual level and b) whole team level between the experimental conditions?

ARQA found that the recurrence rate of valence was higher in the WTC condition from beginning to the end of the gameplay compared to the NTC condition. It should be noted that higher recurrence in valence scores does refer to positive or negative emotions. Rather, it implies that valence scores exhibited more similarity within each participant in WTC than the NTC. This similarity could a result of both recurring high, medium or low valence scores.

MDRQA results indicate that valence scores showed more collective recurrence to among the teammates in WTC from beginning to the end of gameplay compared to the NTC group. This finding suggests that team members in WTC were more in synch with each other in terms of the valence of their facial expressions (see Figure 1).

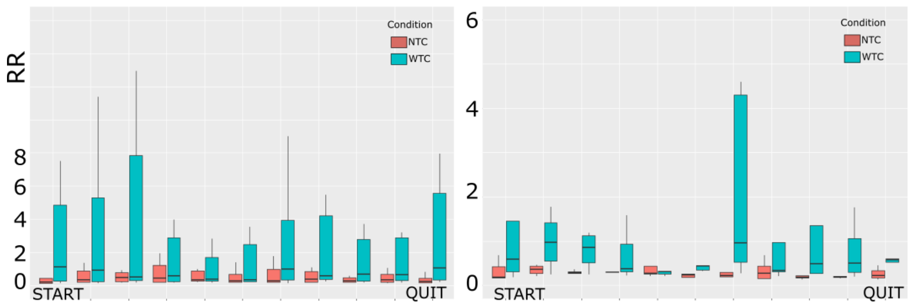

Fig. 1. ARQA (left) and MdRQA (right) results for Valence. RR: Recurrence rate.

RQ2. Is there a difference in the recurrence of arousal at the a) individual level and b) whole team level between the experimental conditions?

ARQA and MdRQA results did not show distinct patterns that indicate differences in the recurrence rate of arousal between the experimental conditions from beginning of gameplay. However, a downward trend was observed in both conditions towards game quitting (see Figure 2).

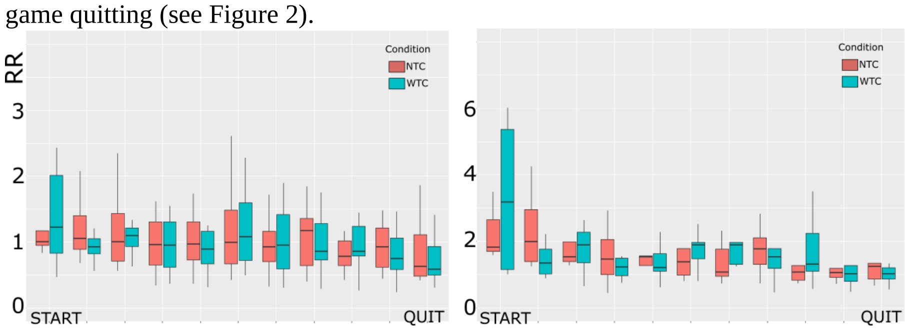

Fig. 2. ARQA (left) and MdRQA (right) results for Arousal. RR: Recurrence rate.

RQ3. Is there a difference in the recurrence of emotions (joy, anger, sadness, surprise, fear, and neutral) at the a) individual level and b) whole team level between the experimental conditions?

Joy. ARQA results showed that, overall, joy recurred to a higher extent at the individual level in NTC condition compared to the WTC condition. It was also observed that recurrence of joy was higher towards the end of the task compared to the initial stages of gameplay. MdRQA results showed that at the team level, teams in the NTC were also exhibited more recurring joy collectively, specifically during the final minutes before task quitting. In WTC, joy did not demonstrate collective recurrence by the whole team in most of the gameplay episodes (see Figure 3).

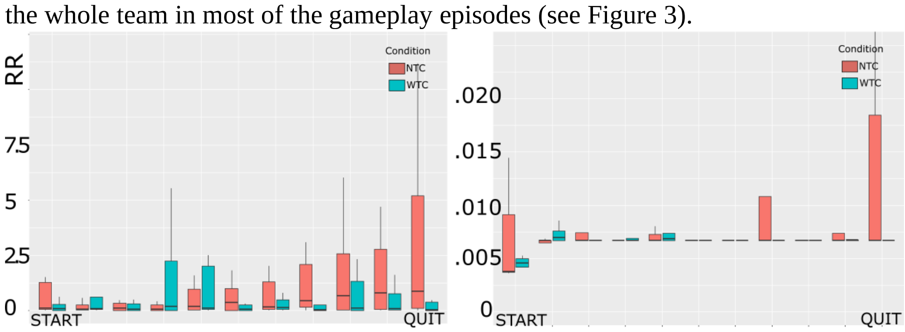

Fig. 3. ARQA (left) and MdRQA (right) results for joy. RR: Recurrence rate.

