The Effects of Rejection Sensitivity on Confusion Regulation during Learning in Multiagent Intelligent Tutoring System Environments

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Abstract. Confusion is a popular epistemic affective state during team learning, indicating that there is a problem with the current state of one's knowledge. Previously, we have successfully induced learner's confusion during virtual team learning within a Multiagent Intelligent Tutoring System that teaches research methods. The desirability of confusion induction is relatively unequivocal, but how and to whom confusion regulation enhances learning remains an open question. This study addresses these challenges through three experiments in virtual team learning examining potential relationships between confusion regulation and subsequent learning outcomes among learners with different rejection sensitivity. In Study 1 (n = 81), we compared the effects of cognitive support, socio-affective support, and control condition on confusion regulation learning outcomes within a Multiagent Intelligent Tutoring System environment that offers virtual team learning. In Study 2 (n = 102) and Study 3 (n = 102), we examined if learners with different rejection sensitivity could benefit from cognitive or socio-affective support respectively. In these studies, participants received support from a virtual team on how to regulate confusion after a confusion induction. The results indicated that cognitive support in response to low rejection sensitivity learner's confusion had positive effects on enhancing learning outcomes, while socio-affective support was more suitable for high rejection sensitivity learners. Hence, learning is more increased when the virtual team environments capitalize on the benefits of personalized confusion regulation besides confusion induction.

Keywords: Confusion Regulation, Rejection Sensitivity, Multiagent Intelligent Tutoring System.

1 Introduction

Confusion is a popular epistemic affective state during team learning, which can be beneficial for learning, particularly at deeper levels [1-3]. Confusion provides a learning opportunity indicating that there is a problem with the current state of one's

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knowledge. Previously, we have successfully induced learner's confusion in a Multi-agent Intelligent Tutoring System (MITS) [3]. The MITS is a virtual team learning environment, designed to increase human learner's learning by using two peer conversational agents that detect and respond to learner cognitive and affective states. When facing contradictory information over the course of learning research methods concepts presented by agents in MITS, human learners reported more confusion. Experiences of confusion have been found to result in modestly enhanced learning outcomes. The findings can be explained by theories of learning that emphasize cognitive conflict (see [4] for a review), cognitive disequilibrium [5] and impasse-driven learning [6]. These theories propose that it is not the mere occurrence of confusion that leads to learning, but rather it is the effortful cognitive activities that are triggered by a desire to resolve the confusion and benefit learning. It is important to note, however, that many of these learning opportunities are missed because although learners acknowledge there is a problem with their current mental model, they fail to resolve their confusion [7]. These findings suggest that the MITS should be designed not only to induce the occurrence of confusion but also to support learners in confusion resolution. The question then arises of what type of support in MITS is effective.

1.1 Support as a Function to Regulate Confusion

When people experience protracted confusion in the group, they typically feel the urge to tell or ask others about their experience, a phenomenon also termed social sharing [8]. One review found that almost all emotional experiences are shared with others [9]. Social sharing can be seen as a means of emotion regulation, in that the person who is sharing attempts to receive help from another in regulating their own emotions. Then what type of support do individuals seek when sharing their emotions?

Two primary types of support have been distinguished by Rimé [8]. Listeners may offer socio-affective support, which includes comfort and validation, or cognitive support, which is directed at altering cognition related to the emotional experience by recreating meaning and reappraisal. It has been argued that these two types of support are differentially effective: whereas socio-affective support temporarily alleviates emotional distress, cognitive support is thought to be effective in bringing about more long-term recovery [8, 9, 10]. What is unknown, however, is whether this differential effectiveness existed in the learning domain and whether learner differences map onto this differential effectiveness. Do learners indeed gain from the support that would be best for them to regulate their confusion? The aim of the present paper is firstly to investigate the learning outcome of these different types of support which are supposed to regulate learners confusion, and secondly to establish whether the learning effectiveness of support depends on the learner difference, such as rejection sensitivity.

