Studying Human-Agent Interactions in Space Invaders

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ABSTRACT

We conducted an exploratory study to investigate human-agent interactions in the context of the Space Invaders game. In the study, the participants experienced an Uncooperative and a Cooperative agent. Although cooperation was unexpected, our results suggest that the participants identified the Cooperative agent as more helpful than the Uncooperative agent, and that they were inclined to reciprocate the helping actions more to the former agent than the latter one. We discuss the possibilities of further using Space Invaders as a practical scenario to study human-agent cooperation.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in collaborative and social computing**.

KEYWORDS

human-agent interaction, helping, cooperation, multi-player game

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1 INTRODUCTION

While significant research has investigated human-agent cooperation within teams [1, 11], ad-hoc cooperation can also occur. This may happen without pre-coordination [10] and when interactants have different initial goals, e.g., during prosocial interactions [4, 8].

To explore ad-hoc cooperation, we investigate human-agent interactions in a custom-made, multi-agent Space Invaders game. In particular, we compare an uncooperative and a cooperative agent in the game, and study perceptions of the agents and differences in human reciprocity based on the type and order of the agents that was experienced. Although the game is simpler than real-world encounters, our findings suggest that the game is an interesting and practical setup for studying ad-hoc cooperation. In comparison to repeated social dilemmas [3, 5, 9], which have often been used with a similar purpose, Space Invaders involves more continuous interactions and more nuanced decision making.

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Figure 1: Space Invaders game with a cooperative agent.

2 METHOD

We conducted a within-subjects experiment where participants played Space Invaders at the same time as a rule-based Artificial Intelligence (AI) agent. Players got 10-50 points for each of the 25 enemies on their side of the screen that got destroyed, with the farther away enemies being worth more points. The human player gained points for enemies destroyed on the left side of the screen.

Conditions: Each participant experienced an Uncooperative and a Cooperative agent. Both agents shoot at an approximate rate of twice per second, targeting the nearest enemy (horizontally). The Uncooperative agent only targeted enemies on the right (AI) side of the screen, whereas the Cooperative agent targeted enemies on both sides, giving points to the human player when it killed left enemies (Fig. 1). In order to help the participants differentiate between the agents, the Uncooperative agent was colored orange while the Cooperative agent was colored gray.

Hypotheses: First, we expected the Cooperative agent to be perceived as more helpful than the Uncooperative agent. Second, we expected the number of human enemies that were killed by an agent to correlate with the number of AI enemies that were killed by the human player. This means that participants would help the Cooperative agent more than the Uncooperative agent, despite the game score not promoting cooperation. The first hypothesis was motivated by our agents' design, whereas the second one was inspired by prior evidence of human-agent reciprocity [2, 7, 9].

Procedure: The experiment was conducted through an online survey which included JavaScript versions of the game. The first part of the survey asked demographics questions. In the second part, the participants played a single-player version of Space Invaders to get familiar with the game. Third, they were provided instructions that introduced the multi-agent version of the game, including that there would be an AI agent playing as well and that they would get points only for killing enemies on the left side. Half of the participants then played two games with the Cooperative agent first; the rest played two games with the Uncooperative agent. Afterwards, the participants answered a brief survey about their experience, providing their impressions of the game and the agent. Next, they played

two other games with the other agent followed by the experience survey. Finally, the survey asked open-ended questions about agent preferences and whether participants helped the agents.

Participants: We recruited 20 female participants for the study through Amazon Mechanical Turk, but two were excluded due to technical difficulties. The 18 valid participants spoke English as their native language and spent the majority of their childhood in the US. Their average age was 46.78 years old (SE= 3.63), they used a computer daily (M= 7.00 on a 7-point responding format from rarely to daily), and sometimes played video games (M= 4.83, SE= 0.47). Also, 77.78% of participants had played Space Invaders before, 16.67% had not played the game, and 5.55% were unsure. The participants were paid $4.00 for completing the 15 min study.

3 RESULTS

We analyzed both quantitative survey results and qualitative open-ended answers. For quantitative results, we conducted REML analyses with Participant ID as random effect, and Order (Cooperative or Uncooperative first) and AI Agent (Uncooperative, Cooperative) as main effects. We conducted post-hoc tests when appropriate.

