Online Appendix: "An Experimental Investigation of Stochastic Adjustment Dynamics"

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APPENDIX

A Behaviour in Period 1

How might a subject approach the Language Game? That is, what might/ought one play in period 1? There are two reasons this is of interest. First of all, the Language Game is a novel game in the literature so there is no chance that the subjects, even if they are students of economics, have been exposed to it before. Acclimatising to a new environment can take time, and it is of independent interest how subjects might approach a novel strategic environment. Second, while 200 periods is more than most experiments, it is still nowhere near the glacial time horizons required for long run stochastic stability results to 'kick in', so path dependence may well become an issue. If a subject recognises this, then he may tailor his initial behaviour accordingly.

To address the above, we illustrate how the Language Game is effectively a fusion of two of the classic existing large population games, a Stag Hunt + a Battle of the Sexes, and we consider how the differences between them may affect behaviour. We emphasise this fusion as some of our subjects were economics undergraduates and so would have been exposed to these games before. The issue then is how they might play a richer game that is effectively the simultaneous playing of two existing games of which they are familiar.

Despite the heterogeneity and the fact that subjects are interacting with more than one 'type' of player, local interactions are *opponent independent*, in that a subject's payoff is determined solely by his choice of action and the action choice of his opponent. That is, in any pairwise interaction the identity of the opponent, or in this case his group affiliation, is irrelevant. This feature 'scales up' to the population level in that a player cares only about the number of others using each action and not on how those others are distributed across the two groups. Formally, this can be seen from equations 1-4 in the text as the only variable that matters to an individual is the scalar summary statistic $n_a(\mathbf{s})$.

While the Language Game is a coordination game where actions are strategic complements, it is not a *pure coordination game* in the standard sense since it does not possess a unique Pareto efficient equilibrium.[1] Despite the fact that the game is richer than both a Stag Hunt and a Battle of the Sexes (G^{AA} and G^{BB} are both normalised Stag Hunts, while and G^{AB} is a Battle of the Sexes), we believe most subjects will recognise that the payoff to each action is increasing in the number of those choosing it, and given that there are only two actions, will further deduce that there is a clear most-preferred outcome for them. The immediate issue then faced by a subject is whether to choose this most-preferred action. Clearly this decision depends on his conjecture about everyone else. A sophisticated subject may then work through something like the following checklist of questions: Have those in my group reached this same conclusion? Have those in the other group realised that they have a most-preferred action? If everyone in the population has realised that they have a most-preferred action, have they also realised that this choice differs for those in different groups?

As mentioned above, the only information a subject needs to best-respond is the total number choosing each action. Implicitly, a subject has realised that there is a *threshold* fraction of people at which each action becomes optimal. A subject may then realise that this threshold is shared by everyone in his group, and may further recognise the tension that exists because, for any action, each group's threshold for it being a best-response lie on opposite sides of 50%.[2]

The above highlights that the Language Game has a flavour of *tension* à la a Battle of the Sexes (see the "asymmetric contests" of Samuelson and Zhang (1992) for the large

[1]However, the Language Game is a 'pure coordination problem' according to Young (2001), who defines such a game as one wherein all players have m strategies, and strategy sets can be ordered such that it is a strict equilibrium for each player to play their m^{th} strategy. In fact, when profile $(\mathbf{a}, \mathbf{b})$ is an equilibrium, there is more than one such ordering available.

[2]This seems to have the flavour of a statement about *risk dominance*, however, to us at least, it is not clear how one ought define risk dominance in this setting. If the standard definition of a best-reply to 50% of the population using either action was adopted, then the risk dominant profile is always $(\mathbf{a}, \mathbf{b})$. But this could yield the undesirable conclusion of the risk dominant profile not being an equilibrium. If an alternate definition of a best-reply to the profile $(\mathbf{a}, \mathbf{b})$ is used, then the risk dominant profile, while always an equilibrium, could involve players from the smaller group adopting the other group's preferred action, and this may not sit well either.

population analog). The big difference is that in the Language Game, a subject cares directly about the behaviour of everyone, whereas in a large population Battle of the Sexes only the behaviour of those in the other group affects your payoff directly.[3] To put it another way, one interpretation of the Language Game is that it is an extended Battle of Sexes that has been enriched in a way so that members of each "sex" also interact amongst themselves, i.e., men also interact with men and women also interact with women.[4] So, a considerate subject will then have to start making conjectures about the conjectures of those in his own group (despite their preferences being perfectly aligned) and also those from the other group. After this, a considerate subject might start looking at the relative sizes of the groups and considering relative strength of preferences of each.

