ODD description of model used in experiment to study human decision-making of coalition formation - Human-in-the-loop Experiment of the Strategic Coalition Formation using the glove game

3.1.1. Purpose and patterns

The purpose of the model is to collect information on human decision-making in the context of coalition formation games. The model uses a human-in-the-loop approach, and a single human is involved in each trial. All other agents are controlled by the ABMSCORE algorithm [1]. The glove game, a standard cooperative game, is used as the model scenario.

Patterns: To determine what human characteristics would affect their play in a coalition game (glove game).

3.1.2. Entities, state variables, and scales

The simulation model is a representation of a cooperative game theory game known as a glove game. The glove game involves players combining their endowment of gloves to create pairs, which they can sell. The focus of the game is which coalitions of player will form. The main agents of this model are the players. The gloves are not considered agents since they are inert.

Agents: players

Environment: Abstract social environment where all agents are assumed to be able to communicate with each other with complete information.

State variables: All variables are associated with the players, as we can see in Table 3.

Table 3
Variables.

Variable	Type, Range	Owner	Temporal
Coalition Membership	Integer, [0, # players]	Players	Dynamic
Left Gloves	Integer, [0, ∞)	Players	Static
Right Gloves	Integer, [0, ∞)	Players	Static

Coalition Membership: It gives the index number of the coalition that the player is a member. If a player is not a member of a coalition, it is assumed to be in a singleton coalition, and an index number is still assigned.

Left Gloves: This variable indicates the number of left gloves that a player has in its initial endowment. Gloves are used to work out the value of a coalition.

Right Gloves: This variable indicates the number of right gloves that a player has in its initial endowment.

All other variables are calculated from these variables.

Scales

The temporal scales within the model are arbitrary. Each round represents an opportunity for several coalitions to be suggested to the agents and, if necessary, updating the coalition structure.

3.1.3. Process overview and scheduling

The game is played over a number of rounds. Each round represents an opportunity for the players to propose new coalitions and, if acceptable to all potential members of that coalition, the formation of a new

coalition. The human player proposes first, followed by the computerized players. The computerized players propose coalitions are created by the ABMSCORE algorithm.

The main loop of the simulation is as follows:

1. The human player determines if they wish to create a new coalition of players or remain with their current coalition
2. If a new coalition is selected by the human player, then the computerized agents in that proposed coalition are asked if they wish to join.
    - If all the affected agents wish to join, then the new coalition forms.
        - Players' membership is updated.
    - If any agent rejects the proposed coalition, then it does not form. The human player is informed that their proposed coalition was rejected.
3. The ABMSCORE algorithm steps go through the seven types of coalitions. At each step, a randomly selected coalition type is proposed. First, all the computerized agents in the proposed coalitions are asked if they wish to join.
    - If any agent rejects the proposed coalition, then the algorithm moves on to proposing the next type.
    - If all computerized agents agree to join the proposed coalition, then it is checked to see if the human player is part of the proposed coalition
        - If the human player is not, then the proposed coalition forms, and computerized players update their membership.
        - If the human player is part of the proposed coalition, then the human player is asked whether they wish to join the new proposed coalition.
            - If they say yes, then the proposed coalition forms, and players update their membership.
            - If they say no, then the proposed coalition does not form.
4. Once all algorithm proposed coalitions are assessed and new coalitions are formed, the coalition indexes are normalized using the approach outline in Djokić, Miyakawa [2].
5. All agents' internal values are updated to reflect the new coalition situation if they have not already been done so.
6. Loop to next Round

This main loop is shown in a flow diagram in Fig. 1. The critical point is that the ABMSCORE algorithm will suggest several coalitions that are proposed to the agents. This algorithm is discussed in the sub-model section below.

