GroupDynamics: Agents in Group Game

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ABSTRACT

The need for cooperation among people with individual differences such as preferences, generation, and goals is an undeniable fact in our society. In this project, we choose to focus on a specific individual characteristic, the generation. We develop a new experimental platform to test if people tend to think about future generations or only care for present personal gains. We test if information about other generations' behaviours has an impact on human prosociality. In our experiment, a human user joins a team with two virtual agents for a collaborative task. This collaborative task takes place in the context of an inter-generational goods game called For The Planet that fits the theme of climate change. The objective of the team is to avoid planet disaster for future generations. To achieve this goal, they must not exhaust the Common-Pool Resource. In some scenarios, the team will play the game without facing a planet disaster, consequences of a previous selfish generation, living on a planet that they can always take benefits from its resources. In other scenarios, the mixed team will see their potential gains ruined by the selfish acts of previous generations by the occurrence of a planet disaster. We also test the influence of knowing the collaborative actions of previous generations in team collaboration. In this thesis we will investigate if confronting the human players with previous generations' selfish or collaborative acts will have an impact on their actions and improve their cooperation.

KEYWORDS

Social Dilemmas, Inter-generational Goods Games, Virtual Agents

1 INTRODUCTION

1.1 Motivation

As part of their daily routines, people regularly engage in group activities, through group dynamics, doing so in different contexts and with different goals. We eat together, conduct group projects, play sports, and even work at a distance in distributed teams. The dynamics of interactions that emerge in the actions of a group may lead to different results, such as conflicts, complete breakdown, or cooperation and friendship. Yet, the dynamics of these interactions may be shaped to achieve more favorable outcomes, like cooperation. Indeed, the need for cooperation among people, even with different characteristics, is an undeniable fact of our society. In a world constantly changing, with new technological developments in various fields, the world is regularly facing new challenges and problems, and cooperation is without a doubt the best way to address our major problems like climate change. Some of these issues can be captured as social dilemmas, commonly defined as circumstances where short-term self-interest runs counter to long-term collective interests but if a sufficient amount of people choose the selfish alternative the whole group loses.

Some of the most commonly spoken social dilemmas of our time concern the ecological well-being of our world, including fish harvesting, rainforest destruction, and greenhouse gasses buildup due to over-reliance on vehicles that run on petroleum fuels. The world is the shared resource of many generations living on our planet. To preserve and save the environment, it is important to convince people to be less selfish. To achieve this goal, it is necessary to understand when a person is likely to collaborate (or not). What leads to cooperation in individuals? Do people think about future generations when they use the planet resources?

1.2 Problem

In this research, we will explore how collaboration can be achieved in situations where people team up with virtual agents in a game that presents a social dilemma in an inter-generational goods game in a context focused on environmental issues.

In the past, agents were mostly tools that followed instructions given by a human controller. Yet, as agents technology advanced and agents became more autonomous and integrated into our society, they reached a state in which they can become partners or even peers while working together with humans to accomplish common tasks. Taking this into consideration, this thesis will use two virtual agents to partner with human users in a collaborative task.

The collaborative task is a game called For The Planet that fits the theme of climate change. As the first generation on the planet or by inheriting the planet from another generation, the players try as a team to avoid "planet disaster" for future generations. However, the game maps a social dilemma and each player can adopt a more or less collaborative policy. As such, the strategy of each player and the team itself, as a whole, can be translated into an objective metric of collaboration /altruism / pro-sociality.

So, taking this into consideration, this thesis tries to answer the following research question:**How can we increase the level of collaboration between generations using virtual agents and information about previous generations.**

1.3 Hypotheses

This experiment will be conducted in a scenario of a paradigmatic social dilemma that captures the conflict between the individual and collective interest is the so-called inter-generational good game.

In the For the Planet game, a person will play with two virtual agents. Each round the mixed team will face a decision between cooperating or defecting to obtain an individual benefit.

The players will play as four generations on a planet, where they can be the first generation on the planet or an intermediate generation. Their action will decide if that planet will continue to have a future generation who can benefit from it. When they start a new generation they are informed about the planet and have the possibility to know the behavior of their pre-descendants. With the goal to improve collaboration between generations, we will try two mechanisms.

We believe that knowing the cooperative nature of the previous generations can increase cooperation in the participants. Comparing to not knowing how the previous generations behave.

Secondly, we will study if placing players in a world that is in ruins, where they can't play and have individual benefits, will make players more cautious and more collaborative, compared to players that only play on healthy planets. With this mechanism, we expect that a confrontation of a planet disaster has a positive influence on cooperation.

This work contributes to the research field of Human-Agent Interaction (HAI) by suggesting a direction for understanding the relational dynamics in mixed groups of humans and virtual agents.

1.4 Document Outline

The remainder of the document is structured as follows. Section 2 presents the related work, starting with human-agent collaboration in groups. After that, work done in Social dilemmas, and lastly, the work done in Inter-generational Goods Game. Section 3 describes the implementation of the Inter-generational Goods Game in the game For the planet. Section 4 describes the results received and how were they evaluated. Finally, Section 5 expresses the conclusions of this document.

2 RELATED WORK

This section will start by presenting work done on the topic of human-agent collaboration, especially when forming a mixed team to perform a task collaboratively. Afterwards, it will be analysed various studies that tested social behaviours that influence the group dynamics and also social dilemmas and what influence collaboration and selfish acts in a social dilemma. Finally, it will be presented work done on collaboration between generations.

