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The INVITE Research Tool:
A computational framework of public goods experiments

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Abstract The INVITE framework is a computational research tool which allows the configuration of a wide range of public goods experiments from the simplest strategic paradigms such as the 2-person prisoner's dilemma to complex team games, in a three-dimensional environment for virtual and human participants. It aims to address the limitations of the existing computational frameworks which place the participants in an oversimplified environment and to provide a greater control over the experiments in comparison to physical labs. The three-dimensional environment of the framework allows the creation of a virtual world where several aspects of decision framing can be explored in a controlled manner such as, the characterization of participants and visual cues, and enhances the sense of presence of participants enticing them to act in a similar manner to a real life situation. In this article we describe in detail the general scenario and the configuration parameters of an experiment, show how it is possible to parametrize a number of well-known paradigms and cover possible applications of the framework.

Keywords Computerized research tool · Economic experiments · Public goods games · Three-dimensional environment · Virtual and human participants ·

1 Introduction

Economic experiments such as public goods games constitute a scientific area of continuing interest. Topics such as the effects of social identity (Simpson, 2006) and decision framing (Rutte et al, 2011) representing research questions

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open to further experimental investigation. Nevertheless and despite the importance of promoting research in this field, the number of computational research tools to perform experiments of this type is somewhat reduced. Among the most well-known tools are the Plott's tool (Plott, 1991), the Colored Trails (CT) framework (Grosz et al, 2004) and the z-Tree toolbox (Fischbacher, 2007). These tools tend to neglect the importance of the creation of a context for the experiment (Levin et al, 1998) placing the participant in an abstract environment where most of the visual aspects of the depicted situation such as the characterization of each participant and surrounding scenario are absent. To address these shortcomings, we present the INVITE (social Identity and partNership in VIrTual Environments) framework which allows configuring public goods experiments in a 3D environment for virtual and human participants over the Internet.

The use of 3D technologies for experimentation has been advocated by scholars such as Bainbridge (2007) and Castronova et al (2008) who argue that virtual worlds such as Second Life and World of Warcraft represent platforms of high research potential. Even though experimental research in 3D environments may be considered of value in its own right, greater significance can be attributed to it after the findings of Chesney et al (2009) whose replication of classical economic experiments in virtual worlds suggest that the results obtained in virtual environments can be carried to the real world. These results support the case for the use of 3D environments, such as the one of the INVITE framework, for economic experimentation. Hence, the framework represents an attractive alternative to the oversimplified interfaces of the existing computational frameworks and to physical labs given the greater control provided over the experiment.

The 3D capabilities of the INVITE framework are important not only for exploring decision framing (Levin et al, 1998) but also for the benefits of the increased sense of presence that participants experience. The immersion of participants in the INVITE framework, due to the enhanced degree of interaction and control provided by the 3D environment (McMahan et al, 2006), aims to promote an increased level of involvement in the experiment, in comparison to the existing computational frameworks. This in turn, provides more guarantees that participants are engaged in the fictional scenario and more likely to act similarly to a real life situation.

The motivation underlying the INVITE framework is to allow researchers to be to deploy without difficulty experiments where hypothesis regarding the behaviour of individuals as well as of artificial intelligence agents and their interactions can be tested. The possibility to have virtual and human agents interacting in the same platform is one of the advantages of the INVITE framework. For instance, it is possible to reduce significantly the cost of experiments with a high number of participants with virtual agents. Moreover, virtual agents also allow the experimenter to have a greater degree of control over the experiment by configuring the behaviour of the virtual participants prior to the experiment.