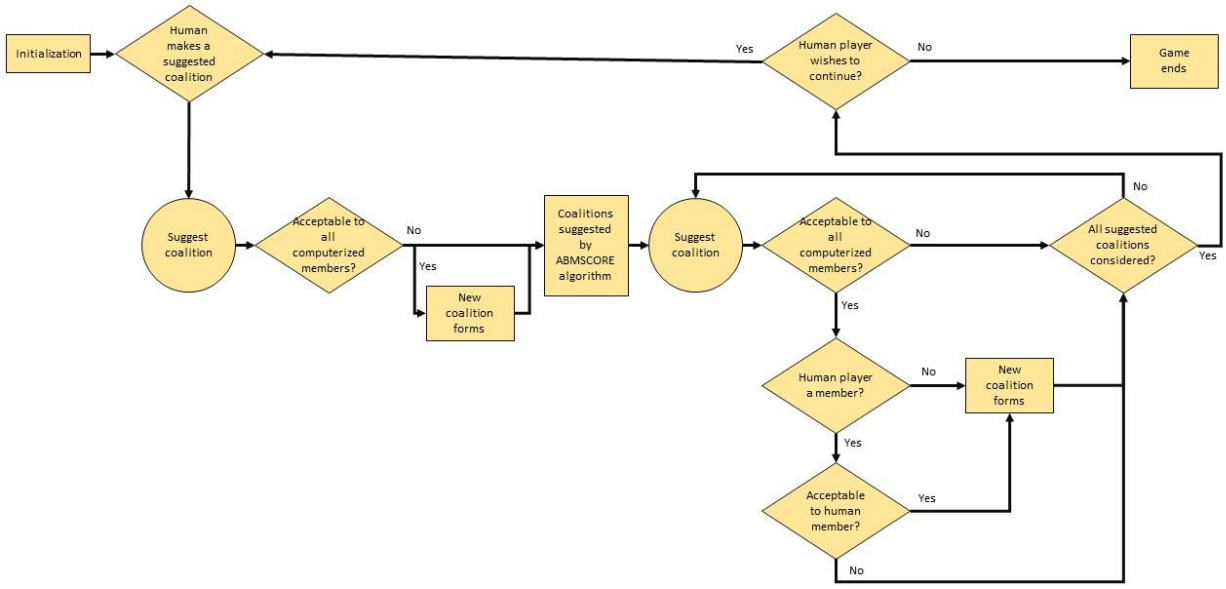

Fig. 1. Flow diagram of decision processes in the model

3.1.4. Design concepts

Basic principles

The underlaying game of the model is a replication of the glove game, a classic game in cooperative game theory [3] that has been used in human-subject experimentation [4]. The computerized agents are assumed to be utility maximizers, which is consistent with game theory standards. The utility is the sole driver for the computerized agents' decision-making, and complete information is assumed. The utility value that a player gets is called its payoff.

Emergence

There are two emergent phenomena that are hoped to be observed from the simulation run. The first is that human players play like the computerized agents; that is, their decisions are consistent with what the computerized agents would do in a similar situation. The second emergent behavior is that the final coalition structure, the collection of all coalitions that covers all players, is a core partition.

Adaptation

The ability of an agent to accept suggested new coalitions to join is the adaptive part of the model. The agents are only able to change to a coalition that is suggested to them, either from the human player or the ABMSCORE algorithm. Further, a new coalition only forms if all potential members of that coalition choose to join that coalition. This means that every agent has the veto power to stop a new coalition that includes them from forming. The agents will choose to join a new coalition if it increases their utility.

Note that agents might find themselves in a new coalition because other members of their coalition have decided to leave that agent's coalition. Agents cannot stop other members from leaving; they can only stop a new coalition forming that includes them.

Objectives

The objective of all the computerized agents is to join the coalition that maximizes their utility. The utility is quantified as a payoff (reward). In the glove game, the payoff of a given agent 'a' in coalition 'S' is:

$$R(a,S) = {min(\sum_{b \in S} L(b), \sum_{b \in S} R(b))}/{|S|}$$

The human agent is also instructed that the goal of the game is to maximize their utility; however, whether they choose to try and do that or not, it is completely their choice. It is possible that human players follow other objectives, e.g., complete the experiment as quickly as possible.

Learning

There is no learning incorporated into this model.

Prediction

There is no prediction incorporated into this model.

Sensing

There is no agent sensing incorporated in this model for the computerized agents. Through a graphical user interface (GUI), the human player has complete knowledge of the game situation, i.e., what are the current coalitions and what are the glove endowments of each agent. The graphical representation that the human player sees is shown in Fig. 2..