2.1 Human-Agent Collaboration in Groups

Do people act the same when interacting/collaborating with a person and a machine? Despite the evidence in different studies that people can treat agents like humans in social settings [6], recent research shows that there are still important differences in the way people behave with agents when compared to humans. Humans tend to favor other humans to machines, in particular when engaging in cooperative activities and social decision making. Furthermore, people spent more effort inferring mental states of humans than machines (if we consider that machines exhibit such states).[2] For example, people do not feel guilty when exploiting machines in comparison to humans, as shown in Celso de Melo et al. [5] study. The reason seems to be that people try to avoid harming others to prevent the unpleasant experience of guilt. However, they experience less guilt when engaging with machines, and consequently, are more comfortable exploiting machines.

Despite this difference, many studies have been devoted to analyzing the interaction between agents and their human partners. A new trend of research is emerging dedicated to the study of collaboration scenarios between mixed teams of agents and humans.

Humans were always exceptionally good at working in groups, from trivial tasks such as, jointly carry a sofa through a doorway, to some complex endeavours such as work in big corporations[4]. With the rapid progress in robotics, there is a common fear in our culture that robots will eventually replace us, taking jobs from humans in certain fields such as transportation with self-driving cars, healthcare with surgical robots, and many others. However, many researchers believe that agents will only complement our teams by supporting us and enhancing our work experience, atmosphere, and success of our activities. So is with this view that agents are being developed today, to be part of our teams and interact with us in all our different fields.

However, when considering Human-Agent teams, many different scenarios of interaction are conceivable. We may have a single agent engaging with a single user or an agent interacting with multiple users or, at last, multiple agents interacting with multiple users. Over recent years, there has been more and more studies on the last two cases, showing that new trend is emerging in the study of groups of people collaborating with agents.

Agents also can be of different types, embodied as robots, or as virtual characters, or simply disembodied ones, that the users do not see.

A case of robotic embodied agents is the one by Breazeal et al.[1] describing an experiment where participants (one at a time) were tasked with teaching the names of the buttons to a single agent and then directing the agent to perform a physical task of turning certain buttons on, using only speech and gesture. The robot would respond to this stimulation with implicit behaviors or explicit behaviors through non-verbal social cues such as the eye gaze and head nods. With this research, they found that the social signals used by the robot improves the agent's likeability and increase the efficiency of the mixed team's cooperation.

An example of research with multiple robotic agents engaging with multiple users is the work of Oliveira et al.[7]. The players involved in this research had to play a card game called Sueca with another person and two robotics playing as partners or as opponents. With this study, they aimed to investigate non-verbal behavior and socioemotional interactions in the mixed group. The results showed that participants direct their gaze more often towards the relationship-driven robot when this robot was their partner, compared with the other scenarios when they form a team with a competitive robot or a human. Confirming that the gaze is connecting on in-group members that contribute to the cohesion and building of interpersonal relationships. Regarding the gaze towards the opponents happened more often to the competitive robot. Confirming that we tend to look more often at a threat perceived as a way of tracking or seeking information to have a better sense of control.

2.2 Dealing with Social dilemmas

People are regularly faced with circumstances where their goals are at odds with team objectives. In these circumstances, it's said they're facing a social dilemma, and in these situations, selfish attitudes are more captivating, endangering cooperation.

A social dilemma is characterized as a situation where each decision-maker has a dominant strategy dictating non-cooperation, and if everyone follows this dominant strategy, they all end up worse off than if everyone had cooperated [8]. An Inter-Generational Goods Game is a paradigm of social dilemma that captures the conflict between the individual and collective interest.

The main objective of this project is to influence the participants to select the positive and cooperative strategy in an adaptation of an Inter-Generational Goods Game known as For The Planet. It is therefore important to understand what kind of actions will influence people in the right way, in a cooperative way, but also what encourages people to choose selfish acts.

In the psychology study of social dilemmas[8], they discussed various types of influences and mechanisms that affect decision making in a social dilemma and promote the evolution of cooperation.

Reciprocal altruism, also referred to as reciprocity (or direct reciprocity), is an evolutionary theoretical concept that suggests that human actions are conditioned by others. Indeed there is considerable evidence that people's cooperative behavior is heavily affected by the decisions of others. Human Participants decide in the sense of a social dilemma that can be described as reciprocal, behaving as cooperatively as they expected the other participants to cooperate.

Another theory that explains what influences a person during a social dilemma is the Indirect reciprocity theory. **Indirect reciprocity** theory suggests that individuals respond to information related to other's reputations as being cooperative (or non-cooperative) by behaving cooperatively (or non-cooperatively). It also means that people value a cooperative reputation over a non-cooperative reputation. There is evidence that in the absence of clear reciprocity, people respond to reputational information by giving more to those who have been cooperatives in the past. This theory shows how cooperation can grow and thrive when updated information on reputation is available.

2.3 Inter-generational Collaboration

Is it possible for people of a different generation to collaborate? Do people think about future generations when exploiting renewable resources? Do we have obligations to Future Generations?

Providing for future generations is central to the survival of genes, families, organizations, nations, and the global ecosystem. Yet providing for the future poses a challenge, as it requires making sacrifices today, many people are not purely selfish.

We consider Generation collaboration as the care the previous generation has with the future generation. If they only care about maximizing their profit the generation is selfish. If they don't mind receiving less payoff in order for the next generation can still have a profit, they are cooperators.

