Impact of Error-making Peer Agent Behaviours in a Multi-agent Shared Learning Interaction for Self-Regulated Learning

Sooraj Krishna[1][a] and Catherine Pelachaud[2][b]
[1]*ISIR, Sorbonne University, Paris, France*
[2]*CNRS-ISIR, Sorbonne University, Paris, France*

Keywords: Pedagogical Agents, Collaborative Learning, Self-Regulated Learning, Human-agent Interaction.

Abstract: Agents in a learning environment can have various roles and social behaviours that can influence the goals and motivation of the learners in distinct ways. Self-regulated learning (SRL) is a comprehensive conceptual framework that encapsulates the cognitive, metacognitive, behavioural, motivational and affective aspects of learning and entails the processes of goal setting, monitoring progress, analyzing feedback, adjustment of goals and actions by the learner. The study aims to understand how error-making behaviours in the peer agent role would influence the learner perceptions of agent roles, related behaviours and self-regulation. We present a multi-agent learning interaction involving the pedagogical agent roles of tutor and peer learner defined by their social attitudes and competence characteristics, delivering specific regulation scaffolding strategies for the learner. The results from the study suggests the effectiveness of error-making behaviours in peer agent for clearly establishing the pedagogical roles in a multi-agent learning interaction context along with significant influences in self-regulation and agent competency perceptions in the learner.

1 INTRODUCTION

Computer-supported collaborative learning environments have enabled interventions in the social processes during learning by the means of artificial pedagogical agents such as virtual agents or social robots and their roles and behaviours towards the learner. Pedagogical agents can be described as intelligent artificial learning partners that can support the student's learning and use various strategies in an interactive learning environment. According to (Stone and Lester, 1996), a pedagogical agent should essentially exhibit the properties of contextuality (providing explanations and responding appropriately in the social and problem-solving context), continuity(maintaining pedagogical, verbal and behavioural coherency in actions and utterances) and temporality(timely intervention in learning to communicate concepts and relationships) to be effective in a learning interaction. Socially shared regulation in learning (SSRL) (Järvelä et al., 2013) constitutes multiple learning partners regulating themselves as a collective unit, through negotiations, decision making and knowledge sharing. Such a shared learning environment would involve entities of different social attitudes and competencies which makes the learning interaction interesting in terms of the types of regulation behaviours emerging from each learning partner. The shared regulation of learning may involve various distinct types of regulation scaffolding such as:

- External regulation: facilitated by more capable or knowledgeable learning partners such as an expert or tutor providing instructions, feedbacks or prompting strategies that can enhance regulation of the learner.
- Co-regulation: when a peer learner influence the regulation behaviours in the learner through jointly constructed goals and decisions. Artificial pedagogical agents have great potential to be used for learning interactions with specific regulation goals and behaviours.

Accurate perception of the pedagogical roles associated with each agent in the learning interaction is essential to ensure that the learner receives and processes the regulation strategies as intended by the design of learning interaction ((Baylor and Kim, 2005)). To date, multi-agent learning interactions involving different role of pedagogical agents in SSRL context

[a] https://orcid.org/0000-0002-6171-1573
[b] https://orcid.org/0000-0002-7257-0761

Krishna, S. and Pelachaud, C.
Impact of Error-making Peer Agent Behaviours in a Multi-agent Shared Learning Interaction for Self-Regulated Learning.
DOI: 10.5220/0010881400003116
In *Proceedings of the 14th International Conference on Agents and Artificial Intelligence (ICAART 2022) - Volume 1*, pages 337-344
ISBN: 978-989-758-547-0; ISSN: 2184-433X

remains largely unexplored (Panadero, 2017), and in this research, we aim to address this opportunity for orchestrating shared regulation interactions with agents of various roles and related regulation scaffolding strategies.