1.2 Rejection Sensitivity and Support

Students depend on others for confusion regulation and knowledge acquisition in a group. Yet, efforts to connect with others and seek support from others holds the potential for rejection. People vary greatly in the extent to which they identify cues of a social threat as personally threatening and in how they respond to them [11, 12]. This variability can be described in individual differences in rejection sensitivity. The phenomenon of rejection sensitivity has a long descriptive history in clinical psychology. Building upon cognitive social-learning theories of development, Downey and colleagues [11, 12] have developed a model of rejection sensitivity (RS) that defines the phenomenon in social-cognitive terms -- as the disposition to anxiously expect, readily perceive, and intensely react to rejection. The RS model proposes that prior exposure to the pain of rejection, perhaps in conjunction with biological vulnerability, leads individuals to become sensitized to the possibility of future rejection by significant others and motivated to protect themselves from it.

There is considerable evidence to support the notion that RS contributes to problems by leading individuals to process information in ways that prioritize detecting and quickly responding to threats of rejection. People high in RS have preexisting expectations for rejection that are readily triggered and used to make sense of social interaction cues in the current situation [12]. For example, those high in RS interpret short information of others' naturalistic emotional responses as expressing more interpersonal negativity, but not more positivity [13]. Back to the learning domain, do these processes that serve early detection and management of potential rejection threats in rejection-sensitive learners block the way of benefits from support in confusion regulation? In the current study, we examine the learning effects of support as a MITS function in helping with regulating different learner's confusion. We focus on the RS difference of learners that differ on whether they anxiously expect, readily perceive, and intensely react to rejection when facing support from others.

2 Study 1

In Study 1, we examined the potential learning effect of support to regulate confusion within a MITS environment that offers virtual team learning. The MITS experimentally induces and regulates human learner's confusion via two animated pedagogical peer agents during research method learning. Former researches showed that only some learners could automatically take effective actions to regulate confusion and gain knowledge. So we hypothesized in Study 1 that better learning gains would appear when the confusion was induced and appropriately regulated by supports.

2.1 Participants

Eighty four undergraduates at a general university in China were recruited to participate in exchange for extra course credits. They had no learning experience in the experimental material (research methods). Three volunteers were dropped from the dataset because their finishing time of the experiment was over 3 standard deviations above average time. This resulted in a final sample of 81 participants (54 female and 27 males, mean age = 21.2 years).

2.2 Mixed Design

The study involved a 4 (Social Confusion Induction: true-false, false-true, false-false, true-true) x 3 (Social Confusion Regulation: cognitive support, socio-affective support, no support) mixed design. Participants have received all four types of social confusion induction in a Graeco-Latin Square order and were randomly assigned to one of the social confusion regulation conditions. Proportional learning outcome was computed as (posttest - midtest)/(1 - midtest).

2.3 Social Confusion Induction Manipulation

Similar to D'Mello et al. [2], social confusion induction was operationalized by varying contradictory information in agent agreement and information correctness during the trialogues (three-party conversation: a participant and two pedagogical peer agents) phase. In the control condition, both agents agreed on the correct information (true-true), while in the other three experimental conditions, two agents either disagreed with each other or agreed with the incorrect information. After both agents presented their respective opinions, then the participant would be asked by an agent to express oneself. The contradiction between the agents' opinion was expected to trigger the participant's confusion.

2.4 Social Confusion Regulation Manipulation

We operationalized social confusion regulation by varied support types. *Cognitive support* was always characterized by triggering participants to stop, reflect, and further deliberate over which agent's opinion was correct and why that opinion was correct (e.g. "XX, remember to think about how students in the control and experimental groups behaved during the study. Try to put together a convincing argument to get me on your side."). *Socio-affective support* messages from agents always included validation of participants' confusion, understanding, and encouragement (e.g. "You know, this feeling is actually a good thing in learning. It helps us to notice that we ignore some knowledge about experimental groups. Let's keep trying to figure out this concept."). All supportive reactions were tailored to the specific trialogue background to enhance ecological validity.

