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Coordination and the Effects of Complexity, Focality, and Payoff Asymmetry: Experimental Evidence from Pie Games

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1 Introduction

The coordination of economic decisions is essential for successful performance (see Cooper and John (1988) and Schelling (1960)). We refer to a coordination game's number of feasible actions as the game's *complexity*, and ask: is it, in asymmetric coordination situations of the battle of the sexes type, harder for decision makers to coordinate their behavior when complexity is high than when it is low – and how does this depend on whether or not the game has a focal point[1], and on the size of the payoff asymmetry? Moreover, is the pure effect on coordination of a focal point negatively or positively related to complexity? The mixed Nash equilibrium predicts that higher complexity reduces coordination (in what follows, 'coordination' always means 'expected coordination rate'). The intuition is straightforward: An increase in complexity means that both players 'disperse' their decisions (mixing probabilities) over more and more actions, and so it becomes less likely that the players coordinate on any action. Our experiment allows us to assess how empirically plausible this prediction and intuition is.

We use as game frame the 'Pie Game', a simple coordination game also used in Crawford et al. (2008) (see also Blume and Gneezy (2000) and Blume and Gneezy (2010)). We vary complexity and the payoff asymmetry, and collect data for games both with and without focal points; this allows us to assess the pure effect of 'adding' a focal point to a game with a given complexity and payoff asymmetry.

While higher complexity is indeed observed to be detrimental to coordination in games without focal points, the picture is very different for games with focal points: when the payoff asymmetry is small, coordination holds up and increases somewhat in spite of higher complexity. The reason is that higher complexity increases coordination on the focal point and hence ceteris paribus coordination (we say there is a *concentration effect*), and does so sufficiently much that it outweighs the negative impact of complexity due to players dispersing themselves over the larger set of non-focal actions (a *dispersion effect*). The theoretical benchmark outlined above is not supported by the data. When the payoff asymmetry is high,

[1] In this paper 'focal point' refers to equilibrium selection based on payoff-irrelevant aspects (the game's 'labels'). See Bardsley et al. (2010), Crawford et al. (2008), Mehta et al. (1994), Arjona (2011), and Schelling (1960). A large literature studies the role of payoff-relevant selection criteria, see e.g. Rankin et al. (2000) and Huyck et al. (1990).

however, going from an intermediate to a high level of complexity generates a strong *negative* concentration effect (and an insignificant dispersion effect), so coordination falls dramatically.[2]

We can cleanly measure the pure effect of a label salient focal point on behavior by comparing two games that differ only in whether there is a focal point or not. There is no significant difference under low complexity (both for low and high payoff asymmetry). But when the payoff asymmetry is small and complexity is high, the presence of a focal point significantly raises coordination. If the payoff asymmetry is high, there are no significant differences for a high level of complexity.

Crawford et al. (2008) also collect data for the pie game with low complexity, low payoff asymmetry, and a focal point (cf. their 'AM2' game), and our data for this game replicate theirs. But they did not vary complexity and did not collect data for games without focal points, so our experiment can be seen as a generalization and extension of theirs to games with higher complexity and to studying the pure effect of focal points on coordination. Our data show that while, as found in the previously mentioned study, label salient focal points exert little influence on behavior in low complexity games, they can significantly raise coordination when the payoff asymmetry is low and complexity is high. Our results contribute to an emerging literature (see Crawford et al. (2008) and Isoni et al. (2011)) that empirically investigates how payoff asymmetries influence the power of label salient focal points in coordination situations.

In Section 2 we describe the experimental design and procedures. Section 3 describes the experimental findings. Section 4 concludes. The Appendix contains the data set. An appendix with screenshots and formal proofs can be downloaded from
`https://sites.google.com/site/aupoulnew/`.

2 Experimental Design and Procedures

2.1 The Games

Each matched pair of subjects saw on their computer screens a 'pie' that was divided into a number of 'slices' (see Figure 1). The subjects sepa-

[2] Isoni et al. (2011) also observe that large payoff asymmetries weaken the relevance of focal points (in a bargaining context).

rately, simultaneously, and without pre-play communication chose one of the slices. If they chose the same slice the numbers written on the chosen slice were paid out (the first number is Player 1's reward, in British Pounds[3]); if they chose different slices, neither player earned any money, except a £3 show-up fee.