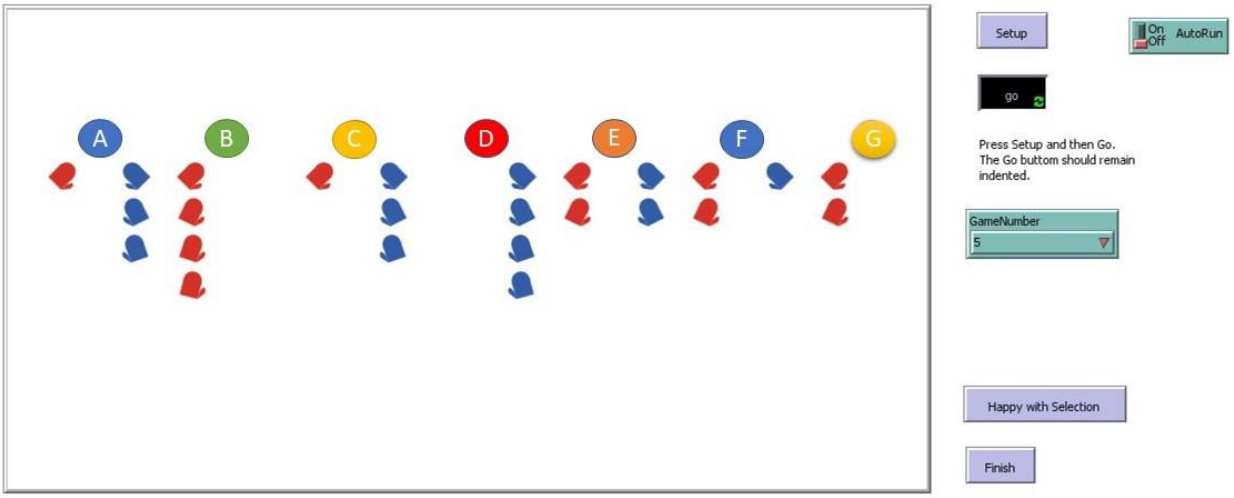

Fig. 2. Graphical User Interface (GUI) used in the simulation. The agents are represented by alphabetic circles. The colors of the circles represent the current coalition of the agents.

In the GUI, each agent is represented by a static circle. Each agent's glove endowment is shown immediately below the agent's circle; for example, Fig. 2. shows player F has two left gloves and a right glove, whereas player B only has four left gloves. The current coalitions are represented in the GUI as colors of the agents; for example, Fig. 2. shows that players A and F are in a coalition so are players C and G; all other players are in a singleton coalition.

Interaction

All agent interactions are mediated. That is, the agents do not directly interact with each other, but their actions do affect each other. These effects are due to the decision that they made with regard to coalition membership. If an agent leaves or joins a coalition, then the value of that coalition might change, which, in

turn, affects the utility of coalition members. The value of a coalition is the number of glove pairs it can generate, whereas the payoff of its members is this value divided by the coalition size.

To understand this indirect interaction, consider players C and G in the example game shown in Fig. 2.. While these two players are in a coalition together, they can create three pairs of gloves and get a payoff of 1.5 each. However, if player C leaves the coalition, player G would get a payoff of zero. Thus, player C's actions indirectly affect player G's utility.

Stochasticity

The only stochastic element of the model is "which coalitions are suggested by the ABMSCORE algorithm". The algorithm generates seven different suggested coalitions during this step of the model; each of the seven suggested coalitions is derived by a different coalition formation approach. An example of a coalition formation approach would be combining two randomly chosen coalitions to create a suggested coalition. The different coalition approaches are discussed in the sub-model section below.

In all cases, the uniform distribution is used when selecting an agent or coalition. That is, all agents or coalitions will have the same probability of selection in a given coalition formation approach.

The inclusion of an actual human's decisions within the model creates uncertainty; however, this behavior is not necessarily stochastic *for a given individual*. The human player's decision-making type is stochastic with an unknown distribution.

Collectives

The model has a focus on coalitions, which are a form of collective. The coalitions determine the payoff that each agent would get, and, in turn, this payoff drives the computerized agent decision to join any proposed coalition. The coalitions are explicitly represented in the model as a number; each agent has a coalition number assigned to it. Note that the set containing only one agent is still a coalition; it is known in cooperative game theory as the singleton coalition.

Observation

There are a variety of observations that are recorded after the human player makes a decision in a given model trial. These include the current coalition structure, the suggested coalition, and human players' current payoff. We also want to know how the game situation is related to the core solution of the game. As such, it is also recorded whether the coalition structure is a core partition and whether the human agent is in a coalition that belongs to a core partition (note that there can be more than one core partition). Finally, all human player's decisions are compared to what the computerized agents would do, and a Boolean is recorded to see whether their behavior is consistent with the computerized agent.

3.1.5. Initialization

All agents are assumed to start in their singleton coalitions. The number of players and their glove endowments is determined by which game is being considered. The inputs for the two trial games are given in the glove game section above. Note that a player's glove endowments do not change throughout the game.