In general, a learning interaction with pedagogical agent(s) in socially shared regulation context can be broken down into three elements which are (i) a human learner, (ii) pedagogical agent learning partner(s) and (iii) a collaborative learning activity. For our research, we design the shared learning interaction with two pedagogical agents, where one agent assumes the role of a tutor, the more knowledged other (MKO), providing external regulation support and the other is presented in the role of a peer learner facilitating co-regulation functions. We have operationalized the roles of tutor and peer collaborator to represent sources of external regulation and co-regulation respectively. Hence the proposed learning interaction would involve a human learner, and two agents with distinct regulation behaviours engaging in a collaborative learning task as represented in Figure 1.

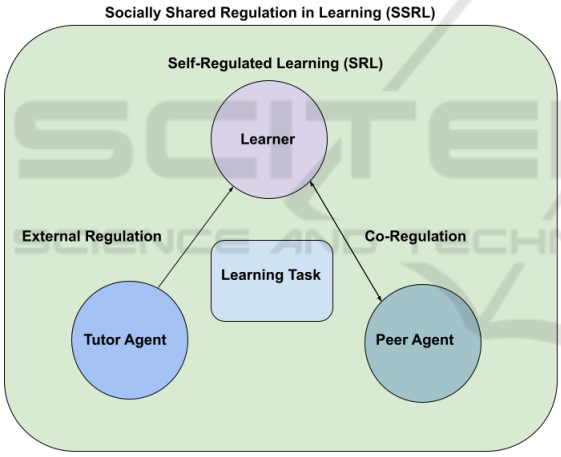

Figure 1: Triadic learning interaction elements constituting SSRL.

2 RELATED WORK

2.1 Error-making Peer Agents

In the self-regulation context, the role of peer is considered as the source for co-regulation strategies which involves supporting and influencing each other's regulation of learning, typically in an independent and reciprocal manner through behaviours such as thinking aloud, seeking help, suggesting alternatives etc. Prior research on pedagogical agents has shown that the learners apply social judgements to agent behaviours and respond to their social cues in accordance to the attributed roles ((Kory-Westlund and Breazeal, 2019); (Breazeal et al., 2016); (Kim et al., 2006)). For instance, (Weiss et al., 2010) found a significant drop in the credibility of the peer agent when it provided an incorrect hint to the learner during the game. (Yadollahi et al., 2018) designed an interaction with a robot peer reading to the child and sometimes making mistakes which the learner is supposed to correct. The mistakes committed by the peer in the task were either contextual, representational or concerning the pronunciation or syntax of the reading material. The study results suggested that the use of pointing gestures by the agent helped the learners to identify and respond to the peer's mistakes. In another study, (Ogan et al., 2012) regarding the interaction with teachable agents where the learners were instructed to narrate their experiences in teaching the virtual agent Stacy, it was found that the agent's task errors were a significant predictor for learner engagement. The authors also suggested making the error more realistic and making the agents acknowledge their errors socially to correctly convey the agent competency level. Concerning the trust factor of the agents, (Geiskkovitch et al., 2019) explored the effect of informational error by the peer in a learning task which observed that the error behaviours do impact the learner's trust on the agent although the effect was limited to the task phase involving the mistake.

Regarding the effect of error behaviours of agents on the regulation of the learner, (Coppola and Pontrello, 2014) observed that learning from error can be an explicit strategy for teaching and can promote self-monitoring and reflection. (Okita, 2014) examined self-training and self-other training in a computer-supported learning environment, designed to assist the learners in assessing and correcting their own learning. The self-training practice involved the learners solving problems on their own while self-other training involved working with a virtual character, taking turns to solve problems and monitoring each other's mistakes. The results suggested that self-other training involving a peer agent which made task errors helped the learners in engaging in metacognitive activities of self-monitoring and correction. Thus error making behaviours by a peer agent can complement the regulation aspects as well signify the associated competency level of the peer.

3 RESEARCH QUESTIONS

The proposed multi-agent learning interaction in SSRL context involves a virtual tutor agent respon-

sible for external regulation and a virtual robot peer exhibiting co-regulation behaviours. The results from the previous perceptive studies that we conducted for understanding the learner perceptions of agent roles and associated behaviours suggested the potential of a multi-agent learning interaction in promoting self-regulation. However, some participants who were observed to have held a wrong perception about the agent roles were reported to be confused over the correct judgement of the peer agent's role. According to the design of the learning interaction, it is necessary for the learner to associate the role of tutor and peer to the intended agents in order to avoid misinterpretation of the regulation strategies and behaviours. Hence, the objective of this study is to introduce error-making behaviours in the peer agent during the learning activity and to understand how it influences the agent role perception and self-regulation in the learner.