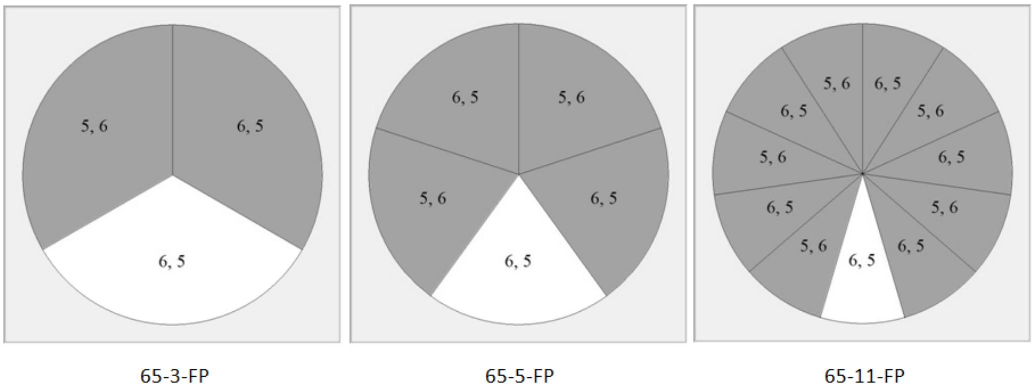

Figure 1: Three Pie Games with 65 payoffs, 3,5, and 11 slices, and with a focal point (white slice). FP = focal point.

In the games with a focal point one slice was white and the others were purple. The focal slice was always at the bottom, as in Crawford et al. (2008), whose games all had three slices. Both players choosing the white slice is a potential focal point. In the games without a focal point all slices were purple. Our treatments differed in payoff asymmetry (the numbers assigned to slices), the number of slices (complexity), and in the presence or absence of a focal point (white slice). The payoffs assigned to slices were either $(6,5)$, $(5,6)$, $(6,5)$,... (as in Figure 1), or $(10,5)$, $(5,10)$, $(10,5)$,... (in Figure 1, replace '6' with '10'). We refer to these as '65' and '105' games, respectively. There were either 3, 5, or 11 slices. Finally, each game came in two versions, one with a focal point ('FP'), and one with no focal point ('NFP'). We refer to the game with 65 payoffs, three slices, and a focal point as 65-3-FP, and so on.

[3]At the time of the experiment, £1 was equal to about \$ 1.5 and 1.2 Euros.

2.2 Procedures

The experiment took place at Centre for Behavioural and Experimental Social Science (CBESS) at University of East Anglia, during July – October 2011. It was programmed and conducted with the software z-Tree (Fischbacher (2007)). Recruitment was done using ORSEE (Greiner (2004)). Each subject made a single decision for one pie game only. Subjects were seated at separate and visually isolated computer terminals. The instructions appeared on their screens and were also read out (see online appendix). After any questions were answered, subjects made their decisions, were informed of the outcome and money earnings, and received these privately in cash. 523 subjects took part in 38 sessions. Average earnings, including the £3 show-up fee, was £4.66. A typical session lasted 15 minutes.

3 Results

Starting at the bottom slice and moving clockwise we label the slices S1,S2,.... Figure 2 and 3 show the expected coordination rates for 65 and 105 games (see Table 1 and 2 in the Appendix). For each game, the height of the bar measures the expected coordination rate. This equals the sum of expected coordination rates on each slice, corresponding to the height of each separate bar segment. For each game the horisontal broken line shows the expected coordination rate predicted by the completely mixed Nash equilibrium ('MNE'), where each player chooses each slice with a strictly positive probability. The MNE prediction is that an increase in complexity strictly decreases coordination (see online appendix), and that games with a focal point (e.g., 65-5-FP) is behaviorally indistinguishable from the same game without a focal point (65-5-NFP).

65 Games Figure 2 clearly shows that in NFP games higher complexity leads to lower coordination, as predicted by the mixed Nash equilibrium.[4]

[4] The difference between 3-NFP and 11-NFP is statistically significant at the 10 % level (Fisher's Exact test, $p = .08$, one-tailed). We also conduct a bootstrap test (see Appendix). The null hypothesis that the expected coordination rates based on our data equal the ones predicted by the mixed Nash equilibrium cannot be rejected at 5 % significance level for any level of complexity.

