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The Sustainability Game: AI Technology as an Intervention for Public Understanding of Cooperative Investment

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***Abstract*—Cooperative behaviour is a fundamental strategy for survival; it positively affects economies, social relationships, and makes larger societal structures possible. People vary, however, in their willingness to engage in cooperative behaviour in a particular context. Here we examine whether AI can be effectively used to to alter individuals' implicit understanding of cooperative dynamics, and hence increase cooperation and participation in public goods projects. We developed an intervention—the Sustainability Game (SG)—to allow players to experience the consequences of individual investment strategies on a sustainable society. Results show that the intervention significantly increases individuals' cooperative behaviour in partially anonymised public goods contexts, but enhances competition one-on-one. This indicates our intervention does improve transparency of the systemic consequences of individual cooperative behaviour.**

***Index Terms*—serious games, behavioural economics, persuasive technologies, agent-based modelling**

I. Introduction

As we develop systems to model our own action selection, we gain opportunities to further our understanding of natural intelligence. Here we document the introduction of an intervention originally designed in a hope of promoting cooperative behaviour by helping individuals recognise when cooperation is beneficial. This intervention, *The Sustainability Game*, is a single-player serious game derived from agent-based models informing studies of public-goods phenomena such as sharing culture, punishing free riders, and understanding contemporary political economy. The underlying simulation is of an ecosystem of agents competing and cooperating for the accumulation of resources and for their own survival. The dynamics of this spatial simulation are based on ecological modelling and scientific theory. We developed this intervention to alter players' *implicit* understanding of the dynamics of public goods investment. All participants in public-goods studies must show *explicit* understanding by passing a test, yet performance in public goods games varies broadly [Herrmann *et al.*2008], [Sylwester *et al.*2013]. Our hypothesis was that the direct experience of the dynamics of public-goods investment might induce the inclinations or additional intuitions that would help subjects better benefit from this explicit knowledge. Our findings bore out our predictions at least in the standard, anonymised context; however head-to-head, subjects manifested increased competitiveness. This apparently counter-intuitive outcome is congruent with known triggers for competitive behaviour Burton-Chellew2017, so may also indicate increased transparency of cooperative outcomes.

II. Background and Design Considerations

Cooperation is a fundamental strategy for survival and social behaviour. Contrary to popular conceptions of Darwinian evolution, cooperation is pervasive in nature. Every instance of life demonstrates cooperative investment in a single organism by competing genes. Further, organisms as simple as bacteria or as complex as humans invest considerable time and effort in creating public goods to provide shelter, security, and nourishment [Rankin *et al.*2011]. In this Section we present the various technological and scientific considerations and literature that influenced our development.

a) Agent-Based Modelling: Agent-based models (ABMs) are computer programs in which intelligent agents interact in a set environment based on a defined set of rules. As the agents interact with each other and their environment, patterns of behaviour emerge. These emergent phenomena, which are not explicitly programmed into the model, represent the collective consequences of the agents' actions. ABMs offer a way to model social and economic systems, allowing researchers to examine macro-level effects from micro-level behaviour. Applications of agent-based modelling span a broad range of areas and disciplines; they can expose the basic principles of animal sociality, including humans' [Axelrod1997], [Gallagher *et al.*2015].

b) Serious Games: While ABMs are often used in graphical environments, we distinguish them from the widespread simulation in computer games. Non-serious games are made for entertainment and invest in believability [Riedl and Young2005], rather than realism like scientific simulations. Agents in games should appear believable but be of limited complexity, as is appropriate to their purpose in the game and the attention they receive from the player [Millington and Funge2009]. Serious games fall between these objectives,

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being designed with both entertainment and non-entertainment objectives. They convey learning experiences [Abt1970]. Serious games have been widely used in the military, business, and education. By providing an engaging interactive experience, they increase learners' motivation, time-on-task, and consequently learning outcomes compared to lecture-room training. Knowledge or behaviour gained in a gaming environment is known to be transferable to the real world, though this effect can be moderated by learner and context variables [Vandercruysse *et al.*2011].

c) Public Goods Investment and Games: Games of another sort are a standard tool of behavioural economics, aiming to investigate how we (humans) collaborate to achieve a common benefit. Typically, experimental subjects are allocated into groups. Group members are not identified to each other and only interact through computer screens, in order to ensure group members do not act out of fear or expectation of retribution or repayment after the game. Of particular interest to cooperation studies are public goods games. A *public good* is a resource shared by a social group. Investments in public goods do not necessarily imply an understanding of the economic payoffs of a such investment nor even interest in the long-term benefit of the group [Binmore and Shaked2010].