While the subjects are most likely unaware of the formal definition of risk dominance, they presumably appreciate that there is risk (however defined) associated with each action choice. This again goes to the interpretation of the Language Game. A second interpretation involves taking the most commonly used setting in the literature on large population games (a normalised Stag Hunt) and simply "doubling" it.[5] That is, suppose that there are two groups, A and B, each located on a distinct island. For each of these island economies, the local interactions are given by G^{AA} and G^{BB} respectively. The Language Game can then be viewed as an "opening up" of the islands to one another (thereby requiring the addition of the across group local interaction G^{AB}). If a subject views things in this way, he may well believe that everyone in the population will choose their most-preferred action. The subject then compares the size of his group to

[3]In a repeated large population Battle of the Sexes, the behaviour of those in your group could affect your payoff via its effect on those in the other group. However, in a repeated Battle of the Sexes, conjecturing how those in your group would behave in period 1 is pointless.

[4]This feature of the Language Game allows it to provide a more realistic framework for studying the emergence of standards and operating systems (Farrell and Saloner, 1985; Katz and Shapiro, 1985; Arthur, 1989), since it does not insist that preferences are homogeneous but still allows a given player to interact with everyone in the population.

[5]Settings where a large homogeneous population interact via Stag Hunt are so pervasive in the literature that giving a full list of citations is impossible. Some well-known examples include Blume (1993, 2003); Ellison (1993); Foster and Young (1990); Kandori and Rob (1995); Morris (2000); Morris and Shin (2003); Myatt and Wallace (2004); Peski (2010).

the threshold needed for his most-preferred action to be optimal.

Lastly, we mention the most commonly used prediction device for one-shot games, *level-k* (Nagel, 1995). The level-k model is a non-equilibrium model of strategic behaviour that is entirely pinned down by specifying the behaviour of the level-0s. It has been traditional to model level-0 behaviour as randomising uniformly over all choices.[6] Given that profile $(\mathbf{a}, \mathbf{b})$ is an equilibrium in all of our treatments, such level-0 behaviour would lead everyone of level $k \geq 1$ to adopt their most-preferred action, and as such players of different levels would not be distinguishable.

[6]Some recent experiment evidence challenges this. See Burchardi and Penczynski (2014).

B State Space for each Treatment

Here we illustrate the state space under the best-reply dynamic for each treatment.

A given game is defined by the tuple $(N^A, N^B, \alpha, \beta)$. Our three treatments are:

G1 : $(11, 9, 0.57, 0.67)$

G2 : $(12, 8, 0.58, 0.71)$

G3 : $(15, 5, 0.58, 0.80)$

B.1 State Space for each Treatment

Treatment 1: $(11, 9, 0.57, 0.67)$

For Treatment G1, the state space looks as in Figure 1 below.

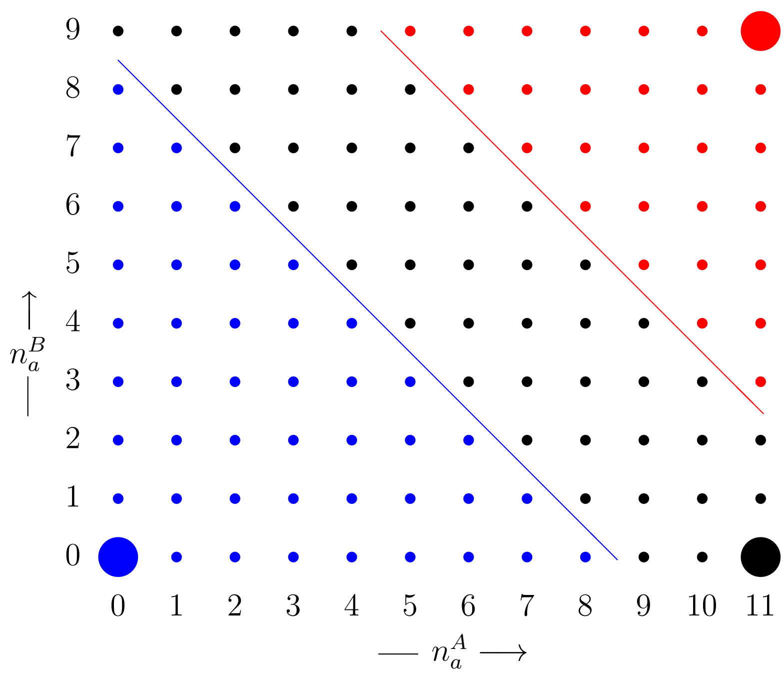

Figure 1: State Space for Treatment G1.

Treatment 2: $(12, 8, 0.58, 0.71)$

For Treatment G2, the state space looks like as in Figure 2 below.