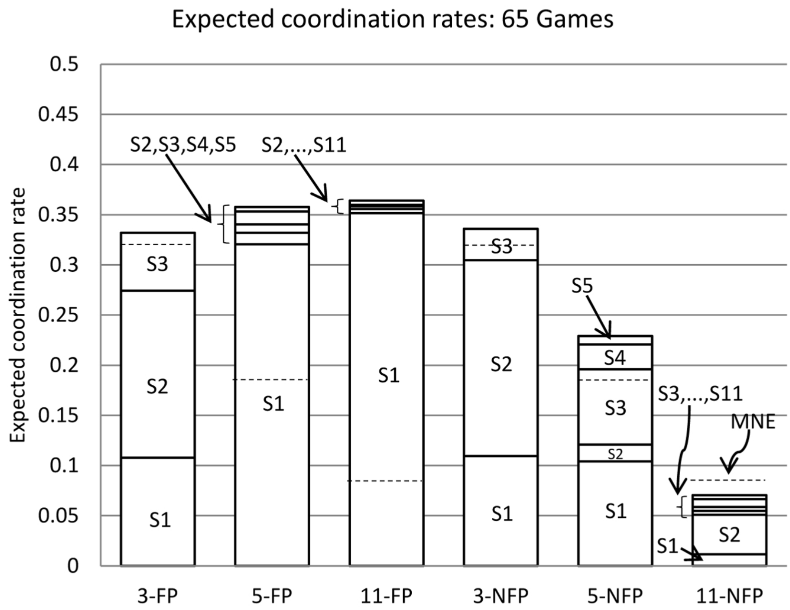

Figure 2: Expected coordination rates in 65 games. MNE = Mixed Nash Equilibrium. S1 = bottom slice. FP = Focal Point. NFP = No Focal Point.

Both player 1s and 2s tend to disperse themselves over all actions (see Table 2 in the Appendix), and higher complexity thus leads to a fall in the likelihood that any two subjects choose the same slice, and to a drop in both sides' expected earnings (.38 and .4 in 65-11-NFP versus 1.820 and 1.875 in 65-3-NFP, cf. Table 2). Consider then the games with a focal point. For these games we define the *concentration effect* as the change in the expected coordination rate on the focal slice (S1) as complexity increases. The *dispersion effect* is defined as the change in the expected coordination rate on slices S2,S3,... as complexity increases. See Table 3 in the Appendix. Each, and both, effects can be positive (coordination increases) or negative (coordination decreases). The change in the expected coordination rate when complexity increases is thus the sum of the concentration and dispersion effects. Figure 2 clearly shows a strong positive concentration

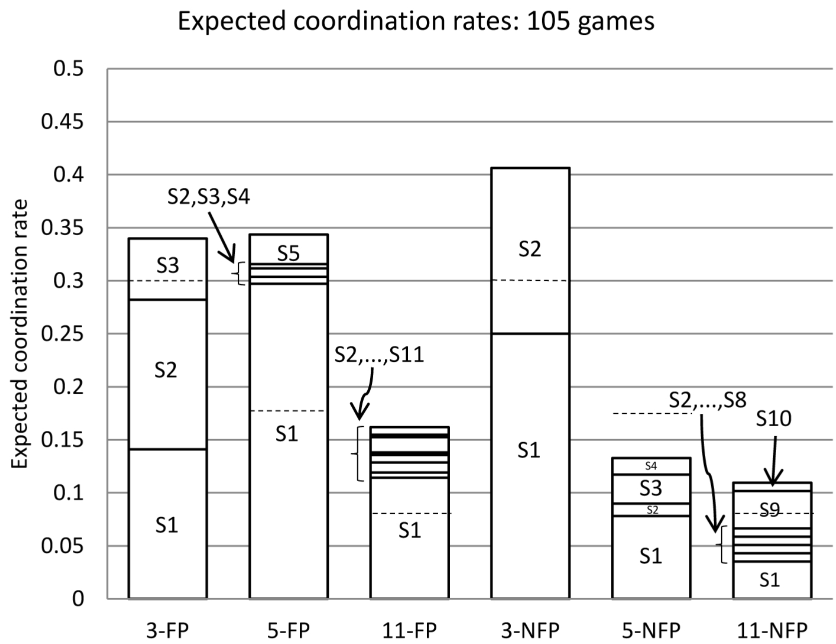

Figure 3: Expected coordination rates in 105 games.

effect as we go from three to five slices, and that it diminishes but remains positive when complexity increases from five to eleven slices. The figure also shows that there is a negative dispersion effect, but the concentration effect neutralizes it, so coordination holds up, and in fact increases somewhat as we go from three to five and from five to eleven slices, although none of these differences in coordination are statistically significant.[5]

The pure effect of the focal point can be measured by comparing games with and without a focal point (e.g., 65-5-FP and 65-5-NFP). See Table 4 in the Appendix. The difference in the expected coordination rate between the FP and NFP game increases in complexity, due to a concentration ef-