Impressions of the Game: Participants expressed enjoying the game (M=5.78, SE=0.26 on a 7 point Likert format), perceived it as having low to medium difficulty (M=3.14, SE=0.30) and being fun (M=5.14, SE=0.38). We found no significant effects for these results.

Agent Perceptions: Table 1 details the participants perceptions of how helpful, intelligent, proficient at the game, and annoying the agents were (7-pt format, 1 being lowest). Only AI Agent had a significant effect on the agents' helpfulness ($F[1, 16] = 20.45$, p= 0.0003). However, a trend was observed for the interaction of AI Agent and Order on helpfulness (p= 0.0547). When the participants faced a Cooperative agent first, the Cooperative agent was moderately helpful (M= 4.7, SE= 0.76); but when the participants faced an Uncooperative agent first, the Cooperative agent was perceived as very helpful (M= 6.75, SE= 0.16). The levels of helpfulness of the Uncooperative agent did not vary as much (M= 3.4, SE= 0.73 for Cooperative first, and M= 3.25, SE= 0.75 for Uncooperative first). This suggests that participants may have felt particularly grateful for the Cooperative agent's help when individual (uncooperative) actions were the established norm.

At the end of the survey, 12 participants expressed preferring the Cooperative agent, 4 preferred the Uncooperative agent, and 2 did not have a clear preference. The main reason for preferring the Cooperative agent was that it helped the participants (N= 7). Another reason was that it made the game feel cooperative (e.g., *"it felt like team work"*). Three out of four people that preferred the Uncooperative agent said that it was better because it did not interfere with them (e.g., *"it didn't get in my way"*). One of the participants without a clear preference said that *"It is a toss up. When the ship came over to my side, I felt like I wasn't doing enough. When the ship just stayed on their side, I felt the need to rush."*

Table 1: Perceptions of the agents (mean and std. error)

Attribute	Cooperative	Uncooperative
Helpfulness	5.61 (SE=0.49)	3.33 (SE=0.51)
Intelligence	5.05 (SE=0.55)	4.67 (SE=0.46)
Proficiency	6.67 (SE=0.11)	6.11 (SE=0.40)
Annoyingness	2.00 (SE=0.42)	2.05 (SE=0.36)

Interestingly, four participants indicated in their open-ended answers that the Cooperative agent was aggressive while one person expressed the same for the Uncooperative agent. We associate the former opinions to the agent crossing to the human side early in the game when the person was not necessarily in need of help.

Reciprocity: We grouped open-ended responses to the question of whether participants helped the agents at the end of the survey. In total, 13 people said that they did not help the agents. From that set, 9 people said they did not have time to help and 3 of them explicitly indicated that they would have helped if they have had the chance. This suggested that the agents were better at the game than a good proportion of the participants. Additionally, 4 people indicated helping an agent, including two who said explicitly that they helped the Cooperative agent and one who helped accidentally. Lastly, one person answered the question in an unintended way.

We inspected when the human players killed AI enemies: nobody killed right enemies for the Uncooperative agent, whereas 5 people killed from 1 to 7 enemies corresponding to the Cooperative agent. Further, we computed the correlation between the number of human enemies that were killed by the Cooperative agent and the number of its enemies that were killed by a human player per game. The correlation was positive and significant ($r(34) = 0.51$, p= 0.002). These results suggest that there was an inclination for the participants to reciprocate the helping actions from the Cooperative agent in the game.

4 CONCLUSION AND FUTURE WORK

In general, the participants enjoyed playing Space Invaders and, as expected, perceived the Cooperative agent as more helpful than the Uncooperative agent. Helping was associated with the majority of participants preferring the Cooperative agent, and further correlated with the participants reciprocating the helping actions. Interestingly, a trend that suggested that the order in which the AI agents were experienced could affect how helpful they were to the participants. Thus, perceptions of helping in the game may have not only been influenced by the agent's actions but also by human expectations, as it can happen in human-human interactions [6].

Our exploratory study was limited in several ways. First, we recruited only female participants, but it would be interesting to study if the results would differ by gender. Second, the agents were implemented following simple rules. What if their logic was more complex? Lastly, we considered a single type of cooperative behavior for the AI agent. How would helping actions be perceived if they happened only after the agent completed killing all of its enemies? Or what would happen if we allowed the players to communicate explicitly? While these questions are focused on Space Invaders, we believe that studying them could be valuable to better understand how behavioral factors may affect human-agent cooperation.

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