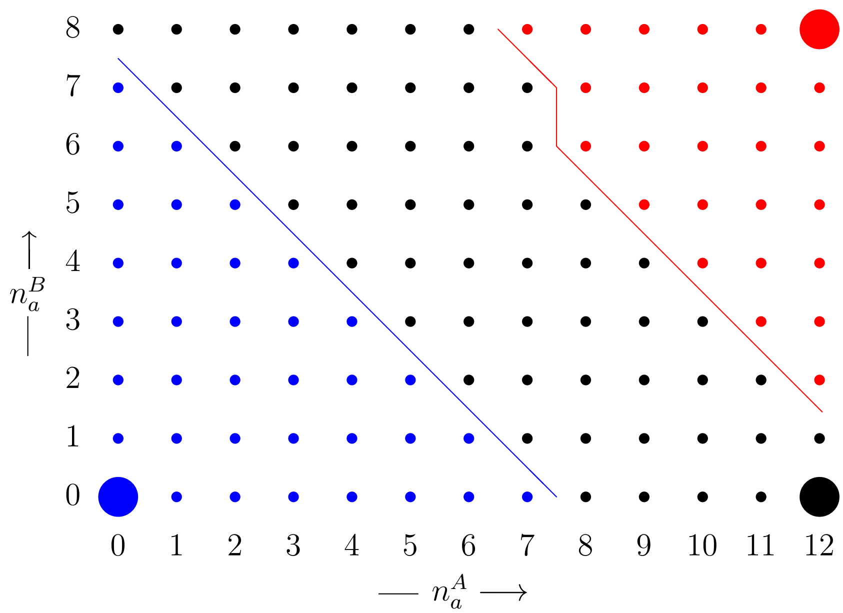

Figure 2: State Space for Treatment G2

Treatment 3: $(15, 5, 0.58, 0.8)$

For Treatment G3, the state space looks like as in Figure 3 below.

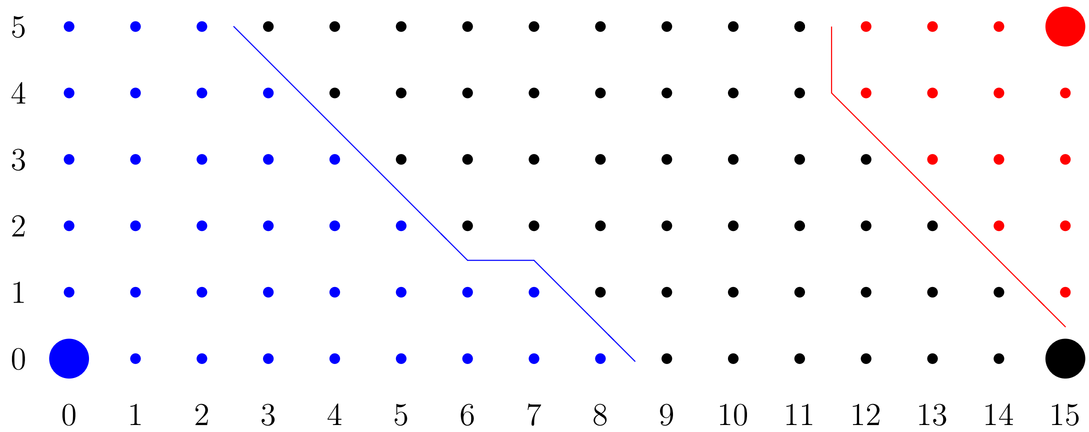

Figure 3: Treatment 3. State Space for Dynamic D1.

C Experimental Instructions (Game 1)

INSTRUCTIONS

Welcome to the study. In the following hour, you will participate in 200 rounds of decision making. Please read these instructions carefully; the cash payment you will receive at the end of the study depends on how well you perform so it is important that you understand the instructions. If you have a question at any point, please raise your hand and wait for one of us to come over. We ask that you turn off your mobile phone and any other electronic devices. Communication of any kind with other participants is not allowed.

Your Role

There is a total of 20 participants in the study. These 20 individuals are randomly assigned into two different Groups: Group A and Group B, with **11** individuals assigned to Group A and **9** individuals assigned to Group B. These group assignments are fixed throughout the study.

In each round, you play a game with the rest of the participants - both those in the same group as you and those in the other group. Each player will be asked to take a decision that will affect the earnings of every other player including themselves. At the end of the round, a summary of what happened in that round, along with your earnings for that round, will be displayed on the computer monitor.

Your Decision in Each Round

You will play a 2-player game with each of the 19 other participants. You must choose one of two actions, labeled '#' and '&'. This action will be used in every 2-player game that you play. Thus, you are using the same action with each other participant.