Hauser et al. [3] devise a new experimental paradigm known as the "Inter-generational Goods Game" that builds on previous work using Common Pool Resource games, Public Goods Games, and Threshold games to answer the question: "What mechanisms can maintain cooperation with the future?". In the **IGG** a line-up of successive groups, called generations, can choose to extract a resource to exhaustion or preserve it for the next generation. Exhausting the common-resource leads to the maximum payoff for the present group (generation) but leaves all future groups (generations) empty-handed.

In the Inter-generational Goods Game (IGG), all the advantages generated by the collaboration of the present generation are going to be collected by the following groups (generations). Because of this, it is no longer true that a group of cooperators gains more than a group of defectors. Instead, a sequence of cooperative groups, who have sustained a common-pool over several generations, earn more in total than a series where one defective group exhausts the common-pool early. However, an individual's benefit is unaffected by the decisions taken by the other members of his generation. Opposed to the Public Goods Game (PGG), an individual payoff increases when others in the same group cooperate. In the IGG, the individual payoff increases when members of the previous groups have collaborated.

As a result, a member of a generation maximizes the IGG reward by extracting the entire quantity and is indifferent to the extraction quantities of the other members of the generation. Because of this, greedy players would prefer to take the full number in the IGG, as opposed to the PGG. This would lead to the conclusion that median voting is not a successful option for the promotion of inter-generational cooperation. However, things change when social preferences are taken into consideration. In many contexts, the majority of individuals are not solely selfish, but rather to some degree, concerned with the well-being of others. People with these kinds of pro-social values could be willing to pay a price for the benefit of future generations. Nevertheless, they may also have 'conditional cooperation' tendencies, which means that they choose to cooperate as long as others (both in their generation and in future generations) also cooperate.

For all their experiments, participants were recruited using the Amazon Mechanical Turk (AMT) (AMT). In their IGG experiments, participants form up groups of five, which are referred to as generations. The first generation has a common-pool of 100 units, and each person will collect between 0 and 20 units from this common-pool. When the total percentage of units collected from the common pool is equal to or below the commonly known extraction threshold, T, the common-pool is renewed to 100 units for the next generation. However, if the percentage extracted is above T, the common-pool is exhausted, and all future generations will earn no compensation.

With this research, they proved that the shared resources between generations were almost always lost when the extraction decisions were made individually. The inability to collaborate with future generations is motivated by a handful of people who extract far more than is sustainable. On the other hand, they found that extractions determined by vote preserved the resource more often. Voting is valid on two grounds. First, it helps the majority of cooperators to prevent defectors. Secondly, it convinces conditional cooperators that their actions are not in vain.

3 IMPLEMENTATION

This section will present an overview of the adaptation of The For The planet game for the inter-generational goods game achieved in this work

3.1 First Inter-generational adaptations

The first version of the game For the Planet was played on separate tablets within the same network by a group of three human players. Due to the current pandemic, we changed the game to be played on a Website using the Unity WebGL and changed its groups to one person and two virtual agents. We can see in Figure **??** the first UI of the For the Planet with this new design.

In this version, the players received a Common-Pool that could vary between 30 units, 60 units, and 90 units and are given the task to preserve it for the rest of the game. From this Common-Pool they were allowed to take between 0 and 14 units each round. At the end of the round, the Common-Pool would renew 50% of its current value. The players would play the game to a maximum of 10 rounds that we called generations if they preserved the Common-Pool. If at any moment the Common-Pool reached a value of zero, the game would end abruptly. When the players reached the final round (generation), if they preserved the Common-Pool above the commonly known threshold (of half the starting value) they would win the game (preserving the common-pool for future generations) and keep the benefits they collected during the game. If they had been careless with the common-pool and its value was bellowed the threshold, they would lose the game (destroy the planet for future generations) and lose all their gains.

In addition to changing the common-pool resource start value between minimal, average, and abundant amounts, there was an additional variable adjustment during this version. The players could start as the first generation of the planet and play for the first ten generations of the world. Or instead, started as an Intermediate generation, and play as the generations between ten and twenty.

3.2 Cooperating with the future For The Planet

After testing the first version, we decided to change the game for an approach more closely to the IGG of the work of Hauser [3].

According to Hausers' work [3], is IGG groups (generations) are composed of five members. The first generation has a Common-pool of 100 units, and each person will collect between 0 and 20 units from this common-pool. When the total percentage of units collected from the Common-pool is equal to or below the commonly known extraction threshold, T, the common-pool is renewed to 100 units for the next generation. However, if the percentage extracted is above T, the common-pool is exhausted, and all future generations will earn no compensation.

In our adaptation of the work of Hausers, the groups are constituted of three elements. The first generation receives a Common-Pool of 60 units, and each round, they give continuation to a different planet that can be healthy or in ruin. If healthy, the players are allowed to take between 0 and 20 units from the Common-Pool. They played the game for four rounds that we called generations. At the end of the round, if the cumulative amount of units extracted from the common-pool is equal to or below the commonly known extraction threshold, T, the common-pool shall be renewed to 60 units for the next generation. However, if the percentage extracted is above T, the common-pool is exhausted, and all future generations will earn no compensation.

During this version we upgraded the UI of the game, so the players had a pleasant experience during the game as we can see on Figure 2.