Anger. Overall, higher recurrences of anger were observed at the individual in the NTC condition than the WTC condition. Specifically, anger demonstrated more recurrence at the individua level in the NTC condition during the final minutes before task quitting. According to MdRQA results, anger did not recur collectively at the team level in any of the conditions (see Figure 4).

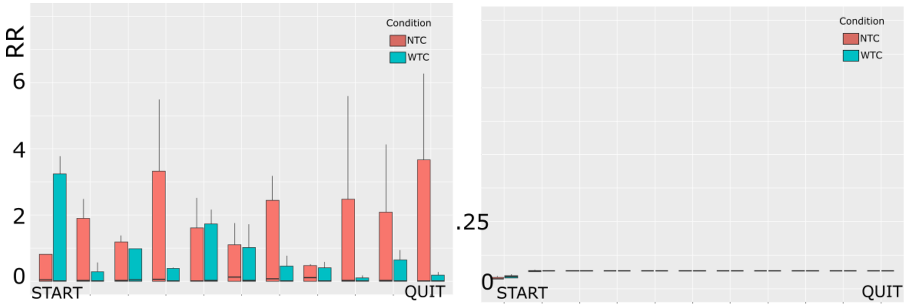

Fig. 4. ARQA (left) and MdRQA (right) results for anger. RR: Recurrence rate.

Sadness. The ARQA results showed that sad facial expressions recurred to a higher extent at the individual level for participants assigned to the WTC condition compared to the NTC condition. However, MdRQA results showed that sadness did not recur collectively (at the team level) by either condition (see Figure 5).

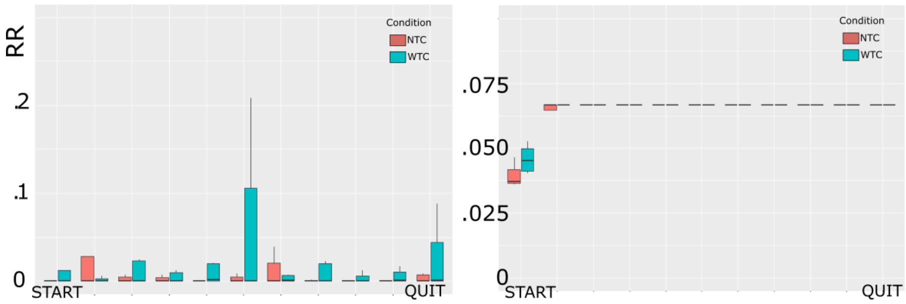

Fig. 5. ARQA (left) and MdRQA (righy) results for sadness. RR: Recurrence rate.

Surprise. ARQA results showed that surprised facial expressions recurred to a higher extent at the individual level for those assigned to the WTC group than NTC group. MdRQA results showed no team level recurring surprise in any of the conditions (see Figure 6).

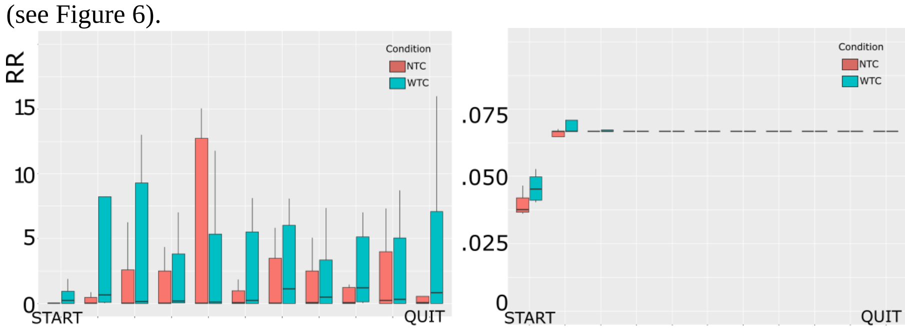

Fig. 6. ARQA (left) and MdRQA (right) results for surprise. RR: Recurrence rate.

Fear. The ARQA and MdRQA results demonstrated no recurrences of scared facial expressions at both the individual and team level between both conditions (Figure 7).