Your total earnings in a given round will be the average of the earnings you received in each 2-player game. The tables on the next page show how earnings are determined with each cell corresponding to the choices of actions by you and your opponent in a particular 2-player game. The first number in a given cell represents your earning in a 2-player game, and the second number represents your opponent's earning.

Since there are two Groups, there are two cases.

		opponent in Group A	
		#	&
You	#	$57, 57$	$0, 0$
	&	$0, 0$	43, 43

		opponent in Group B	
		#	&
You	#	57, 33	0, 0
	&	0, 0	43, 67

Figure 4: When you are in Group A

1. When you are in Group A, earnings are as follows:

   In words this says,

   (a) If you and your opponent both choose action '#', you get 57. If your opponent is in Group A, he/she gets 57; if your opponent is in Group B, he/she will get 33.

   (b) If you and your opponent both choose action '&', you get 43. If your opponent is in Group A, he/she gets 43; if your opponent is in Group B, he/she will get 67.

   (c) If you and your opponent choose different actions, you each get 0.

2. When you are in Group B, earnings are as follows:

		opponent in Group B	
		#	&
You	#	33, 33	$0, 0$
	&	$0, 0$	$67, 67$

		opponent in Group A	
		#	&
You	#	33, 57	0, 0
	&	0, 0	67, 43

Figure 5: When you are in Group B

   In words this says,

   (a) If you and your opponent both choose action '#', you get 33. If your opponent is in Group B, he/she gets 33; if your opponent is in Group A, he/she will get 57.

   (b) If you and your opponent both choose action '&', you get 67. If your opponent is in Group B, he/she gets 67; if your opponent is in Group A, he/she will get 43.

   (c) If you and your opponent choose different actions, you each get 0.

This is a quick reminder for how you read entries in the tables that you can refer back to throughout the study:

Your earning, Your opponent's earning

The following shows how to calculate your average earning in each round:

1. When you are in Group A.
   (a) If you pick action '#', your payoff is $57 \times \frac{x}{19}$, where 'x' is the number of other players who chose action '#'.
   (b) If you pick action '&', your payoff is $43 \times \frac{y}{19}$, where 'y' is the number of other players who chose action '&'.
2. When you are in Group B.
   (a) If you pick action '#', your payoff is $33 \times \frac{x}{19}$, where 'x' is the number of other players who chose action '#'.
   (b) If you pick action '&', your payoff is $67 \times \frac{y}{19}$, where 'y' is the number of other players who chose action '&'.

where $x + y = 19$.

Rundown of the Study

1. At the beginning of the first round, you will be assigned to a group, and you will be shown the two tables specifying earnings that are relevant to your group. Below the tables, you will be prompted to enter your choice of action. You must choose either '#' or '&' within 30 seconds. If you do not choose an action, one will be *randomly* assigned to you.
2. The first round is over after everybody has chosen an action. The screen will then show you a summary for the first round:
   (a) how many players chose each action,
   (b) your choice of action, and
   (c) your (average) earning in the round, and
   (d) a table displaying your (average) earnings in all previous rounds.

3. Below the information feedback, you will be prompted to enter your choice of action for the second round. The game does not change, so as before you must choose either '#' or '&'.

   All future rounds are identical to except for one **important** difference. The difference concerns how much time you have to choose an action. In rounds $2-10$, you have 15 seconds to make a decision. If you do not make a decision within the 15 second window, then you will be assigned whatever action you used in the previous round. For rounds $11-200$, you have only 10 seconds in which to make a decision. Again, if you fail to choose an action in this timeframe, you will be assigned the same action as in the previous round.

Your Cash Payment

We will randomly select 2 rounds out of the 200 to calculate your cash payment, so it is in your best interest to take each round seriously. Each round has equal chance to be selected. The sum of the points you earned in the 2 selected rounds will be converted into cash at an exchange rate of HK$1 per point. Your total cash payment at the end of the study will be this cash amount plus a HK$40 show-up fee. Precisely,

Your total cash payment = HK$ (*The sum of the points in the 2 selected rounds*) + HK$ 40

Adminstration

Your decisions as well as your cash payment will be kept completely confidential. Remember that you have to make your decisions entirely on your own; do not discuss your decisions with any other participants.

Upon completion of the study, you will receive your cash payment. You will be asked to sign your name to acknowledge your receipt of the payment. You are then free to leave.

If you have any questions, please raise your hand now. We will answer questions individually. If there are no questions, we will begin with the study.