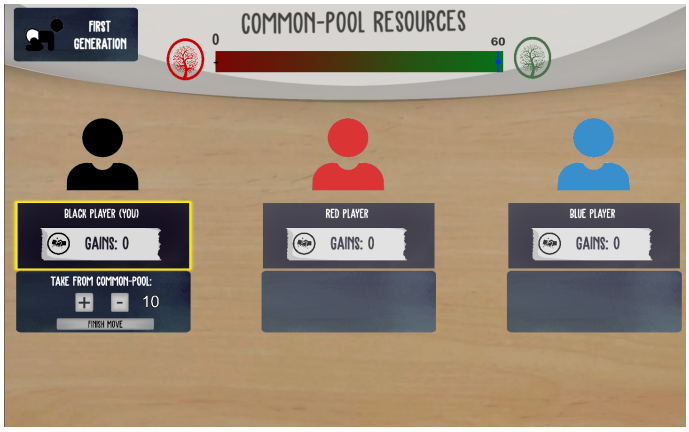

Figure 1: Final Main-area of the For The planet Game

3.2.1 Architecture. The For The Planet consists of teaming up with two virtual agent partners to play the game. The interactivity is achieved by playing over the browser accessing the game link and enjoying the interaction with the agents.

The system behind this game accommodates two virtual agents. The game engine and interface were developed using Unity and they mediate the game interaction between a human player and the virtual agents.

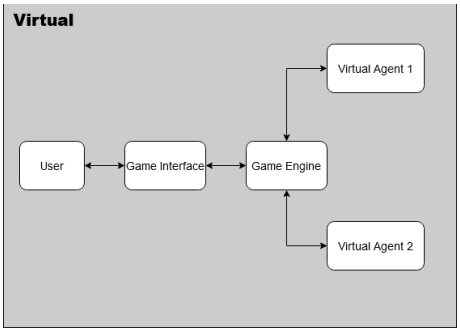

Figure 2: The system's architecture for playing For The Planet with two virtual agents.

3.2.2 Game dynamic. One of the most important parts of the game is the tutorial. In the tutorial, the participants are told the rules of our game and user study experiment.

After the players concluded the Tutorial the game will continue as follow. The participants will enter an introductory screen, that welcomes them to the game. This screen explains the current situation (their generation and the value of the common-pool). After

this introduction, the player enters the game area. The game area screen will be seen each time the players have to do a decision about how many units to take from the common-pool. When all the players have made their choice, they see at the bottom of the screen, how much the team took from the common-pool.

When the participant continues to the next round, he encounters a screen that resumes their team performance as a group during this generation and if they succeeded in preserving the planet for future generations. After this screen, a new generation begins, and they receive the information about the state of the planet in that generation if the planet is well or a planet disaster had occurred.

After the player concluded the four generations of our game, he reaches the end and sees the End game table. This table resumes their actions during the game: how much they take each round, the state of the common-pool at the end of the generation and, receives the SessionID in order to continue the user study.

3.2.3 Virtual agents. During the User Study, the participants are told they're playing with two more individuals, but in fact, they're playing with two virtual agents. To help our virtual agents pass as human participants, we add two mechanisms to the game:

- **Waiting Screens**: After the tutorial and the Introductory screens, participants are asked to wait for the rest of the group to be ready. They wait, watching a transitory screen for a random time between 5 to 10 seconds. Besides that, after the human participant played, he needs to wait for the rest of the group to play, as the agents simulate their plays by pressing buttons and an additional waiting screen.
- **Basic Player UI**: Players during the game are represented by one color icon. The color of the icon will be their codename for the rest of the game and user study.

3.2.4 Agents Strategies. With the changes in this version, there was a need to change the virtual agents' strategies. Firstly now, the common-pool had a fixed value of 0 or 60 units each round. Secondly, in this version, a player can take between 0 and 20 from the Common-Pool per round. Taking the last change into consideration, we consider a player to be:

- Ultra-Fair: If he takes between 0 and 5.
- Fair: If he takes between 6 and 10.
- Selfish: If he takes more than 10.

In our User study, we will use two neutral agents to better perceive the impact on the other changes of the game, this agent will use the **Fair strategy**. As we explained previously, an agent using the Fair strategy will always try to be "fair" which means takes the right amount that is not prejudicial to the Common-Pool Resource (environment). In this scenario playing fair as a player is to take between 6 and 10. So a Fair agent will take from the Common-Pool each round a random value between 6 and 10.

As explained in the previous version of agents strategy, one important aspect of our agents is that in order to pretend to be a human participant, they will always add Noise to their play, which translates into adding or subtracting to their play a value of 1, in order to difficult the human perception of their true nature.

3.2.5 Game Parametrizations. In the final version of the For The Planet, there are three independent variables of the game:

- **Generation Information**
- **Planet Condition**
- **Starting Generation**

In the **Generation Information** variable, there are two possibilities. Firstly, the players have knowledge about previous generations, how they played until the planet they inherited. This information will be available in the change of the rounds (generations) and be available via graphs. Because there are no prior generations, these graphs are manipulated. In the second option, the players have no information regarding the previous generations and must play only knowing if the planet is still habitable or in ruins.

In the **Planet Condition** variable, there are two conditions too. In the first scenario, which we called a Good Planet, the players during the four rounds of the game always encounter a healthy planet with a Common-Pool of 60 units that they can take advantage of. In the second condition, which we deemed as the Bad Planet. The players in the second generation they encounter on the game, experience a devastated planet (Common-pool at 0). They will take no advantage of this planet and must skip to the next round (generation).

In the final manipulable variable, the **Starting Generation**, it changes, as the name suggests, the starting generation of the game for the players. Firstly, they can start the game as the First generation on the planet and have the first impact on that planet. Secondly, they can begin the game as an Intermediate generation that has already been inhabited by other groups (generations).