[5]Chi-square test for the three and five slice game, $p = 0.76$, two-sided, and the same p-value for the five and eleven slice game comparison. A bootstrap test rejects the null hypothesis that the expected coordination rates based on the data equals the ones predicted by the mixed Nash equilibrium at 5 % for five and eleven slices, but not for three slices.

fect[6] that more than outweighs the dispersion effect (the exception is the three slice game, but both effects are in this case tiny), and is statistically significant for eleven slice games, but not for three and five slice games.[7] Intuitively, since subjects find it almost impossible to coordinate when complexity is very high in the NFP game, making a label salient coordination device available makes a significant difference for coordination. In 65-11-FP both player 1 and player 2 subjects' expected earnings are much higher than in 65-11-NFP (2.18 and 1.82 versus .38 and .4, cf. Table 1 and 2). A game theoretic approach based on an assumption that decision makers from the outset ignore any payoff-irrelevant labels is unable to explain these observations.

105 Games As for 65 games, higher complexity in NFP games leads to lower coordination.[8] For FP games the effect on coordination of going from three to five slices is similar to the one for 65 games, i.e., positive but insignificant. The main difference from 65 games is that coordination in FP games sharply drops as complexity increases from five to eleven slices. The concentration effect is now *negative* (coordination on the focal slice drops by more than 60 percentage points, see the Appendix). The dispersion effect is very close to zero, so coordination drops markedly from 34 % to 16 %.[9]

The pure effect of the focal point on coordination (the FP versus the NFP version) is also weaker under high payoff asymmetry. When complexity is low coordination *drops* somewhat when a focal point is present (from 40 % to 34 %), due to a now negative concentration effect and a positive dispersion effect (Table 4). A focal point can thus be harmful for coordination (although the difference is not statistically significant, chi-square

[6]When comparing the FP and NFP version, the concentration effect is naturally defined as the difference between the expected coordination rate on slice 1 (the bottom slice) in the FP and the NFP game. Similarly, the dispersion effect is the difference between the expected coordination rate on the other slices (S2,S3..,) in FP and NFP.

[7]Chi-Square test, one-sided p-value for eleven slices is $p = .04$, for five slices $p = 0.26$, and $p = 0.41$ for three slices.

[8]The data for five and eleven slice games are well organized by the mixed Nash equilibrium (bootstrap test), with the exception of the three slice game, where a bootstrap test leads to a rejection of the game-theoretic null hypothesis at 5 %.

[9]A bootstrap test leads to rejection of the null hypothesis that the expected coordination rate predicted by the mixed Nash equilibrium equals the ones based on the data for both the five and eleven slice game, but not for three slices.

test, $p = 0.41$, one-tailed). In fact, the highest level of cordination among all games is achieved in the three slice game without a focal point. For five and eleven slices the concentration effects dominate the dispersion effects, but, while the 21.1 percentage point increase in the five slice case seems economically significant, these differences are not statistically significant (chi-square test, $p = 0.11$, one-tailed, for five slices, and $p = 0.48$ for eleven slices). A high payoff asymmetry therefore substantially weakens the ability of focal points to serve as coordination devices, even at a high complexity level.

4 Conclusion

This paper reports the following experimental findings: in asymmetric coordination games an increase in action set size (complexity) can be beneficial for coordination if the game has a label salient focal point and the payoff asymmetry is moderate. Also, the pure effect of a label salient focal point on coordination is positive and significant when complexity is high. If the payoff asymmetry is high, these effects are neutralized and higher complexity hurts decision makers. A natural task for future work is to investigate if our findings hold for other types of coordination games and other game frames, and, if so, to explain why. An interesting conjecture for our data is that the higher the payoff asymmetry is in a coordination game the more decision makers tend to use an individualistic rather than a focal point based mode of reasoning (cf. the discussion in Crawford et al. (2008)). Since the effects of complexity on coordination are likely to be negative under the former but positive under the latter mode of reasoning, this could explain why high complexity is detrimental to coordination games with focal points and to the power of focal points for high but not low payoff asymmetry.

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5 Appendix: Data

The tables below shows the raw data, expected coordination rate, and expected payoffs. Table 1 (2) shows data for games with (without) focal points. For each game (column) and for each of that game's feasible slices (rows, S1,...,S11 = slice 1,..,11), the table shows the relative frequencies of Player 1 and Player 2 subjects who chose that slice, and the expected coordination rate on that slice (the product of relative frequencies). N1 and N2 denote the number of Player 1 and 2 subjects. EC is the expected coordination rate (the sum of expected coordination rates on individual slices). E1 and E2 denote the expected payoffs of Player 1 and 2, and MNE denotes the expected coordination rate predicted by the completely mixed Nash equilibrium (see Appendix B).