2.5 Procedure

The experiment occurred over five phases (each for 2.5 hours): the participants (1) took a pretest for prior knowledge, (2) acquired research methods knowledge through multimedia learning to identify the contradictory of information in later trialogues, (3) took a mid-test to assess and control over learning outcome in multimedia learning, (4) attended eight trialogues (each about one concept) offering contradictory and supporting information to induce and regulate participant's confusion respectively (see Fig. 1), and (5) took a post-test to check each one's overall learning outcome. Each trialogue in the fourth phase began with a description of a research methods practice. Participants read the description and then discussed it with the agents. Each discussion involved four trials. The first three trials were about social confusion induction, and the last trial was for social confusion regulation.

Fig. 1. Screenshot of the learning interface.

2.6 Learning Outcome Measurement

Learning content about eight concepts of research methods covered in eight trialogues were tested three times, including a pretest, a mid-test, and a post-test. Learning outcome served as the dependent variable and was used to assess the benefit of support, indicated by the score gap between post-test and mid-test. Each test had 24 multiple-choice questions with three questions per concept. The three types of items were based on the first three levels of Bloom’s Taxonomy (knowledge, comprehension, application). Three alternate test versions and assignments were counterbalanced across participants.

2.7 Results of the Learning Outcomes

Table 1. Means (*M*) and Standard Deviations (*SD*) of learning outcomes.

	CS (*N* = 27) *M (SD)*	SAS (*N* = 27) *M (SD)*	NS (*N* = 27) *M (SD)*	Total (*N* = 81) *M (SD)*
True-False	.57 (.27)	.36 (.19)	.32 (.13)	.42 (.23)
False-True	.55 (.25)	.35 (.22)	.32 (.23)	.41 (.26)
False-False	.31 (.2)	.28 (.13)	.25 (.09)	.28 (.15)
True-True	.34 (.25)	.44 (.25)	.26 (.14)	.35 (.23)

Notes. CS = cognitive support, SAS = socio-affective support, NS = No support.

To test which type of support benefited learning outcomes, and whether these effects were dependent on the confusion occurrence, a 4(Social Confusion Induction) x 3(Social Confusion Regulation) two-way ANOVA was performed with learning outcome as the dependent measure. The proportional occurrence of test scores for learning outcome is presented in Table 1. The results showed a significant interaction between social confusion induction and social confusion regulation, $F(6, 234) = 2.46$,

$p < .001$, $\eta_p^2 = .11$. Simple-effects analyses suggested that within the true-false condition, the participants who received cognitive support outperformed those who received socio-affective support ($M_{CS\text{-}SAS} = .22$, $SD = .06$, $p = .001$) and no support ($M_{CS\text{-}NS} = .25$, $SD = .06$, $p < .001$); a similar learning benefits trend existed in the false-true condition ($M_{CS\text{-}SAS} = .2$, $SD = .07$, $p = .02$; $M_{CS\text{-}NS} = .24$, $SD = .06$, $p = .001$), but not in the true-true and false-false condition.

3 Study 2

Study 1 showed that purely socio-affective support was a worse choice for social confusion regulation. Before interpreting these patterns, it should be noted that the support messages in Study 1 were not tailored to the specific learners. Therefore, the differential learning effects cannot be solely attributed to the different types of support. To allow for firmer conclusions, we conducted two replication studies in different learners with high or low RS. In Study 2, we examined the potential learning effect of support to regulate confusion among students with low rejection sensitivity (LRS) within a MITS environment. Previous researches showed that LRS is characterized as less anxiously expecting and reacting to social rejection. So we hypothesized that in Study 2 better learning gains among students with LRS would appear when the confusion was induced and appropriately regulated via cognitive support.

3.1 Participants

One hundred and two volunteers (63 females and 39 males, mean age = 20.8 years) were recruited from a general university in China (see table 2). Participants were recruited both through advertisement on campus and through contacting pre-screened individuals with low scores (25th percentiles) relative to the normative sample for the Rejection Sensitivity Questionnaire [14]. Although RS is measured continuously, to simplify the analyses we treated it as a dichotomy. People scoring at or below 25th percentiles were defined as LRS and could be viewed as tending to calmly expect acceptance.