III. Method: The Sustainability Game

The Sustainability Game is meant to be—among other things—a valid ecological simulation. The game is intended to communicate behavioural economics principles to naïve users by displaying the measured impact of the player's different investment strategies on the population and individual agents. A society of agents, called *Spiriduşi*, populate a fictional two-dimensional world (Fig. 1). The agents compose a collective agency; they must invest some resources in their own survival but can also invest in communal goods: bridges and houses. The key gameplay mechanic is that the player selects the percentage of time the agents spend on food gathering and consumption, reproduction, building houses for their families, and on benefiting the entire society by building bridges. These percentages can be changed at any time during playthrough.

The question of where and how much to invest one's resources is complex; there may be multiple viable solutions. Harvested food (apples, grown in two forests) becomes a private good. When an agent eats its stamina level goes up. Once an agent reaches an apple it is consumed and removed from the game immediately. There is a finite amount of food available at a given time, so there is competition for resources among agents. The forests 'grow food back'; each unit of food previously consumed, grows back at its original or a nearby location after at least three in-game days pass.

Following a common simplification in ecological simulations, the agents reproduce asexually. Reproduction is not guaranteed and each attempt costs and therefore requires stamina. It also requires a house. If an attempt is successful, a 'newborn' agent is spawned in the house. A Spiriduş' stamina status is indicated by colour: 1) Dark green: the Spiriduş is full—any further consumption is wasted. 2) Light green: the Spiriduş is of a good stamina level. 3) Dark Yellow: the Spiriduş is low on stamina—still able to build houses and bridges, but unable to procreate. 4) Yellow: the Spiriduş is near starvation. 5) Red: the Spiriduş will stop whatever it is doing to find food. Unless quickly successful, it starves.

Fig. 1. Screenshot of game. Player allocates time to given tasks using the sliders in the top left-hand corner. Clockwise: 1) eating (private); 2) housing (semi-private); 3) bridge (public); 4) procreation (semi-private). Red agents are near starvation. Five bridges are erected, allowing agents to cross the river and access food from the second forest. Rain warns of an upcoming flood.

Time is expensive and should be treated as a resource; a delay in acting may mean that another agent takes advantage of a situation before you. This is communicated through the SG's food ecology. Moreover, as time passes the Spiriduşi grow older and eventually die from old age. There is also inorganic decay from the passage of time, making both bridges and houses collapse. Thus, if the players want the population to continue having usable houses and bridges, they need to continue investing time to these public goods.

How much it is sensible to invest in public goods varies by context. To communicate this principle, we introduced environmental variability. As the game progresses there is an increasing possibility of the river flooding, wiping out the bridges. If the river floods, it will temporarily expand and then return to normal. This decreases the value of a long-term commitment to the public good projects, because a bridge that agents spend time building could be destroyed. Before each flood, there is rain to warn the players that a flood is imminent. This early indication system allows players to reallocate time spent by the Spiriduşi on building bridges to other tasks. Floods and decay are not the only change beyond the player's control; there are also the possibility of immigrants joining the society. While immigration, like procreation, increases the number of workers available for the construction of public and semi-private goods, it also increases competition for food.

Notice that if all players play altruistically, more public goods may be produced than are of use and there may be no net benefit to the community. Ironically, the existence of 'freeriding' agents may help a population balance its investments and sustain itself over time [Sylwester *et al.*2013]. The game is designed so that if a player focuses exclusively on any single form of investment, the population is likely to go

TABLE I

INDEPENDENT SAMPLE t-TEST FOR PARTICIPANT COUNTRY ON DEPENDENT VARIABLES M = MEAN. SD = STANDARD DEVIATION. RPB1 = RESPONSE TO PARTNER'S BEHAVIOUR IN TRIAL BLOCK 1; RPB2 = RESPONSE TO PARTNER'S BEHAVIOUR IN BLOCK 2; IPD = ITERATED PRISONER'S DILEMMA; IPGG = ITERATED PGG.