	65-3-FP	65-5-FP	65-11-FP	105-3-FP	105-5-FP	105-11-FP
S1	.4,.269,.108	.577,.556,.321	.571,.615,.351	.423,.333,.141	.552,.539,.297	.286,.4,.114
S2	.433,.385,.167	.154,.074,.011	.107,0,0	.385,.367,.141	.172,.039,.007	.071,.067,.005
S3	.167,.346,.058	.039,.222,.009	0,.077,0	.192,.3,.058	.069,.115,.008	.143,.067,.010
S4	–	.115,.111,.013	.107,.039,.004	–	.103,.039,.004	.107,.067,.007
S5	–	.115,.038,.004	.036,0,0	–	.103,.269,.028	.036,.067,.002
S6	–	–	.036,0,0	–	–	0,0,0
S7	–	–	.036,.077,.003	–	–	.143,.1,.014
S8	–	–	0,.039,0	–	–	.036,0,0
S9	–	–	.036,.039,.001	–	–	.071,.033,.002
S10	–	–	.036,0,0	–	–	.107,.067,.007
S11	–	–	.036,.115,.004	–	–	0,.133,0
N1,N2	30,26	26,27	28,26	26,30	29,26	28,30
EC	.332	.358	.363	.340	.344	.161
E1,E2	1.826,1.827	2.124,1.814	2.177,1.822	2.691,2.405	3.385,1.773	1.526,.906
MNE	.331	.198	.090	.300	.179	.081

Table 1: Data for games with a focal point.

	65-3-NFP	65-5-NFP	65-11-NFP	105-3-NFP	105-5-NFP	105-11-NFP
S1	.25,.438,.109	.313,.313,.104	.188,.063,.012	.5,.5,.250	.625,.125,.078	.188,.188,.035
S2	.625,.313,.195	.125,.133,.017	0,0,0	.5,.313,.156	.188,.063,.012	.125,.063.,008
S3	.125,.25,.031	.375,.2,.075	0,.063,0	0,.188,0	.063,.438,.027	.063,0,0
S4	–	.125,.2,.025	.313,.125,.039	–	0,.25,0	.125,.063,.008
S5	–	.063,.133,.008	.063,.063,.004	–	.125,.125,.016	.063,0,0
S6	–	–	.188,0,0	–	–	0,.125,0
S7	–	–	0,.375,0	–	–	.063,.125,.008
S8	–	–	.063,.063,.004	–	–	.125,.063,.008
S9	–	–	.125,.063,.002	–	–	.188,.188,.035
S10	–	–	.063,.063,.004	–	–	.063,.125,.008
S11	–	–	0,.125,0	–	–	0,.063,0
N1,N2	16,16	16,15	16,16	16,16	16,16	16,16
EC	.335	.229	.065	.406	.133	.110
E1,E2	1.820,1.875	1.333,1.188	.375,.398	3.281,2.813	1.270,.723	.625,.578
MNE	.331	.198	.090	.300	.179	.081

Table 2: Data for games without a focal point.

	3-5	5-11	3-11
65-FP	.026, .213,-.187	.005,.030,-.025	.031,.243,-.212
65-NFP	.-.106,-.005,-.101	-.164,-.092,-.072	-.270,-.097,-.173
105-FP	.04,.156,-.152	-.183,-.183,.001	-.179,-.027,-.152
105-NFP	-.273,-.172,-.101	-.023,-.043,.020	-.296,-.215,-.081

Table 3: The table shows, for each payoff structure with and without a focal point (rows), the change in the expected coordination rate (first number), which equals the sum of the concentration effect (second number), and the dispersion effect (third number), as complexity increases from 3 to 5 slices, from 5 to 11 slices, and from 3 to 11 slices (column). Note: In the (row three, column four) cell, the dispersion effect is so small that the change in the coordination rate and the concentration effects are only different in the fourth decimal, (not shown in the table).

	3	5	11
65	-.003, -.001,-.002	.129,.217,-.088	.298,.339,-.041
105	-.066,-.109,-.043	.211,.219,-.008	.051,.079,-.028

Table 4: The table shows, for each payoff structure (rows) and complexity level (columns), the difference in the expected coordination rate (first number), which equals the sum of the concentration effect (second number), and the dispersion effect (third number), between the game with a focal point (FP) and the game without a focal point (NFP).