3.1 Hypotheses

- **H1:** Error making behaviour of the peer agent would promote the correct perception of agent roles and associated qualities.
- **H1a:** The peer agent will be perceived to be less intelligent than the tutor agent after the activity.
- **H1b:** The learner's role perception of peer agent will improve after the activity.
- **H2:** Error making behaviours of the peer agent would promote better regulation in learners.

4 METHODOLOGY

We have conceived a perceptive study that employs within-subjects design to understand the effect of introducing error making behaviours in the peer agent on the perception of agent roles, associated qualities and the regulation of the learner. The participants were asked to watch videos of tutor and peer agents presenting, performing and regulating themselves or each other during the learning task and to answer questionnaires about their perception of both agents, learning activity and their regulation behaviours.

4.1 System Design

The learning interaction for the study was based on the FRACTOS learning task, which involves building fractions using virtual LEGO blocks (Figure 2), in which the virtual agent (named Alice) is presented as the tutor and the virtual robot (named Bot) is introduced in the role of a peer learner. The Tutor agent is modelled in GRETA platform (Pelachaud, 2015) and animated in Unity3D environment and is characterised by behaviours of moderate dominance and friendliness that defines the social attitude and external regulation strategies that present the agent as a more knowledgeable entity. The peer agent is characterised with moderate levels of dominance and friendliness through multimodal behaviours such as informal, emotional and inquisitive speech, expressive gestures, mutual and joint gaze behaviours. The speech of the virtual peer agent were driven by IBM Watson services platform which associated relevant gestures and animations based on sentiment and semantic analysis of the agent's intended dialogues were realised in Unity3d game environment.

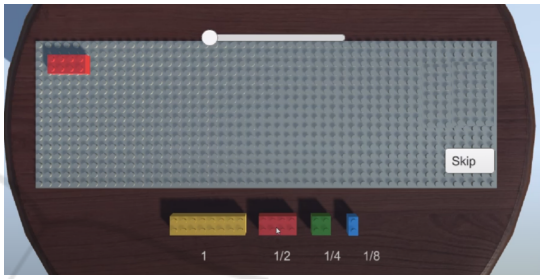

Figure 2: FRACTOS learning task interface.

4.2 Questionnaires

Before the agents were introduced, the participants were introduced to the context of the study and were asked to answer a NARS (Negative Attitudes towards Robots Scale)(Nomura et al., 2006) questionnaire on user's attitudes and prejudices towards virtual characters. The participants gave their ratings for 6 items on a 5-points Likert scale, from 1 = "I completely disagree" to 5 = "I completely agree".

4.2.1 Pre-activity Questionnaire

The pre-activity questionnaire consisted of 17 items in total and was composed of selected items from Godspeed questionnaire (Bartneck et al., 2009) on agent perception (12 items), questions on agent role perception (2 items) and a knowledge test on fractions (3 items). The items of Godspeed scale looked at the aspect of perceived intelligence (3 items) and likeability (3 items) of the tutor and peer agents separately and the participants rated the items on a 5-point Likert scale.

4.2.2 Post-activity Questionnaire

After the activity, the participants were instructed to provide their basic demographic information(gender,

age group, education level, first language and ethnic identity) and a were given a 35 item questionnaire, which measure the agent perception, activity perception, learner's self-regulation, role perception and knowledge on learning topic. The questionnaire contained selected items from Godspeed questionnaire on agent perception (12 items on perceived intelligence and likeability of both agents), Intrinsic Motivation Inventory (IMI) scale (6 items on activity interest and value) (Ryan and Deci, 2000), Academic Self-Regulation Questionnaire (SRQ-A) (12 items of identified regulation, intrinsic motivation, introjected regulation and external regulation) ((Ryan and Connell, 1989); (Deci et al., 1992)), role perception (2 items) and knowledge test (3 items). After answering the questionnaire the participants could also provide general feedback on the activity experience in a separate text field, if interested.