Dependent Variable	America M(SD)	Europe M(SD)	t	p
Cooperation Rate (IPD)	0.67 (0.28)	0.61 (0.39)	0.73	0.468
RPB1 (IPD)	-0.02 (0.37)	-0.03 (0.45)	0.07	0.942
RPB2 (IPD)	-0.01 (0.42)	-0.12 (0.31)	1.18	0.243
Average Sentence (IPD)	1.83 (0.81)	1.89 (0.97)	-0.29	0.768
PG Contribution (PGG)	14.33 (5.72)	15.16 (3.49)	0.66	0 .514
RPB1 (IPGG)	0.36 (5.02)	3.05 (6.52)	-1.78	0.056
RPB2 (IPGG)	0.10 (4.80)	-0.96 (6.34)	0.72	0.478
Payoff in $ (IPPG)	8.91 (1.22)	9.14 (0.99)	-0.88	0.383

extinct. Access to the second forest can allow a larger population to be sustained but spending too much time building bridges leads to starvation. Players' outcomes are stronger if they come to understand that following a single, overly-simple strategy throughout the game is insufficient. Instead, players need to update their strategy based on environmental and societal changes—some mixture of freeriders and altruists in the society is often the most sustainable strategy.

IV. USER STUDY

We recruited a total of 72 participant from our two universities. Participants received $12/£7 turn-up compensation, plus a potential performance-based monetary bonus of maximum $10/£6. We randomly assigned experimental subjects into two groups; a control group where subjects played Tetris (Control) and a treatment group with the Sustainability Game. Each of these groups was further divided into two subgroups, identifiable and anonymous partners, resulting to a 2-by-2 study. Participants completed in order: 1) Video game control/treatment for 20 minutes, 2) the Iterated Prisoners Dilemma, and finally 3) the Iterated Public Goods Game. All groups also participate in the same pre-treatment demographics survey as well as the same post-treatment standard behavioural economic games. Participants who played with an identifiable partner sat face-to-face with their partner. Participants who played with an anonymous partner communicated with their partner via an online chat box. Two pairs were taking the study at the same time to ensure anonymity.

a) Demographics: Detailed demographic analysis was conducted but is omitted here for reasons of space. To determine whether the American and English samples could be collapsed for greater ease of analyses, we conducted a series of independent t tests examining the effect of participant continent on our outcomes. We found no significant main effects of continent on our dependent variablesv(Table I), so therefore collapse the data, leaving a final n of 72.

b) Iterated Prisoner's Dilemma: wThe first game in our list of behaviour economic games is the well-established Iterated Prisoners Dilemma (IPD) [Rapoport and Chammah1965]. Participants were told that the game will be played anywhere between 2 and 18 trials; each game was randomly assigned the number of trials participant would play. Each trial consists of a single move, i.e., the decision to cooperate or blame, by each of two the players. Participant choices were made individually in private, with no discussions allowed between them, and were only revealed to each other at the end of the round. Once their sentences were calculated, they would proceed to the next round.

TABLE II

RESULTS FOR THE LEVELS OF COOPERATION IN ALL FOUR CONDITIONS IN THE IPD. THESE RESULTS SUGGEST THAT THE SG FACILITATES COOPERATION UNDER CONDITIONS OF ANONYMITY BUT ATTENUATES COOPERATION WHEN PARTICIPANTS' PARTNERS ARE IDENTIFIABLE.

	Tetris	SG	F	$p\ (\eta_p^2)$
Anonymous	0.41 (0.08)	0.8 (0.04)	17.77(1,39)	**0.001 (0.32)**
Identifiable	0.8 (0.04)	0.6 (0.08)	4.73 (1.31)	**0.038 (0.14)**
F	14.29 (1.35)	5.93		
$p\ (\eta_p^2)$	**0.001 (0.29)**	**0.02 (0.15)**		

TABLE III

GLM RESULTS FOR THE EFFECT OF GAME TYPE, PARTNER TYPE, AND INTERACTION ON PARTICIPANTS' RATE OF COOPERATION IN THE IPD.