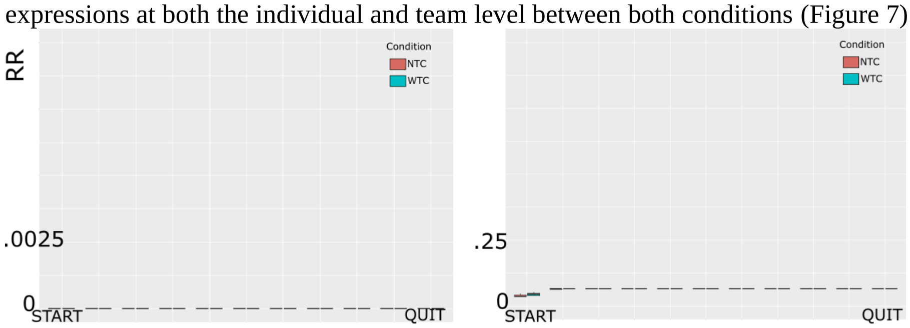

Fig. 7. ARQA (left) and MdRQA (right) Results for scared. RR: Recurrence rate.

Neutral. ARQA results showed that the recurrence rate of neutral facial expressions at the individual level was higher in NTC condition group at the beginning of gameplay compared to the WTC condition. However, recurrence of neutral emotions has become lower at the individual level in the NTC condition towards the end of gameplay. MdRQA results displayed the similar trend as ARQA results at the team level. (see Figure 8).

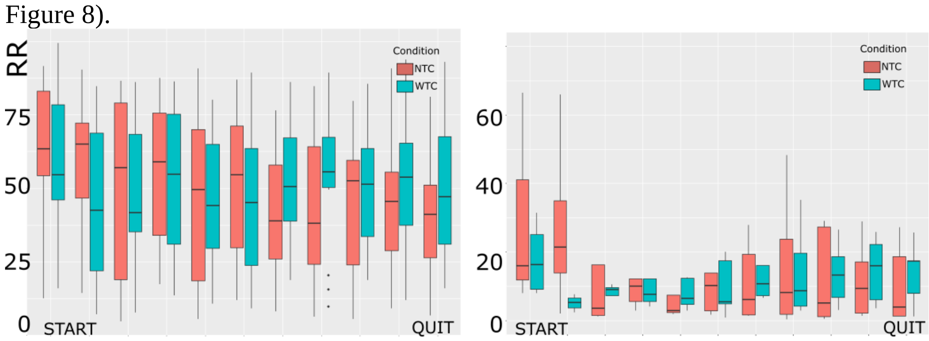

Fig. 8. ARQA (left) and MdRQA (right) Results for neutral. RR: Recurrence rate.

4 Discussion

The objective of this study was to study the facial expressions (arousal, valence, emotions) at the individual and team level during collaborative tasks that teams quit across two experimental conditions: within-team competition and no-within team competition.

The current findings showed that valence scores exhibited more similar and recurring patterns at the individual level for those assigned to WTC teams compared to NTC teams (RQ1). In addition, facial expression valence was higher at the team level for those assigned to WTC teams than NTC teams. Valence represents the pleasuredispleasure continuum of emotions [26]. The current findings imply that the recurring valence during the collaborative gameplay was more common in WTC condition. This indicated that valence was recurring within similar values (e.g., high-high or low-low) throughout the game play in this condition. A possible explanation of these findings would be expressive suppression in team settings. Expressive suppression refers to diminished outward expressivity of emotions to others such as intentionally showing a “poker face” [12]. In WTC condition, team members needed each other’s knowledge and resources (i.e., birds) to succeed in the game while attempting to secure a higher rank within the team. The dilemma of succeeding with others while dominating them might have pushed participants to mask their facial expressions to a higher extent. Thus, they might have intentionally expressed milder positive and negative responses to other teammates to maintain a positive image or appear reliable to gather information and resources from them. It is known that suppression of facial expressions can lead to increased physiological arousal such as heightened heart rate, increased blood pressure or rising electrodermal activity [22]. Future research can test our assumption about the association between suppression of facial expressions and physiological signals by comparing physiological signals of teammates in competitive and non-competitive team settings.

In terms of arousal scores, we could not identify differing patterns between the WTC or NTC conditions (RQ2). However, arousal decreased in both conditions towards task quitting. In learning settings, heightened arousal often refers to increased attention and effort on the learning topic [17]. Arousal tends to decline in conditions of increased fatigue and loss of attention [15]. In the current study, the decreased arousal towards game quitting suggests that teammates in both conditions were displaying less intense facial expressions. Thus, it can be argued that decreased arousal might be an indicator of increased fatigue, loss of attention and control on game task that may have contributed to task quitting. In future research, we will compare facial expression arousal levels between succeeding and failing teams to test this assumption.