4.3 Procedure

The study aimed at improving the role perception of the agents in the learning interaction and the regulation of the learner by introducing an episode of error making by the peer agent during the learning task (Figure 3). The study was conducted online and involved the participants watching the videos of both agents introducing themselves and explaining about the game activity in the beginning and later observing the virtual peer agent performing in the game, while being instructed by the tutor agent. The participants were instructed to actively observe the interaction and attend to the questions and tasks emerging in the game. The participant and the peer agent were often addressed together as a team during the interaction by the tutor agent to emphasize the peer learning scenario. The learning interaction could be broken down into three stages of introduction, activity and wrap-up sessions.

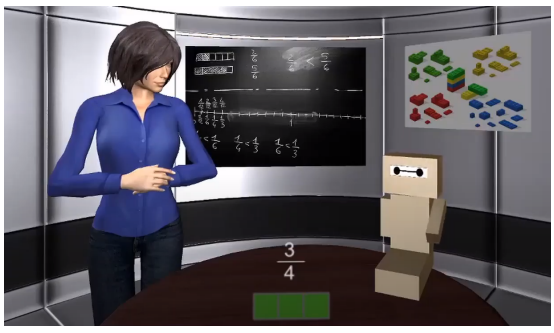

Figure 3: Peer agent making error in the FRACTOS learning task.

S1 Introduction: The participants were introduced to a video of the tutor and peer agents introducing themselves and engaging in a social talk. Later, the tutor agent explains the fundamentals of the concept of fraction and introduces the game elements to the participant and the peer agent. This is followed by an example video of building a fraction using the virtual LEGO blocks present in the game. At, the end of the introduction session, the participants are asked to answer the pre-activity questionnaire.

S2 Activity: The activity session involves the participants watching a video of the tutor agent presenting the three distinct fractions and asking the peer agent to build them using the virtual LEGO blocks of values 1/2, 1/4 and 1/8. The peer agent attends to the tutor's instructions and suggestions during the activity and demonstrates traits of co-regulation such as thinking aloud, seeking help etc. The peer agent doesn't completely follow all the suggestions and hints given by the tutor and thus acts more self-directed in the actions and choices. The activity involves the task of building three distinct fractions and the error making episode occurs in the turn of building the second fraction value of 3/4.

Error Making Episode: The tutor agent presents the task of building the fraction 3/4 and asks the peer agent to try it. In the planning phase, the peer agent makes the wrong choice of using 1/2 blocks for building the fraction and goes ahead building the fraction though the tutor suggests using the 1/4 blocks for the solution. After building the fraction, the tutor gives feedback to the peer agent and the learner that the solution was wrong and shows the correct solution to both. Later the tutor agent asks the peer agent and the learner to observe the number of 1/4 blocks required to build the solution and thus reflect on the mistake that occurred.

Alice: Do you know how to build this fraction?
Bot: I think we can use the 1/2 blocks for this. I mean the red ones.
Alice: Are you sure? Why don't you try using the 1/4 blocks instead?
Bot: I think three blocks of red should make this fraction. Let me try it.
Alice: Okay. Let's see if it is the correct solution
[Correct solution appears]
Alice: That was not correct. Three blocks of 1/4 make the 3/4 fraction. I hope you understood the mistake.
Bot: Yes, I understand now.

S3 Wrap-up: The learning interaction is concluded by both agents thanking the participants and bidding farewell reminding them to continue learning about fractions. After the wrap-up session, the participant is given the post-activity questionnaire on perceptions of agent roles, features, learning task and self-regulation along with a knowledge test on fractions.

5 ANALYSIS AND RESULTS

5.1 Participants

The study involved 30 adult participants (19 Female, 10 Male, 1 not disclosed) recruited online using a survey hosting platform named Prolific. Since the interaction happens in English language, we recruited participants who had English as their first language. Analysis of demographic information collected from the participants shows that the most number of participants belonged to the age group of 21-30 years (43.3%) and 31-40 years (36.7%). Regarding the education level, majority of the participants had an undergraduate degree (43.3%).