Table 2. Description of participants.

	N	*M*	*SD*	*t*	*p*
Low RS	102	5.41	1.6	22.88	<.001
High RS	102	14.14	3.5		

3.2 Rejection Sensitivity Measurement

The Rejection Sensitivity Questionnaire was adopted to assess anxious expectations of social rejection by measuring responses to 18 hypothetical interpersonal interactions in which rejection is a possibility (e.g., "You ask your friend to do you a big favor") [14]. For each hypothetical interaction, the respondent indicated his or her degree of concern or anxiety about the outcome, as well as the perceived likelihood that the interactant (or interactants) would respond with rejection. RS scores were calculated by first weighing the expected likelihood of rejection for each situation by the degree of anxiety and then averaging these weighted scores across all situations. Coefficient alphas for the scale were .83. The research design, variable manipulation, experimental procedure, and learning outcome measurement were all similar to those of Study 1.

3.3 Results of Learning Outcomes

Table 3. Means (*M*) and Standard Deviations (*SD*) of learning outcomes.

	CS (*N* = 34) *M (SD)*	SAS (*N* = 34) *M (SD)*	NS (*N* = 34) *M (SD)*	Total (*N* = 102) *M (SD)*
True-False	.7 (.17)	.42(.32)	.38 (.28)	.5 (.26)
False-True	.66 (.18)	.42 (.3)	.35 (.29)	.48 (.26)
False-False	.45 (.26)	.4 (.11)	.24 (.1)	.36 (.16)
True-True	.34 (.14)	.36 (.08)	.29(.07)	.33 (.1)

To test which type of support benefited learning outcome within LRS learners and whether these effects were dependent on the confusion occurrence, a 4 x 3 two-way ANOVA was performed with learning outcome as the dependent measure. The proportional occurrence of test scores for learning outcome is presented in Table 3. The results showed a significant interaction between social confusion induction and social confusion regulation, $F(6, 297) = 5.06$, $p < .001$, $\eta_{p2} = .09$. Simple-effects analyses suggested that within the true-false condition the LRS participants who received cognitive support significantly outperformed those who received socio-affective support ($M_{CS\text{-}SAS} = .28$, $SD = .06$, $p < .001$) and no support ($M_{CS\text{-}NS} = .32$, $SD = .06$, $p < .001$); a similar learning benefits trend existed in the false-true condition ($M_{CS\text{-}SAS} = .24$, $SD = .06$, $p = .001$; $M_{CS\text{-}NS} = .31$, $SD = .06$, $p < .001$). Within the false-false condition the LRS participants who received cognitive support significantly outperformed those who received no support ($M_{CS\text{-}NS} = .21$, $SD = .05$, $p = .001$). Those who received socio-affective support significantly outperformed those who received no support ($M_{SAS\text{-}NS} = .16$, $SD = .05$, $p = .021$). Within the true-true condition no significant difference existed among three conditions.

4 Study 3

Study 2 suggested that purely socio-affective support was indeed a worse choice for social confusion regulation within LRS learners. Is this conclusion also true in high RS learners? In Study 3, we examined the potential learning effect of support to regulate confusion among students with high rejection sensitivity (HRS) within a MITS environment. Previous researches showed that HRS is related to avoidance of situations that entail a risk of rejection or criticism. So we hypothesized that in Study 3 better learning gains among students with HRS would appear when confusion was induced and appropriately regulated via socio-affective support.

4.1 Participants

One hundred and two volunteers (73 females and 29 males, mean age = 21.3 years) were recruited from a general university in China (see table 2). Participants were recruited both through advertisement on campus and through contacting pre-screened individuals with high scores (75th percentiles) relative to the normative sample for the Rejection Sensitivity Questionnaire [14]. People scoring at or above 75th percentiles were defined as HRS and could be viewed as tending to anxiously expect rejection. The research design, variable manipulation, experimental procedure, and learning outcome measurement were all similar to those of Study 1. The rejection sensitivity measurement was similar to that of Study 2.