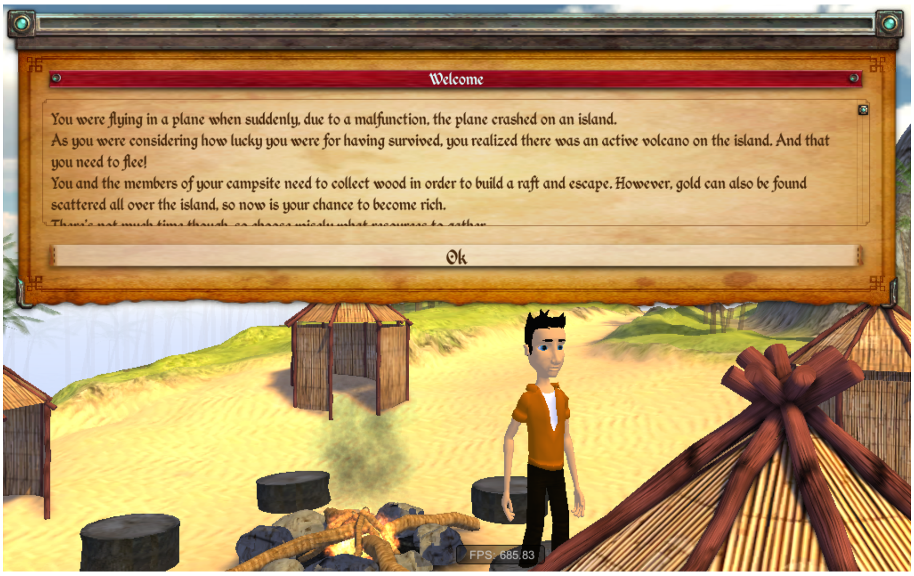

Fig. 1 The 3D environment of the INVITE framework allows exploring decision framing such as, for instance, the visual aspect of participants to further investigate topics such as, personal and social identity.

The ease of configuration is an important property which a computational framework of economic experiments should guarantee. In contrast with the previous tools, the INVITE framework does not require the experimenter to know a programming language to configure an experiment assisting him with a two-dimensional (2D) menu system for that purpose. Moreover a set of already pre-configured templates of experiments is shipped with the framework which can be modified by the experimenter according to his particular needs. This improvement greatly reduces the effort and expertise required of the experimenter.

The goal of the INVITE framework is therefore to stand as a usable research tool allowing an efficient parametrization of a large spectrum of public goods experiments for virtual and human participants in a 3D environment. In the following sections of the article, we will describe the general scenario and configuration parameters of an experiment, illustrate the configuration of some strategic paradigms and discuss possible applications of the framework.

2 Experiment

Even though the majority of the computerized frameworks such as the z-Tree toolbox or the CT framework allow configuring a wide range of types of economic experiments such as public goods, ultimatum games, dictator games, trust, gift exchange and third party punishment some of the intricacies that these types of games may present (such as the existence of a minimum level of contribution for the provision of a step-level public good (Suleiman and Rapoport, 1992)) are impracticable or require considerable programming effort to model in those tools. In contrast, the scope of the INVITE framework is restricted to public goods games, providing however, a great deal of flexibility in that domain while assuring an effortless configuration of an experiment. Hence, the INVITE framework allows the configuration of a myriad of public goods experiments ranging from simple 2x2 games to complex team games (Bornstein, 2003) with an optional enclosed ultimatum game to define the distribution rule of the public good.

All the experiments of the INVITE framework unfold in the same scenario (refer to Figure 2) which takes the form of a public goods game[1]. The fictional scenario can be described as follows:

> The experiment is set on a desert island where participants take the role of a survivor of a plane crash. After the plane crash, the participants soon realise they must evade the island before the eminent eruption of the island's volcano. Hence, their only chance of escaping the island alive is by sailing in handcrafted rafts to a nearby inhabited island. Participants are assigned into groups, each group having the goal of constructing a raft. In order to help build his group's raft, each participant can dedicate part of his day gathering wood. However, instead of collecting wood, the participant can decide to spend part of his time gathering a private resource such as gold. If a group is able to build the raft prior to the end of the experiment (at the volcano's eruption), the members of the group are able to escape the island and the raft is sold since the raft's wood is a rare and valuable resource at the destination's island. The earnings obtained from the raft are then distributed among the members of the group.
>
> The game is won by the participant with the most earnings (derived from individual collection and from the sale of the group's raft). Depending on the experiment configuration, members of groups which do not finish their rafts on time may lose all their earnings. Accordingly, during the experiment, participants face the dilemma of either to contribute to the common good of the group (raft construction) or to contribute solely to their more individualistic goal (collection of the private resource).

To configure a new experiment in the INVITE framework a set of parameters must be defined in the INVITE configuration tool (refer to Figure 3). Each of these parameters is described as follows:

Introductory text defines the text which is presented to each participant at the start of an experiment.

[1] It should be noted that even though the INVITE framework does not support common-pool resources games directly such games are isomorphic to the supported public goods games.

Fig. 2 Participants of the INVITE experiment take the role of survivors of a plane crash at a desert island. Individuals face the dilemma of either to contribute to the common good (construction of a raft) or to act in their own individual interest (collect a private resource).

Fig. 3 The INVITE framework allows a seemingly configuration of a wide range of public goods experiments. It also provides a set of already pre-configured templates of games. In addition, the experimenter can save and load previously saved configurations.

Groups ($M \in \mathbb{N}$) defines the number of groups.