5.2 Attitude towards Agents

The NARS scale on attitudes toward situations and interactions with the agents gave a Cronbach's alpha value of 0.82 on the test for reliability, indicating the good reliability of the measure. We computed the means of the item scores to obtain the overall mean NARS score for each participant and divided them into two groups, "Positive" and "Negative", according to the overall mean *(M = 2.31, SD= 0.80)*. The "Positive" attitude group had 20 participants and the "Negative" attitude group had 10 participants. On performing an independent t-test between these two groups, we found significantly higher scores for the factors of perceived intelligence *(p(Tutor) = 0.01, p(Peer) = 0.029)* and likeability *(p(Tutor) = 0.032, p(Peer) = 0.001)* of both agents prior to the activity. Also the activity interest was higher for the "Positive" attitude group *(M = 3.72, SD = 0.59)* as compared to the "Negative" attitude group *(M = 3.2, SD = 0.34)*. The results suggest that the positive a-priori attitude towards the agents can promote a better perception of the agent qualities as well as the interest in the learning activity (Figure 4).

5.3 Activity Perception

The IMI scale on activity perception was found to have good reliability only for the activity interest factor (α = 0.874) and hence the activity value factor was not considered for further analysis. In general, among all the participants in the study, the FRACTOS learning task based interaction reported high activity interest score (M = 3.55, SD = 0.57). This indicates that the proposed learning interaction was engaging for the learners, in general.

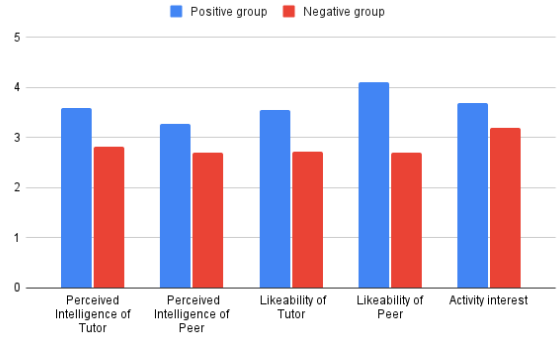

Figure 4: Comparing the groups of positive and negative attitudes towards agents.

5.4 Agent Perception

The Godspeed questionnaires on agent perception was found to have good reliability for pre-activity (*Tutor = 0.92, Peer = 0.87*) and post-activity (*Tutor = 0.94, Peer = 0.92*) for both factors of perceived intelligence (*Tutor = 0.87, Peer = 0.75*) and likeability (*Tutor = 0.91, Peer = 0.91*). On conducting a paired samples t-test on the agent perception variables of both agents, only the perceived intelligence of the tutor agent was found to have improved significantly ($p = 0.003$) while the perceived intelligence of the peer agent remained relatively the same (Figure 5). Post-activity perceived intelligence of Tutor agent was higher (*M =3.76, SD = 0.9*) than before the activity (*M = 3.34, SD = 0.80*). The difference in the perception of intelligence associated with both agents can be attributed to the introduction of error making behaviours by the peer since the perceived intelligence of the peer agent is observed to have not improved after the activity. Thus our hypothesis **H1a** that the peer agent with error making behaviour will be perceived to be less intelligent than the tutor agent, as intended in the design of their roles, is supported by the study results.

5.5 Role Perception

The analysis of the role perception questions for the tutor and peer agent roles given before the learning activity shows that only one participant wrongly perceived the virtual tutor agent in the role of a peer while

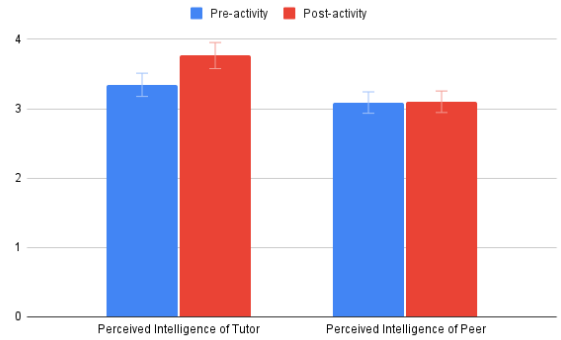

Figure 5: Perceived intelligence factor means of tutor and peer agents along the interaction.