Overall, joy was expressed to a higher extend by the participants in NTC than WTC (RQ3). It has been found that feelings of joy often emerge in psychologically safe contexts [8]. In the current study, WTC teams faced two significant challenges. The first challenge was failing in gameplay, and the one second was competition within the team. Our findings showed that competition within a team has an additive negative impact on feelings of joy in team failure situations. Interestingly, an increasing trend of joy expression was observed towards game quitting in NTC condition. At first sight, it might look odd to see that NTC teammates became more joyous although the failure became more and more evident to them towards quitting. However, several studies have shown that individuals can experience positive feelings even in times of extreme stress [37]. Folkman has developed a model suggesting that positive emotions can serve several functions under stress such as coping and restoring mental resources [7]. Therefore, it can be claimed that in safe collaborative environments, teams might utilize positive emotions such as joy to cope with the collaborative task demands and failure.

Overall, higher recurrences of anger were observed at the individual level in NTC than WTC. Specifically, anger recurred more in NTC during the final minutes before game quitting. Anger, as an emotional experience, is often unwelcome in team settings.

However, anger also helps individuals in overcoming fears and building self-confidence [14]. Anger can also facilitate constructive conversations among the team members and push them to adapt to challenges [11]. In the current study, higher recurrences of anger in NTC condition might refer to the team members' will to change the course of gameplay from an approaching failure towards success. Thus, anger might be utilized by team members as an alert to avoid team failure. However, in WTC condition, team members faced two threats. The first threat is failing as a whole team, and the second threat is falling behind the other members regardless of whether the team succeeds or not. The current findings indicate that players in WTC condition might be more inclined to accept failing as a whole team to avoid the fear of failing individually. Thus, they might have expressed less desire to change the course of the game by expressing less anger. Our current finding about sad emotion supports this claim. Overall, sadness recurred to a higher extent within the WTC team members compared to NTC. Sad emotion is regarded as part of human withdrawal system that facilitates avoidance behavior in relation to cues of threat [3]. Therefore, it can be claimed that in cases of within team competition, team members might prioritize avoiding individual failure to whole team success.

Higher recurrences of surprise were observed at the individual level in WTC than NTC. Considering that teams in both experimental conditions failed in the collaborative task, similar recurrences of surprise would be expected in WTC and NTC. Surprise, as an epistemic emotion, ensues when learners come across with unexpected information or feedback that is incongruous with their cognitive schemas [32]. In the current research context, surprise might refer to situations in which team members receive feedback from the game environment that does not match with their representation of the problem or formulation of their strategies. For example, players might mate specific birds thinking that it will result in producing specific bird features. However, they might be surprised if the mating would not produce the expected bird features. In general, feeling of surprise is often followed by curiosity or confusion [19]. Curiosity is associated with behaviors in gaining more knowledge to resolve the cognitive incongruity. However, the findings regarding the relationship between confusion and knowledge gain is inconsistent [32]. One way to understand the difference between WTC and NTC in terms of recurrences of surprise would be to study cognitive and/or affective states followed by surprise. For example, future research can explore whether WTC and NTC differ from each other in terms of curiosity or confusion instances preceded by surprise.

No recurrent patterns of scared facial expressions were detected in any of the experimental conditions. This might be due to the game design, where the game did not include strong narratives, graphics, sounds or rules that might elicit feelings of fear among the players. Apart from facial expressions of emotions, the current study also explored the recurrence of neutral facial expressions in WTC and NTC towards game quitting. It was observed that neutral facial expressions were recurring more in NTC in from beginning to half-time in gameplay. However, from half-time to the end of gameplay, neutral facial expressions were recurring to a higher extent in WTC. In line with our current findings about other emotions, this shift across the experimental conditions imply that WTC team members were adopting deactivating emotional states whereas NTC team members were adopting activating emotional states towards game quitting.

To put simply, WTC teams were preparing themselves for accepting failure whereas NTC teams were still struggling to tackle imminent failure.

Overall, the current study showed that collaborative and competitive dynamics facilitate differing types and levels of facial emotions in a digital learning game in which teammates fail eventually. Understanding the function of emotions within and between the individuals in team failure conditions might help us to leverage those emotions to facilitate productive team interactions and better well-being in game-based and other technology-enhanced learning environments.

Limitations and future directions

The current study was conducted on a modest sample size. Thus, generalizability of the current findings might be limited. Participants' personality traits and their prior social relationships with their teammates were not taken into consideration when interpreting the current findings. Future research can explore how such confounding factors team collaboration in WTC and NTC context. Collaborative gameplay in the current study was achieved via audio communication among the team members. Although voice-only communication is common in multiplayer games, the current findings might not apply to face-to-face collaborative learning settings in which learners are able to observe others' facial expressions. Another limitation of this study is that it only uses facial expression data. We plan to extend this study with a multimodal approach by studying physiological signals and actual game behaviors of the participants in WTC and NTC conditions.

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