3.3 Logs

Since the game data saving method of the For the planet game was not compatible with a game always running on a Website we had to solve this problem. In order to save the game data of the user study, we used the MongoDB Atlas service, to save the logs of each round of the game. MongoDB Atlas is a hosted MongoDB as a Service provided by MongoDB. It grants the freedom for a limited number of configurations, cloud service platforms, service regions, memory, and storage size. This hosted MongoDB service is very convenient for the end-users.

In order to use MongoDB with the For the Planet, since the game was implemented in Unity WebGL, we implement a simple server in JavaScript that receives the logs from the browser open a session in the collection of the MongoDB, and saves them.

At the end of each round, we save in the database from each player the following:

- SessionID - identification of the player game;
- Generation- the round of the data;
- PlayerName - the identification of the player;
- playerType - Human or agent and the strategy of the agent;
- playerTookFromCP: the amount the player took from the Common-Pool in the round
- playerGains- the amount taken from the CPR during the game until this round;
- NCollaborations - Number of collaborations until this round;
- envState - The amount in the Common-Pool in that round.

4 USER STUDY

In this section, we will cover the final evaluation of our thesis for that we held user study tests in the Amazon Mechanical Turk. The purpose of this final evaluation is to measure the impact our conditions have on the collaboration of our mixed teams of agents and humans. In order to achieve our goals, we used the same strategy on our agent.

4.1 Methodology and Procedures

4.1.1 Data Collection on Amazon Mechanical Turk. Through all of our studies, we recruited residents from four different countries (United States, Canada, Australia, and the United kingdom) to participate in the Amazon Mechanical Turk online labor market (AMT).

AMT is an online platform where employees will pay users for completing brief assignments (typically around 10 minutes) – usually referred to as Human Intelligence Tasks (HITs) – for relatively small wages (normally less than $1). Workers who have been hired to AMT shall receive a base salary and may also receive a bonus based on their success in the assignment. This setup is a good solution to adopt incentivized economic experiments. The baseline payment acts as the 'show up' fee and, the bonus payment may derive from the workers' behavior in the economic game during the experiment.

A significant benefit of using AMT is that the sample of recruited subjects is more diverse and geographically representative than the traditional university-run student sample at major research universities, where many economic games experiments are run.

There exist potential issues on AMT that would not occur in a traditional laboratory setting. Running an experiment online involves giving up some control over subjects since they cannot be monitored, as is usually the case in laboratories. Finally, the participating subject sample, albeit more diverse and representative than the average college students sample, is biased towards those who participate in online labor markets in the first place.

4.1.2 Basic flow of the experiments. In all of our experiments, participants received a $1.50 show-up fee and were given the opportunity to earn up to an extra $1.6 in bonus payments based on the result of the IGG. Participants took part in the experiment through two links, the first one the IGG link provided by Github pages, and a second link, an online survey provided by GoogleForms. The user study proceeded as follows: When the study participant joined the experiment they read the short description of the study. The experiment continued as described next:

(1) **Tutorial**: After reading the rules, the participants enter the For the Planet game and play the tutorial (that we analyzed in Section **??**), with the goal to familiarize them with all the rules, features, and other details about the For The Planet game and the user study.
(2) **For the planet game**: Afterward the tutorial, participants play a game with the virtual agents.
(3) **Post-game Questionnaire**:Finally, after the game with the agents, it will be asked the participants to fill out a post-game questionnaire regarding the results of the game. In the end, the participants are thanked rewarded for their participation.

In order to test if the participants knew the rules of the game and given the intended attention, they had to answer a few comprehension questions on the questionnaire. Those who didn't pass the quiz received only the baseline payment of $1.50 and were excluded from our analyses (following common practice on AMT). The participants had to answer where the answers were the following: 1) "Black, Red, Blue", 2)"No, the Common-Pool will not refill (0 units)", 3) "Yes".

In order to identify the participants and properly pay for their work, during the experiment, they had to write their Worker ID on the IGG and copy the session ID (identification of their game) from the game to the questionnaire. After they completed the task, they would insert the Session code that was written at the end of the questionnaire.

For the sake of quality results, we only accepted workers with Masters Qualification on AMT. Workers that have consistently demonstrated a high degree of success in performing a wide range of HITs across a large number of Requesters. We demanded a HITs approved rate higher than 97% and a higher number of HITs completed than 5000.

The experiments were approved by the Instituto Superior Técnico Ethics Committee on the Use of Human Subjects in Research.

4.1.3 General Experimental Design. In total, our experiment had five experimental conditions: Before describing the details of each condition, we explain the fundamental structure that is similar to all conditions.

In each condition, the Common-Pool resources are initiated with 60 units. We chose a sample size of 20 games per condition at the outset of the experiment.

In each game, a participant would form a group with two virtual agents playing with the fair strategy. Per generation (round) the participant chose how many units to withdraw from the common-pool (out of a maximum of 20 units).

Participants in Generation 1 were informed that they were the first generation. Participants in subsequent generations were informed that the previous generation had either sustained or not sustained the pool. They were not informed, however, of the specific generation number, we did not want to introduce this as a source of bias.

4.1.4 Details of each condition. Our experimental conditions differed in the Game parameters we mention in Subsection 3.2.5. As we can see on Table 1 we have 5 conditions.