five participants wrongly perceived the virtual robot agent as a tutor and three participants remained undecided on their role perception. All other 21 participants reported the roles of the tutor and peer agents as intended by the design of the learning interaction. However, after the learning activity, all participants who had the initial wrong perception of the agent roles except one improved by assigning the role of peer correctly to the virtual robot agent. The only participant who maintained the wrong perception of peer agent after the activity still considered the virtual robot agent as a tutor. Since 88% percentage of the participants improved to gain the correct perception of agent roles and behaviours, we can conclude that the hypothesis **H1b**, which expects the error making behaviours of the peer agent to improve the agent role perception of the learner, is sufficiently supported by the results.

5.6 Self-regulation Behaviour

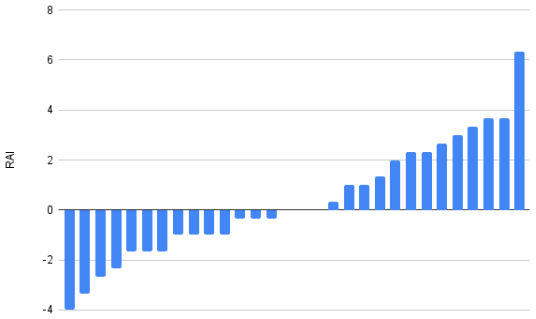

Figure 6: Distribution of RAI scores of participants in the study.

The subscales of SRQ-A showed good reliability scores for identified regulation (α = *0.80*), intrinsic motivation (α = *0.74*), introjected regulation (α = *0.70*) and external regulation (α = *0.67*). The Relative autonomy index(RAI) score was calculated from these subscales for each participant and based on the RAI scores, the participants were divided into two groups, "High" (*N = 13*) and "Low" (*N = 17*), which indicated their self-regulation potential (Figure 6). We then conducted an independent t-test between these two groups which concluded that the differences in the factors of *pre-activity likeability (p = 0.049) of the peer agent, intrinsic motivation (p = 0.003), external regulation (p = 0.048) and activity interestp = 0.045* were statistically significant. The perceived likeability (*M = 4.10, SD = 0.47*) of the peer agent was higher for in the group of "High" self-regulated learner. The "High" self-regulation group also were associated with higher intrinsic motivation (*M = 2.89, SD = 0.51*), higher activity interest (*M = 4.46, SD = 0.90*) and lower external regulation (*M = 2.10, SD = 0.67*) as compared to the "Low" self-regulation group of participants (Figure 7). This suggests that the peer agent influenced the regulation better and facilitated higher engagement and motivation for the learning activity.

A multiple linear regression analysis was performed with RAI score as the outcome and *pre-activity likeability of Peer* along with *activity interest* as predictors. The multiple regression model statistically significantly predicted the RAI score ($F(2,27) = 8.456$, $p = .019$, $adj.R^2 = 0.253$) where both variables added significantly to the prediction. Thus the results from the study support the hypothesis **H2** which states that the error making behaviours by the peer agent can promote better regulation in learners.

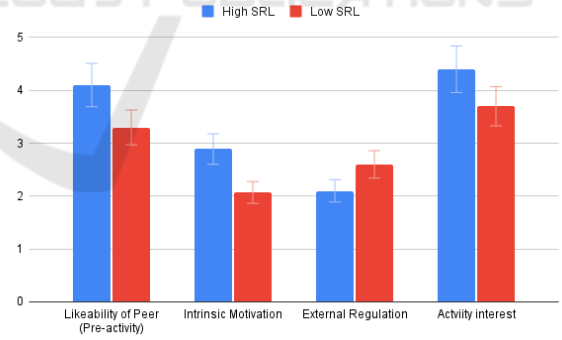

Figure 7: Significant differences between the Higher and Lower Self-regulation groups of learners.