	$F(1,71)$	p	η_p^2
Game Type (GT)	2.05	0.157	0.03
Partner Type (PT)	1.79	0.186	0.03
Two-way GT and PT	19.91	0.001	0.23

We first constructed a Generalised-Linear Model (GLM) to examine the effect of Game Type, Partner Type, and their interaction on participants' rate of cooperation. We used this type of analysis as we had a design with categorical predictor variables (Game Type and Partner Type) and we needed to examine the effect of each factor and their interaction on the dependent variable. We found a significant two-way interaction between Game Type and Partner Type (see Table III). Table II suggests that the SG facilitates cooperation under conditions of anonymity but attenuates cooperation when participants partners are identifiable.

We then constructed a GLM to examine the effect of Game Type, Partner Type, and their interaction on the average sentence participants received, which is a measure of participant performance in the IPD. (See Table II for means of average sentence by Game Type and Partner Type). There was a significant two-way interaction between Game Type and Partner Type (see Table IV. Table V shows that individuals who played with anonymous partners had significantly lower sentences (which indicates better performance) if they played the SG compared to Tetris. Conversely, individuals who played with identifiable partners had marginally higher sentences if they played the SG. Furthermore, in the Tetris condition those with identifiable partners had significantly lower sentencing decisions, while in the Sustainability condition those with identifiable partners had significantly higher sentencing decisions than those with anonymous partners. These results suggest that the SG facilitates game performance under conditions of anonymity but attenuates performance when participants partners are identifiable.

TABLE IV
GLM RESULTS FOR THE EFFECT OF GAME TYPE, PARTNER TYPE, AND THEIR INTERACTION ON PARTICIPANTS' PERFORMANCE IN THE IPD.

	$F(1,71)$	p	η_p^2
Game Type (GT)	0.64	0.428	0.0
Partner Type (PT)	0.1	0.751	0.0
Two-way GT and PT	11.66	0.001	0.12

TABLE V
RESULTS FOR THE PERFORMANCE IN ALL FOUR CONDITIONS IN THE IPD, SUGGESTING THAT THE SG FACILITATES COOPERATION UNDER CONDITIONS OF ANONYMITY BUT ATTENUATES COOPERATION WHEN PARTICIPANTS PARTNERS ARE IDENTIFIABLE.

	Tetris	SG	F	p (η_p^2)
Anonymous	2.27 (0.24)	1.47 (0.11)	9.46 (1,39)	**0.004 (0.2)**
Identifiable	1.56 (0.13)	2.06 (0.24)	3.31 (1.31)	0.076 (0.1)
F	6.14 (1.35)	5.54 (1.35)		
p (η_p^2)	0.018 (0.15)	**0.025 (0.14)**		

c) Iterated Public Goods Game: The second game counting towards the participants' bonus is the Iterated Public Goods Game with two players. Participants' payoff for each trial *payoff* $=$ (*# tokens kept*)$+.50*(1.5*$*# tokens in shared pool*). Participants were told the game would be played anywhere between 2 and 18 trials, with game randomly assigned a number in this range. Participants were told that the outcome of this game would also contribute to their monetary bonus. We first constructed a GLM to examine the effect of Game Type and Partner Type, and their interaction on participants' contribution in the PGG. There was a significant main effect of Partner Type (see VI). Those in the identifiable partner condition contributed more to the public fund ($M = 16.11$, *Standard Error (SE)* $= 0.86$) than those in the anonymous partner condition ($M = 13.40$, $SE = 0.77$). There was no significant interaction $F(1,71) = 2.767$, $p = 0.101$, $\eta_p^2 = 0.04$ but simple slope analyses indicate that Partner Type significantly predicts contributions for those who played Tetris $F(1,35) = 9.52$, $p = 0.004$, $\eta_p^2 = 0.219$), but not for those who played the SG, $F(1,35) = 0.196$, $p = 0.661$, $\eta_p^2 = 0.006$. While the interaction is not significant, the simple slope results seem to follow the pattern of results we saw in the Ultimatum Game and suggest that the SG may mitigate the general tendency for individuals to act less cooperatively towards anonymous partners in the Iterated PGG.

TABLE VI
GLM RESULTS FOR THE EFFECT OF GAME TYPE, PARTNER TYPE, AND THEIR INTERACTION ON PARTICIPANTS' RATE OF COOPERATION IN IPPG.