Participants ($N \in \mathbb{N}$) defines the number of elements in a group. The experimenter can configure for each participant the following characteristics:

- Name: name of the participant.
- Visual aspect: graphical appearance of the participant in the 3D environment including its gender, avatar type, hair color and style, skin color and uniform.
- Type of participant: definition of the participant as human or virtual agent. It is possible to program the behaviour of virtual agents in the INVITE framework. Furthermore, the framework provides a set of predefined behaviours which can be configured directly in the configuration tool.
  In case the participant is a virtual agent it is possible to define its behaviour given a set of possible pre-configured behaviours.

Days ($T \in \mathbb{N}$, $T \geq 1$) defines the number of days (turns) until the eruption of the island's volcano. The eruption determines the end of the game and occurs at the end of the T_{th} day.

Actions per day ($n \in \mathbb{N}$, $n \geq 1$) defines the number of actions per day each participant has to spend collecting wood or the private resource. In each day (t), participant i of group k decides the number of actions he intends to spend gathering wood ($s_{kit} \in \{1, \ldots, n\}$) while the remaining actions ($n - s_{kit}$) are spent collecting the private resource, hereafter referred as gold. It should be noted that each action collecting wood or gold results in one unit of wood/gold respectively.

Starting wood ($B_{ini} \in \mathbb{N}$) defines the units of wood already available at the start of the experiment for each group.

Necessary wood ($B_{min} \in \mathbb{N}$) defines the necessary units of wood for the construction of a raft.

Maximum wood ($B_{max} \in \mathbb{N}$, $B_{max} \geq B_{min}$) defines the maximum amount of wood each raft can encompass. In case this parameter is set higher to the parameter of necessary wood participants can continue to collect wood and augment their raft after the minimum required threshold of wood has been reached.

Departure defines when the group is allowed to leave the island. It can assume one of the following options:

- Raft: The group leaves the island when the necessary wood for the raft's completion is reached.
- Poll: The group leaves the island by decision of the majority of the members of the group as long as the necessary wood for the raft's completion has been reached.

– Eruption: The group leaves the island at the end of the experiment.

Loss of private resource ($\lambda \in \{0, 1\}$) defines if the private resource is accounted in the participant's outcome when he does not leave the island.

Ranking defines the criteria by which the groups are ordered to calculate the earnings from their rafts. The following options are available:
– Effort: Groups are ordered according to the groups' effort in collecting wood.
– Timing: Groups are ordered according to how quickly groups complete their rafts.

Earnings from wood ($\{\gamma_1, \ldots, \gamma_M\}$) defines the earnings obtained from one unit of wood from the raft according to the group's position in the game's overall ranking. At the end of the experiment, $s_k = \{s_{k1}, \ldots, s_{kN}\}$ defines the profile of contributions (wood collected) of group k with s_{ki} defining the contribution of participant i of group k:

$$s_{ki} = \sum_{t=1}^{T} s_{kit}$$

Accordingly, the wood collected by group k in the experiment is defined as:

$$c_k = \sum_{i=1}^{N} s_{ki}$$

The contribution of the groups on the island in wood is therefore defined by $c = \{c_1, \ldots, c_M\}$. These contributions are translated into earnings if they reach the minimum level for each group (B_{min}). According to how fast or how much they contribute (Ranking parameter), groups may have higher or lower rates of conversion of wood into earnings.

Distribution of group's earnings ($q_{ki}(N, s_k)$) defines how the group's earnings derived from the raft's sale are distributed among the group's members. The earnings of one group can be distributed according to one of the following options:
– Egalitarian: The earnings are distributed evenly among the group's members disregarding how much each participant effectively contributed for the raft's construction.

$$q_{ki}(N, s_k) = \frac{1}{N} \tag{1}$$

– By contribution: The earnings are distributed according to individual effort in collecting wood.

$$q_{ki}(N, s_k) = \frac{s_{ki}}{\sum_{i=1}^{N} s_{ki}} \tag{2}$$

– Ultimatum: The distribution of the earnings of the group is decided by playing an altered version of the ultimatum game (Thaler, 1988). The participant with the highest contribution proposes a distribution on the other participants to vote. If the majority of the participants accept such distribution the earnings are distributed accordingly otherwise all the earnings from the raft are lost due to lack of consensus.