5.7 Learning Gain

On calculating the learning gain from the knowledge test conducted before and after the activity, it was observed that five participants improved their scores and two participants got lesser scores after the learning interaction while all the remaining 23 participants were able to answer all questions correctly both in the pre-activity and post-activity tests.

5.8 Comparison with Previous Perceptive Study

The first perceptive study that we conducted looked at the learner's perception's of the agent roles, qualities, learning task and the associated self-regulation behaviours emerging from the learning interaction. The second study differs from the previous one in the aspect of error making behaviours of the peer agent, which was introduced to convey the role of peer and the associated competency level more clearly.

A comparison of the results from both studies reveals some interesting observations on the aspects of regulation, agent perception and activity interest. We conducted a paired samples t-test on the perceived intelligence and likeability of both agents, activity interest and regulation factors between the participant groups of both studies to find that differences in perceived intelligence of peer agent ($p = 0.013$) and activity interest ($p = 0.039$) were significant. The perceived intelligence of the peer agent was significantly lower*($M = 3.1$, $SD = 0.88$)* for the participants who interacted with the peer agent that made mistakes. Similarly, the activity interest also dropped significantly*($M = 3.55$, $SD = 0.57$)* in the group from second study as compared to the study without the error making episode. It can be concluded from the results that the error making behaviour by the peer agent has helped in conveying the role of virtual robot correctly by making the learner to perceive it as less competent compared to the tutor, but the activity interest seems to have dropped in the case of having mistakes in the learning interaction.

6 DISCUSSION

The objective of this study was to understand how error making behaviours by the peer agent would help the learner to perceive the pedagogical roles in the interaction as intended. Regarding the impact of a-priori attitudes of the learners on the agent perceptions, the factors of perceived intelligence and likeability of both agents as well as the interest in the learning activity were observed to be higher in the group of learners with positive a-priori attitudes for virtual agents in general. Thus familiarising the learners with virtual agents can help in ensuring that the learning interaction turns out to be effective and engaging. The learning activity was perceived to be interesting by the majority of the participants.

Regarding hypothesis **H1**, we observed that the error making behaviour by the peer agent had significant effects on the perception of agent qualities as well as the associated pedagogical roles. The perceived intelligence of the tutor agent improved after the activity while that of the peer remained almost the same. This shows that the learners perceived the peer agent to be less intelligent than the tutor after seeing the error making instances during the learning activity. Hence, it can be concluded that the hypothesis **H1a** is supported by the study results. Concerning the perception of agent roles, the study started with 8 participants having the wrong role perceptions but after the learning interaction, 7 among those participants gained the correct association of tutor role to the virtual agent and peer role to the virtual robot agent. This supports our hypothesis **H1b** that the error making behaviour of peer agent would help in improving the role perception. It can be concluded that the difference in perceived intelligence of both agents has complimented the role perception by the learners, since peer agent behaviours were designed to convey lesser competence level as compared to the tutor. Thus the study results support the hypothesis that error making behaviour of the peer agent would promote correct perception of agent roles and associated qualities.

Regarding the self-regulation behaviour of the participants, the learner who had higher self-regulation scores were seen to have higher likeability of the peer agent before the activity as well as higher intrinsic motivation and interest in the learning activity. The hypothesis **H2** expected the error making episode by the peer to promote better regulation behaviours in the learner. The results suggest that the RAI score, which an indicator for the self-regulation potential of the learner, is influenced by the agent perceptions as well as the activity interest. The factors of likeability of the peer agent and activity interest prove to be significant predictors for the regulation of the learner and hence the hypothesis **H2** is supported by the study findings.

7 CONCLUSION

The perceptual study was conducted in the context of introducing error making behaviours in the peer agent for promoting better perception of agent roles and overall self-regulation of the learner in a multi-agent shared learning interaction. The study hypothesised that the error making peer would be perceived less competent compared to the tutor agent, thus conveying its pedagogical role clearly to the learner. The results confirmed the hypotheses and suggest that the error making behaviours by the peer agent as an effective way of manipulating the learner perceptions and thus the regulation. In this study the peer agent

was observed to have influenced the learner more than the tutor. The findings from the results and comparisons across both user studies shows the effectiveness of the proposed learning task and the multi-agent interaction in promoting self-regulation in the learner. Altogether, the insights on perceptions and influence of agent roles and related regulation behaviours in the proposed interaction would act as the basis of our further studies towards understanding distinct regulation strategies and their relevance in various phases of self-regulated learning.