4.2 Results of Learning Outcomes

Table 4. Means (*M*) and Standard Deviations (*SD*) of learning outcomes.

	CS (*N* = 34) *M (SD)*	SAS (*N* = 34) *M (SD)*	NS (*N* = 34) *M (SD)*	Total (*N* = 102) *M (SD)*
True-False	.06(.03)	.33(.25)	.13 (.08)	.17(.12)
False-True	.04 (.02)	.32 (.27)	.12 (.06)	.16 (.12)
False-False	.04 (.02)	.3 (.19)	.1 (.07)	.15 (.09)
True-True	.32 (.16)	.36 (.25)	.28(.09)	.32 (.17)

To test which type of support benefited the learning outcome within HRS learners, and whether these effects were dependent on the confusion occurrence, a 4 x 3 two-way ANOVA was performed with learning outcome as the dependent measure. The proportional occurrence of test scores for learning outcome are presented in Table 4. The results showed a significant interaction between social confusion induction and social confusion regulation, $F(6, 297) = 7.93$, $p < .001$, $\eta_{p2} = .14$. Simple-effects analyses suggested that within the true-false condition the LRS participants who received socio-affective support significantly outperformed those who received cognitive support ($M_{SAS\text{-}CS} = .27$, $SD = .04$, $p < .001$) and no support ($M_{SAS\text{-}NS} = .2$, $SD = .04$, $p < .001$); there was a similar learning benefits trend that existed in the false-true condition ($M_{SAS\text{-}CS} = .29$, $SD = .04$, $p = .001$; $M_{SAS\text{-}NS} = .2$, $SD = .04$, $p < .001$) and false-false condition ($M_{SAS\text{-}CS} = .26$, $SD = .03$, $p = .001$; $M_{SAS\text{-}NS} = .2$, $SD = .03$, $p < .001$); but within the true-true condition no significant difference existed among the three conditions.

4.3 Discussion

In this paper, we grounded the work in social perspectives of learning to investigate through three experiments whether the induction and regulation of confusion could effectively improve learning outcomes among learners with high or low RS. The results indicated that when perceiving confusion, LRS students gained more from cognitive support in confusion regulation. HRS students, however, benefited more from the socio-affective support. These results might be explained by the differences in the internal perception of support information that is being shared in the respective LRS and HRS groups. HRS individuals showed larger arousal responses across cognitive support information from others. This might indicate a general anxious apprehension in a situation characterized by an ambiguous threat, which depleted the psychological resource and weakened their knowledge acquisition.

Compared to their LRS peers, HRS students benefited more from socio-affective support. For LRS, cognitive support creates deep learning opportunities. When receiving cognitive support, LRS learners stop, reflect, and further deliberate over which agent's opinion was correct and why that opinion was correct. However, when HRS students are in this situation, cognitive support is the learning burden instead of a learning opportunity. HRS students are not only aware of the cognitive direction to resolve confusion, but also prepare physiologically for the social exclusion to happen, and fall into an anxious state even before anything aversive has happened. The socio-affective support focuses on the learners themselves instead of others, and therefore, facilitates knowledge acquisition in HRS learners.

Work has been ongoing to develop MITSs to support tailored, guided learning experiences for not only individuals but also teams. As missions become more complex, success requires teamwork. Teams are usually made up of individuals who differ in competency, content comprehension, and disposition. Individuals working in a team not only gain differently but also contribute variously. For example, HRS individuals benefit less from cognitive support in the teamwork environment, and also bring a small contribution to other members' gain and team performance. Hence compared to HRS individuals, HRS team members' interventions are more complicated but more necessary. The complexity lies in the heterogeneous and various team structure and complex interactions. The necessity is mainly embodied in the triple impact from HRS, including himself/herself, other members and the whole team.

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