Game Parameter	Planet Condition	Generation Information	Starting Generation
Condition 1	Good	Yes	Yes
Condition 2	Good	No	Yes
Condition 3	Bad	Yes	Yes
Condition 4	Bad	No	Yes
Condition 5	Good	Yes	No

Table 1: User Study conditions

4.1.5 Hypotheses. The following hypotheses identified our expectations regarding the previously mentioned user study conditions:

- **H1**: When the participants experience a planet disaster, they will cooperate more.
- **H2**: When the participants know the previous groups' collaboration, they will cooperate more.
- **H3**: When the participants start the game in an intermediate generation, they will cooperate more than when starting as the first generation.

Regarding hypotheses of collaboration, it will be used the objective number of times (out of the number of rounds) that each participant chose to cooperate in each round of the game.

The motivation behind the hypotheses are as follows:

- **Motivation behind H1**: We believe when the participants perceive the potential damage of their behaviors, they will start to collaborate more.
- **Motivation behind H2**: As we observed in the related work in the psychologic study of social dilemmas, individuals respond to information related to other's reputations as being cooperative by behaving cooperatively.
- **Motivation behind H3**: As we observed in the related work in the psychologic study of social dilemmas, individuals respond to information related to other's reputations as being cooperative by behaving cooperatively. When starting as an intermediate they have already the influence of the cooperative behavior of the previous groups.

4.1.6 Measurement. We did two types of measurements, a questionnaire, to get how users perceived the results of the game, and we kept logs from all plays done in the games. The logs, as we saw in section **??** contained the following information: identification of the player game, the round, identification of the player, type of the player if he is a Human or agent, and the strategy of the agent, the amount the player took from the Common-Pool in the round, the amount taken from the CPR during the game until this round, number of collaborations until this round and the amount in the Common-Pool in that round. The questionnaire is described ahead.

In order to ascertain the participants' emotions at the end of the game, we used the Geneva Emotion Wheel, with a semantic differential of 7 points.

Sixteen other questions, covering this way:

Q1: Emotions felt at the end of the game: Disappointment; Pride; Happiness; Sadness; Worry; Embarrassment; Guilt; Contempt; Compassion

Collaboration perception: "Q2: During the game, I collaborated significantly when allocating resources from the Common-Pool."

Agents influence:

- "Q3: My strategy was guided mainly by the other two members amount of collaboration and not on the state of the planet."

Result Responsability:

- "Q4: Which player of the team was the main "responsible" for the result achieved?"

Agents preference:

- "Q5: If you had to play again, and you could choose one of the other players to partner with, which player would you choose?"

Team measure:

- "Q6: In this team, everyone was always interested only in their own welfare."
- "Q7: All members of the team were trustworthy."
- "Q8: I feel proud to work in this team."
- "Q9: I am glad to be a member of this team."

Sustainability questions:

- "Q10: Humans have the right to modify the environment to fit their needs."
- "Q11: Humans should live in harmony with nature so that they can survive better"
- "Q12: When humans interfere with nature, this often produces disastrous consequences"
- "Q13: Planet Earth has limited space and resources"
- "Q14: The balance of nature is very delicate and easily disturbed"
- "Q15: Strategies to minimize environmental impacts generate costs for organizations"
- "Q16: The maintenance of resources in a planet is the most important aspect of sustainability"

Answers ranged from 1 - "Strongly Disagree" to 7 - "Totally Agree".

4.2 Results

4.2.1 Sample Description. A total of 109 users took part in this study and completed our questionnaire, where 54 were male, 54 were female and one participant responded other. The ages ranging from 25 to 67 (M=42.98; SD=11.220). In terms of nationalities our users were: 106 Americans, 2 Canadians, and 1 English.

Participants were allocated to one of five different conditions. As we explained in this section, our goal was a sample size of 20 games per condition at the outset of the experiment, however, some users responded wrongly to the comprehension questions or fail to deliver the questionnaire making their work invalid. We ended up collecting more studies in order to equalize the workers per condition. We can see in Figure 3 the number of valid works per condition that were used in the statistic analysis.

Condição * Validation Crosstabulation

Count

		Validation		
		invalid	valid	Total
Condição	GoodPlanetInfo	5	18	23
	GoodPlanetNoInfo	2	20	22
	BadPlanetInfo	4	17	21
	BadPlanetNoInfo	1	19	20
	InterGenGoodPlanetInfo	5	18	23
Total		17	92	109

Figure 3: Valid works

All participants allowed the use of their answers to be used in this study.

4.2.2 Questionnaire Results. There are six different fields of concern in our Questionnaire. Both fields of focus, refer to elements

of the game experience and sustainability aspects that we needed input from the participants. These aspects are: emotions felt during the game, collaboration perception, agents Influence, result responsibility, team measure, and finally sustainability questions. The question sets were given to the player only after he/she had finished playing the game.

In order to evaluate the questionnaire results, we first used the Shapiro-Wilk Normality Test to determine whether the data followed a normal distribution. In all the cases, normality was not observed so, we used the Mann Whitney-U as a nonparametric test.

To check for differences between conditions, we compare all the cases between the Planet Condition(Good Planet scenario and Bad Planet scenario), Generation Information (With Generation Information or without) and Starting Generation (Only between Condition 1 and 5, where they have both the other conditions and only differ in the starting generation).

Regarding the questions of aspects of Team measure and sustainability, they were transform into one variable, since they had a Weak and positive correlation between the questions of the same aspect.

Regarding the emotions felt unfortunately, there were no statistically relevant differences for any the emotions, thus we can not make conclusions based on them. However, we have results closed to statistically relevance that could changed if the sample increased. When comparing the results in Table 2 between the two different Generation Information conditions. Mann-Whitney showed that the groups without Generation Information were almost statistically significantly higher than the groups with Generation Information.