	$F(1,71)$	p	η_p^2
Game Type (GT)	0.05	0.826	0.07
Partner Type (PT)	5.46	0.022	0.03

V. DISCUSSION AND CONCLUSIONS

We have demonstrated success in creating an intervention that alters cooperation versus standard outcomes from explicit instruction such as for the public goods games. Our findings suggest that even a short exposure to the Sustainability Game increases cooperative behaviour in various well-established measures in the standard anonymised procedure, but not when one's partner is clearly identifiable. We had hoped that experience of the ecological dynamics of the SG would allow players to better optimise outcomes on subsequent cooperative tasks, but we also knew there was a chance that the game could make players more cognizant of a cooperative context, which can make players act more selfishly [Bear *et al.*2017], [Burton-Chellew *et al.*2017]. We did not anticipate, however, that the effect of the SG on cooperation would depend on whether one's partner is identifiable. And, perhaps, it has not. It may be that both results indicate increased sophistication in understanding how to utilise cooperative behaviour to achieve goals, but the one-on-one context is significantly more likely to make those goals competitive. Further research is required to ensure whether the SG makes the dynamics of human cooperation more transparent to users, or just facilitates their expression of competitive or cooperative tendencies. Regardless, we have successfully demonstrated that games can be used as interventions to alter cooperative behaviour.

REFERENCES

[Abt1970] Clark C Abt. *Serious games: The art and science of games that simulate life*, volume 6. Viking Press, New York, NY, USA, 1970.

[Axelrod1997] Robert Axelrod. *The Complexity of Cooperation: Agent-Based Models of Competition and Colloboration*. Princeton University Press, 1997.

[Bear *et al.*2017] Adam Bear, Ari Kagan, and David G. Rand. Co-evolution of cooperation and cognition: The impact of imperfect deliberation and context-sensitive intuition. *Proceedings of the Royal Society B: Biological Sciences*, 284(1851):20162326, 3 2017.

[Binmore and Shaked2010] Ken Binmore and Avner Shaked. Experimental economics: Where next? *Journal of Economic Behavior and Organization*, 73(1):87–100, 2010.

[Burton-Chellew *et al.*2017] Maxwell N. Burton-Chellew, Claire El Mouden, and Stuart A. West. Social learning and the demise of costly cooperation in humans. *Proceedings of the Royal Society B: Biological Sciences*, 284(1853):20170067, 4 2017.

[Gallagher *et al.*2015] Elizabeth M. Gallagher, Stephen J. Shennan, and Mark G. Thomas. Transition to farming more likely for small, conservative groups with property rights, but increased productivity is not essential. *Proceedings of the National Academy of Sciences*, 112(46):14218–14223, 2015.

[Herrmann *et al.*2008] Benedikt Herrmann, Christian Thöni, and Simon Gächter. Antisocial punishment across societies. *Science*, 319(5868):1362–1367, 3 2008.

[Millington and Funge2009] Ian Millington and John Funge. *Artificial Intelligence for Games*. Elsevier, 2009.

[Rankin *et al.*2011] D J Rankin, E P C Rocha, and S P Brown. What traits are carried on mobile genetic elements and why? *Heredity*, 106(1):1–10, 1 2011.

[Rapoport and Chammah1965] Anatol Rapoport and Albert M Chammah. Prisoner's Dilemma. *University of Michigan Press*, page 270, 1965.

[Riedl and Young2005] Mark O Riedl and R Michael Young. An objective character believability evaluation procedure for multi-agent story generation systems. In *International Workshop on Intelligent Virtual Agents*, pages 278–291. Springer, 2005.

[Sylwester *et al.*2013] Karolina Sylwester, Benedikt Herrmann, and Joanna J. Bryson. *Homo homini lupus?* Explaining antisocial punishment. *Journal of Neuroscience, Psychology, and Economics*, 6(3):167–188, 2013.

[Vandercruysse *et al.*2011] Sylke Vandercruysse, Mieke Vandewaetere, and Geraldine Clarebout. Game-Based Learning. In *Handbook of Research on Serious Games as Educational, Business and Research Tools*, pages 628–647. IGI Global, 2011.