The outcome of participant i of group k at the end of the experiment, that is his payoff function, is calculated according to his individual earnings and group earnings. Participants can gain earnings directly by collecting private resources $(nT - s_{ki})$ or indirectly after the final distribution of the earnings obtained from the sale of the group's raft. The earnings obtained by group k depend on the group's production function whose general form is the following:

$$p_k(c) = \gamma(c_k + B_{ini}) \tag{3}$$

The general payoff function of participant i of group k is the following:

$$u_{ki}(c, s_k) = \begin{cases} (nT - s_{ki}) + q_{ki}(N, s_k)p_k(c), \text{ if } c_k + B_{ini} \geq B_{min} \\ (nT - s_{ki})\lambda, \text{ otherwise} \end{cases} \tag{4}$$

It is also possible to configure the information available to the participants during the game:

Game information: The number of days to eruption, method of distribution of group's earning and expected earnings from wood for each position in the team's ranking may be information undisclosed to the participants.
Information of team: The wood and gold collected by the team's members of the participant and the total collected wood may be concealed from to the participants.
Information of other teams: The wood and gold collected by the members of other teams and the total collected wood by their teams may be concealed from the participants.
Visual cues: It is possible to configure visual cues of the raft's construction and of the volcano's eruption.

3 Strategic Games

This section describes how strategic games such as the prisoner's dilemma or stag hunt and their variants can be modelled in the framework.

3.1 Prisoner's dilemma

The prisoner's dilemma is perhaps the most widely known paradigm of game theory (Rapoport, 1974). This structure can be recreated in the INVITE framework using the configurations of Table 1. Refer to Figure 2 for the general payoff matrix in the case of two participants.

Table 1 Configuration of the 2x2 prisoner's dilemma.

Parameter	Value	Description
Groups	1	There is one group of survivors in the island.
Participants	N	The only group is composed of N elements.
Days	1	The game lasts only one day (one-stage game).
Actions	n	The participant can either spend his daily actions collecting wood to build the raft (co-operate) or collecting a private resource in his own private interest (defect).
Starting wood	0	The initial amount of wood is set to zero.
Necessary wood	0	There is a rescue boat which the participants can use.
Maximum wood	∞	There is no limit for the wood that the raft can accommodate.
Departure	*Eruption*	At the end of the day participants leave the island with the gold and wood collected.
Loss of private resource	N.A.	Not applicable since participants always leave the island.
Ranking	N.A.	There is only one group in the island so there is not competition among groups.
Earnings from wood	γ	A participant in one action can derive one unit of wood and one unit of gold. Each unit of wood from the raft derives γ earnings to the group. To ensure that the game is a prisoner's dilemma one must guarantee that 1) when all players decide to collect wood to build the raft, the expected payoff of all players is higher than when they all decide to collect the private resource and 2) the expected payoff increase of preferring to collect the private resource over wood must be greater than zero (Rapoport and Chammah, 1965). These conditions are met when $\gamma > 1$ and $\frac{\gamma}{N} < 1$ respectively.
Distribution of group's earnings	*Egalitarian*	The earnings obtained from the raft are distributed evenly among the participants.

3.2 Chicken game

The chicken game (Schelling et al, 1963) can be parametrized in a similar manner to the prisoner's dilemma with the particularity that the collective

Table 2 General payoff matrix of prisoner's dilemma for 2 participants ($n = 1, 1 < \gamma < 2$, $B_{min} = B_{ini} = 0$, $B_{max} = \infty$).

	Cooperate (Wood)	Defect (Gold)
Cooperate (Wood)	γ, γ	$\frac{\gamma}{2}$,$1 + \frac{\gamma}{2}$
Defect (Gold)	$1 + \frac{\gamma}{2}$,$\frac{\gamma}{2}$	1,1

decision of defection yields the worst possible scenario (Bornstein et al, 1997; Santos and Pacheco, 2011). The required configurations differ from the prisoner's dilemma (Table 1) in the fact that the minimum amount of wood is set equal to the number of actions in the game ($B_{min} = n$) and the loss of private resources is enabled ($\lambda = 1$) to guarantee that (1) in the scenario where only one participant cooperates (collects wood) participants are able to build the raft and that (2) in the setting of collective defection (collection of the private resource) participants are unable to complete the raft and consequently do not leave the island alive losing all their private resources and yielding the worst possible scenario.

In the chicken game, the conditions of 1) when all players decide to collect wood to build the raft, the expected payoff of all players is higher than when they all decide to collect the private resource and 2) the expected payoff increase of preferring to collect the private resource over wood must be greater than zero are translated into $0 < \gamma < N$. Table 3 presents the general payoff matrix of the game for two participants.

Table 3 The general payoff matrix of the 2-player chicken game ($n = 1, B_{min} = n$, $B_{ini} = 0$, $B_{max} = \infty$, $\lambda = 1$, $0 < \gamma < 2$).