Emotions	Compassion	Worry
Mann-Whitney U	517,0	540,500
Sig.	0,064	0,081

Table 2: Mann-Whitney U test between the Generation Information conditions

Unfortunately, there were no statistically differences for any of the rest of the questions, thus we can not make conclusions based on them.

Regarding the Team measures, there was no statistical difference between conditions. However, the participants evaluated high the performance of their team, as the mean of the team measure being 5.75 across all conditions, with the score range between 1 and 7. This result means that the participant liked partnering with the two virtual agents.

4.2.3 Game Results. As we mentioned in the previous Section 4.1.6, we kept all the data in the logs of every match played between the virtual agents and the participants. These logs contain a lot of information regarding the state of the game, the plays of each player in every round, and the number of collaborations (rounds where the participants played fair and took from the Common-Pool a value equal or lower than 10) of that players.

Using this information we can measure how each participant performed and how each situation of the game influenced the collaboration of the participant.

Due to the Condition of Bad planet, where players don't play during the second round, we exclude from the other conditions the first two rounds adjusting the number of collaborations to only the third and fourth round, the rounds after the disaster. In order to do a fair statistical analysis.

Comparing this metric of Collaboration on our three conditions we got the following results:

- **Planet independent variable:** Mann-Whitney U test showed that the Good planet group there was no statistically significant difference between the Bad planet group and the Good planet group.(Mann–Whitney U = 614,50, P = 0.357 two-tailed)

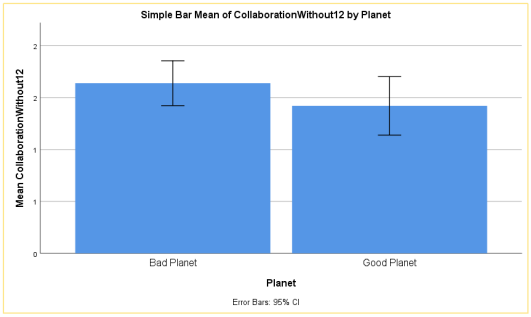

Figure 4: Collaboration between the Planet Condition

- **Generation Information independent variable:** Mann-Whitney U test showed that the group without Generation Information was statistically significantly higher than the group with Generation Information.(Mann–Whitney U = 528,0, P = 0.040 two-tailed). This result means there is a statistically difference between the collaboration of the group without Generation Information and the group with Generation Information.

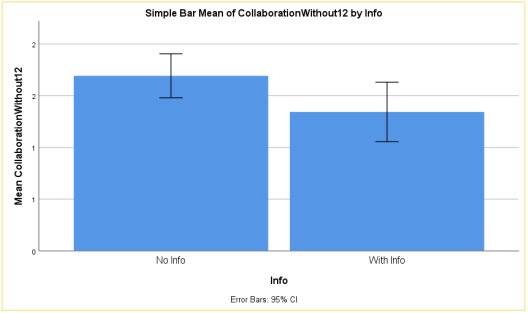

Figure 5: Collaboration between the Generation Information Condition

- **Starting Generation independent variable:** Mann-Whitney U test showed that the Intermediate Generation group was not statistically significantly higher than the First Generation group.(Mann–Whitney U = 123,0, P = 0.226 two-tailed)

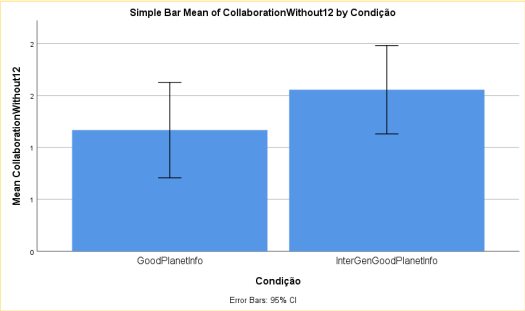

Figure 6: Collaboration between the Starting Generation Condition

When analyzing the gains on three different conditions, unfortunately, the Mann-Whitney U test showed that there was not a statistically significant difference in the gains between the three experimental conditions.

4.2.4 Correlations. During our Statistical analysis, we did correlation tests. Correlation is a statistical technique that shows how strongly two variables are related to each other or the degree of association between the two. During our correlation test, we compared the following metrics: the number of collaborations, sustainability beliefs, Emotions felt (Compassion, Contempt, Sadness, Pride, Disappointment, Embarrassment, Happiness, Guilt, and Worry), Subjective Collaboration, and Team Measure. We can see the results of these tests in Table 3.

There were three statistically significant correlations:

(1) A weak positive correlation between the collaboration and the emotion Compassion.
(2) A weak positive correlation between the sustainability beliefs and emotion Compassion
(3) A weak positive correlation between the collaboration and the sustainability beliefs

The correlation test between the number of times the participants collaborated and the subjective perception of collaboration showed a Weak and positive correlation. This means that the participants evaluated well their level of collaboration.

Team measure had a negligible correlation with the collaboration but had a weak and positive correlation with the emotion of compassion.

All the emotions except compassion had a negligible correlation with collaboration. The correlation tests between the emotions, as expected showed there is a weak and positive correlation between compassion and both pride and happiness.

4.3 Results Discussion

These results contradicted one of our hypotheses. We speculated that when the participants know the previous groups' collaboration (Generation Information), they will cooperate more. However, the results showed that the participants collaborated more when they didn't know about previous groups. This contradicts many studies[9][8]. A possible explanation for this result is the comparison of the previous groups (generations) and their team. Since the previous generations took more of the Common-Pool than their current group was taking each round, the selfish participants felt more at ease to take more from the common-pool and don't collaborate.