REFERENCES

Bartneck, C., Kulić, D., Croft, E., and Zoghbi, S. (2009). Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International journal of social robotics*, 1(1):71–81.

Baylor, A. L. and Kim, Y. (2005). Simulating instructional roles through pedagogical agents. *International Journal of Artificial Intelligence in Education*, 15(1):95.

Breazeal, C., Harris, P. L., DeSteno, D., Kory Westlund, J. M., Dickens, L., and Jeong, S. (2016). Young children treat robots as informants. *Topics in cognitive science*, 8(2):481–491.

Coppola, B. P. and Pontrello, J. K. (2014). Using errors to teach through a two-staged, structured review: Peer-reviewed quizzes and "what's wrong with me?". *Journal of Chemical Education*, 91(12):2148–2154.

Deci, E. L., Hodges, R., Pierson, L., and Tomassone, J. (1992). Autonomy and competence as motivational factors in students with learning disabilities and emotional handicaps. *Journal of learning disabilities*, 25(7):457–471.

Geiskkovitch, D. Y., Thiessen, R., Young, J. E., and Glenwright, M. R. (2019). What? that's not a chair!: How robot informational errors affect children's trust towards robots. In *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pages 48–56. IEEE.

Järvelä, S., Järvenoja, H., Malmberg, J., and Hadwin, A. F. (2013). Exploring socially shared regulation in the context of collaboration. *Journal of Cognitive Education and Psychology*, 12(3):267–286.

Kim, Y., Baylor, A. L., Group, P., et al. (2006). Pedagogical agents as learning companions: The role of agent competency and type of interaction. *Educational technology research and development*, 54(3):223–243.

Kory-Westlund, J. M. and Breazeal, C. (2019). Assessing children's perceptions and acceptance of a social robot. In *Proceedings of the 18th ACM International Conference on Interaction Design and Children*, pages 38–50.

Nomura, T., Kanda, T., and Suzuki, T. (2006). Experimental investigation into influence of negative attitudes toward robots on human–robot interaction. *Ai & Society*, 20(2):138–150.

Ogan, A., Finkelstein, S., Mayfield, E., D'Adamo, C., Matsuda, N., and Cassell, J. (2012). " oh dear stacy!" social interaction, elaboration, and learning with teachable agents. In *Proceedings of the SIGCHI conference on human factors in computing systems*, pages 39–48.

Okita, S. Y. (2014). Learning from the folly of others: Learning to self-correct by monitoring the reasoning of virtual characters in a computer-supported mathematics learning environment. *Computers & Education*, 71:257–278.

Panadero, E. (2017). A review of self-regulated learning: Six models and four directions for research. *Frontiers in psychology*, 8:422.

Pelachaud, C. (2015). Greta: an interactive expressive embodied conversational agent. In *Proceedings of the 2015 International Conference on Autonomous Agents and Multiagent Systems*, pages 5–5.

Ryan, R. M. and Connell, J. P. (1989). Perceived locus of causality and internalization: examining reasons for acting in two domains. *Journal of personality and social psychology*, 57(5):749.

Ryan, R. M. and Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, 55(1):68.

Stone, B. A. and Lester, J. C. (1996). Dynamically sequencing an animated pedagogical agent. In *AAAI/IAAI, Vol. 1*, pages 424–431.

Weiss, A., Scherndl, T., Buchner, R., and Tscheligi, M. (2010). A robot as persuasive social actor a field trial on child–robot interaction. In *Proceedings of the 2nd international symposium on new frontiers in human–robot interaction—a symposium at the AISB 2010 convention*, pages 136–142.

Yadollahi, E., Johal, W., Paiva, A., and Dillenbourg, P. (2018). When deictic gestures in a robot can harm child-robot collaboration. In *Proceedings of the 17th ACM Conference on Interaction Design and Children*, pages 195–206.