

The Impact of Communication on a Human-Agent Shared Mental Model and Team Performance (Extended Abstract)

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ABSTRACT

There is a growing interest in the use of heterogeneous teams comprised of humans and Intelligent Virtual Agents (IVAs). Human teamwork studies have provided cumulative knowledge about team features and performance; however, transfer of this knowledge to human-IVA teams is challenging. Novelty, this paper investigates the impact of multiple communication channels on the development and maintenance of a Shared Mental Model (SMM) between humans and IVAs. The results from two studies involving a collaborative activity show a significant positive relationship between the IVA's verbal and non-verbal communication and the development of a SMM related to taskwork and teamwork as perceived by the human teammate. Moreover, the results indicate that a SMM tends to improve overall team performance.

Categories and Subject Descriptors

I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—*intelligent agents, multiagent systems.*

Keywords

Human-Agent Collaboration; Performance; Communication.

1. INTRODUCTION

The idea behind Shared Mental Model (SMM) is that the overall performance of teams improves if team members have shared knowledge about the teammate and knowledge about the task [1]. In human teams, effective and comprehensive communication was found to positively affect the degree of coordinated performance attained by teammates which in turn fosters the development of a SMM [2]. As SMM has been found to have a positive impact on human teams, this notion has found its way into agent studies. Sycara and Sukthankar [6] stated that the biggest challenge in human-agent team work is to establish a SMM.

Limited research has studied the development of a SMM between IVAs and humans [4]. Moreover, to the best of our knowledge, no

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study has investigated the impact of multimodal communication, verbal and nonverbal communication, between a human and an IVA on the development and maintenance of a SMM between them. The research reported in this paper seeks to address this gap. In order to understand the relationship between IVAs' multimodal communication and the development of a SMM with humans while they achieve a collaborative task, the following research questions are proposed:

Q1: Do comprehensive verbal and non-verbal communication methods impact on taskwork SMM between humans and IVAs? Moreover, which method is more effective?

Q2: Do comprehensive verbal and non-verbal communication methods impact on teamwork SMM between humans and IVAs? Moreover, which method is more effective?

Q3: Do taskwork and teamwork SMMs impact on human-IVA team performance? Moreover, which SMM has greater impact?

2. METHOD

Two studies were conducted to investigate the factors that affect the use of communication to aid humans and IVAs to establish a SMM in the context of a collaborative task. Sixty-six (66) second-year undergraduate students chose to participate in the first study. Twenty (20) secondary school students chose to participate in the second study.

The goal of the first study was to evaluate the comprehensibility of the IVA's verbal and non-verbal communication. The second study aimed to investigate the impact of the IVA's communication on the development of a SMM with the human. The second study was designed with five variables, i.e. IVA's verbal communication, IVA's non-verbal communication, taskwork SMM, teamwork SMM and team performance.

Both of the studies required the participants to do the following: complete a biographical survey (e.g. age, gender, frequency of playing video games); participate in a collaborative activity with the IVA; and answer questions related to the experience and SMM in a post-survey.

In the collaborative activity, the human and the IVA needed to collaborate together to trap a virtual animal. The animal was surrounded by eight regions. The human and the IVA took turns to select one region at a time to build a fence around the animal, observe each other's actions, i.e. non-verbal behaviour; and exchange verbal messages to convey their intentions.

3. RESULTS

The result of the first study showed that 53.13% and 12.50% of the participants agreed and strongly agreed respectively that the verbal communication was comprehensive. Moreover, the result of the first study showed that 49.23% and 23.08% of the participants agreed and strongly agreed respectively that the nonverbal communication was comprehensive.

Research question 1 inquired if comprehensive verbal and non-verbal communication between a human and an IVA while achieving a collaborative task tends to influence the development of a taskwork SMM. To assess the overall statistical significance of the relation, the results indicated that both verbal and non-verbal communication were significant $R^2 = 0.814$, $F(2, 13) = 33.80$, $p < 0.01$. Furthermore, the results indicated that standardized coefficient β of IVA's nonverbal communication (0.839) is greater than standardized coefficient β of the verbal communication (0.082).

Research question 2 asked if comprehensive verbal and non-verbal communication between a human and an IVA while achieving a collaborative task tends to influence the development of teamwork SMM. To assess the overall statistical significance of the relation, the result showed that both verbal and non-verbal communication were significant $R^2 = 0.891$, $F(2, 13) = 62.07$, $p < 0.01$. Furthermore, the results indicated that standardized coefficient β of IVA's verbal communication (0.752) is greater than standardized coefficient β of the non-verbal communication (0.210).

Research question 3 asked if taskwork and teamwork SMMs impact on human-IVA team performance. The results showed that both taskwork and teamwork were significant predictors to team performance $R^2 = 0.891$, $F(2, 13) = 62.11$, $p < 0.01$. Moreover, to evaluate which one of the two factors, i.e. taskwork or teamwork SMM, contributed more to team performance, the results indicated that standardized coefficient β of taskwork SMM (1.085) is greater than standardized coefficient β of teamwork SMM (-0.167).

4. DISCUSSION

The aim of this paper is to investigate the association between an IVA's communication methods and the human's perception of the SMM between him/herself and the IVA. In addition, the study aimed to show the impact of a SMM on human-IVA team performance.

Regarding the first research question, the result showed a significant positive association between the IVA's communication, i.e. verbal and non-verbal, and the development of a taskwork SMM as perceived by the human teammate. To answer the second part of the research question about which method is more effective in building a taskwork SMM, the results demonstrated that the IVA's non-verbal communication tends to be more effective than its verbal communication.

Regarding the second research question, the result demonstrated a significant positive association between both IVA's verbal and non-verbal communication and the perception of the development of teamwork SMM as perceived by the human. This result is supported by other researchers' findings that human involvement with IVAs is likely to increase the possibilities of communication

with IVAs [3]. Moreover, to answer the second part of the research question about which method is more effective in building a teamwork SMM, the result showed that the IVA's verbal communication tends to contribute more to teamwork SMM. This contribution seems reasonable as the exchanged speech acts gives better understanding of the teammate's thoughts and capabilities.

Results answering the third question showed that there is a significant positive correlation between the existence of taskwork and teamwork SMMs and team performance. This finding is consistent with tens of other human-based studies that have tested the relationship between SMM and team performance and reported significant correlations between higher degrees of shared thinking and positive team performance [5].

5. CONCLUSION

Our results confirm the importance of designing IVAs capable of using multiple methods of communication with humans, as this tends to build SMM with human user and impact on the overall performance of human-IVA teamwork. To evaluate the generality of our findings, further studies are needed involving more participants of different ages and educational levels, the implementation and testing of different and possibly less sequential scenarios and the inclusion of additional and alternative interaction styles and communication modes.

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