3.1.6. Input data

As Grimm, Railsback [5] specify in their ODD description, input data refers to data that input during the simulation run as opposed to its initialization. As such, there is no input data for our model.

3.1.7. Sub-models

There are two sub-models worthy of discussion. The first is the Graphical User Interface (GUI) used by the human player. The second is the ABMSCORE algorithm.

Graphical User Interface

The purpose of the GUI is to provide the human player with an overview of the game situation as well as suggest coalitions or respond to suggested coalitions. The GUI allows the human player to see the endowment of other players and the current game situation, as discussed in the sensing section above. Fig. 2. shows a screenshot of the GUI.

The GUI allows the human player to suggest coalitions on their turn; this is achieved by clicking on other agents' circles that they wish to form a coalition with. These circles turn into squares if selected. Once the human player is happy with their selection, they simply press "happy with selection." If they do not wish to make a selection, then simply selecting no agent and pressing "happy with selection" will move the game onto the computerized agents turn. Once the human player is happy with the coalition structure presented, they simply press finish to end the game.

Algorithm Steps

There is one human player in the model, and all other players are controlled by the ABMSCORE algorithm. The purpose of the algorithm is to simulate the computerized agents' behavior of joining and suggesting coalitions. The version of the algorithm used in the model was the advanced version developed by Vernon-Bido and Collins [1].

There are three parts used within the algorithm: coalition selection, coalition evaluation, and coalition updating. These three parts control changes to the coalition structure, which is the main output of the model.

Coalition Suggestions

There are six coalition suggestions (S) that are made at each round of the game by the computerized agents. They are suggested in the order given below. A description in prose and mathematical notation is given for each. The six suggestion types are:

Join Coalition

Two agents from different coalitions (U, V) in the current coalition structure (CS) are chosen randomly.

$$If\ N \notin CS: S = U\ \cup V\ s.t. U \neq V, \{U, V\}\ \subseteq CS$$

Exit Coalition

An agent from a coalition whose size is greater than one, i.e., not a singleton coalition, is randomly selected. The coalition minus the agent is the suggested coalition.

$$if\ \exists U \in CS\ s.t.\ |U| > 1: S = U \backslash \{i\},\ \ i \in U$$

Create a Pair Coalition

Two agents are randomly selected. A suggestion coalition pair is created.

$$S = \{i\} \cup \{j\},\ \ i \neq j, \{i, j\} \subseteq N$$

Defect Coalition

A randomly chosen agent selects a coalition to which he does not belong. The suggested coalition is this agent combined with the selected coalition.

$$S = \{i\} \cup U, i \in N, U \in CS \cup \emptyset$$

Split Coalition

A coalition is randomly chosen, and a random subset of agents from the coalition are selected to form a separate coalition. The two split coalitions are considered the suggested coalitions in this step, i.e., if either coalition approves its formation, then the split occurs.

$$S_1 = X, S_2 = Y, X \cap Y = \emptyset, X \cup Y = U, U \in CS$$

Return to an Individual Coalition

An agent is randomly chosen, and the suggested coalition is its singleton coalition. This is known as the individual rationality concept [6].

$$S = \{i\}, i \in N$$

Coalition Evaluation

Each of the six suggestions is evaluated to determine if they are acceptable to members of the coalition (or either coalition is the case of a split). For each affected computational agent, their current payoff (utility) is compared to the payoff (utility) of the suggested coalition. If all the affected agents would experience an increase in payoff, then the suggested coalition forms if the human player is not involved in the suggested coalition. That is:

$$if\ \forall i \in S, u_i(S) > u_i(C_i)\ then\ C_i \coloneqq S, \forall i \in S$$

If the human player is involved in the suggested coalition, then they are asked if they would like to join the suggested coalition as a final step in this process. The payoff that each player gets is the number of glove pairs divided by the number of players in their coalition, i.e.,

$$u_i(C_i) = \frac{\min(\sum_{x \in C_i} L(x), \sum_{x \in C_i} R(x))}{|C_i|}$$

Coalition Updating

If a new coalitions form, then the agents of that coalition simply change their Coalition Membership number to a unique identification number assigned to the new coalitions. The forming of new coalitions will affect the payoffs of many of the agents, but this information is updated when needed. After all coalition updates are made, the coalition number is normalized follow the approach outlined in Djokić, Miyakawa [2]. This result in the human player always being in coalition' 0.'

References

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