D Screen Shots of Z-tree

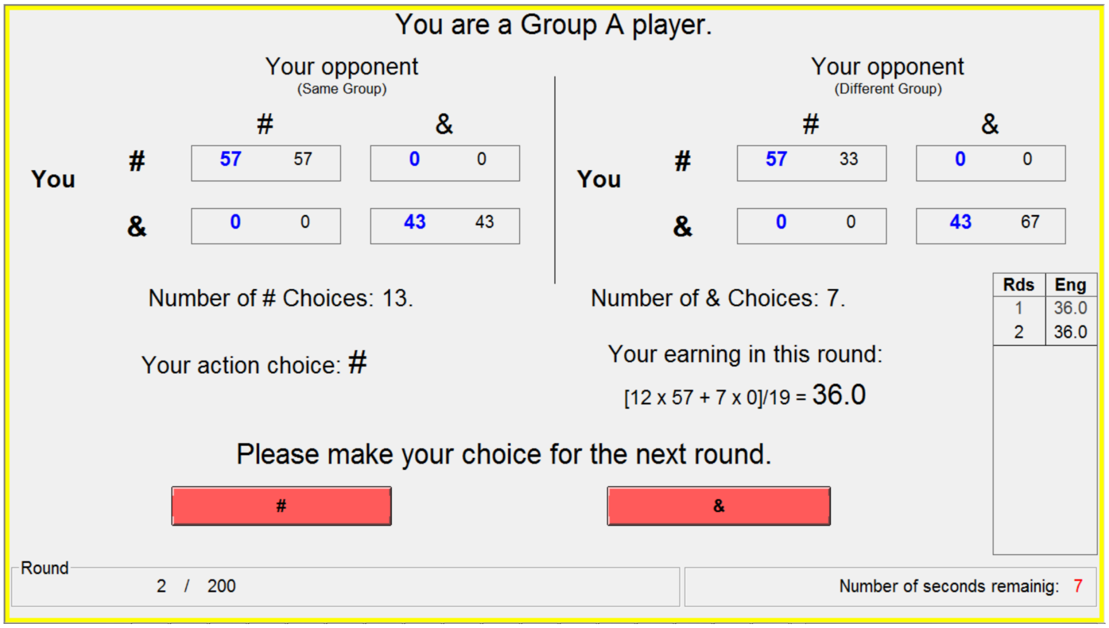

Figure 6: Member A's Decision Screen

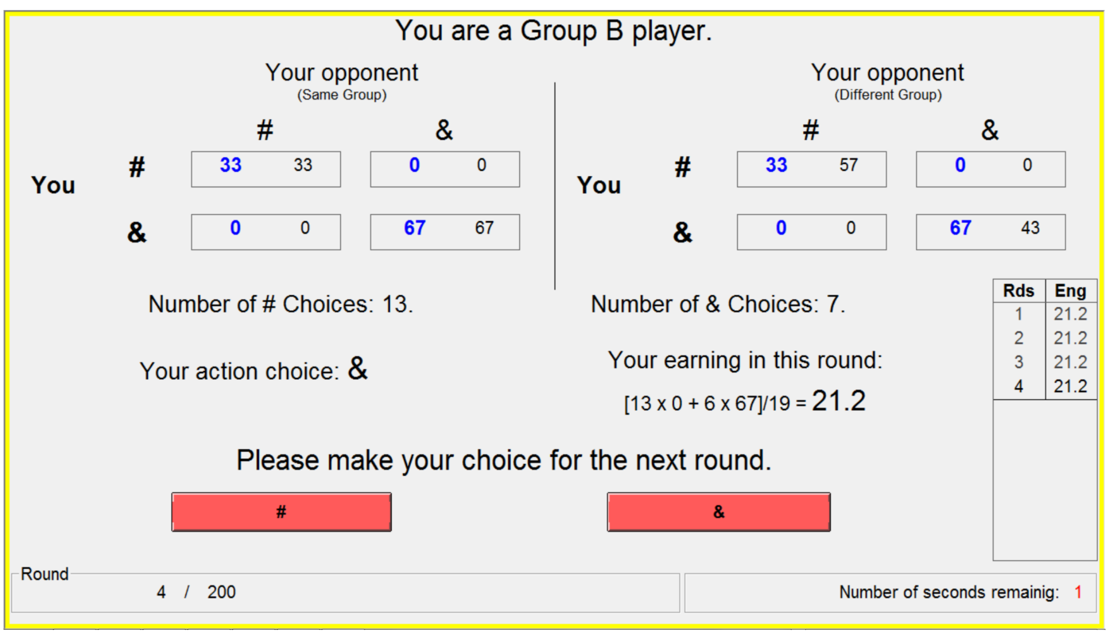

Figure 7: Member B's Decision Screen

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