	Collaboration	Sustainability beliefs	Compassion
Sustainability beliefs	0.308*		0.335*
Compassion	0.382*	0.335*	
Subjective Collaboration	0.442*	0.370*	0.498*
Team Measure	0.173	0.257*	0.358*
Contempt	0.042	-0.016	0.229*
Sadness	0.002	-0.011	0.112
Pride	0.200	0.275*	0.565*
Disappointment	-0.104	-0.074	-0.071
Embarrassment	-0.132	-0.154	0.060
Happiness	0.147	0.273*	0.572*
Guilt	-0.003	0.097	0.013
Worry	0.147	-0.004	0.284*

Table 3: Correlations with Collaboration (Pearson Correlation)
***.Correlation is significant at the 0.05 level (2-tailed)**

As expected people with higher levels of sustainability beliefs collaborate more and tend to be less selfish and more compassionate. Sustainability is usually defined as actions through which humankind avoids the destruction of natural resources, in order to keep an ecological balance that doesn't allow the quality of life of societies to decrease. To achieve this important goal, there is a need for collaboration between all humankind. So people with higher sustainability beliefs should be collaborators.

Another hypothesis of our study was "When the participants experience a planet disaster, they will cooperate more.". The results of our user study did not support this hypothesis as a difference between the cooperation on each planet condition was not statistically significant. One possible explanation for the planet disaster condition, not influence collaboration is that perhaps the players didn't understand what had happened. The Game interface during the planet disaster is simple and explained majorly through. Perhaps if used a better description of the occurrence aided with visual animation the results could change.

The final hypothesis of our study was "When the participants start the game in an intermediate generation, they will cooperate more than when starting as the first generation." The results of our user study did not support this hypothesis as a difference between the cooperation on each starting generation condition was not statistically significant. A possible explanation for the starting generation independent variable did not influence collaboration is the absence of a playable tutorial round. The first time the players interact with the game, they tend to be cautious and play something neutral since they are not yet familiar with the game dynamic and, they don't know what to expect from their partners. By doing this, they ignore the generation factor (being a first or intermediate generation). If we introduced a playable tutorial, perhaps we could see some difference in the first playable generation.

With the results of the team measure, we can see that the participants enjoy being part of the group with the virtual agents. These

results reinforce the belief that agents can be a great addition to our team and help us during our tasks.

5 CONCLUSIONS

The purpose of this thesis was to find a solution for increasing the level of collaboration in mixed teams of humans and agents when dealing with the environmental social dilemma.

This thesis aimed to find a solution for increasing the level of collaboration in mixed teams of humans and agents when dealing with the environmental social dilemma.

We researched several studies related to mixed teams of humans and agents and how these new teammates can be a great addition to our future teams. We also explore the way prosocial behaviors can benefit these mixed teams. We researched social dilemmas and the many factors that influence people during this scenario. And especially analyze the Inter-Generational Goods Game that presents a social dilemma to multiple groups.

Based on the Inter-Generational Goods Game and studies we researched, we changed the For The Planet game to an IGG. Then we sought to influence the participants to change into a collaborative strategy, using the game parameters and different scenarios. To do this, we tested whether facing a planet disaster will encourage the player to collaborate in the next rounds and whether we can increase that player's amount of collaboration by informing him about the previous groups' collaborations.

To test our approach and answer our hypothesis, we conducted a user study on Amazon Mechanical Turk with five different types of sessions. Our sessions differ on the occurrence of planet disaster, generation information available, and starting generation. The number of times that each participant has chosen to cooperate in each round of the game will be used to test the hypotheses in all the sessions.

From the results we obtained, we get that our hypothesis, "When the participants know the previous groups' collaboration, they will cooperate more." was contradicted, with the groups without this knowledge collaborating more. Our second hypothesis, "When the participants experience a planet disaster, they will cooperate more." we could not conclude anything with our results. Regarding our final hypothesis, "When the participants start the game in an intermediate generation, they will cooperate more than when starting as the first generation." we could not conclude anything with our results.

In conclusion, even though we could confirm our hypothesis, the perception of participants over the two virtual agents was positive, and we found that people with sustainability beliefs are more compassionate and collaborate more.

This work is contributing to the field of Human-Agent Interaction (HAI) by suggesting a direction for understanding the relational dynamics in mixed groups of humans and virtual agents when facing a social dilemma.

5.1 Future Work

As future work, we would like to go back to the original plan, which was changed due to the COVID-19 pandemic. Originally we planned to use robotic partners in our mixed-teams and explore non-verbal and verbal behaviours recognition to understand the players' behaviours when they were gonna collaborate or be selfish. We wanted to use punishment as a mechanism to influence collaboration by using the eye gaze of the agent, increasing when the participants were collaborators as an incentive and reducing to selfish players as a social marginalization. All our plan is described in Appendix **??**.

Regarding future works to our current implementation, it would interest to change groups of participants each generation as the work of Hauser did. This feature was very difficult due to the pandemic.

Another worthwhile addition to the work is to test the influence of different agent strategies on the participants during the IGG. We develop these strategies such as a TIT-For-TAT, Outcome-Based, Compensator, and we didn't test them to not increased the complexity of our already big user study.

To finish our propositions for the future we hope that the next iteration of this work can deal with the problem of players not understanding the occurrence of the planet disaster. A possible solution is introducing a better animation and explanation of the situation.

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