	Cooperate (Wood)	Defect (Gold)
Cooperate (Wood)	γ, γ	$\frac{\gamma}{2}$,$1 + \frac{\gamma}{2}$
Defect (Gold)	$1 + \frac{\gamma}{2}$,$\frac{\gamma}{2}$	0,0

3.3 Stag hunt game

Stag hunt (Skyrms, 2003) can be configured similarly to the prisoner's dilemma by creating a scenario in which the collective decision of cooperation (gathering wood) yields the best possible scenario. This can be achieved by (1) setting the minimum required wood to a value that enforces that raft's construction is only guaranteed if all individuals cooperate ($B_{min} = Nn$) and (2) by disabling the loss of private resources ($\lambda = 0$) so that scenarios in which at least one participant defects yield better payoffs to defectors than to cooperators.

In contrast with the prisoner's dilemma the only restriction that stag hunt imposes is that 1) when all players decide to collect wood to build the raft, the expected payoff of all players is higher than when they all decide to collect the private resource which implies that $\gamma > 1$. Table 4 presents the general payoff matrix of the game for two participants.

Table 4 The general payoff matrix of the stag hunt game for 2 participants ($n = 1, B_{min} = 2n$, $B_{min} = 0$, $B_{max} = \infty$), $\lambda = 0$, $\gamma > 1$).

	Cooperate (Wood)	Defect (Gold)
Cooperate (Wood)	γ, γ	0,1
Defect (Gold)	1,0	1,1

3.4 Team Games

Bornstein (2003) defined a “team game” as a game in which both the elements of inner and outer group conflicts are present. In such games, players are assigned into groups, with each group facing an in-group social dilemma and an out-group strategic game. It is straightforward to configure this type of games in the INVITE framework by setting the number of teams (M) and the number of players per team (N) to values greater than 1.

We can identify two major distinguishing types of team games: competitive and neutral team games. In competitive games there is competition among teams (either by timing or by effort) and the conversion rate of the wood in the group’s rafts into earnings varies according to the team’s performance. In neutral games the conversion rate of wood into earnings is equal to all teams.

We can also classify the team game according to the internal public goods game which may be step-level or linear. In the first case, the public good is only provided if a certain level of contribution has been reached. This condition is translated into the form $B_{min} > B_{ini}$ implying that there should be a minimum amount of wood required for the completion of the raft above the initial amount of wood. Conversely, the linear case occurs when $B_{min} \leq B_{ini}$.

4 Applications

Problems of public goods provision will continue to stem interest in the experimental field and be prone to further investigation. Research will unfold into questioning why people behave in “irrational” ways and how to promote cooperation. In this context, the INVITE framework aims to provide valuable insight into the complexity of public goods games from its basic to its most elaborate shapes. We hereafter briefly review a list of topics to investigate in the framework.

Virtual agents The possibility provided by the INVITE framework to have virtual agents interacting with human participants in a 3D environment opens new scientific perspectives. It enables less costly and more controlled studies of how humans react to certain behaviours in scenarios of social conflict by the configuration of experiments with pre-defined artificial intelligence participants. The framework can also be used to investigate the reasoning processes which guide human behaviour by designing complex virtual agents whose believability can be subject to test. In addition, it is also of interest to investigate how humans react and develop partnerships with agents they know in advance to be non-human in such settings.

Decision framing and visibility of parameters It has been show that individuals react very differently in economic experiments according to the description of the setting even if the incentive structure is objectively the same (Brewer and Kramer, 1986; Cookson, 2000; Rutte et al, 2011). These framing effects can be further investigated in the INVITE framework by changing for instance the introductory text of the game, the visuals of the private resource or by enabling the visual cues of the volcano's eruption or of the raft's construction. The INVITE framework can also be used to investigate how the visibility of certain parameters such as the number of days until end of game, gold and wood collected by each team member, can affect the behaviour of the participants.

Social identity Social identity is an important factor in economic experiments since studies such as the one conducted by Brewer and Kramer (1986) report that an increase in the salience of the social identity of individuals leads to an increase of the cooperation rates. The salience of social identity can be manipulated in the INVITE framework resorting to the available 3D technologies. The framework allows modifying the visual aspect of the avatars which could be explored to create groups with distinct visual characteristics and in theory distinct group identities and provides a set of graphical scenarios with group's gathering places to foster group's cohesion.

5 Conclusion and Future Work

Frameworks of economic experiments have to be easy to configure and and allow the configuration of a wide range of strategic paradigms. With the INVITE framework, we propose a novel research tool of public goods experiments which allows researchers to test their hypothesis regarding the behaviour of both human and virtual agents in a 3D environment.

In the future, we aim to research how to develop artificial intelligence agents which can interact with the human players of the INVITE framework as believable decision-makers. To accomplish this, rational choice as well as social identity theory and anticipation algorithms should play an important role in the development of the reasoning mechanisms of the agents (Prada et al, 2012).

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